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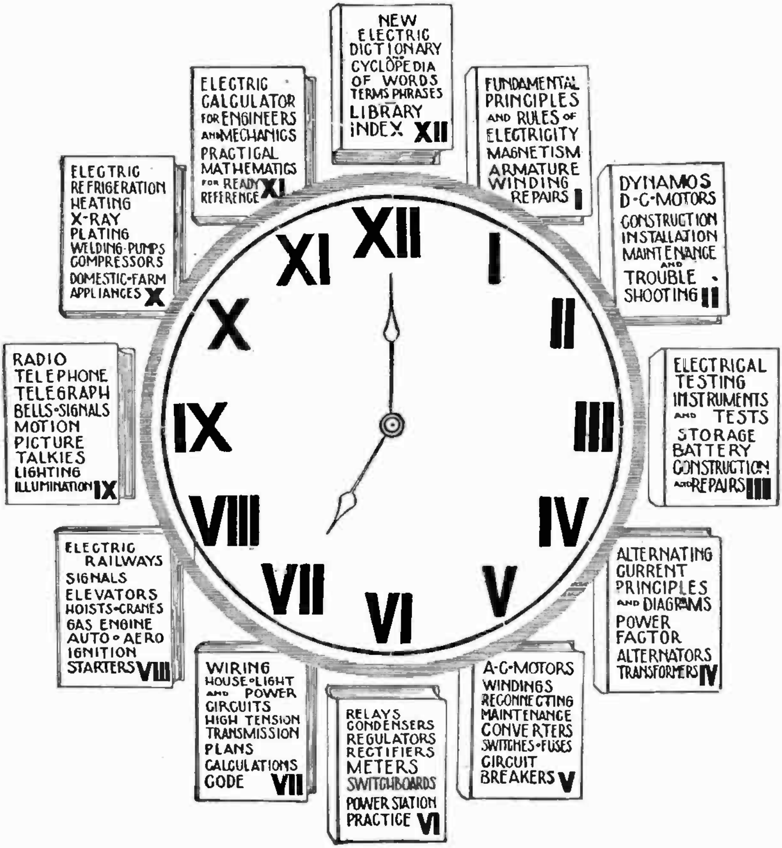

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The author and publishers here gratefully acknowledge the hearty and generous help and co-operation of all those who have aided in developing this helpful series of Educators.

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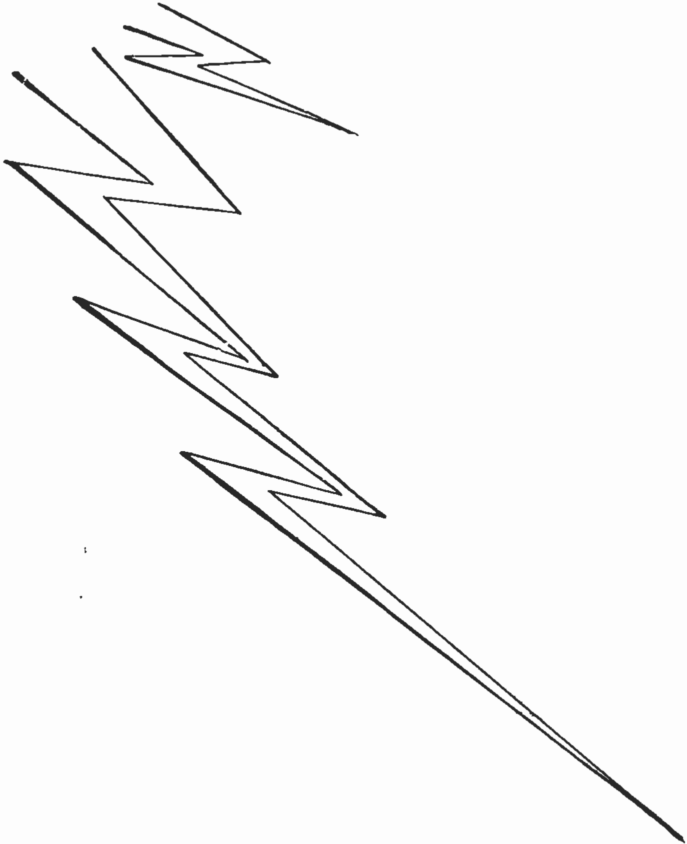

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The secret that took the whole year to find;
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Were all on a library shelf to commence."

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CHAPTER 130

Electric Railway Systems

Any system of electric car propulsion includes besides the track and rolling stock, suitable apparatus: 1, to produce the current, and 2, to transmit and distribute it to the electric motors on the cars where it is transformed into mechanical energy to give motion to the car.

The extensive development of the electric railway has given rise to numerous systems, which may be classified in several ways:

1. With respect to the current, as

   a. Direct.

   b. Alternating { single phase; three phase.

   c. Combination alternating and direct.

2. With respect to the kind of power for current generation, as

   a. Steam;

   b. Hydraulic;

   c. Gas engine.

3. With respect to the power system, as

   a. Direct current transmission and distribution;

   b. Alternating current transmission, direct current distribution;

   c. Alternating current transmission and distribution.

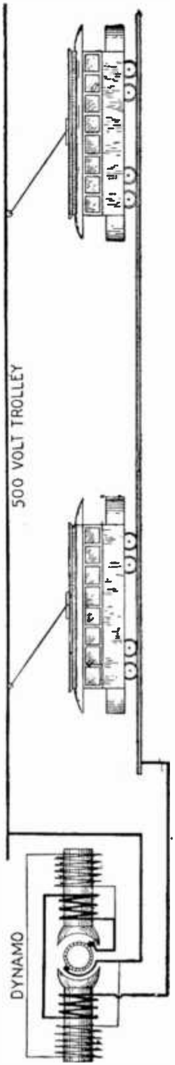


FIG. 6,103—*Direct current transmission and distribution.* The first system and the one most generally used in connection with city or short lines having a radius of 5 to 8 miles from the power house. The dynamo delivers current direct to the line at 550 volts, with the distribution system designed to deliver as nearly as possible 500 volts direct current at the motors on the cars. This system operates very satisfactorily and economically where the power is not transmitted further than mentioned above, but when it becomes necessary to extend the railway lines to greater distances into suburban districts and elsewhere, the excessive amount of copper required to transmit the power at the low voltage and maintain the proper voltage at the cars necessitates the use of *boosters* for increasing the voltage on the feeders in proportion to the demand, as shown in fig. 6,104.

4. With respect to the current collecting devices, as

- *a.* Trolley;
- *b.* Surface contact;
- *c.* Third rail;
- *d.* Conduit.

5. With respect to the location of the electrical source, as

- *a.* External { power station.
- *b.* On the car { storage battery; gas-electric plant.

6. With respect to the distribution pressure, as

- *a.* Low tension { pressures up to 600 volts.
- *b.* High tension { pressures above 600 volts.

7. With respect to the service, as

- *a.* City lines { elevated; surface; subway.
- *b.* Interurban or suburban;
- *c.* Long distance lines;
- *d.* Industrial short lines.

Direct Current Transmission and Distribution.—This system is especially well adapted for densely populated sections

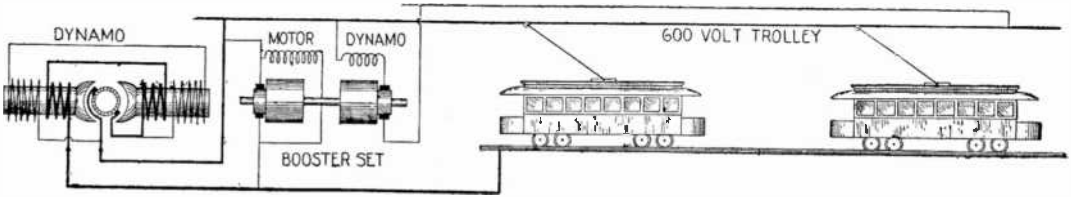


FIG. 6,104—Direct current transmission and distribution with booster. 650 volts at the dynamo, radius 7 to 15 miles from the power station. The booster, which consists, usually, of a series wound dynamo driven by an engine or a motor is connected directly in series with the feeder on which it is desired to raise the voltage. Its economy is due to the fact that the cost of the power for raising the voltage sufficiently to maintain the proper voltage at the end of the feeder is less than the interest charge on the larger amount of copper which would be required to accomplish the same result with the normal voltage loss of the system. The booster has the additional advantage, that in the case of a motor driven outfit, its loss varies substantially with the demand for current, whereas if copper were used, it would be necessary to employ a sufficient amount to take care of the maximum demand and still give normal voltage at the end of the line.

such as in large cities. It is also used on interurban and on a large percentage of the trunk line electrifications. The voltage used ranges from 500 to 3,000 volts. The lower voltage is not well adapted to the operation of roads covering large areas and is becoming obsolete, owing to the great amount of feeder copper required to transmit large amounts of energy at such low pressure.

Ques. Why is the use of boosters objectionable on these lines?

NOTE.—In addition to boosters of the motor generator type, as shown in fig. 6,104, some generating stations employ storage batteries to take care of peak loads and the sudden fluctuations of load characteristic of electric railway work. Batteries are used also in sub-stations at distant points on the system, where by means of reversible boosters, the battery is caused to take current from the power house feeder at a time when the power demand is low on the section supplied from the sub-station, thus storing up current which it subsequently delivers to the line when the power demand is heavy. In some cases the batteries are simply *floated* on the line and tend to equalize the demand and the voltage. By these means the radius of successful operation of direct current systems is extended to about 15 miles from the power house.

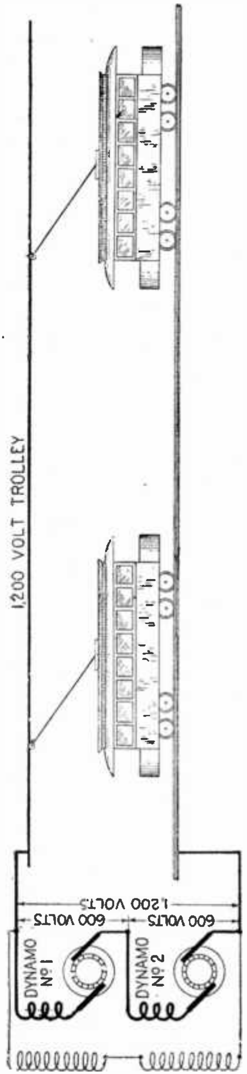


FIG. 6,105.—*Direct current transmission and distribution*; 1,200 volt two stage generation, radius 10 to 20 miles from the power station. ***The generating plant consists of*** two 600 volt dynamos operated normally in series, thus feeding into the trolley at 1,200 volts. Either 1,200 volt or 600 volt motors may be used; in the latter instance the motors are series connected in pairs. Most of the roads equipped with 1,200 volt apparatus have employed motors wound for 600 volts and insulated for 1,200 volts, two motors connected in series. When this arrangement is adopted with four motor equipments, the pairs are connected in series and parallel to give the excellent result obtained by series parallel control.

Ans. They add largely to the fuel expense.

A floating storage battery at the end of a long feeder is sometimes more expensive to install and operate than some of the other systems.

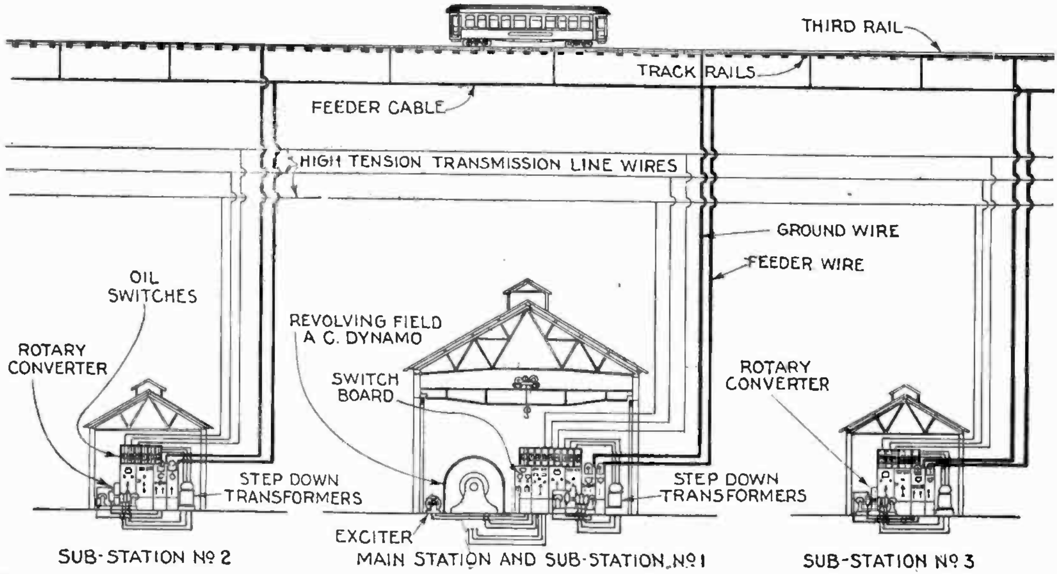
Ques. What are the standard voltages?

Ans. 600, 1,200, 1,500 and 2,400.

Ques. How are the motors operated at these various pressures?

Ans. The motors for the 600 volt system are designed for full trolley voltage. For the 1,200 volt system, both 1,200 volt and 600 volt motors are used, in the latter case, the motors are series connected in pairs. For the 2,400 volt system 1,200 volt motors are used, series connected in pairs.

Alternating Current Transmission, Direct Current Distribution. — The advantages accruing from the use of both *a.c.* and *d.c.* must be evident, thus, a



FIGS. 6,106 to 6,108.—*Alternating current transmission, direct current distribution.* The diagram shows the main station and two sub-stations with apparatus and connections to the line. In the system here shown three phase current is generated at the main station, where it passes to *step up* transformers to increase the pressure a suitable amount for economical transmission. At various points along the railway line are *sub-stations*, where the three phase current is reduced in pressure to 500 or 600 volts by *step down* transformers, and converted into direct current by rotary converters. The relatively low pressure direct current is then conveyed by *feeders* to the rails, resulting in a considerable saving in copper in moderate and long distance lines.

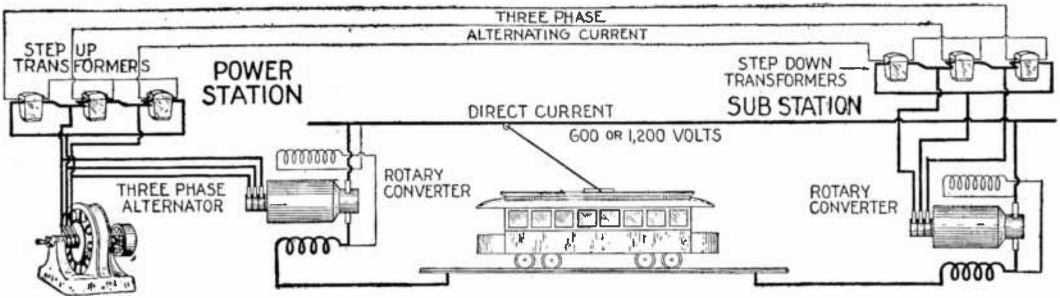


FIG. 6,109.—*Alternating current transmission, direct current distribution.* Sub-stations for 1,200 volt direct current trolley using two rotaries in series. Alternating current radius depends on the transmission voltage. ***The system shown consists of*** three phase 25 cycle alternator(s), wound for 360 to 390 volts, depending on the direct current voltage desired; step up transformers for raising the generated voltage to the voltage necessary for transmission; sub-stations each having one or more rotary converters, with each converter having a set of three step down transformers for lowering the alternating current voltage to the proper value for reception by the converter for conversion to the proper direct current voltage supplied by it to the trolley, and in some cases the installation of rotary converters in the power station, as shown, for taking current directly from the dynamos without transformation. In cases where a large amount of direct current is required near the power station, and for plants of moderate capacity where the transmission pressure is higher than 13,500 volts it is desirable to have the alternators wound for the low voltage stated; but for cases where the transmission voltage does not exceed 13,500 volts, the use of the step up transformer may be avoided by winding the alternators for the high voltage; while for cases where the units of power handled at the switchboard exceed 1,500 kilowatts it is almost essential that the generated voltage should be higher than 390 volts.

NOTE.—***The system*** shown in fig. 6,109 ***may be varied in several ways*** to satisfy special conditions, for example: 60 cycles may be used where the general lighting circuits are supplied from the same power house, and storage batteries may be installed in the sub-stations for equalizing the demand and reducing the rotary converter capacity necessary to take care of the load. The primary elements of all such installations are practically the same, however, and the sub-stations are usually placed from 10 to 15 miles apart, depending on the character of the road and the traffic.

large amount of power can be transmitted by alternating current at high voltage reducing the cost of copper to a minimum, and by means of rotary converters,

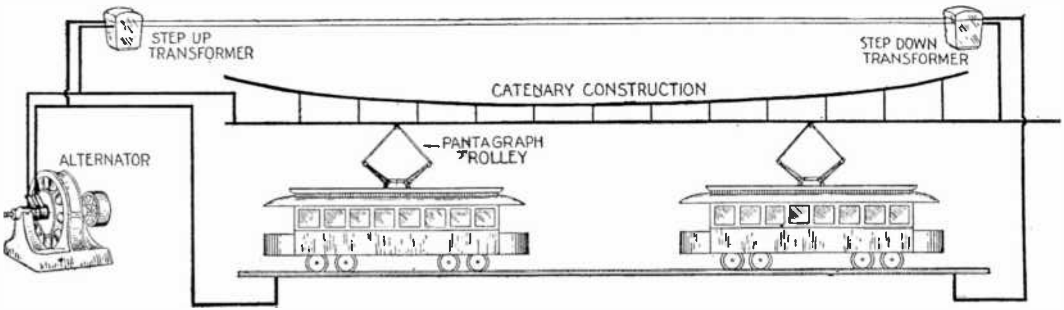


FIG. 6,110.—*Alternating current transmission and distribution*. For current supply a single phase alternator may be used, or one leg of a three phase machine. ***For short lines*** the alternator may be wound for the trolley voltage, but ***for long lines*** a high pressure machine must be used in connection with step down transformer sub-stations or a medium pressure machine with step up and step down transformer as here shown. A three phase alternator is used to advantage in cases where it is desirable to furnish polyphase current for stationary power service, one leg being used to furnish single phase current to the railway, and the two other legs to furnish current for the stationary service. Trolley voltages of 3,300, 6,600, 11,000, and as high as 13,000 are in use, but the usual pressure is 6,600 volts for ordinary trolley roads, and 11,000 for the electrification of existing steam railways.

converted into direct current of suitable working voltage for the motors at the distribution points.

Ques. Why is current generated at high voltage and then reduced to low voltage?

Ans. To cut down the cost of transmission.

Every additional car put on a line adds current consumption to that line, which means additional copper wire or cable needed. As the voltage or pressure has no bearing on the size of wire, but current or quantity (amperes) has, it can be transmitted at high voltage and low amperage, and then

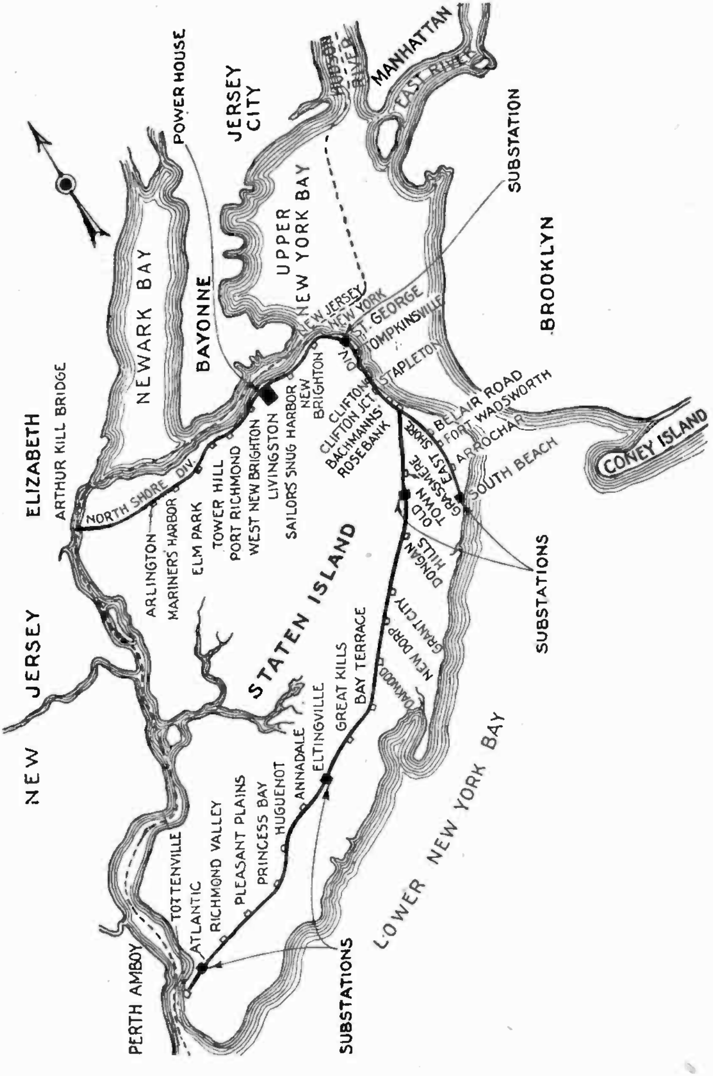


FIG. 6,111.—Map of Staten Island, showing route of electrified section of the Rapid Transit Railway Company and generating station and sub-stations along the route.

converted to low voltage and high amperage at the points where needed, requiring only short cables of large size.

Alternating Current Transmission and Distribution.—Systems employing alternating current for both transmission and distribution, may be either

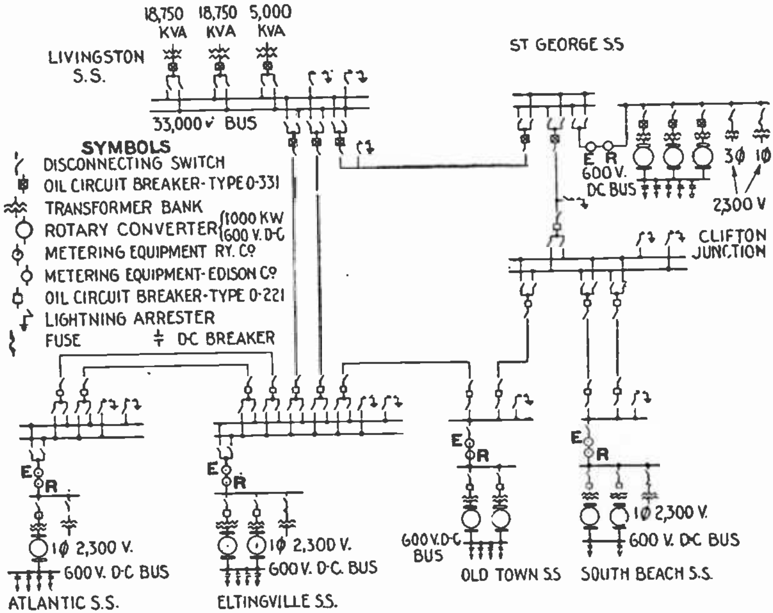
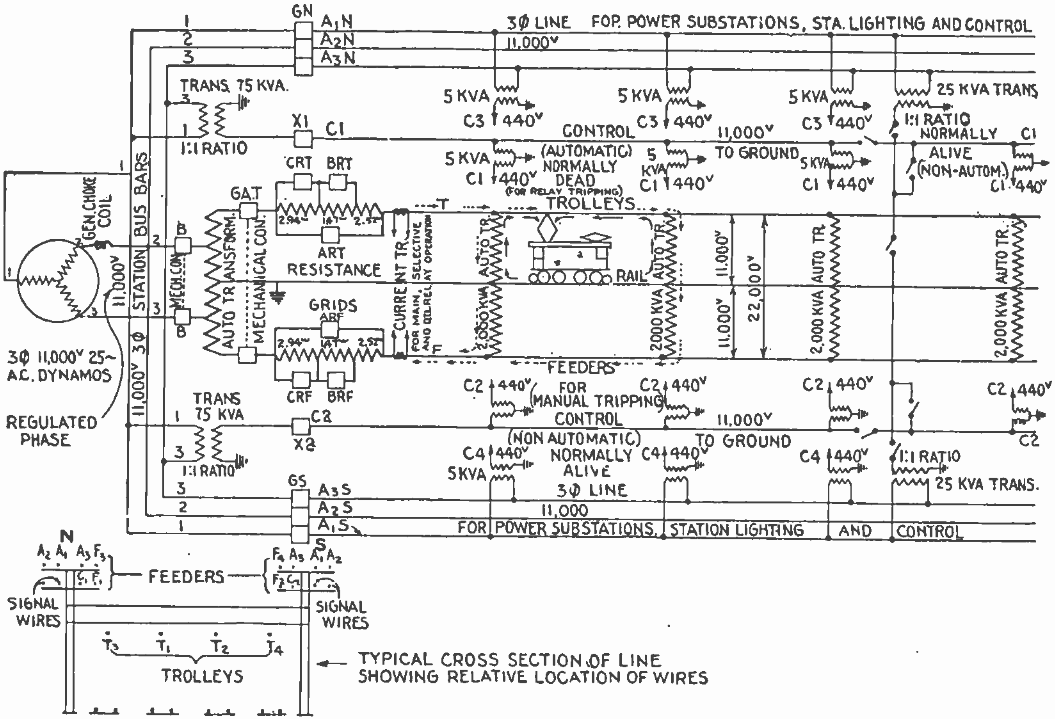


FIG. 6,112. Single line diagram of the 33,000 volt distribution system, Staten Island Railway, showing the distribution of the 33,000 volt power to the several sub-stations and the equipment it goes through for conversion to 600 volts direct current for the 3rd rails and trolleys.

1. Single phase, or
2. Three phase.

In the single phase system either series or modified repulsion, commutator type, single phase motors are used. Contact



FIGS. 6,113 and 6,114.—Schematic diagram of distribution system of New York, New Haven and Hartford Railroad, showing current limiting equipment, and auto-transformers on the electrified section. This is operated on a three wire system wherein

FIGS. 6,113 and 6,114—*Text continued.* the rails form the neutral between trolley and feeder circuits. The generation is at 11,000 volts; is stepped up to 22,000 volts for transmission, and trains operate on 11,000 volts by running between the trolley and the tracks which is one half the circuit. *Wire symbols.*—A_1-A_2-A_3, 3 ϕ line (AN,. North 3 ϕ line) (AS, South 3 ϕ line); C1, automatic control line (for relay tripping of bridge circuit breakers); C2, non-automatic control line (for manual operation of bridge circuit breakers); C3 and C4, non-automatic control (for emergency operation of bridge circuit breakers). *Circuit breaker symbols:* ARF, ART, 1,500 amp. type "E" automatic (energized by selective and main relays); BRF, BRT, CRF, CRT, 300 amp. type "E" automatic; B, 1,200 amp. type "C" non-automatic; GA.F, GA.T, 1,500 amp. type "GA" automatic (energized by main and definite time limit relays); GN, GS, 600 amp. type "G" automatic; X1, X2, 300 amp. type "E" (X1 automatic X2, non-automatic); *Operation sequence;* (For short circuit on trolley side of line). 1, main and selective relays, energized by short; 2, selective ring trips ARF; 3, ART is opened; 4, BRF and BRT, open simultaneously and X1 closes; 5, CRF and CRT, open simultaneously and X1 closes; 6, X1, energizes tripping coils of bridge circuit breakers through relays affected by short; 7, if short is severe and persistent, D.T.L. relay trips, GA breakers, removing power from line. Steps 2, 3, 4 and 5, above, throw resistance in series with the line, cutting down the current flow. Selective relay always selects the "AR" circuit breaker on opposite side of line from short, for step 2, above.

line voltages range from 3,300 to 25,000 volts. The contact line receives energy from transformer sub-stations located along the line. This system has been used only in interurban and trunk line service, the high contact line voltages being considered too dangerous for operation on city streets.

The alternators are usually wound for the trolley voltage and feed directly into the line without transformation, thus supplying the whole of the road. Where the length of the road exceeds 35 or 40 miles, it is equipped with step down transformers to lower the transmission voltage to that of the trolley. In cases where it is desirable to furnish polyphase current for stationary power service and for the operation of rotary converters, three phase alternators having one phase the full capacity are required, utilizing only one of the three phases for railway work. The cost of such installation does not differ materially from that of installations having single phase alternators.

In the three phase system the locomotives are equipped with three phase induction motors.

Two overhead contact lines are used, the track rails forming the third conductor of the three phase circuit.

Transformers on the locomotive are used to lower the contact line voltage to a value suitable for the motors where high contact line voltages are used, although for voltages up to 3,000 the transformers are often dispensed with. The contact lines receive their energy supply from transformer sub-stations, as in the single phase system.

While the great majority of railways now using electric motive power use either the direct current or the single phase systems, three phase locomotives with an aggregate rating of approximately 600,000 *h. p.* are in use at the present time, chiefly on the mountain grade railways of Italy.

Comparison of the Various Systems.—For ordinary street railway service the 600 volt direct current system is almost universally employed, but for interurban and trunk line service there is a great difference of opinion as to which of the various systems is the most economical when all the factors are taken into account. The factors which must be considered in comparing the three systems in any particular case are the following:

1. For a given weight and length of trolley or third rail the per cent. power loss for a given amount of power transmitted varies inversely as the square of the trolley or third rail voltage.

2. The higher the trolley or third rail voltage the fewer are the number of sub-stations required for the same efficiency of distribution and weight of conductor.

3. The higher the trolley or third rail voltage the more costly are the insulation and supporting structure, and also the greater is the cost of maintenance of the distribution system.

4. Both the first cost and annual expense of the sub-stations are less for the alternating current systems than for the direct current systems since, for the former, static transformers only are required, whereas, for the latter, rotary converters must be used.

5. The relatively low power factor of alternating current motors (80 to 90 per cent.) as well as the relatively low power factor of the line (due to the reactance of the trolley wire and track return) gives rise to a greater power loss in the alternating current distribution system for the same power delivered than in the case of the direct current system, and this great loss and lower power factor make necessary the employment of generating apparatus of greater kva. capacity.

6. The 600 volt direct current motor, for the same horse power rating and speed, costs less, weighs less, and occupies less space than either type of alternating current motor. The high voltage direct current motors cost more, weigh more, and occupy more space than the 600 volt type.

7. With the alternating current motors, transformers are required on the locomotives, which add to the cost and weight of the locomotive equipment.

8. The 600 volt direct current motor costs less to maintain and is liable to fewer operating troubles than any of the other motors.

9. With the commutating type of alternating current motor the power lost in the control equipment is practically negligible, since the pressure type of control can be used. For both the direct current motor and the induction motor a resistance control is necessary, with consequent loss in power.

10. The induction motor is inherently a constant speed machine, and consequently the power input varies directly as the opposing resistance. The direct current motor and the alternating current commutator motor are inherently variable speed machines, and the power input varies approximately as the square root of the opposing resistance, the speed at the same time falling off.

11. The three phase induction motor, when kept connected electrically to the source of power, automatically operates as an alternator when the train is going down grade at a speed greater than the synchronous speed of the motor, the motor thus returning power to the line and at the same time acting as a brake preventing any considerable increase in speed. *Regeneration*, as this action is called, can also be obtained with the other types of motor, but only at increased expense for the additional control equipment required.

Comparison of Current Collecting Devices.—The various methods of collecting current from the line wire are due to experience with different operating conditions. Each has features especially suited for the conditions under which it is to work.

The overhead trolley system is largely used in towns and cities.

The surface contact system may be advantageously used in some industrial works where an overhead trolley is objectionable, and a third rail is not permissible.

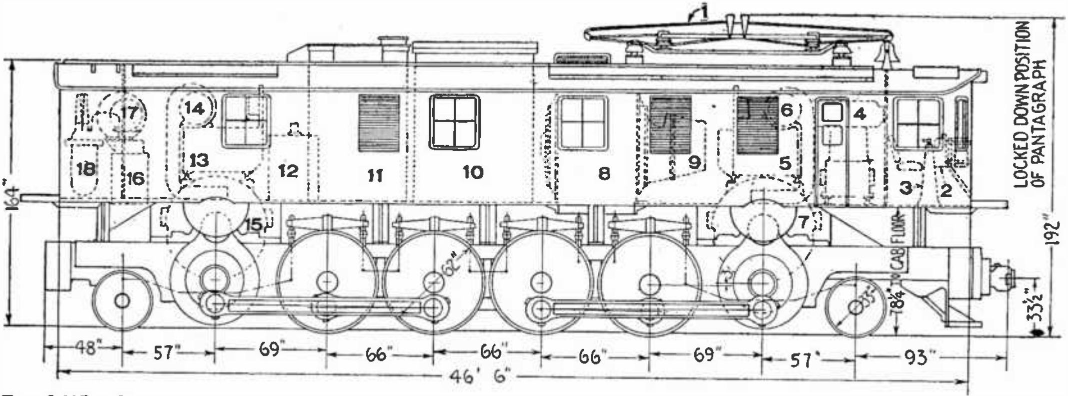


FIG. 6,115.—General arrangement of apparatus and principal dimensions of the Virginian locomotives. They are of the split phase, constant speed type with one three phase induction motor driving, through a jack shaft and side rods, two of the driving axles in each truck. Single phase, 25 cycle power at a pressure of either 11,000 or 22,000 volts is supplied to the transformer on the locomotive through a pantagraph collector. Low voltage power for the three phase traction motors and for the auxiliaries is taken from the transformer and phase converter. The traction motors are of the induction type arranged for two comparatively constant running speeds of 14 and 28 *m.p.h.* ***The parts are:*** 1, pantagraph; 2, master controller; 3, air brake valve pedestal; 4, air compressor; 5, control apparatus on traction motor; 6, traction motor blowers; 7, traction motor; 8, phase converter; 9, phase converter starting motor; 10, liquid rheostat; 11, main transformer; 12, preventive coil; 13, control apparatus on traction motor; 14, traction motor blower; 15, traction motor; 16, transformer oil cooling radiator; 17, radiator blower; 18, oil circuit breaker.

As this system can be used without poles or overhead wires, it leaves yards and buildings free from all obstructions.

The third rail system is extensively used on elevated railways, subway systems and on those roads which have a private right of way, as in the case of electrified steam roads, which operate heavy trains at high speed.

By means of the third rail it is possible to successfully deliver to the cars much heavier currents, and to operate the cars safely at higher speeds than is possible with the ordinary type of overhead or underground trolley construction, two important features which serve to greatly expand the field of application of the 500 volt direct current motor.

The underground trolley or conduit system is used in the streets of large cities where the use of overhead trolley wires is objectionable, but the cost of construction is very great.

The underground trolley system differs from the overhead trolley in that it has a metallic circuit (two insulated conductors) while the overhead trolley has a ground return, that is to say, the track rails which are not insulated from the ground are used as the return.

Source of Power.—On main lines the current is generated in a power station and fed direct to the line at various points or to sub-stations where it is stepped down to the proper voltage for distribution to the lines. However, on branch lines having light traffic it has been found more economical to employ separate power units on the car, this system being known as gas electric drive is fully described in another chapter.

Single Phase System.—Almost since the early days of light electric traction, the problem of heavy electric traction has been given much thought. In the earlier considerations, the principal difficulty was supposed to lie in the ability of the manufacturers to produce sufficiently powerful equipment. However, it was not long before more serious difficulties presented themselves and some of these are with us even to the present day.

With direct current generation and distribution for 550 to 600 volts which was the accepted standard, railway engineers were confronted with the problem of transmitting large units of power for considerable distances.

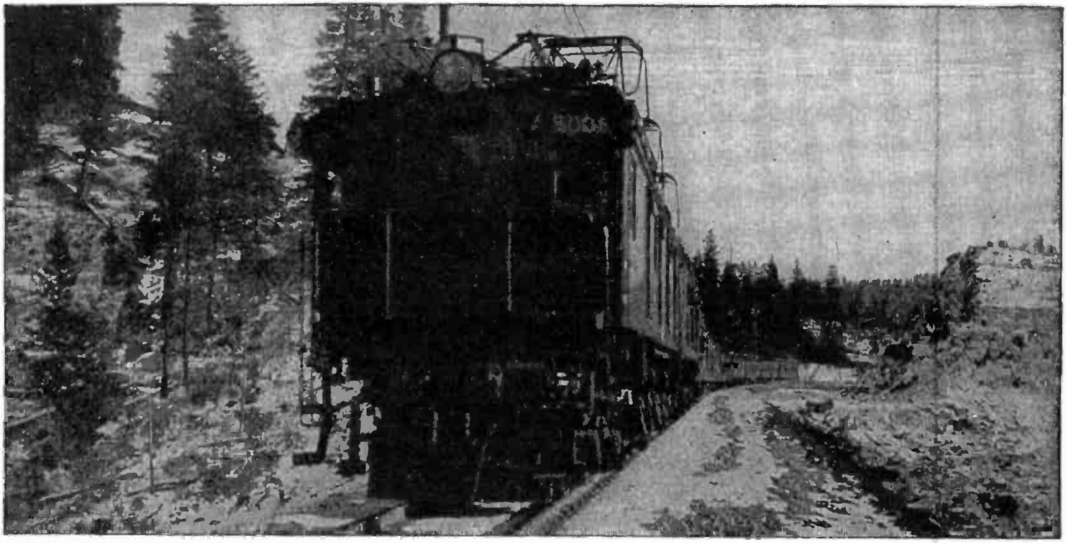


FIG. 6,116.—Two Baldwin-Westinghouse single phase motor generator type locomotives in service on the Great Northern Railway.

This meant closely spaced power supply stations and, with direct current generation, this implied subdivision of the power supply into a number of separate units, which was in opposition to the growing tendency to concentrate the power generation into large central stations. In other words, this was in the direction of subdivision instead of centralization.

A second serious difficulty was in supplying this power to a moving locomotive or train.

With low voltage and large power the collection and handling of the current was then, and still is, a serious problem.

With these two conditions encountered, heavy railway electrification was practically at a standstill, and, in the minds of those who knew, there seemed but little promise for future railway electrification on a large scale.

It is true that a number of attempts were made to build electric locomotives in the early days, but these were mostly by those who were familiar with the traction problem only and who had but little or no experience with the generation and transmission problems.

The rotary converter presented a solution of one of the difficulties for by means of polyphase *a.c.* generation and distribution at high voltage, and conversion to *d.c.* through distributed sub-stations, the problem of centralization of the power stations was accomplished. However, the problem of collection and handling of the low voltage current was still to be met, so that the rotary converter only partially solved the heavy railway problem.

Another step, however, represented a very material advance, namely, the development of the third rail.

This permitted relatively high amounts of current to be transmitted from the sub-station to the moving vehicles, and thus it appeared, for a while, to solve the second part of the heavy railway problem. In consequence, after the development of the rotary converter and the advent of the third rail, the heavier work went forward by leaps and bounds. However, it may be noted that this was only where traffic was very heavy, such as for elevated and subway service in the larger cities, for city terminals, suburban railway service, etc.

As soon as application of the third rail and the rotary converter system began to be considered in connection with longer lines, with infrequent service, the limitations of this arrangement began to be apparent, these being largely of a financial nature.

In other words, while it would be possible, from an engineering standpoint, to build and operate successfully a long main line railway by means of rotary converters and the 600 volt third rail system, yet the figures showed most positively that the first cost and the operating expense would render such an arrangement unprofitable. Thus, the rotary converter and third rail solution of the problem was not a general one and applied only to isolated cases where the traffic was very heavy and the service very frequent, or where there was some serious limitation to the use of steam, necessitating either the abandonment of the steam locomotive altogether, or an excessive expense in some form due to its retention.

The well known Zossen experiments in Germany with a three phase, high voltage trolley system, with induction motors, attracted a great deal of attention, all out of proportion to the true value of the results.

This was a very spectacular undertaking and indirectly had a bearing on the future railway work.

High Voltage Necessary for Heavy Electric Traction.—Owing to the amount of energy required in heavy traction, obviously a high voltage is necessary to reduce the amount of current required and in turn the amount of copper. With *a.c.* it was easy enough to meet the high voltage, but there were other limitations.

In the three phase traction system, as brought out by the Ganz Company in Europe, three phase motors of large power could be used, but there was the handicap of two overhead wires at different voltages, thus involving a double collection of current.

Moreover, this system was apparently limited to about 3,000 or 4,000 volts and if one were to use *a. c.* at all, there should be no such limitation in the voltage. Furthermore, for lighter service, involving relatively small motors, the polyphase induction motor did not seem to furnish a very satisfactory solution of the traction problem.

Direct current was recognized, even at this time, as a possible solution, provided very materially higher voltages than 600 could be used, but almost everybody had doubts as to the practicability of sufficiently high voltage, either on the dynamos or on the motor equipment. Thus much thought was given to the possibilities of single phase, alternating current, for here one could use the single overhead trolley with the voltage limitations very largely removed. However, engineers were faced by the fact that there was as yet no suitable single phase motor available.

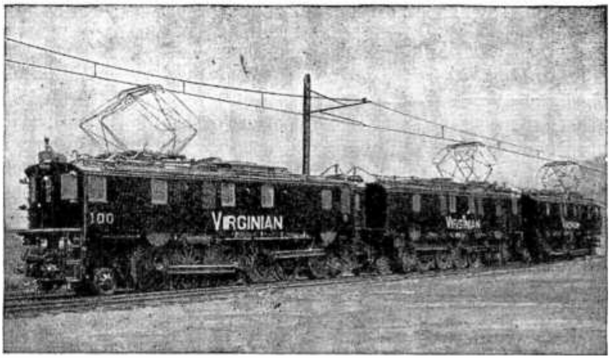


FIG. 6,117.—Westinghouse equipped, single phase, 215 ton motive power units as used on Virginian Railway.

Experiments resulted in a series type single phase motor with commutator, resembling in characteristics the series type direct current motor. It had been recognized for years that the variable speed characteristics of the series type motor were ideal for traction service and thus in attempting this new solution of the railway problem, engineers attempted to retain the fundamental characteristics of the existing *d.c.* system.

The single phase commutator type railway motor, although it is not as economical or efficient as the *d.c.* motor, has the advantages of simplicity and economy of the transmission system, together with the more economical speed control.

From the speed control standpoint, the single phase system was far ahead of the direct current, for the flexibility of the alternating current system allowed voltage variations for controlling the motor speed, without the use of regulating rheostats for absorbing the extra voltage and power. Here was considered one of the major advantages, especially for locomotive work.

Within a few years it developed that the single phase system was not a satisfactory alternative to the existing direct current system in general, but that it had its own field, and this field was where the special characteristics and advantages of high trolley voltages would apply. In other words, the single phase system really began where the existing direct current system was handicapped by trolley limitations.

While there were at first some misapplications of the single phase system, due largely to over enthusiasm, yet within a very few years it began to be applied to heavy service and in all such installations it has persisted, and not only persisted, but has enlarged its field. One of the first systems to adopt this was the St. Clair Tunnel under the Detroit River, which was initiated about 1906. This electrification was necessitated on account of the smoke problem. The equipment consisted entirely of slow speed locomotives and the first locomotives installed are still in use with a most remarkable record of reliability and low maintenance cost.

One of the principal requirements of this system was that any locomotive must come up against its load with full load, or even overload torque for a period as long as five minutes. At that time, this was a prohibitive condition for the single phase commutator type motor, and, therefore, the three phase

NOTE.—***The Norfolk and Western Railroad*** uses three phase motors. In electrifying its Road, the Norfolk and Western system on the mountain grades in West Virginia encountered the problem of carrying heavy loads up a steep grade and letting them down on the other side. In other words, to some extent, it represented a hoisting problem. There were certain conditions presented from the operating standpoint which seemed to be met better by the induction motor than by any other type. However, the induction motor would not operate from the single phase contact line and the polyphase system was not applicable on account of the complication of trolleys and the difficulties of high voltage. Consequently, a modification of the single phase system was used in which single phase current was supplied to the locomotive and was there converted to polyphase current by means of a "phase splitter" or "phase converter."

seemed to be the most practicable solution. The Norfolk and Western installation, therefore, simply represents one of the modifications of the single phase system in general.

Subsequent orders for locomotives for the Norfolk and Western were filled with locomotive equipments more powerful than the original and with improved auxiliary equipment. This has resulted in an improvement in the line power factor and in consequence an improved regulation of trolley voltage is obtained.

TEST QUESTIONS

1. *Give classification of electric railway systems.*
2. *Why are boosters objectionable on* d.c. *transmission and distribution systems?*
3. *What are the standard* d.c. *voltages?*
4. *Why is current used at low voltage on* d.c. *systems?*
5. *What type motors are used for single phase systems?*
6. *Give a comparison of the various systems.*
7. *Where is the overhead trolley system largely used?*
8. *For what service is the third rail system especially adapted?*
9. *Where is the underground trolley used?*
10. *Where is the current generated for main lines?*
11. *How is the current obtained for branch lines?*
12. *For what service is high voltage necessary and why?*
13. *Why is high voltage objectionable on commutator motors?*

14. *Is a single phase commutator motor as efficient as a* d.c. *motor?*
15. *What advantages has the single phase system over the* d.c. *system?*
16. *What kind of motors are used on the Norfolk and Western Railway electrification?*

CHAPTER 131

Gas Electric Bus Drive

During the last ten years there has been a rapidly growing demand for some flexible means of transportation to handle traffic which lies away from established routes or which has become too great for the existing systems. The satisfactory manner in which the motor bus is meeting this demand is shown by the fact that in this period the number of motor buses in transportation service in the United States has grown from almost nothing to approximately 95,000. This comparatively new type of vehicle is being used extensively, not only to form new systems, but also to extend systems that have been in operation for many years.

From the time when motor buses were introduced into the transportation field, operators have been confronted with the problem of finding a flexible and automatic means of converting the constant torque of the gasoline engine into speed and tractive effort at the rear wheels. Many difficulties were experienced with the use of the conventional transmission gears and clutch.

Comparison of Gear Shift and Electric Drive.—With the gear shift, the time lost in gear shifting as compared with the quick acceleration of the electric motor, is appreciable. Moreover, during this time, the gasoline engine is doing no useful work. A third objectionable feature of the gear shift is that the uneven application of power due to gear shifting causes excessive strains in all parts of the vehicle. This shortens the life of the entire coach; increases the maintenance costs and lastly the uneven acceleration adds to the discomfort of the passengers.

The gas electric bus drive is *a substitute for the clutch, transmission and differential of the gas direct drive.* As already explained, this substitution is to obtain rapid and even acceleration and flexibility.

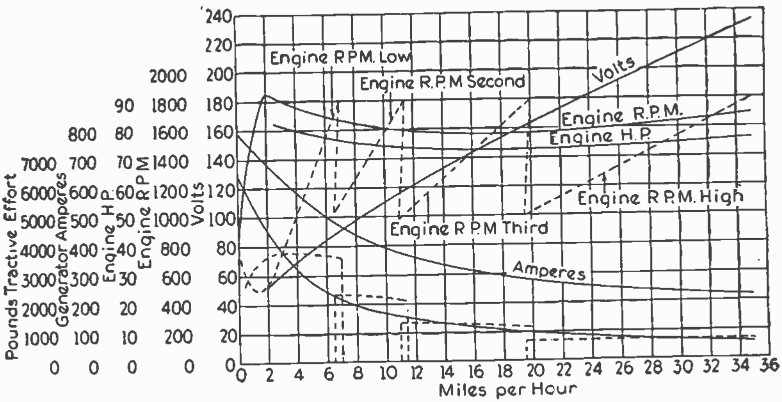


Fig. 6,118.—Comparison of characteristics of gas electric and mechanical drives. The curves show engine characteristics and tractive effort at the rim of the wheels, obtained with a typical gas electric drive application, compared with that of a mechanical drive bus equipped with a prime mover of the same capacity.

Gas Electric Power Plant.—The gas electric drive consists of *gas engine, dynamo, controller and one or more motors.*

With this outfit, the operator has no clutch to pedal, and has no gears to shift, but obtains acceleration merely by depressing a pedal; this is of importance to him because it vitally affects the two most costly phases of operating expense, namely, labor costs and accidents. These advantages offset the additional fuel which may be necessary to carry the additional weight of the electrical apparatus.

A gain in rapidity of acceleration means a gain in speed, and a gain in speed means a reduction in the cost of wages per mile, due to getting more miles for an hour of driver's time.

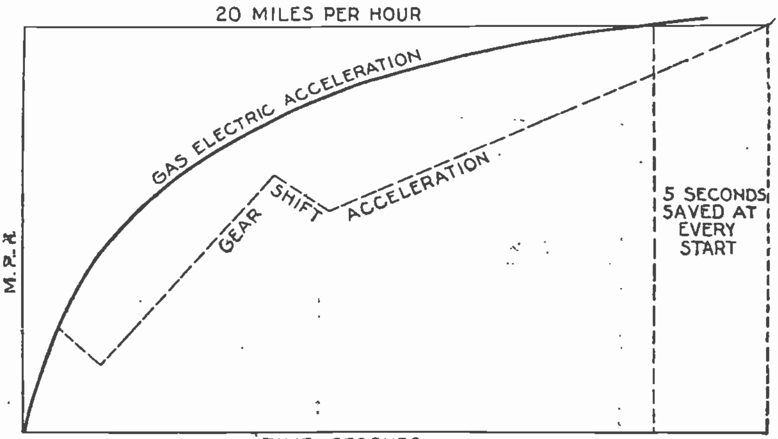


FIG. 6,119.—Comparative acceleration curves for gas electric and gear shift drives.

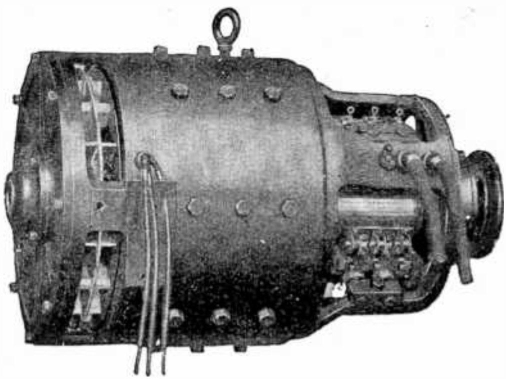
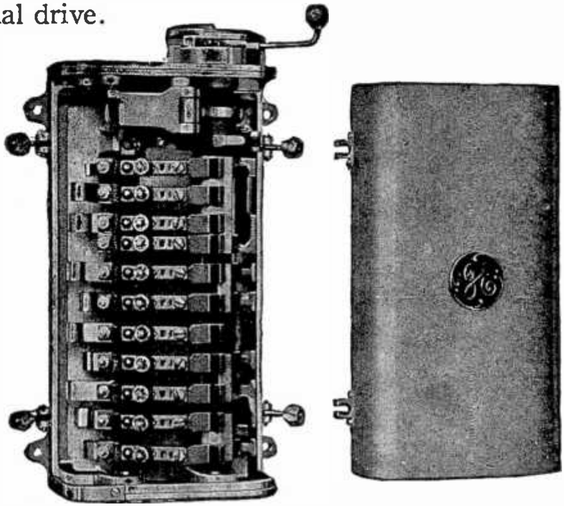


FIG. 6,120.—General Electric dynamo for gas electric drive; covers removed.

The vehicle with the electric drive starts off and continues up to its crest speed with a gradually increasing torque, and without at any time putting a severe strain on any part of the mechanism. This is the nearest approach to the flexibility of steam power.

There are two types of drive in general use, classed as

1. Single motor drive;
2. Dual drive.



FIGS. 6,121 and 6,122.—General Electric controller for double motor gas electric drive.

The advantages of these two types are as follows:

Single Motor Drive

1. The equipment is lighter in weight and has a lower first cost.
2. It permits the use of standard rear axles.
3. Any chassis can be more readily adapted to electric drive of this type.

Dual Drive

1. The differential is eliminated, thus reducing the chance of wheel slippage and skidding.
2. Better clearance is afforded below the motors for a given floor height.
3. Operation with one motor is possible in emergencies.

Fig. 6,124 shows assembly of chassis and power plant of the single motor type, and fig. 6,125 the double drive type. Other details are shown in the accompanying illustrations.

Maintenance of Gasoline-Electric Buses.—Although gas electric drive eliminates those destructive forces which characterize the ordinary mechanical drive, regular inspection and thorough periodic overhauling are necessary for satisfactory operation. An important test is the engine test.

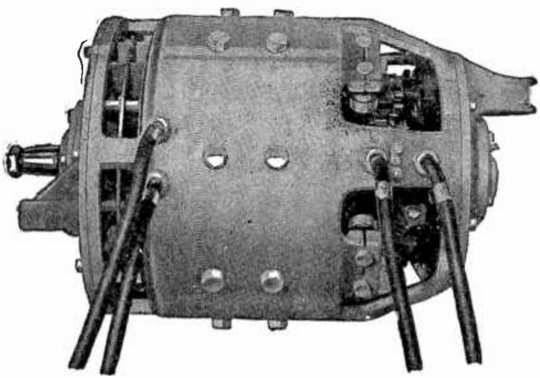


FIG. 6,123.—General Electric motor for gas electric double motor drive.

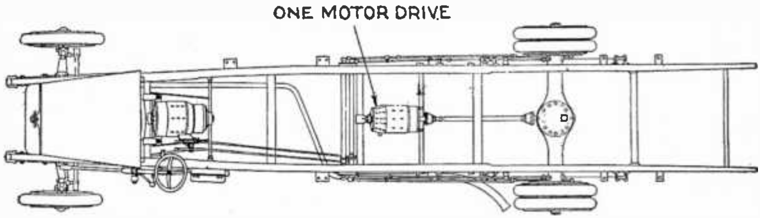
To make this test, connect the dynamo with a water rheostat, and read the meter,—volts and amperes, at various speeds. Compare with the original test chart which provides a definite indication of the power plant's condition. The effect of every change or adjustment is immediately visible in electric output.

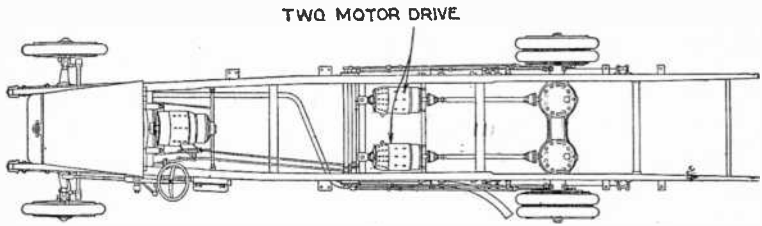
A further check will be made by keeping an accurate record of the gas consumption for each bus.

When a bus shows a reduced number of *kw*. hours per gallon of gasoline it is a definite indication that the engine or dynamo should be inspected.

1,000 Mile Inspection.—After each 1,000 miles of service each part of the vehicle should be inspected, and all wheel bearings and wearing parts lubricated.

The commutators of dynamos and motors should be tested for loose bars or high mica, the brushes checked for wear and free movement in the brush-holder.





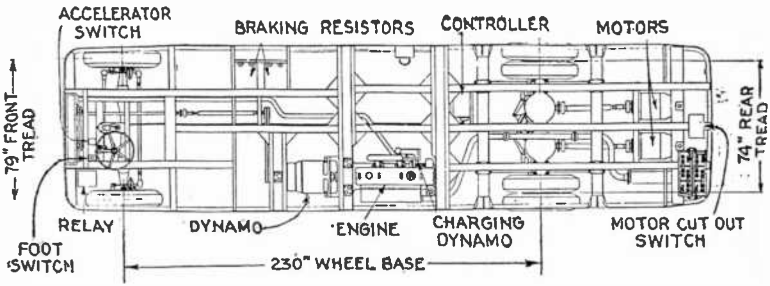
FIGS. 6,124 and 6,125.—Bus chassis with single motor gas electric drive and with double motor gas electric drive.

Controller, relay and accelerator switch should be inspected for burned contact fingers and the necessary adjustment made. The braking resistor should be checked for broken grids.

This entire inspection should take from two to four man-hours, of which time one-half hour of this time should be devoted to the electrical equipment.

2,000 Mile Inspection.—The 2,000 mile inspection should cover a more rigid survey of the mechanical portions of the vehicle with the viewpoint of replacing abnormally worn or defective parts. In addition to the oiling and greasing done at 1,000 miles, the oil in the engine crank case should be changed.

At this time the electrical equipment should be inspected as at 1,000 miles and in addition dynamos and motors should be inspected for proper brush spring tension. Any road dirt or dust that has collected inside the machines should be blown out with dry compressed air and bearings checked for noise.



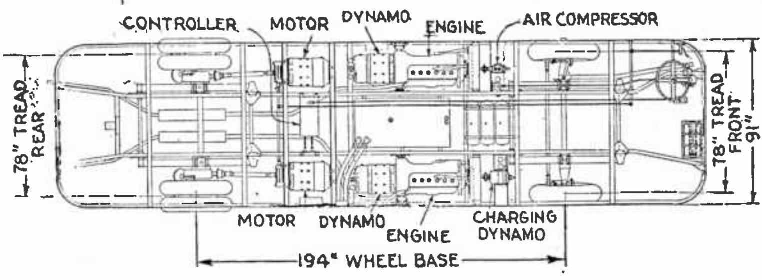


Fig. 6,126.—Equipment layout of 40 passenger single power plant gas electric coach.

Fig. 6,127.—Equipment layout of 40 passenger dual power plant, gas electric coach.

The controller, relay and accelerator switch finger pressure should be checked and adjusted if necessary.

The complete inspection should take from five to seven man-hours. Approximately one hour should be spent on the electrical equipment.

30,000 Mile Inspection.—After 30,000 miles of service it has been found economical to include certain maintenance work on the vehicle in addition to the regular inspections previously outlined. This work is usually done in the regular

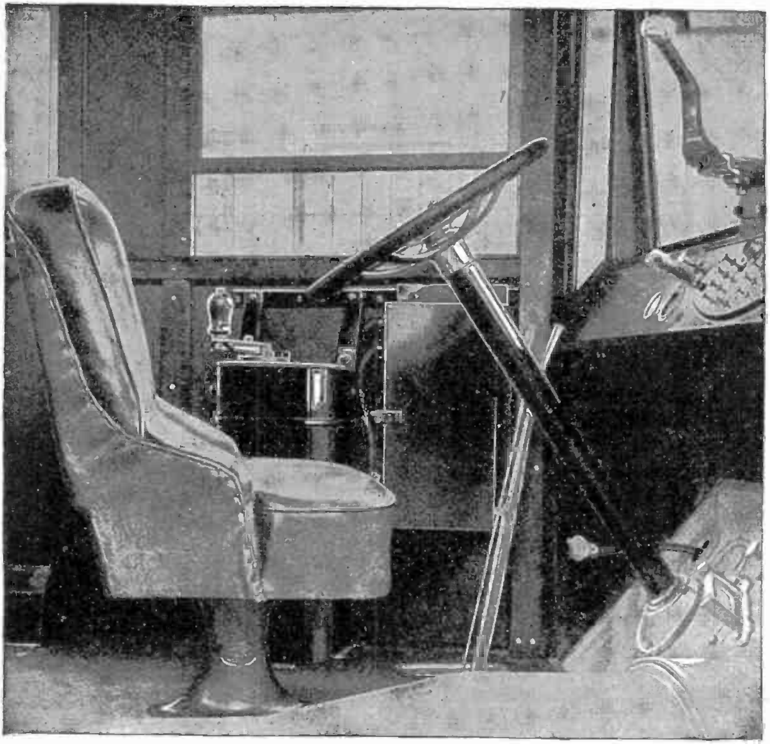


Fig. 6,128.—Interior view of General Electric gas electric drive bus showing dash and control. In addition to the regular pedal operated service brake and a hand lever emergency brake, this drive has an electric brake operated by a controller handle. On long, steep grades this method saves wear on brake bands and provides a positive uniform retarding force against which the bus cannot get out of control. It is also available as an emergency brake under any operating condition.

inspection garage although the electrical units are not usually removed from the chassis. At this time the gasoline engine is completely overhauled and other mechanical portions of the chassis are checked for wear and replaced if necessary.

In addition to repeating the work done on the electrical equipment at the 1,000 and 2,000 mile inspections, it may be found necessary in the case of the earlier types of equipment, to remove the dynamos from the chassis and turn down and under cut the commutators.

This inspection should take from ten to twelve man-hours, about two hours of which should be spent on the electrical equipment.

Unit Overhaul Periods.—In addition to the regular inspection periods outlined, it is almost universal practice among gasoline electric motor bus operators to establish a regular unit overhaul period at which time each individual unit is disassembled, checked for wear and repaired or renewed if necessary.

The length of service between these overhaul periods varies with the class of operation, but a good average figure is 100,000 miles. At this time all electrical units should be removed from the chassis.

Motors and dynamos should be completely disassembled and each part thoroughly cleaned. All armatures and field coils should be dipped in a good insulating varnish and thoroughly baked. The commutator should be tightened, turned down and undercut. Ball bearings on all electrical machines should be checked for worn or cracked balls, and replaced if defective. Brush holder boxes should be checked for wear.

Before reassembling the dynamo and motors each individual part should be given a high voltage test of twice the normal voltage and after assembling, each complete machine should be given a similar high voltage test. The main controller should be thoroughly cleaned and all burned spots on the drum should be dressed with a fine file. Fingers that show signs of heating or burning should be replaced. When work is completed on the controller it should be given the high voltage test recommended for the armatures. The contacts, fingers, and springs of the relay and accelerator switch should be replaced. The braking resistors should be checked for broken grids and given the high potential test recommended for the motors and dynamos.

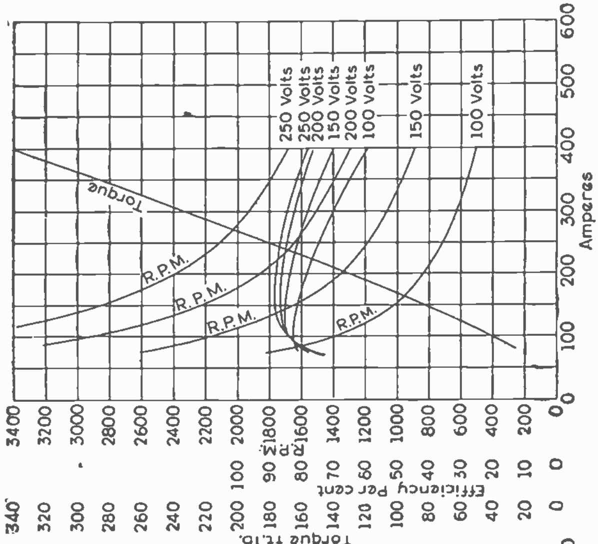
This entire procedure so far as the electrical equipment is concerned should consume from 20 to 30 man-hours. The time taken for doing all of the overhaul work is approximately eight working days.

After the vehicle has been overhauled it should be in first class condition for another 100,000 miles of service with the intervening inspection periods as above outlined. The question of body painting has purposely been excluded as this item is subject to the desires of the particular operator involved. The number of men necessary to carry out the inspection and maintenance schedule outlined will, of course, depend on the garage facilities available and the number of vehicles operated.

A survey of the operation of 1,400 gasoline electric motor buses covering a number of properties of different sizes has shown that 3.5 vehicles per garage employee is a fairly good average figure for carrying out this work. This includes garage foremen and assistants, mechanics and helpers, electricians and helpers, carpenters, gassers and oilers, greasers and stock room employees. An attempt was made during this survey to determine the ratio of electricians per vehicle operated, but it was found that this was impossible due to the variation in the system of rating employees used by different carriers.

TEST QUESTIONS

1. *What is understood by the term "gas electric drive" for buses?*
2. *Give a comparison of gear shift and electric drive.*
3. *For what is the gas electric bus drive a substitute?*
4. *Of what does the gas electric power plant consist?*
5. *Is acceleration quicker with the gas electric drive than with the gear shift drive?*



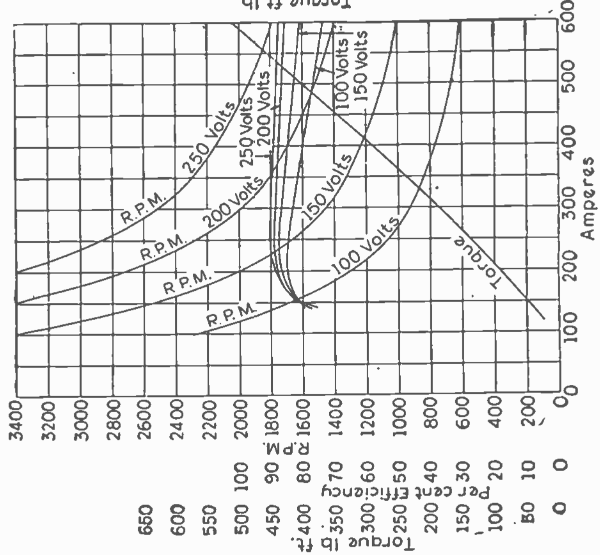


FIG. 6,129.—Characteristic curves of General Electric single motor for gas electric drive.

FIG. 6,130.—Characteristic curves of General Electric double motor for gas electric drive.

6. *What two types of gas electric drive are in general use?*
7. *Give a comparison of the two types of gas electric drive.*
8. *How is the engine test made of a gas electric power plant?*
9. *When a bus shows a reduced number of* kw. *hours per gallon of gasoline, what does it indicate?*
10. *Describe the* 1,000 *mile inspection.*
11. *What should the* 2,000 *mile inspection cover?*
12. *How much time is required for a* 2,000 *mile inspection?*
13. *What should be included in a* 30,000 *mile inspection?*
14. *When should a unit overhaul be made?*
15. *Describe fully what should be done in a unit overhaul.*

CHAPTER 132

Gas Electric Railway Cars

One of the most difficult problems facing the railroads is the operation of the light traffic and branch line trains. With modern highways paralleling the railroads throughout the country, the competition of automobiles, motor buses, and trucks has resulted in a heavy loss of business. This is a problem which requires a double solution; first, the reduction of operating costs; second, the increase of revenue from passenger and freight traffic.

The principal operating costs, wages, fuel, maintenance and terminal expenses, cannot be reduced materially with steam operation; nor is it profitable to replace the old rolling stock with new, modern cars to attract passengers.

The solution of the problem lies in the operation of gas electric railway cars.

Many railroads have decided on this form of transportation and have inaugurated programs for a complete adoption of these cars for light traffic service. It has been demonstrated that operating and maintenance costs are materially decreased because of lower cost of fuel, reduced engine and train crews, increased availability and simplicity of the entire equipment. It has also been found that passengers are attracted by the cleanliness and smooth riding qualities of this type of car.

Gas electric cars are in service in all parts of the country and are handling light traffic runs with mileage up to 400 miles per day.

They are operated usually in two car trains, handling a light passenger or combination baggage car. The engine equipment varies in horse power from 135 to 400, and some cars have two engines. The power available in such cases varies from 240 to 800 *h.p.*

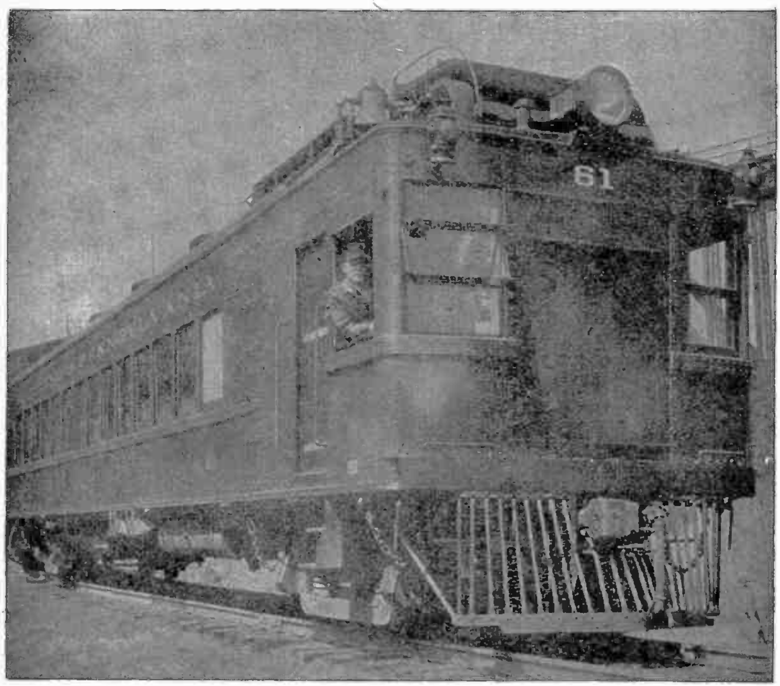


FIG. 6,131.—General Electric all passenger gas electric railway car used on the Maryland and Pennsylvania Railroad.

General Description.—Gas electric railway cars are made for all types of service. They range from the 75 foot car with engine, postal, express, baggage, smoking and passenger compartments, to the 40 foot power unit with larger engines and small baggage space, as well as lighter cars with small power

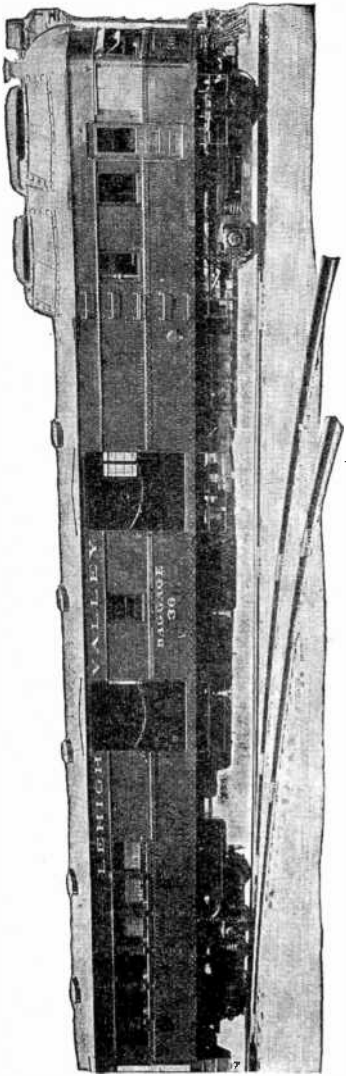


FIG. 6,132.—General Electric combination car with baggage and passenger compartments.

units for special light service. Most of these cars have an installed engine capacity ranging from 200 to 800 horse power.

The service handled in the majority of cases requires a motor car and a 35 ton trail car, which is usually a light passenger, baggage, or combination car.

Many standard sizes of power plant equipment, ranging from 135 to 800 horse power are available.

Some railroads prefer a single, large engine unit, whereas others prefer two smaller equipments in one car. Many cars have two large engine units for heavy service. The most popular, however, is the 275 horse power car.

The larger cars handle several coaches, depending upon the character of the service and the profile of the road. The trend is toward larger engines and equipments. The single car train, with a 225 horse power engine equipment, weighs approximately 42 tons with an average load of passengers and baggage.

A two car train with a 35 ton trailer weighs approximately 77 tons. Cars with 275 horse power engines have an average weight of 50 tons, and with a 35 ton trailer, can handle heavier schedules than a smaller car. The usual gear ratio recommended for this class of service is suitable for operation at a maximum car speed of 60 miles per hour under full power. Gear ratios may be selected from special service and train weight to meet local conditions of tonnage and grade.

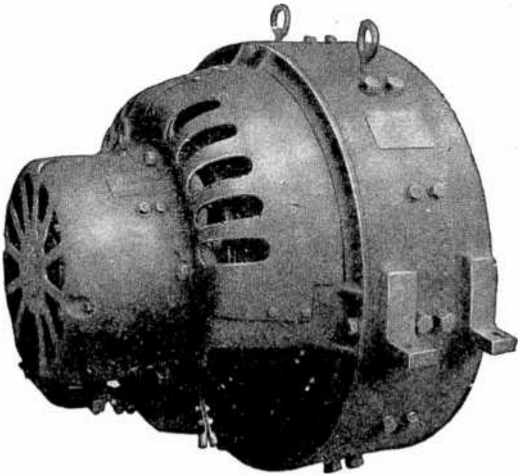


FIG. 6,133.—General Electric dynamo with direct connected exciter.

NOTE.—*The gas electric car* is considered by some to be a piece of electrical equipment with an incidental engine and car body, by others as an engine with an incidental car body and electric transmission equipment, and still by others as a car with an incidental motive power equipment. These points of view are taken by the several contributing manufacturers of the gas electric motor car. Some railroad operators have tried to assemble parts from different concerns into an old railroad coach and have it operate successfully as a rail car. These people can testify as to the importance of purchasing a finished motor car in which all the various functions have been properly engineered into the finished product. It is difficult to take an engine, dynamo and traction motor without careful study and engineering knowledge and make them work properly and economically in a smooth and reliable manner. Recent years have resulted not only in the development of modern rail cars, but in the development of recognized expert motor car builders.

Some builders have adopted crosswise mounting of the power plant as standard.

This requires an engine room approximately 8 feet long for a single unit and 14 feet for a double unit power plant. Other car builders install the engine lengthwise in a compartment 12 feet to 14 feet long.

The weights of the motor car trains vary from 30 tons for one car to 195

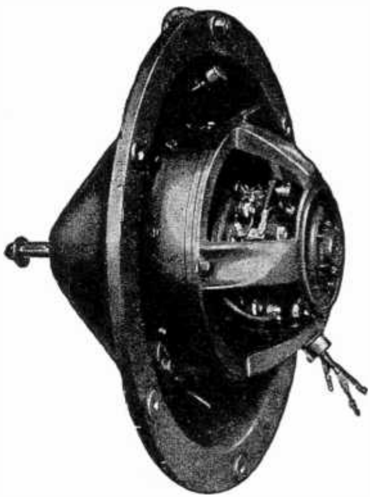


FIG. 6,134.—General Electric radiator fan motor equipped for vertical or horizontal mounting. Many car builders require a forced ventilated engine radiator to maintain proper cooling water temperatures. The motor is controlled by the motor car engine man, and turned on and off in accordance with the water temperature gauge on the engine.

tons for three or four cars. The car horse power varies under these conditions from 135 to 800, with a corresponding horse power per ton of from 5.35 to 3.14.

Engines.—Electric transmission equipments are used with engines which have been designed especially for railway use. These engines operate at moderate speeds with economical fuel consumption and are easily maintained at a minimum cost.

The engines are usually started from a storage battery by means of a series winding on the dynamo. A few use a starting motor and a ring gear on the fly wheel, while many have the additional feature of compressed air starting from the air brake system through a distributing valve on the engine.

Dynamos.—These are designed to give full engine output consistent with minimum size and weight throughout the operating range of the car. A typical dynamo is shown in fig. 6,133.

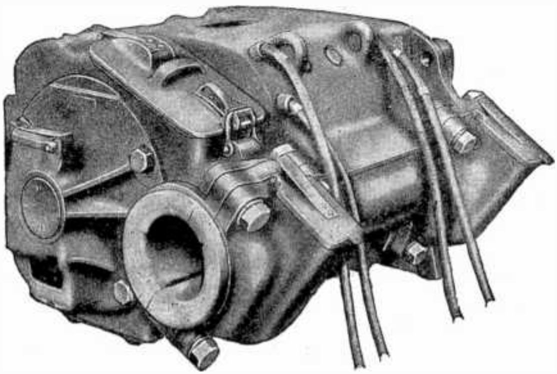


Fig. 6,135.—General Electric truck mounted driving motor, axle side.

The engine builder usually supplies the flexible coupling between the engine and dynamo. This coupling absorbs the harmonic vibrations of the crank shaft, and protects the set from stresses caused by slight misalignment.

The dynamo conforms to the requirements of standard railway service in construction, insulation, finish of parts, and bolt fastenings. The dynamo is so designed that it has a characteristic which is inherent and gives an output curve which automatically follows that of the engine throughout the normal operating range of the car. This characteristic, combined with the governor characteristic of the engine, results in the maximum utilization of power and in the operation of the engine at its normal capacity with the least possible complication of equipment.

Power for the dynamo field is supplied by a direct connected exciter, the magnet frame of which is supported on the dynamo bearing bracket.

Motors.—The driving motors, shown in figs. 6,135 and 6,136, are carried on the car truck and connected to the axle by spur gearing in accordance with well established practice. One side of the motor is carried by the car axle, and the other is supported on the truck transom by a spring nose suspension. This method of support reduces vibration and shock to the

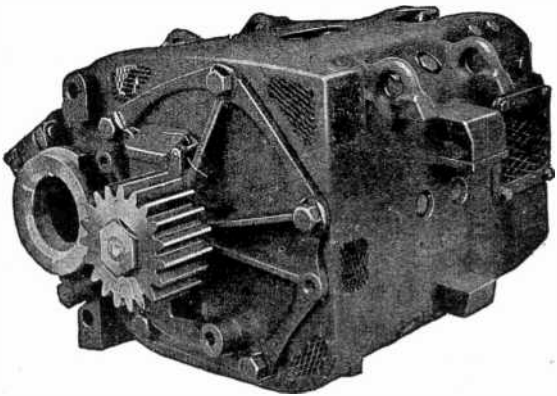


FIG. 6,136.—General Electric truck mounted driving motor. suspension side.

motors, caused by switches, frogs and irregularities in the tracks. This is particularly important on branch lines where the track is often less carefully maintained than on the main line.

The motors have a high output consistent with light weight. and are capable of operation under the varying characteristic of the dynamo power. Among the most popular of these motors are the 150 horse power for cars up to 300 horse power and the 220 horse power motor for the larger cars. They are particularly designed to match the dynamo characteristics and to give the best efficiency. Reduced field operation of the motor is provided at the higher car speeds. This method of operation is necessary in order to obtain the greater outputs at the higher speeds and still retain the compact design.

Control Equipment.—For gas electric cars, control equipment consists of a switch gear and cable through which power is supplied from the dynamo to the motors. It provides a

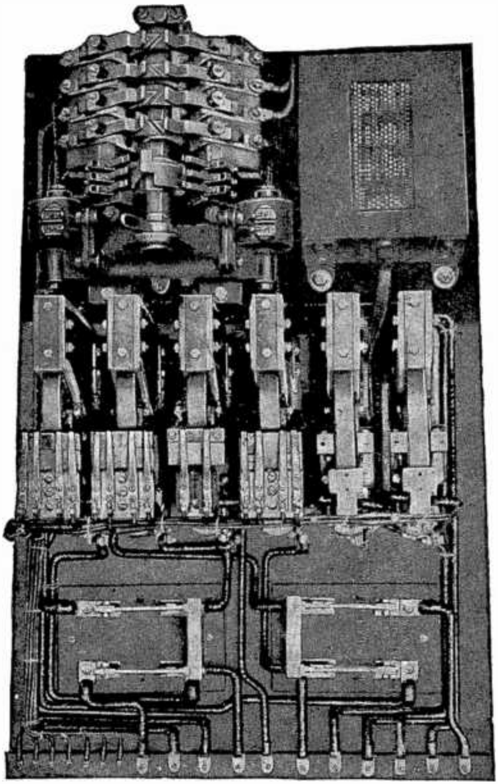


FIG. 6,137.—General Electric high voltage remote contactor control. This equipment includes a master controller with contactor and reverser panels, as well as the auxiliary switches and battery charging equipment. Remote contactor control is well adapted to double power plant and double equipment. The pneumatic type of remote control is actuated by air from the brake system with magnetic valves operated from the master controller. The magnetic type of control consists of the usual contactors, which are operated directly from the master controller.

means of connecting the motors in series and parallel combinations for the best car operation.

This control is not to be confused with the differential field control of the dynamo, which is inherent and regulates the power output.

Either direct drum control or remote contactor control may be used.

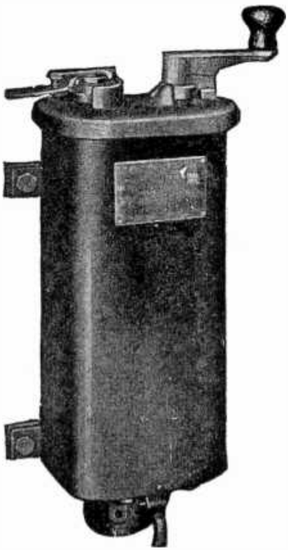


FIG. 6,138.—General Electric master co ıtroller for remote control.

FIG. 6,139.—General Electric direct dru n controller.

The drum type control is the simpler of the two and consists of a controller which makes all of the required connections between the dynamo and the motor.

This controller is manually and positively operated. The wire, cable, auxiliary switches, and small battery panel complete the equipment. Drum type control is an extremely popular type and is used on the majority of cars. It is employed with all sizes of units.

The remote type of control has been designed for flexibility of arrangement, since it is panel mounted and can be readily located in any part of the engine room.

It is often used where it is not convenient to provide space for the drum controller at the operator's post.

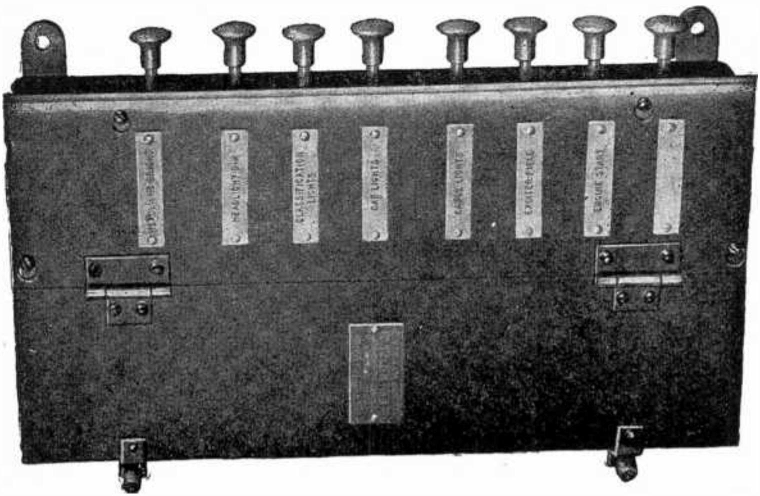


FIG. 6,140.—General Electric push button switch for control of lights, exciter field and engine start.

Air Compressors.—Motor driven air compressors are available in a large range of capacities. The sizes used for gas electric cars vary from 20 to 50 cubic feet of free air per minute. Compressors operate from the terminals of the dynamo through a pressure governor which automatically cuts off the power supply when the main reservoir is at the required pressure.

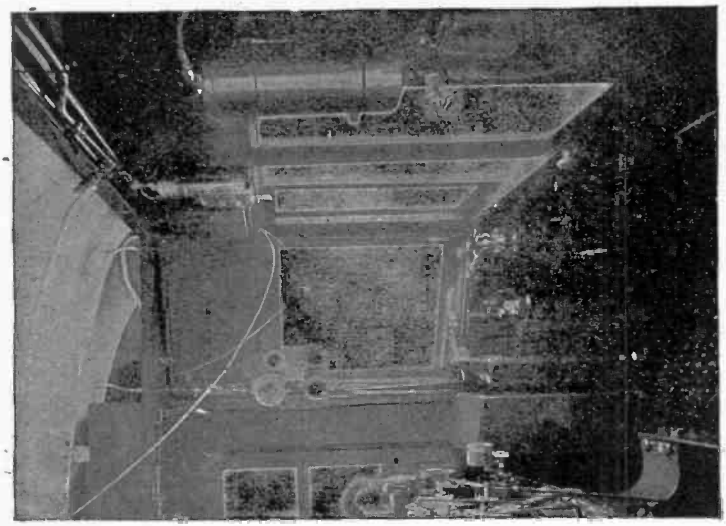


FIG. 6,141.—Interior operating compartment showing remote contactor control.

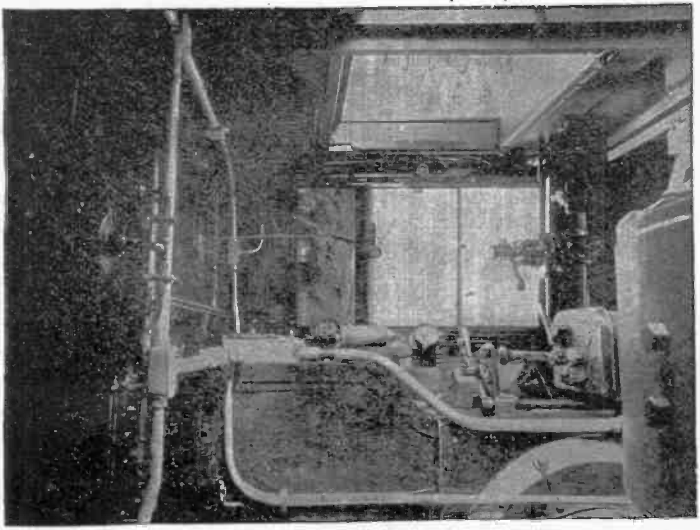


FIG. 6,142.—Interior operating compartment showing drum type control.

Battery Charging.—Each car is supplied with a storage battery for lights, control, starting and for energizing the field of the exciter. The battery is charged by the direct connected exciter through the B field of the dynamo, and a reverse current battery switch.

The B field absorbs any excess voltage difference between the exciter and the battery, and, at the same time, supplies necessary additional field excitation for the dynamo.

The charging rate to the battery is dependent upon the engine speed and the load on the dynamo, and can be adjusted and regulated by a by-pass

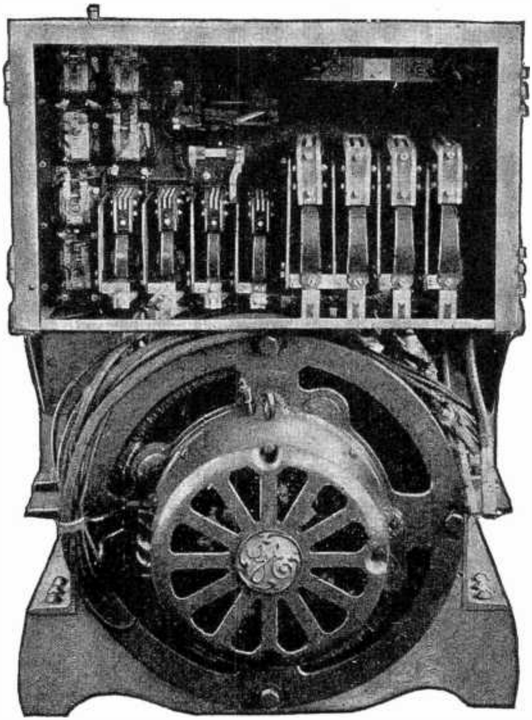


FIG. 6,143.—General Electric 135 *h.p.* unit with contactor control mounted above the dynamo.

resistance connected across the B field and having a switch to regulate it for three charging steps. This is so arranged that the car maintainers check the battery charging setting weekly, at the time of battery inspection. This scheme of battery charging is simple and reliable and gives long life to the storage battery. The small number of parts and the fact that it requires no adjustment are among the chief advantages.

Single Motor for Engine.—The usual gas electric car equipment has *two motors operating in series or parallel from one dynamo*.

Some car builders have found it desirable, because of engine size, to operate a single engine dynamo unit with a single

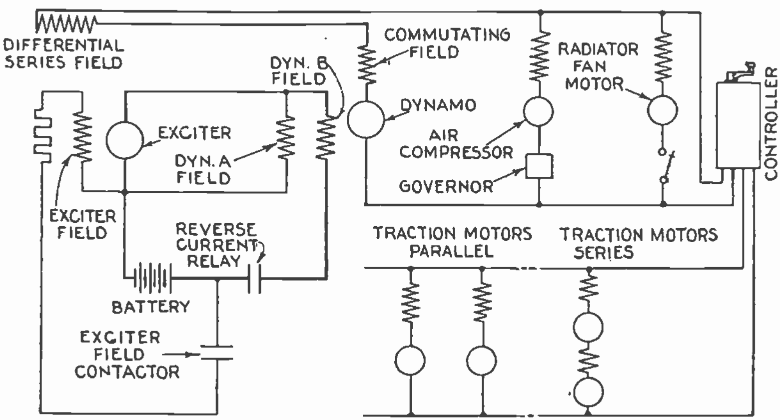


FIG. 6,144.—Diagram for gas electric car equipped with one engine dynamo set and two traction motors. The dynamo has a differential characteristic to give full engine output, and operates as a unit with the traction motors. The characteristic of the dynamo limits the power output so that at heavy loads, such as short circuits or heavy starting duty, it is impossible to stall or overload the engine. In addition, this characteristic is such that it does not unload the engine or cause it to race. This feature is obtained by a differential series winding mounted on the exciter and so designed that the power output is maintained within definite limits throughout the full operating range. As the current and voltage build up in the dynamo, the opposing effect of the differential winding limits the excitation of the dynamo in proportion to the amperes demanded. The two dynamo fields are energized by the direct connected exciter. The A field of the dynamo furnishes 70 to 85 per cent of the field excitation and the B field supplies the remaining field energy. As indicated previously, the B field absorbs any voltage excess between the exciter and the battery. The storage battery provides excitation for the exciter field and also is used to start the engine.

motor, two motors with two power plants, and even a triple power plant car with one motor connected to each dynamo.

In order to obtain equivalent operating conditions of the series parallel control with two motors and one dynamo, a dynamo with a dual voltage characteristic is used. The first or major characteristic is such that the dynamo is utilized at low voltage and high starting current for maximum tractive effort and acceleration, and the second characteristic supplies the high voltage for high and free running car speeds. This wide range dynamo characteristic is obtained by a slight modification of the standard scheme of connections.

The first characteristic is obtained in the usual manner by separate excitation of the exciter.

The second characteristic is obtained by self excitation of the exciter and the use of a voltage relay.

The combination of these characteristics with a single motor gives a constant engine output over a wide range of car operation comparable to the regular dynamo with two motors. The potential relay which operates at the voltage corresponding to the crossing of the two curves, automatically controls the changeover from the separate excited to the self excited dynamo operation. The important features of this scheme of control are simplicity and the absence of all torque or power relays.

Operation of Gas Electric Car.—The method of operating this type of car, which is similar to that of a steam locomotive, is by means of a throttle, air brake valve, and controller, the latter being similar to the reversing lever on the steam locomotive. The car is controlled entirely by the engine throttle. With the throttle in the "off" position, the operator first puts the controller in the series or first running position, and then opens the throttle. As the throttle is opened, the engine speeds up and the throttle switch, operating through a contactor, closes the battery circuit to the exciter field and supplies excitation to this unit. This, in turn, permits the voltage of the dynamo to build up and the car to start.

As the engine speed increases, the voltage of the exciter also increases, until it is above that of the storage battery, at which time the reverse current battery switch closes, and the exciter then charges the battery.

After the car has reached a speed of 10 to 12 miles per hour, the operator moves the controller from the series to the parallel position. This is done with full throttle and the transition of one motor connection to the next is made smoothly without hesitation or jolt to the car. As the car continues to accelerate, the controller is turned to the full speed or shunt field position. This last controller change is made at about 25 miles per hour.

To reduce the speed of the car, it is necessary only to ease off the engine throttle, which automatically gives a dynamo output proportional to the reduced engine power.

The B, field is valuable, as it increases the dynamo excitation at free running speeds of the car and supplements the differential characteristic to give increased power output from the engine. This also has the desirable feature of changing dynamo excitation rapidly with a slight change in engine speed, and assists in utilizing the full engine output over a comparatively wide range of current load and at the same time automatically reduces any excess load on the engine.

TEST QUESTIONS

1. *What is the most difficult problem facing the railroads?*
2. *To what cause is a heavy loss of railway business due?*
3. *What are the advantages of gas electric railway cars?*
4. *Give a general description of a gas electric railway car.*
5. *What range of* h.p. *is used for gas electric railway cars?*
6. *What are the characteristics of the engines used?*
7. *Describe a typical gas electric drive dynamo.*
9. *What kind of coupling is used between engine and dynamo?*

10. *How are the motors mounted?*
11. *Describe the control equipment.*
12. *Name two types of control used.*
13. *How are the air compressors driven?*
14. *How is current obtained for lighting?*
15. *Describe the various motor hook-ups.*
16. *Describe in detail the operation of a gas electric car.*

CHAPTER 133

Electric Locomotives

The designing and building of a successful electric locomotive, calls for a combination of the highest type of electrical and mechanical engineering skill. Such a locomotive must be considered not only as a transformer of power, but also as a vehicle; and the experience acquired in steam locomotive building and operation is invaluable in railway electrification work.

Electric locomotives may be classified

1. With respect to the drive, as

a. Gearless;

b. Geared.

2. With respect to the current, as

a. Direct { from dynamos; from storage batteries.

b. Alternating;

c. Gas electric;

d. Oil electric;

e. Diesel electric.

3. With respect to voltage, as

a. Low;
b. Medium;
c. High.

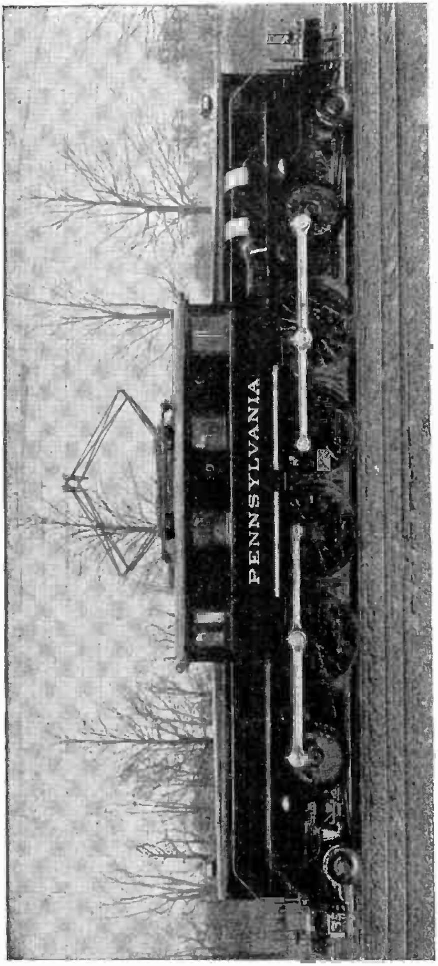


FIG. 6,145.—Westinghouse 204.3 ton, 11,000 volt, single phase motive power unit for freight service.

4. **With** respect to the collecting device, as

a. Trolley;

b. Pantagraph;

c. Third rail.

5. With respect to the application of the current, as

a. Direct connected;

b. Transformer;

c. Motor generator.

6. With respect to service, as

a. Passenger { short haul; interurban; local; express; heavy; trunk line.

b. Freight { industrial mine.

c. Switching.

Motors.—Except in a few instances, city and interurban electric railways employ *d.c.* motors of the series type, supported by the truck transom and axle, geared to the axle and entirely or partially enclosed for protection against water and dirt.

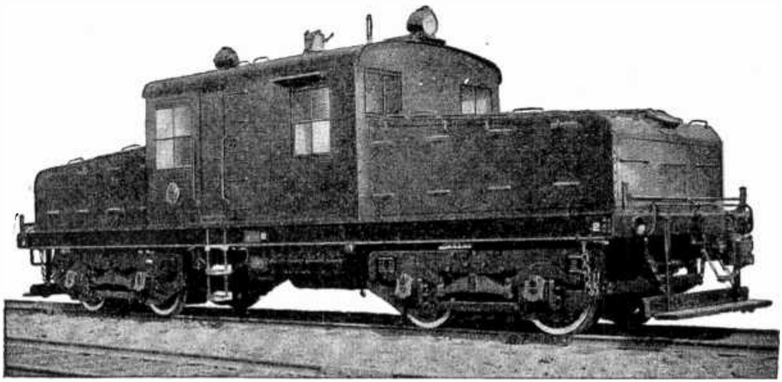
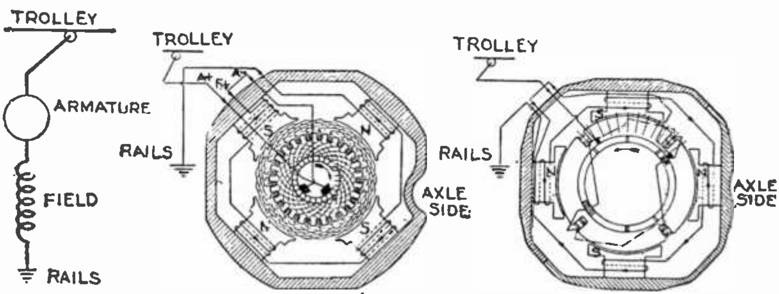


FIG. 6,146.—General Electric 60 ton storage battery type industrial haulage locomotive. The particular application is handling heavy loads for short hauls as is found in yard shifting, dock service, quarries, etc. Operation and repairs can be performed by men of ordinary ability.



FIGS. 6,147 to 6,149.—Electric circuits of the simple series motor. As shown in these illustrations the motors have four poles and the armature winding is of the two circuit wave length which permits the use of only two sets of brushes, makes cross connections unnecessary, requires the fewest number of turns per coil, the largest and therefore strongest conductors, and the least voltage per coil. The majority of railway motors still in service are of this type.

The series type motor is so called because *the same current passes through the field and armature windings consecutively or in series*. The electrical circuits of the simple series motor are illustrated in figs. 6,147 to 6,149.

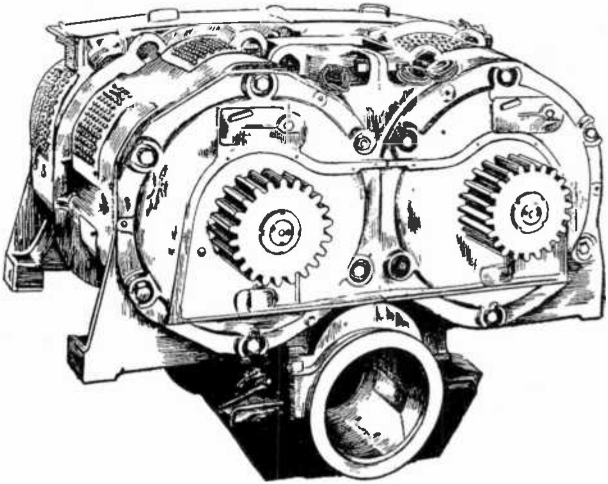


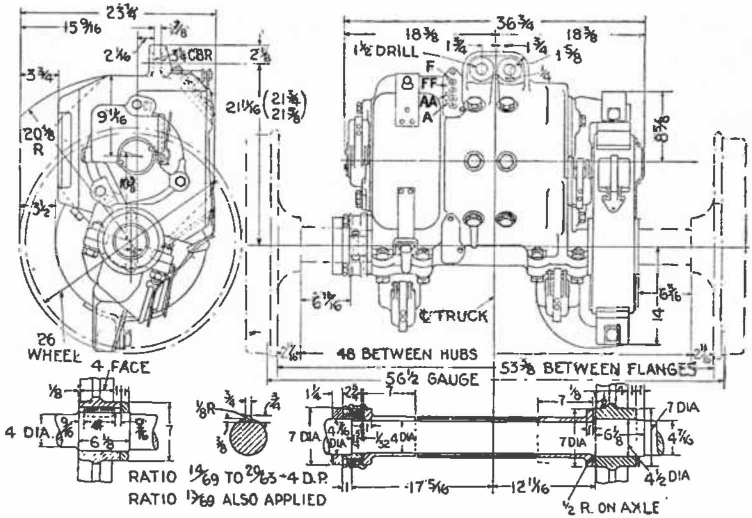
Fig. 6,150.—Westinghouse twin motor used on freight locomotives and high speed passenger locomotives. Note that two motors drive one pair of wheels. The same type motor in a suitable frame is used in multiple unit cars.

An improvement in railway motors was the introduction of the commutating pole.

This feature improves the commutation, reduces the wear of brushes and commutators, and makes possible the use of field control and high voltage systems.

The commutating pole series motor is now the standard for *d.c.* railways, and is shown in figs. 6,156 to 6,158.

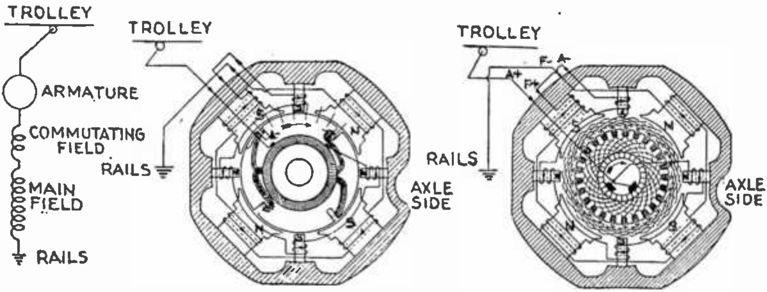
Field Control.—A further development is the field control motor as shown in figs. 6.159 and 6,160. The idea of securing additional efficient running speeds by varying the effective field turns on a railway motor is an old one, but on account of commutation difficulties it did not prove successful until the commutating pole was developed.



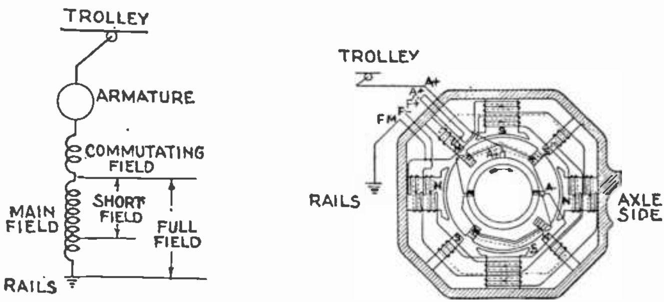
FIGS. 6,151 to 6,155.—Westinghouse box frame commutating pole direct current railway motor details.

The field control motor has *the field arranged in two parts which are connected in series with a lead brought out from the point FM, where they are joined together, as in* fig. 6,160.

In starting, the entire motor current passes through both parts of the field in series, called the full field connection, setting up a very strong field and developing a large torque with a relatively small current. When desired, one portion of the field is cut out, leaving only the short field in the circuit, so that a comparatively weak field results and higher speeds are secured. These arrangements give economy and flexibility, in that less starting current is required and the motor provides two efficient running connections instead of one. Fig. 6,160 shows the ground connection for the short field position.



FIGS. 6,156 to 6,158.—Diagrams of commutating pole series motor. The commutating pole improves the commutation, reduces the wear of brushes and commutators, and makes possible the use of field control and high voltage systems.



FIGS. 6,159 and 6,160.—Diagrams of field control motor.

NOTE.—*In practically every instance,* where railways have been electrified the change has been made because under the special conditions existing, electric locomotives could accomplish results that were impossible with steam operation. A study of the leading characteristics of steam and electric locomotives will explain the reason for this. The steam locomotive generates its own power and its output is limited by the capacity of the boiler. The electric locomotive, on the contrary, is simply a transformer of power, and with ample power house capacity behind it there is practically no limit to its output. The maximum tractive force of both types is, of course, primarily dependent upon the weight on the driving wheels, but after the train is started the maximum speed of the steam locomotive, especially on ascending grades, is limited by the steaming capacity of the boiler; while the electric locomotive is limited by the capacity of its motors.

Ques. How is the voltage reduced in electric locomotives from high tension to low tension for the motors?

Ans. By step down transformers contained in the body of the locomotive.

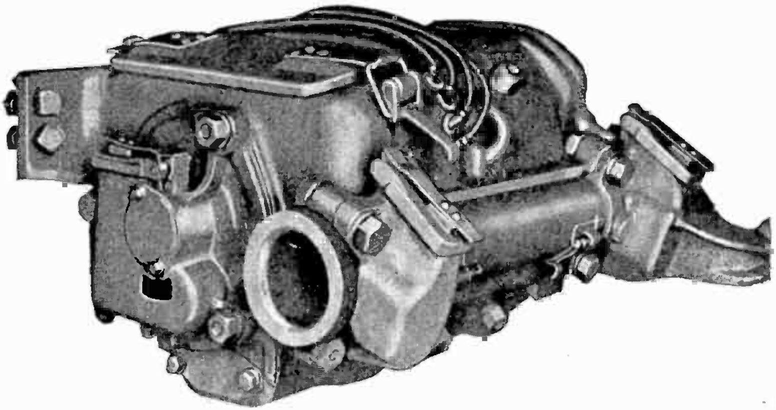


Fig. 6,161.—Westinghouse railway motor, 60 *h.p.*; 600 volts; 87 amperes, 770 *r.p.m.* suitable for light weight interurban cars where high running speeds are necessary, in double equipments on modern city cars and in quadruple requirements for trailer hauling. It is adaptable to all conditions requiring a 60 *h.p.* motor with 26 in. or 28 in. wheels.

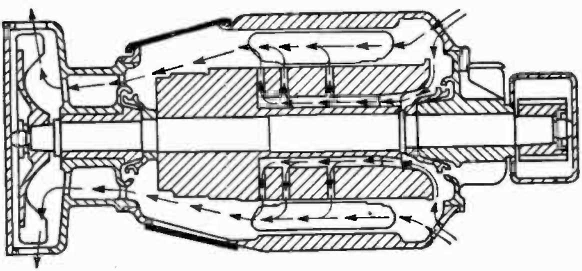


Fig. 6,162.—Westinghouse non-ventilated motor arranged for ventilation with an external fan. The fan is attached on the end opposite the pinion and its method of drawing the air through air ducts provided for the purpose is indicated by the arrows. Cooling a motor increases its capacity and it can be used for heavier loads.

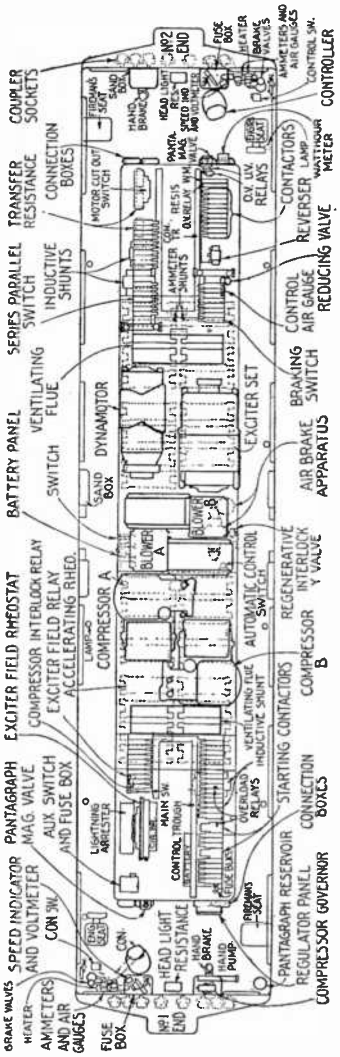


FIG. 6,163—General Electric 150 ton, 3,000 volt *d.c.* locomotive for the Mexican railway. Diagram showing location of apparatus.

Ques. How are locomotives designed for both overhead wire and third rail operation?

Ans. The locomotives contain, in addition to the step down transformer, a motor generator set which converts the *a. c.* to *d. c.* for the motors.

When operating on third rail the pantagraphs or upper contact shoes, are drawn down and the inside equipment disconnected so that only the motors are in circuit and get their current from the third rail.

The controlling devices for starting and speed acceleration are of the electro-pneumatic type.

Gear Ratio.—A single size of motor is suitable for a variety of service and is adapted to meeting different conditions by using different gears to connect the motor shaft to the car axle. In order that gears may mesh properly, the distance between centers of the gear and the pinion must be constant. The center of the pinion coincides with the center of the motor shaft and the gear center with that of the axle. Hence, for any motor, the gear center distance is fixed, since the axle runs in bearings carried on the motor frame between the axle brackets and axle caps.

In laying out gears for a fixed center distance SA, fig. 6,169, this center distance is divided into two parts such that BA, divided by SB, gives the speed reduction desired.

Example.—If a speed reduction of 4.6 to 1, be required, BA, is taken 4.6 times as long as SB. Then two circles are drawn with S and A, as centers

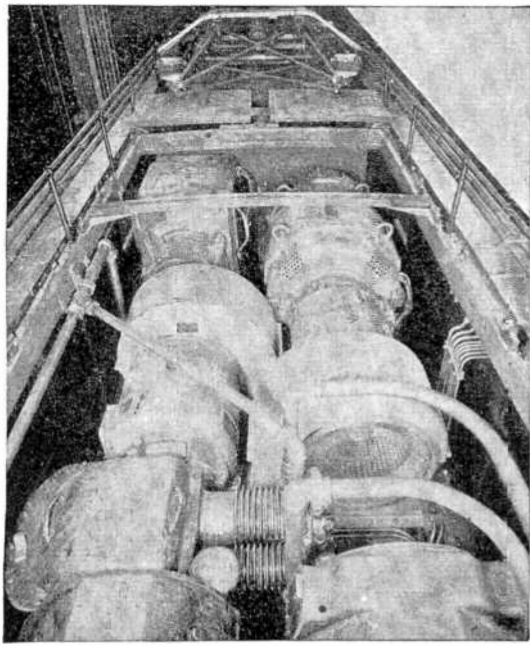
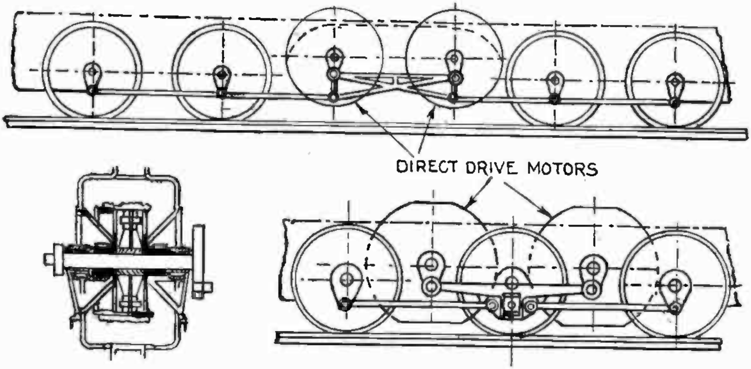


FIG. 6,164.—Auxiliary machinery compartment of General Electric 150 ton, 3,000 volt *d.c.* locomotive.

and SB, and BA, as radii. The circumferences of these circles are of course in the same ratio as their radii, BA, and SB, that is, 4.6 to 1. These circles are known as the pitch circles of the gear and pinion respectively, and the teeth are laid out around these circles. To mesh properly, the distance between centers of adjacent teeth measured along the pitch circles must be the same; so the number of teeth in the gear will be 4.6 times the number of teeth in the pinion. It is evident then that the ratios of radii, diameters and circumferences of the pitch circles, and number of teeth of



FIGS. 6,165 to 6,167.—New York, New Haven and Hartford motor mountings.

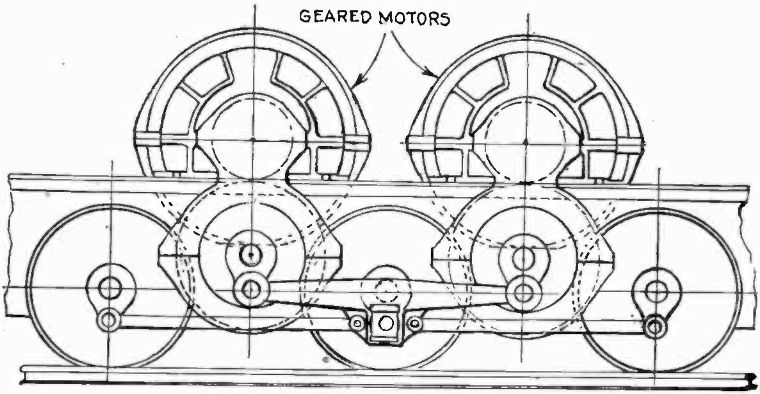


FIG. 6,168.—Method of mounting locomotive motors with both gears and connecting rods The drive is through a form of Scotch yoke and side rods as shown.

gear and pinion are all the same and measure the amount of speed reduction from armature shaft to car axle.

For convenience the gear ratio is customarily expressed by *giving the number of teeth in gear and pinion.*

To determine the size and strength of the teeth used, the pitch of the teeth must be known. There are two common ways of expressing pitch. The distance between adjacent teeth measured along the pitch circle is known as the circumferential pitch and of course is equal to the circumference of the pitch circle divided by the number of teeth.

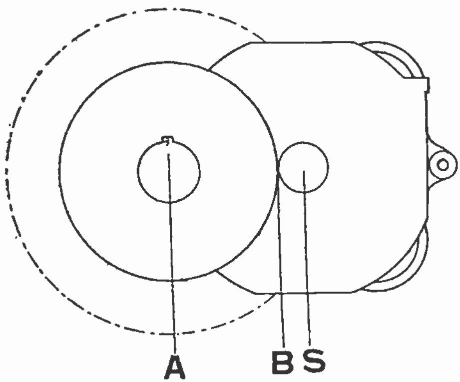


FIG. 6,169.—Diagram for laying out locomotive motor gears.

The more usual and convenient form is *to give the number of teeth per inch of pitch circle diameter* and is called diametral pitch.

In the example cited, assume that the gear center distance SA, is 14 in. and that the diametral pitch is 3. Then SB, is 2.5 in. BA, is 11.5 in.; the diameter of the pitch circle of the pinion is 5 in. and that of the gear is 23 in.; the number of teeth in the pinion is 15 and in the gear 69.

The sum of the diameters of gear and pinion is *twice the gear center distance and is therefore constant.*

Then as long as the pitch and gear center distances are constant, the total number of teeth in gear and pinion is constant irrespective of gear

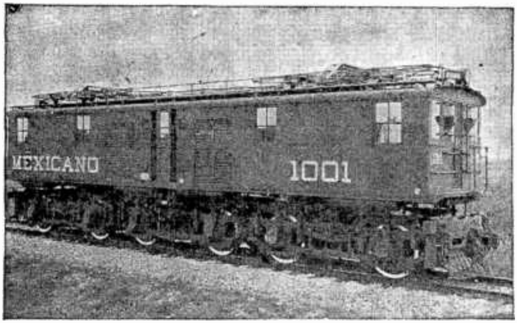


FIG. 6,170.—General Electric 150 ton, 3,000 volt *d.c.* locomotive. *It is* of the twin geared, articulated truck type. A single cab is mounted on two equalizer frames which, in turn, are carried upon three two axle articulated trucks. A motor is geared directly to each axle with twin, cushion type gears. The six motors, with which each locomotive is equipped, are of the box frame, twin geared commutating pole, railway type with forced ventilation. They are designed to operate two in series on a 3,000 volt circuit, or 1,500 volts per commutator. The windings are therefore insulated for 3,000 volts to ground. An 18 tooth steel pinion is mounted on each end of the armature shaft, and these mesh with 90 tooth cushion type gears on the axle. An unusual feature of the design of this locomotive is the provision for removing the motor, wheels, or axle from any of the trucks without removing the cab. By disconnecting the motor leads and jacking up the motor and the side frames, the wheels and axle and finally the motor can be lowered into a pit. The power for the operation of the auxiliaries is provided by a 3,000-1,500 volt dynamotor which carries a 4 *k.w.* 65 volt control dynamo mounted on a shaft extension. The two blower motors and the two compressor motors are normally operated in series across the 3,000 volt supply, using the mid-point of the dynamotor for equalization. This scheme allows the operation of the compressors and blowers directly from the trolley in case of failure of the dynamotor, and of one compressor or blower in case of the failure of the other machine. An exciter set, used for regeneration, is driven by a 1,500 volt motor operated from the 1,500 volt dynamotor bus. If it be not necessary to operate the blowers at maximum capacity, they can also be operated on the 1,500 volt circuit by connecting them in series. The control dynamo supplies current at 65 volts for lights, head lights, foot warmers, and control circuits, and for charging the storage battery.

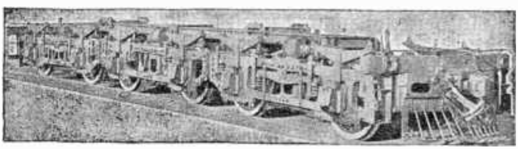


FIG. 6,171.—General Electric running gear of 150 ton, 3,000 volt *d.c.* articulated type locomotive.

ratio. This fact makes it very easy to find the number of teeth in the gear and the pinion for changing the gear ratio. In this case, for 14 inch gear centers and 3 pitch, the total number of teeth is 84. Assume a gear reduction of 3.2 is desired; that is, the number of gear teeth is to be 3.2 times the number of pinion teeth. The total number of teeth will be $(3.2 + 1) = 4.2$ times the number of pinion teeth which will be $84 \div 4.2 = 20$. The gear will have $3.2 \times 20 = 64$ teeth and the ratio will be 20:64.

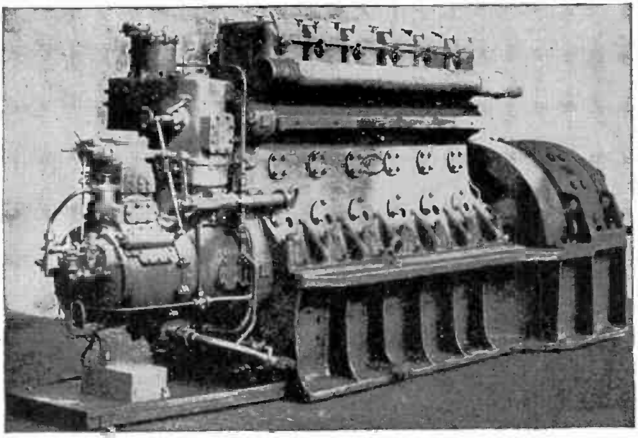


FIG. 6,172.—Westinghouse intake side of 300 *h.p.* oil engine for oil electric locomotive. The four stroke cycle engine is arranged to idle at 300 *r.p.m.* and to deliver full output at 800 *r.p.m.* The speed characteristics are such as to effect a reduction in weight per *h.p.* The engine, including fly wheel weighs approximately 7,000 lb. or 23.3 lb. per *h.p.* The main dynamo is a 750 volt, 210 *k.w.* variable voltage *d.c.* machine receiving field excitation from a 64 volt, 5.3 *k.w.* auxiliary dynamo. The auxiliary dynamo armature is pressed on an extension of the dynamo shaft while the stator is bolted to the main dynamo bracket and is easily removable. The commutator end of the armature is carried on a sleeve type bearing while the engine end of the armature is bolted to the fly wheel and is carried by a double bearing in the engine. The principal function of the main dynamo is that of supplying power to the traction motors. It is also used as the starting motor for starting the engine, receiving its power from the 64 volt, 204 ampere hour storage battery. Lastly, it serves to charge the battery and supplies power for operating the compressors and auxiliaries at engine idling speed of 300 *r.p.m.* The auxiliary dynamo besides supplying power for excitation of the field of the main dynamo, furnishes power for compressor operation and battery charging when the main dynamo is running at higher than idling speeds. The motor equipment consists of four locomotive type traction motors, 16:61 gear ratio and having an hourly rating of 146 amperes at 600 volts or a continuous rating of 85 amperes at 300 volts. They are self ventilated. This type of motor was designed for a high tractive force at low speed for trolley type locomotive service and is an ideal application for switching service with an oil electric locomotive.

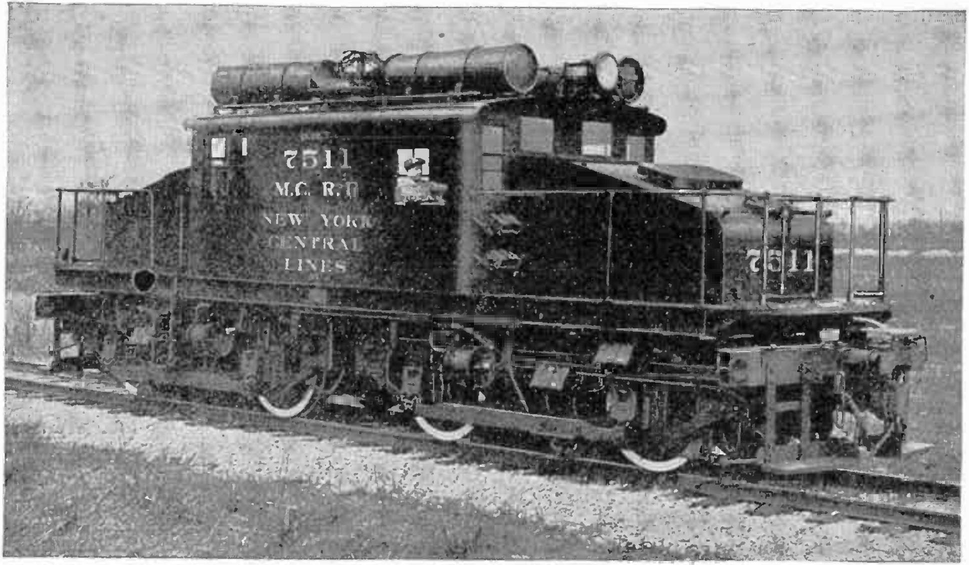


FIG. 6,173.—General Electric 120 ton, 600 volt *d.c.* locomotive.

Locomotive Selection.—There are many factors, some of them seemingly unimportant, that must be considered in selecting an electric locomotive and its equipment for a given service. It is possible, with little difficulty, to choose a motor equipment that will be more than large enough for the work. However, to determine the proper combination of weight, horse power and speed to accomplish the tonnage movement desired over a given profile with highest efficiency, low maintenance and minimum first cost, requires careful study of all operating conditions as well as definite knowledge as to what work can actually be performed with certain electric motive power equipment under the specific conditions encountered.

Safe and sane operating conditions for the train crew, rolling equipment and freight are of course the first consideration in such computations.

The fundamental law applying to train movement by electric locomotive is that in pulling a trailing load of cars weighing a certain number of tons, the motors must be capable of exerting a certain variable number of pounds tractive effort or pulling force at the driving wheels in order to overcome the forces tending to retard the movement of the train.

From this it is evident that the friction between the rails and wheels is a function of the capacity of the locomotive to move tonnage. The maximum tractive effort rating of Baldwin-Westinghouse standard electric locomotives is 25% of the weight on the driving axles. With clean, dry rail, the coefficient of friction between wheels and rail may be as high as .35 giving an instantaneous tractive effort of 35% of the weight on drivers. If the pull required at the drawbar plus the locomotive frictional resistance exceed this number of pounds and the motors have torque in excess of this value, the wheels will slip and not permit the train to start.

Motor capacity or output is *largely a matter of temperatures.*

A relatively small motor can exert a comparatively enormous tractive effort for an instant, but the heat developed in its windings will be so great that it will burn up if operated continuously. A motor equipment may be large enough to haul a train at schedule speed, over a long stretch of level track and remain at a safe temperature, but, if grades or long sharp curves are encountered the temperature of the motor may rise to a dangerous degree.

Much more power is required to bring a train up to speed than is required to run it after that speed is attained.

Motors for Mine Locomotives.—These are similar in many respects to motors for street railways.

Both of these types are *d.c.* motors and commonly transmit power to the driving wheels through single reduction gearing. The method of mounting is also similar, one side of the motor being suspended from the axle by means of axle bearings, and the other side by an attachment to the truck framing. There are, however, a number of requirements affecting the design of mine locomotive motors which serve to separate them as a group from other forms of traction motors. These requirements are of course a result of the kind of work which the mine locomotive must do and the conditions under which it must be done. Comparatively few years of motor evolution have established the features which enable one to recognize a mine locomotive motor even if seen alone and not as a part of the locomotive.

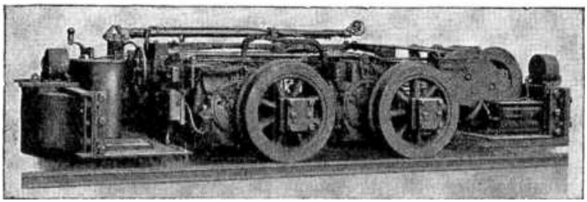


FIG. 6,174.—A mine locomotive with side frames removed to show position of motors.

Having in mind the space limitations, the motor designer has the problem of so proportioning the parts as to obtain a maximum torque from a frame of certain dimensions.

The active electrical parts must be proportioned, however, with due regard to clearances between revolving and stationary parts, mechanical strength, access to brush-holders, correct lubrication, etc.

A careful distinction should be made between motor torque (or tractive effort) and horse power.

If a locomotive be equipped with motors that develop a certain torque at the armature shaft, the locomotive will have a corresponding tractive effort developed at the wheels. In other words, the locomotive will pull a certain number of cars of coal or ore. This pulling ability represents the torque which the designer has been able to get out of a motor of given frame dimensions and is practically independent of horse power. The horse power is the result of both this pulling ability and the speed at which the pulling is done as shown in the familiar formula:

$$\text{horse power} = \frac{\text{torque} \times r.p.m.}{520}$$

The error is often made of assuming that, of two locomotives otherwise the same, the one having motors of higher horse power will pull more loaded cars. It is true that five horses may be able to pull a load that four cannot, but it does not follow that a locomotive equipped with 50 horse power motors can pull more cars of coal than one equipped with 40 horse power

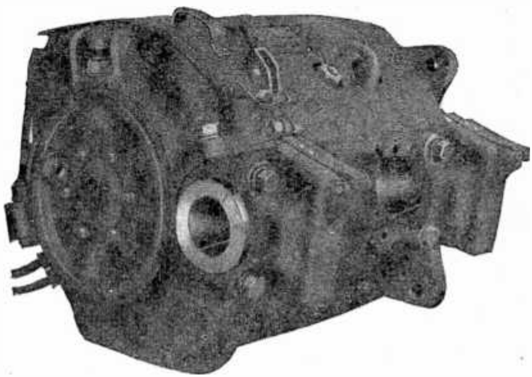


FIG. 6,175.—Typical mine locomotive motor.

motors. The difference is that all horses pull at about the same speed while electric motors may be designed for a wide variety of speeds. Knowing the torque that may be obtained from a given motor volume, the correct speed is dependent upon the desirable locomotive haulage speed.

Locomotives used for gathering cars within the mine may operate at speeds as low as four to six miles per hour, while main haulage locomotives have a most desirable speed at eight to twelve miles per hour. The tendency is toward lower speeds than formerly for gathering locomotives, and for higher speeds for main haulage.

The standard voltages for trolley type mine locomotives are 250 and 500 volts.

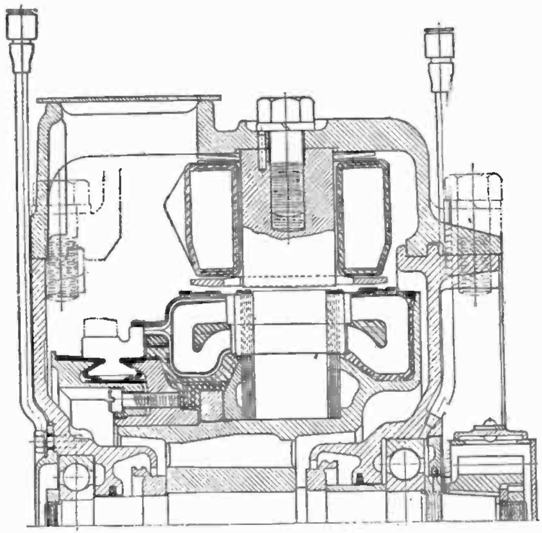


FIG. 6,176.—Top half of extremely narrow gauge motor.

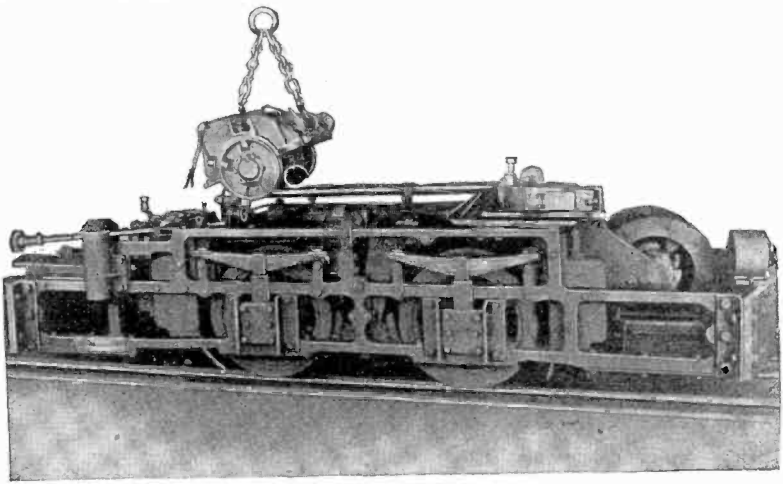


FIG. 6,177.—Method of removing top half of split frame motor and armature.

The 500 volt trolley has proved dangerous due to workmen coming in contact with it. The 250 volt standard is rapidly coming into more general use, while 500 volts is seldom used in a mine.

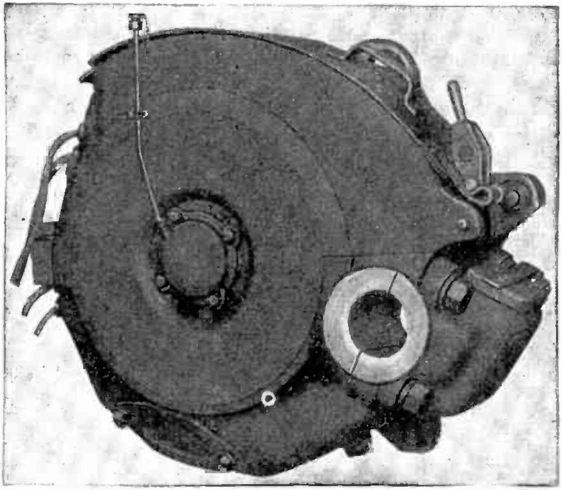


FIG. 6,178.—Mine locomotive motor for use on 18 inch track.

NOTE.—*Several states* have passed legislation prohibiting the installation of a 500-volt trolley in new mines. For storage battery locomotives 80 volts is usual, 48 cells of lead or 80 to 88 cells of Edison battery. The mine motor, along with other types of electric motors, has become standardized in the use of commutating pole windings for voltages of 250 and above. The 80-volt motors for operation from storage batteries are usually of the non-commutating pole type, as commutating poles are not necessary at this voltage to obtain sparkless commutation.

NOTE.—*Flame proof construction.* The explosion tested or permissible construction has resulted from the necessity for motors that can be safely operated in the presence of explosive gases or coal dust. The U. S. Bureau of Mines has established a schedule of construction details and tests which must be met in order to obtain its approval of the apparatus as being permissible for operation in gaseous mines. The final tests which are made on new motors by the Bureau definitely prove that an explosion of gas inside will not cause an explosion of gases surrounding the motor. The fully permissible locomotives are naturally limited to the storage battery type. The trolley locomotive is eliminated due to the sparking between trolley wheel and trolley. Some operators not favorable to storage battery locomotives have greatly minimized the danger of explosions by using locomotives equipped with explosion tested motors and control and obtaining power through a cable reel and cable. This cable is hooked to a trolley in the main entry where the ventilation is good and the probability of explosive gases is small.

Accordingly, the duty on the motor is very severe at starting. It is apparent then, that in order to select the most suitable motor equipment for a given service, the track, grade and traffic conditions must be fully understood.

It is also obvious that the motor equipment must be capable of exerting a tractive effort for short periods approaching the tractive limits of the complete locomotive mechanically without serious temperature rise if the locomotive is to be a successful application. These facts indicate the danger that may arise if a locomotive be over ballasted. The weight of a locomotive for a certain service may be limited also by the strength of bridges and the weight of rail.

The maximum current which the locomotive can safely take from the sub-stations, the probable tonnage to be handled daily

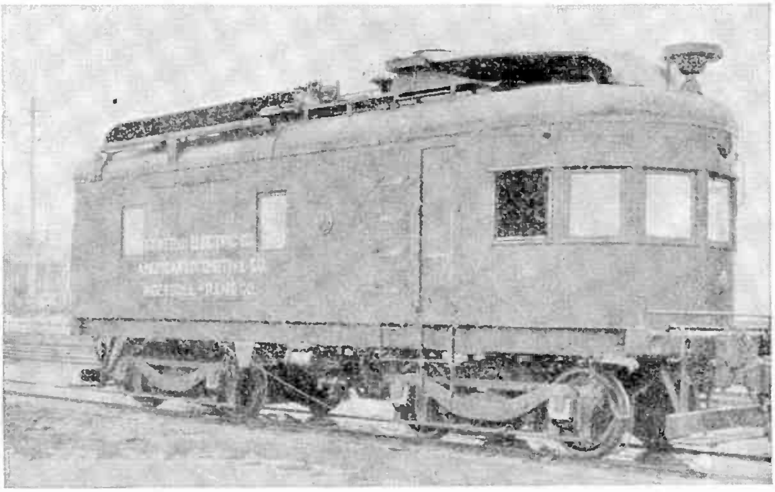


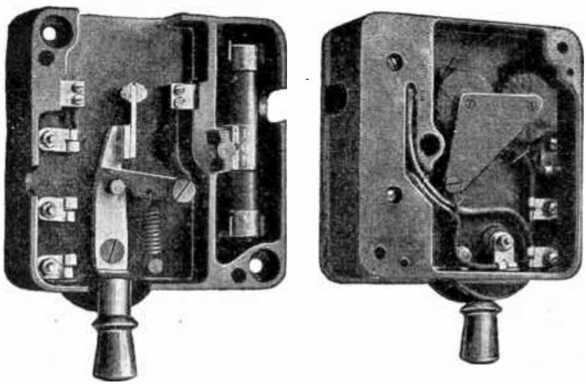
FIG. 6,179.—General Electric Diesel electric locomotive. Built essentially for switching service, the 4-4 wheel locomotive here shown mounts a 300 *h.p.* Ingersoll-Rand airless injection oil engine direct connected to a 200 *k.w.*, *d.c.* General Electric dynamo, which furnishes current to four motors of the same make geared to each of the four axles. The under frame was built by the American Locomotive Co. of rolled steel channels carrying two 4 wheel trucks of the pedestal type. Carried on board the locomotive are also the following apparatus: 2 G. E. motor driven air compressors; 1 G. E. automatic air brake schedule; 1 straight air brake schedule; 1 gasoline air starting set; 5 contact switches; 1 storage battery set; 1 charging relay; 2 fuel oil tanks; 2 cooling water tanks; 1 cab, lights, head lights, etc.

and at what points it will originate and be delivered, are other factors which affect the proper selection of locomotives.

The four major service requirements of a locomotive may be summarized as follows:

1. It must have sufficient weight on drivers to start the heaviest train on the maximum grade at reasonable adhesion.

2. It must have sufficient continuous motor capacity to avoid overheating in continuous service.



FIGS. 6,180 and 6,181.—Westinghouse locomotive control and reset switch.

3. It must have sufficient overload capacity to successfully meet short time load demands imposed by starting or running train on grades.

4. It must have proper speed characteristics to suit the traffic requirements. Slow speed operation reduces power demands on sub-stations, but may interfere with passenger service or not be sufficiently fast for express freight service.

Locomotive Control Equipment.—As an example of control the standard unit switch system as used on Baldwin Westinghouse locomotives is here described. This type of control has the following advantages as applied to locomotive installations and operation:

1. Hand acceleration is particularly necessary in switching operations for safety reasons in order that the engineer may have complete control of the locomotive speed at all times. The unit switch control is well adapted for, and is always applied to, locomotives arranged for hand acceleration.

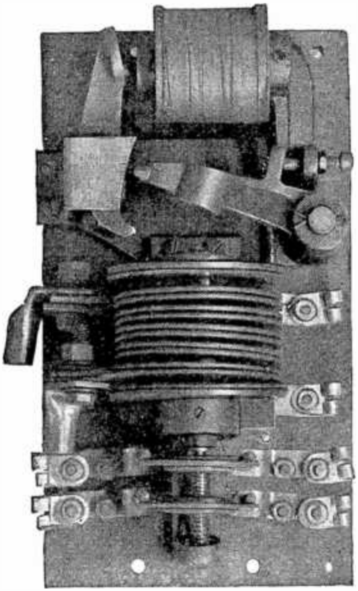


FIG. 6,182.—Westinghouse overload relay for locomotive.

2. The contact pressure of the unit switches is independent of the line voltage. This feature is useful in handling heavy seasonal freight on parts of a railway system where voltage may be low.

3. Ample protection is provided against excessively heavy overloads, grounds, short circuits, surges in the contact line and lightning.

4. Two or more connected locomotives may be operated from any one master controller.

Main Circuit Switches.—The various main circuit connections are made by unit switches operating by compressed air supplied by the air brake system.

The admission of air to the unit switches is controlled by electro-pneumatic valves. These valves are actuated by current from a low voltage control circuit carried through a train line from the master controller. This low voltage control circuit is obtained by tapping from points on the control resistor, which is connected between trolley and ground.

Each switch is closed against a powerful spring, by a piston actuated by compressed air when its control circuit is energized. The switch will be opened quickly by this spring when the air is released. The movement of the switch, either opening or closing, is rapid and positive, and heavy contact pressure is obtained.

Reverser.—The movement of a locomotive is directed either forward or backward by means of an electro-pneumatically operated reverser.

The reverser consists of a number of stationary fingers mounted on a rigid base and pressing upon one or the other of two sets of contacts which are mounted on a rotating drum.

The lever on the master controller controls the rotation of the drum to place the correct set of contacts for the direction of movement desired, in contact with the stationary pressure fingers.

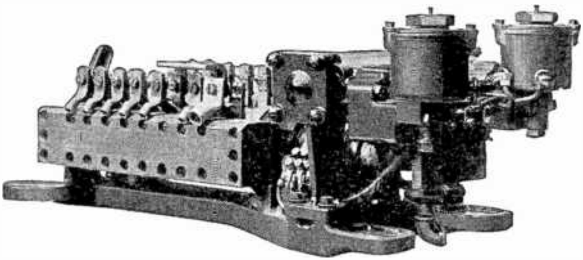


FIG. 6,183.—Westinghouse electro-pneumatically operated reverser for locomotives.

The reverser is so interlocked that it cannot be operated unless the controller handle be in the *off* position.

Main Fuse Box.—To protect the locomotive equipment from grounds or short circuits, a fuse is connected in the main circuit next to the trolley.

An overload relay is provided with its operating coil connected in the main circuit ahead of the line switch. This relay, adjustable over a wide range in current values, will cause the main circuit to be opened when a predetermined limit of current has been reached.

Grid Resistors.—The grid resistors consist of the required number of 8 in. three point suspension cast iron grids, arranged in a suitable number of frames.

The grids comprising each frame are held together between sheet steel end plates by three mica insulated tie rods arranged at the three points of an equilateral triangle, which gives a very solid and substantial construction.

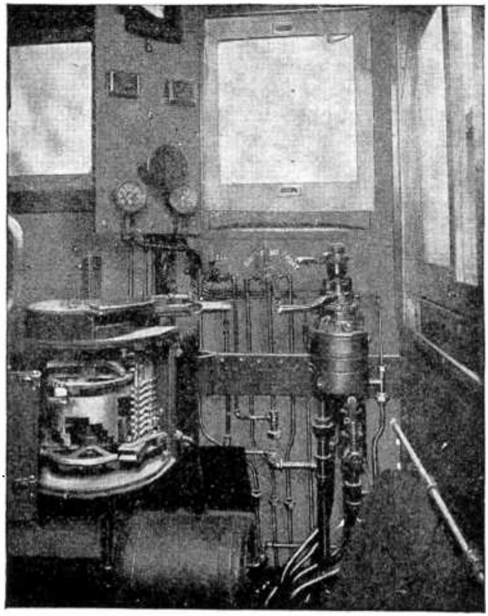


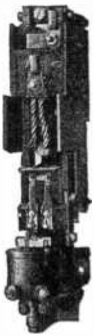
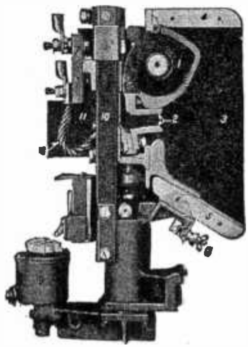
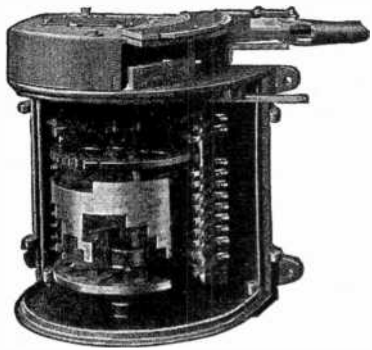
FIG. 6,184.—The engineer's locomotive operating equipment.

Master Controller.—The control circuits for operating the unit switches and the reverser are established by means of the master controller levers. One lever is provided for notching up or accelerating the locomotive and another lever for reversing the direction of movement as explained under the heading *Reverser*.

The reversing lever is interlocked mechanically with the operating handle, so that it cannot be thrown to another position unless the main drum is in the *off* position.

Sixteen notching positions are provided on the master controller. A master controller is located in each end of the cab for double end operation.

Meters, Gauges, Etc.—An instrument board is located within easy vision from the engineer's position.

FIGS. 6,185 and 6,186.—Westinghouse side and front of a typical main control circuit unit switch for locomotive. ***The parts are:*** 1, blowout coil; 2, contacts; 3, arc box side; 4, upper arc block; 5, lower arc block; 6, arc box latch; 7, terminal board; 8, shunt; 9, magnet valve; 10, mounting bar; 11, barrier.

FIG. 6,187 —Locomotive master controller with cover removed.

An ammeter connected in the main circuit, air gauges, and a volt meter are mounted on this board, and each is well illuminated from a central light by reflectors which also shield the light from the direct vision of the operator. An instrument board is installed in each end of the cab.

The control equipment includes also, all necessary auxiliary apparatus such as motor cut out switch, main switch, lighting switches and lightning arresters.

Locomotive Air Brake Equipment.—This consists of double air compressor units to provide an ample and reliable air supply, an automatic governor which controls the operation of the

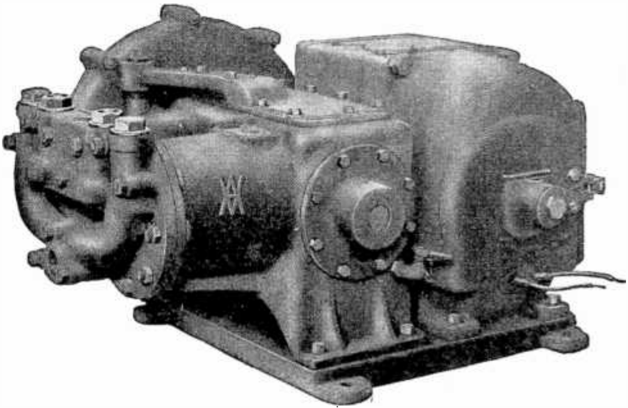


FIG. 6,188.—Westinghouse motor driven air compressor for locomotive.

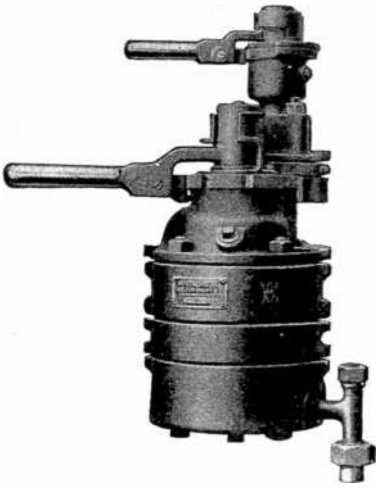


FIG. 6,189.—Westinghouse operator's brake valve. The upper lever is for locomotive brakes only. The lower lever operates the automatic brakes. The air brake has two functions, namely, to stop the train in the shortest possible time, and to insure smoothness and reliability in train handling. To obtain these, the equipment is a combined automatic and independent brake, allowing the locomotive brakes to be controlled independently of, or in conjunction with, the train brakes.

compressors between predetermined maximum and minimum pressures, reservoirs with sufficient storage capacity, double end brake valves with an independent and automatic position, a distributing valve and the brake cylinders.

Severe service demands double air compressor units to provide sufficient air for braking and other purposes. The control of the compressors is so arranged through a governor synchronizing system that each unit will carry its share of the load, both when operating as a single cab locomotive or with two cabs in multiple. The compressors may also be operated independently when necessary.

TEST QUESTIONS

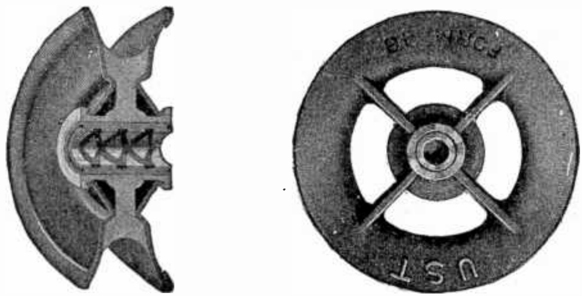
1. *Give a classification of electric locomotives.*
2. *What types of motor are used on electric locomotives?*
3. *What is the advantage of inter-pole motors?*
4. *How is the field arranged in a field controlled motor?*
5. *How is the voltage reduced in electric locomotives from high tension to low tension for the motors?*
6. *How are locomotives designed for both overhead wire and third rail operation?*
7. *What types of drive are used between motor and power wheel axle?*
8. *Describe the method of laying out gears.*
9. *How is a gear ratio usually expressed?*
10. *What are the points relating to locomotive selection?*
11. *Give comparison of the power required for train operation, in accelerating and at constant speed.*

12. *What are the features of mine locomotives?*
13. *Describe a Diesel electric locomotive.*
14. *Describe at length the locomotive control equipment.*

CHAPTER 134

Current Collecting Devices

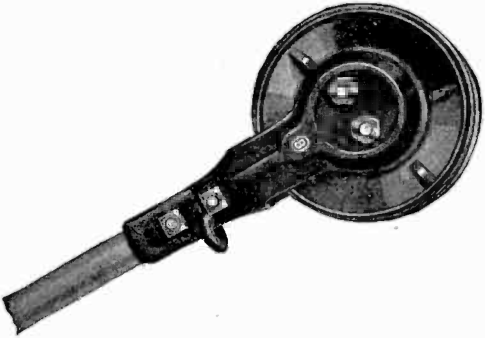
Classification.—The various electric traction systems in successful use as distinguished by the mechanical means provided and special methods adopted for supplying current to the motors are, as already mentioned, divided into four classes:

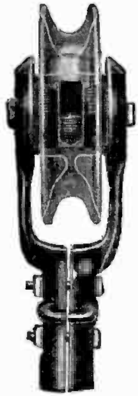


FIGS. 6,190 and 6,191.—Trolley wheels. Fig. 6,190, Ideal trolley wheel; fig. 6,191, Union standard trolley wheel. The trolley wheel must not be hard enough to wear the wire unduly, it must not be soft enough itself to wear out readily, and it must have maximum conductivity. Union standard trolley wheels are made of phosphor bronze, while the Ideal trolley wheel is made with a forged copper center on either side of which steel flanges are pressed.

1. Overhead trolley system;
2. Pantagraph system;
3. Third rail system;
4. Underground rail or conduit system.

The Overhead Trolley System.—In this arrangement which is largely used in towns and cities, the current for the motors





FIGS. 6,192 and 6,193.—Ohio Brass trolley wheel and harp.

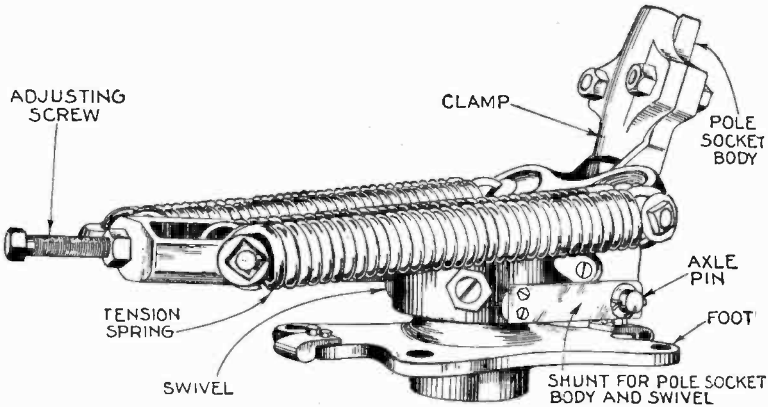


FIG. 6,194.—Nuttall roller bearing trolley base for interurban or city service. This base is supplied with copper shunts which connect the pole socket axle pin to the swivel casting and obviate the necessity of carrying current through the bearing. Its wheel pressure increases as the pole approaches the perpendicular.

is taken from an overhead wire by means of a "trolley" with grooved wheels, which is held up against the wire by a flexible pole. The wires from the contact wheels pass down the pole to the car controller and thence to the motor, the return circuit usually being through the rails.

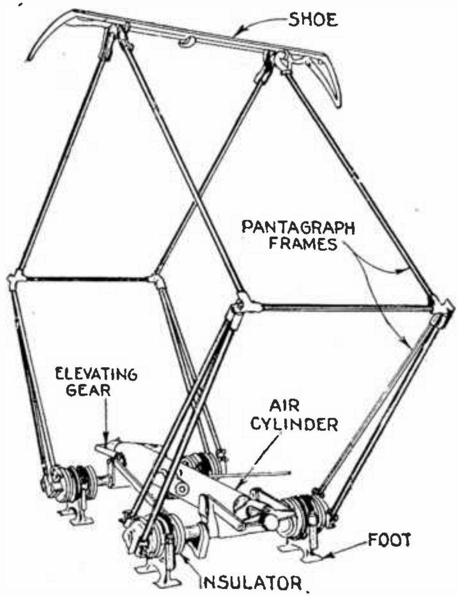
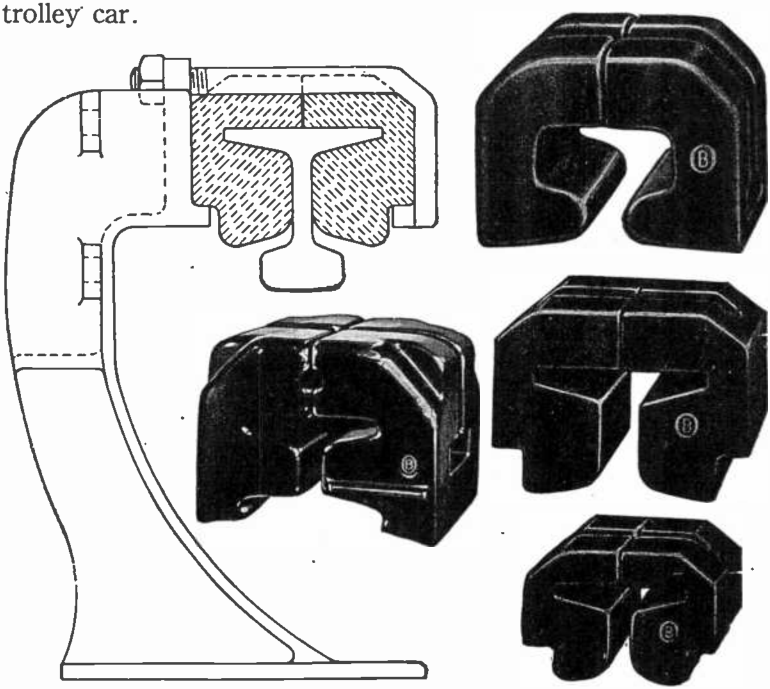


FIG. 6,195.—Pantagraph, single shoe type.

Pantagraph System.—This is a *form of trolley used in high speed electric traction*. A broad contact shoe formed of conducting material is supported by jointed elbows resembling a pantagraph carried on springs. The trolley is raised and lowered by compressed air. The top of contact member of the pantagraph slides along the overhead wire and is used where the voltage is high; for instance, 1,100 volts or over.

The Third Rail System.—In this system a rail called the "third rail" is laid outside the track rails. The current is taken by means of a suitable contact shoe which slides along the rail, and the car is controlled by the motorman as in the case of a trolley car.



FIGS. 6,196 to 6,200.—Ohio Brass third rail support and insulator, for under contact operation. This is used in open roadways where snows may be heavy and it is necessary to have greater distance between the live rail and the ground. The shoe slides under the rail instead of on top of it as in subways or other protected places.

The third rail contact shoe is a projecting foot or shoe at the base of the car, supported by springs and which presses against and slides upon a rail energized to give the current.

In the operation of trains as in subways or on elevated roads where the consumption of current is considerably heavier than for single cars, third rails displace the trolley wires for conveying the current to the motors.

Ques. What are third rails?

Ans. Track rails set on insulators alongside of tracks to provide a means for supplying large quantities of current to trains.

Ques. How is this done?

Ans. By means of shoes extending from the bottom of the cars which slide along the top or underside of the rails.

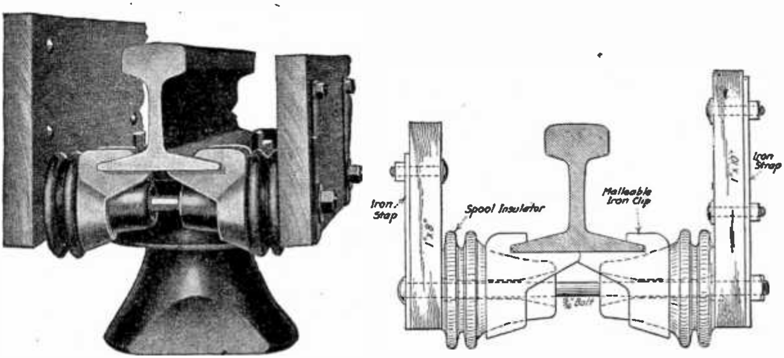


FIG. 6,201 and 6,202.—Third rail support and insulator for higher than 600 volt operation and protection boards at the side for protection against side contact.

Third rails are installed in various ways as regards protection against contact and for workmen; and these ways depend upon the roadway, the type of shoe used, and the amount of protection required.

For top contact shoe, side boards are used as shown in fig. 6,201; for sliding contact shoe, a top covering with sufficient spacing for the shoe to come in at the side is used; for under-contact shoe, a metal insulator holder covers the rail and offers the necessary protection.

Ques. How are third rail sections made continuous electrically?

Ans. Either by welding the joints or by putting on splice plates, as on track rails, and copper bonds across them.

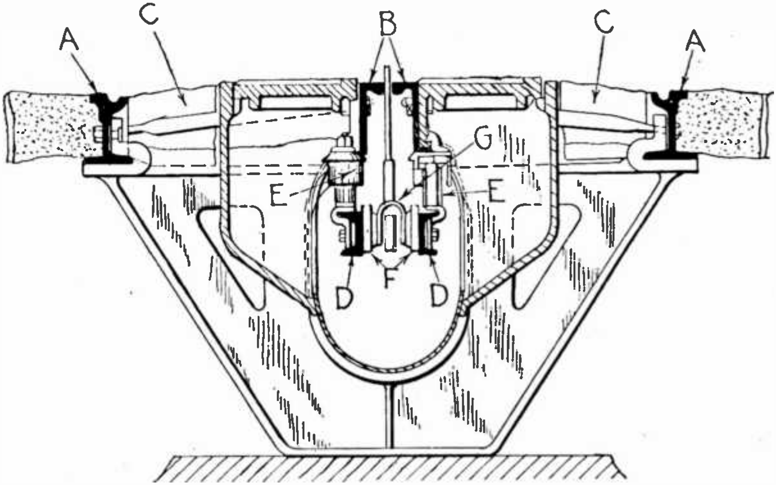


FIG. 6,203.—Yoke construction for conduit or underground trolley, as installed on Metropolitan Railways, New York City. These yokes were placed 5 feet apart in an excavation made through the street. The track rails A, A, and the slot rails, B, B, were then laid on the yokes, and the ties C, C, inserted. The whole structure was then blocked up, surfaced and lined, and constituted the track construction. The conductors consist of two channel beams, D, D, placed 6 inches apart and supported by insulators E, E, at each yoke. The contact rail joints are bonded in a manner somewhat similar to ordinary rail bonding, and form a complete metallic circuit having a pressure of 500 volts between the conductors. The current from these conductors passes through the slot or opening between the slot rails and extends into the conduit to a distance sufficient to bring the plow contacts or shoes F, against the conductors. The spring G, tends to keep the shoes normally about 8 inches apart, so that when they are pressed into the 6 inch space between the conductors, they maintain a firm sliding contact with the latter. Hand holes provided with iron covers are placed about 15 feet apart directly over the insulators. The manholes are placed about 150 feet apart, and usually between the tracks. Arrangements are made at these points to drain the conduit into the sewers. The bottom of the conduit is given a minimum grade of 2 inches to 100 feet, so as to insure proper drainage on sections of level track. The contact rails are treated like a double trolley wire, and the feeders and mains are laid in underground conduits. This system is so expensive to install that its use is limited to only the largest cities where for various reasons the use of the overhead trolley is objectionable and prohibited.

Ques. What are bonds?

Ans. Bonds are copper straps with terminals for carrying the current around the track joints.

Ques. How are they fastened?

Ans. By drilling holes in the rails and compressing the ends or terminals of these copper straps in the holes.

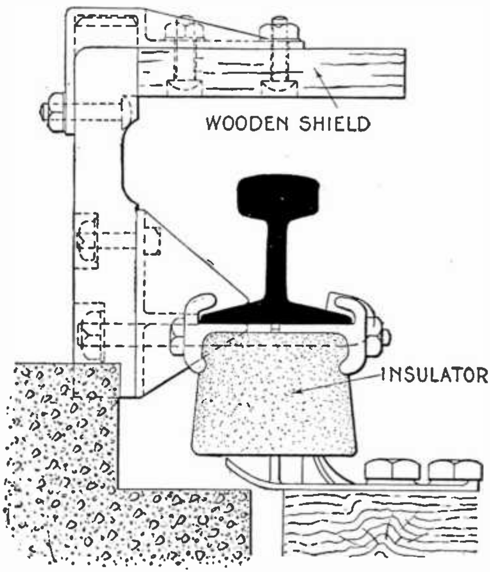
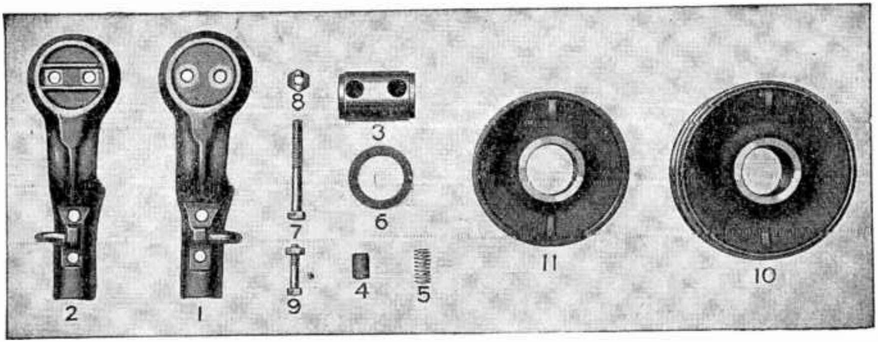


FIG. 6,204.—Cross section showing construction of protected top contact third rail.

The Underground Trolley or Conduit System.—This system is used only in large cities where trolley cars are maintained and poles and overhead wires are not permitted. The construction is extremely high in cost compared with trolley wire installation.



FIGS. 6,205 to 6,215.—Ohio Brass Co. trolley wheel and harp parts. Harp (includes one of 1, one of 2, two of 9). ***The parts are:*** 1, harp casting, right hand (smooth face for axle bolt nuts); 2, harp casting, left hand (ribbed face for axle bolt heads); 3, axle (without plugs or springs); 4, graphite plug (three required per axle); 5, spring for graphite plug (three required per axle); 6, fibre washer (two required per axle); 7, axle bolt, without nut (two required per axle); 8, grip nut, special, for axle bolt (two required per axle); 9, pole attachment bolt with nut (two required per harp); 10, 6 inch trolley wheel; 11, 5 inch trolley wheel.

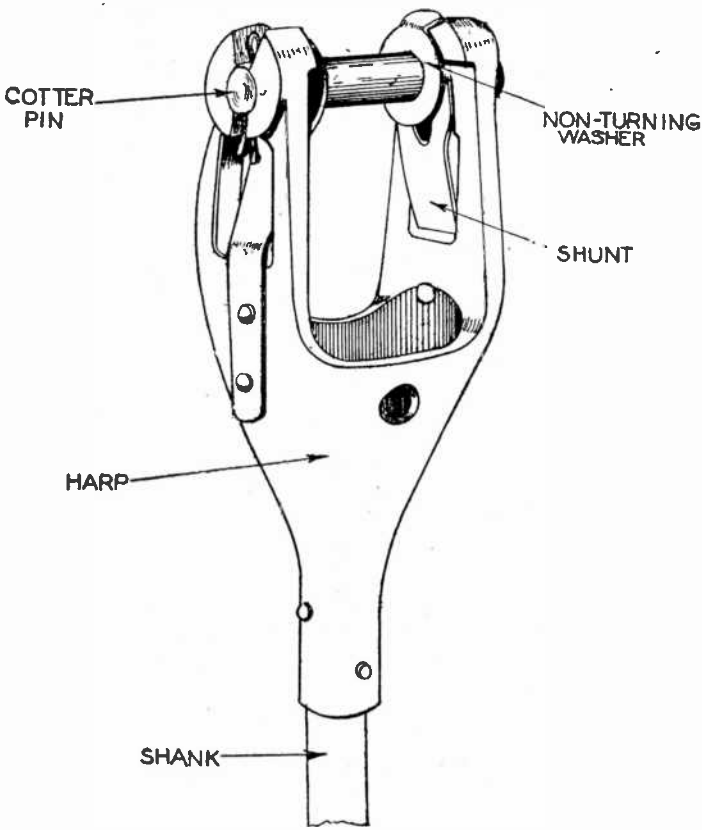


FIG. 6,216.—Typical trolley harp. ***In construction*** a harp is best made of malleable iron as this metal is best adapted for the strenuous overhead service because harps so constructed are strong enough to withstand shocks caused by wheels leaving the wires. Heavy harps place a severe burden on the springs in the trolley base and make the spring action sluggish, but malleable iron harps, because of their light weight, do not retard the function of the springs. Furthermore, there are no sharp corners or projections to catch and tear down overhead. The features of these harps are: 1, Non-turning washer—a lip on the edge of the washer fits down into a slot in the harp and locks the contact washer in place. 2, Phosphor bronze shunt springs—the shunt springs are turned into a slot and riveted to the outside of the harp. The shunt springs do not come in contact with the wheel and consequently there is no friction wear. 3, Axle pin—the axle pin is case hardened. The cotter pin which holds it in place is easily accessible and may be removed on the job quickly and without difficulty.

TEST QUESTIONS

1. *Give a classification of the various current collecting devices.*
2. *In what localities is the overhead trolley largely used?*
3. *Describe the overhead trolley.*
4. *What is a pantagraph?*
5. *How is a pantagraph raised or lowered?*
6. *Describe the operation of the pantagraph system.*
7. *What is a "third rail"?*
8. *How is current taken from a third rail?*
9. *Describe several types of third rail mounting.*
10. *Name two methods of shoe contact.*
11. *How are third rail sections made continuous electrically?*
12. *What are bonds?*
13. *Describe the underground trolley or conduit system.*
14. *What are the requirements of a conduit system?*

CHAPTER 135

Railway Control Methods

The control apparatus on a car provides for the correct application of power in starting, for operation "forward" or "backward" for opening the power circuits in order to slow down or stop, and for the protection of the equipment.

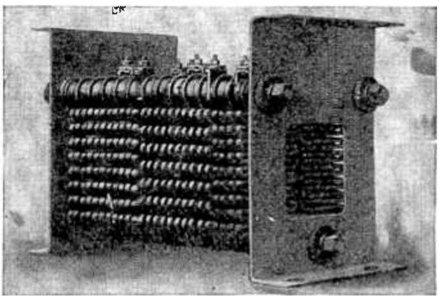


FIG. 6,217.—Westinghouse standard resistor for *d.c.* railway equipment.

If full trolley voltage were applied to the motors at standstill, an enormous current would flow through them and they would develop an immense tractive effort. The result would be disastrous both electrically and mechanically; in fact, satisfactory operation would be impossible.

The control, therefore, includes electrical resistance, made up in the form of grids mounted in one or more frames, fig.

6,217, which is connected in series with the motors during the starting.

This resistor is provided with taps so that the amount of resistance in the circuit may be gradually reduced from the maximum at the instant of starting until it is finally all cut out of circuit and the motors are receiving full voltage.

The various connections are made through a controller, each step at which a connection is changed being known as a "point" or "notch" on the controller.

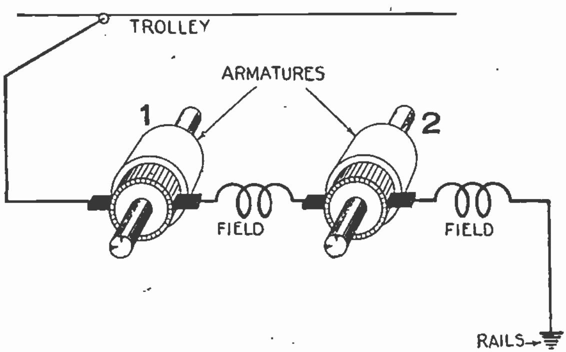


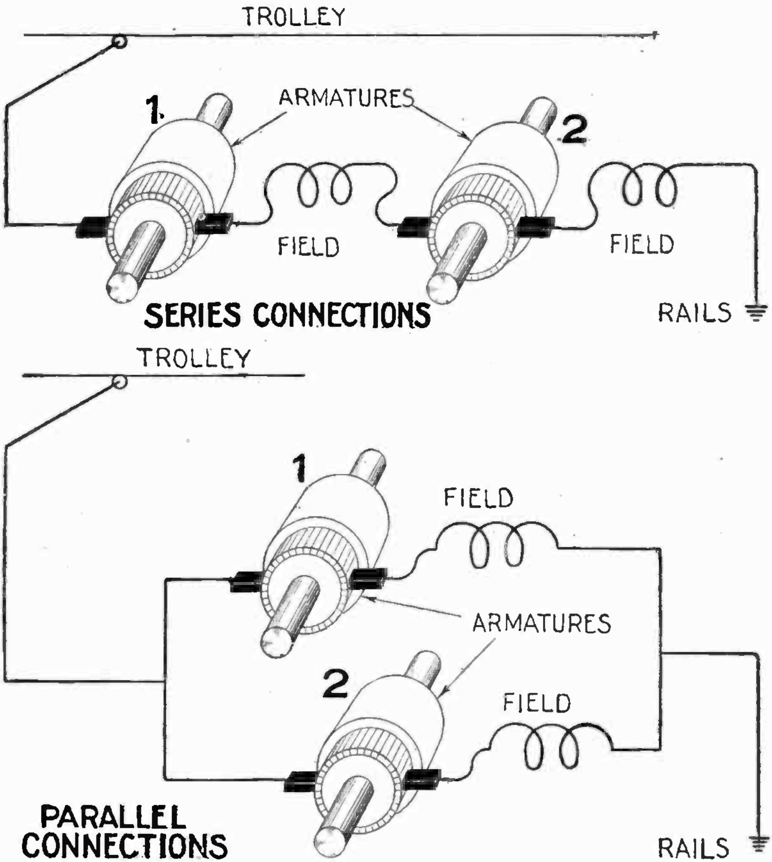
FIG. 6,218.—1,200 volt *two motor* equipment.

As a controller has comparatively few points, the voltage applied to the motors is increased gradually by steps, instead of continuously, which would be the ideal method, if practicable. Hence, the current and consequently the tractive effort of the motors vary during the "notching up" process.

Controllers and resistors are designed so that with ordinary handling the voltage steps will be fairly regular and the variation of current in the motors limited so that smooth starting results.

Fig. 6,221 shows approximately how the current CC[1] and the voltage at the motors VV[1] change as the controller is operated.

All modern railway equipments include an even number of motors.



FIGS. 6,219 and 6,220.—Series, and parallel hook ups for 600 volt *two motor* equipment.

With one motor equipments and where only two motors are used and are connected in series so that they may be operated from the trolley at twice the motor voltage (such as two 600 volt motors in series on a 1,200 volt trolley), fig. 6,219 and 6,220, indicate the starting conditions and proportion of rheostatic loss. Only a small number of such car equipments are in use and their field is very limited. The platform controllers used with them are known as R type or rheostatic controllers. Hence, it may be said that the majority of car equipments may have the motors individually connected in series or parallel with each other, or the motors may be grouped two in series or two in parallel and the groups connected in series and

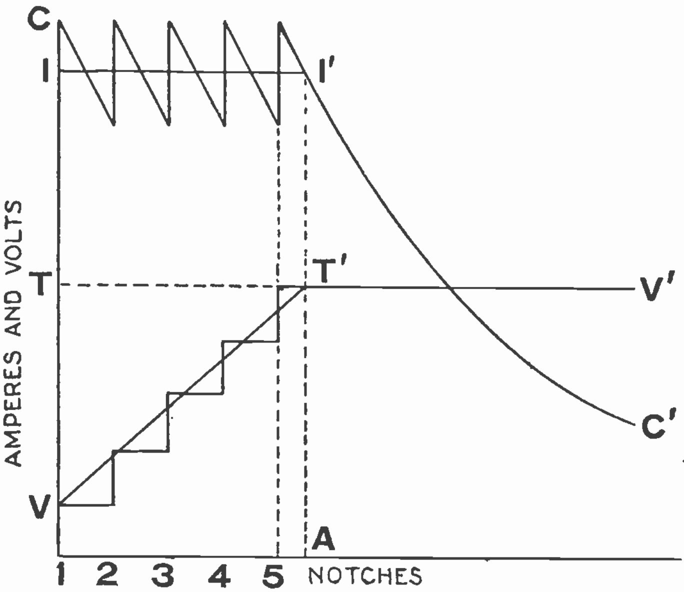


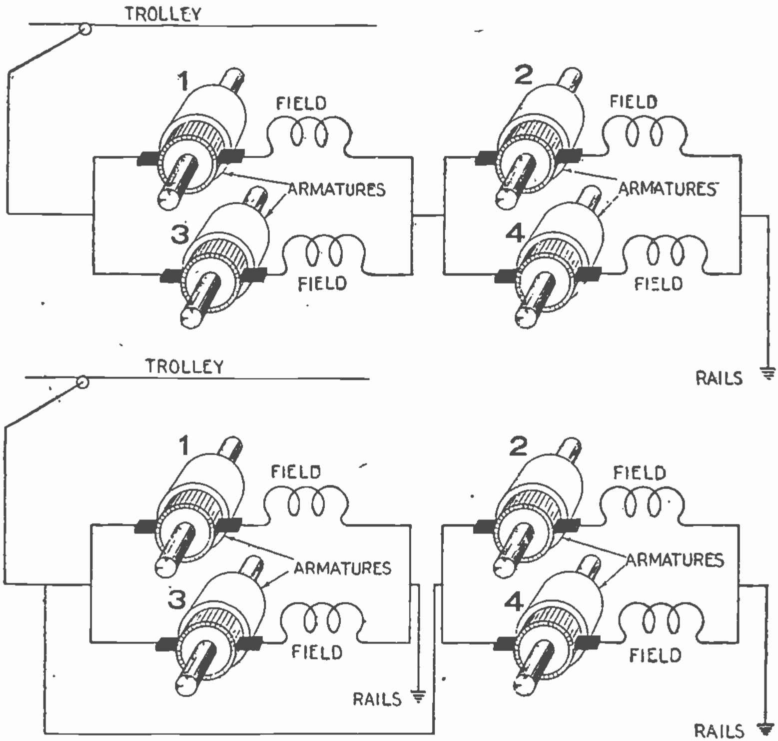
FIG. 6,221.—Volt and ampere diagram for various positions of the controller. For simplicity in calculation the voltage is assumed to vary continuously as indicated by the line, VT', and the current is assumed constant during notching as shown by the line II'. Although the voltage applied to the motors themselves varies from V to T', the voltage at which current is taken from the trolley is constant at TT'. The difference between trolley and motor voltages is taken up by the resistor. In the diagram, the area TT'A1, is a measure of the total energy taken from the trolley while notching up the controller and the area, VT'A1, measures the portion of this total energy received by the motors. The area VTT', represents that portion of the total energy which is absorbed in the resistor and is a total loss, as it does no useful work but is dissipated by the resistor as heat. In the figure this resistance loss is nearly one-half of the total energy taken from the trolley during the starting period.

parallel for starting. The purpose of such series parallel arrangements is to reduce the rheostatic loss below the amount indicated by fig. 6,221.

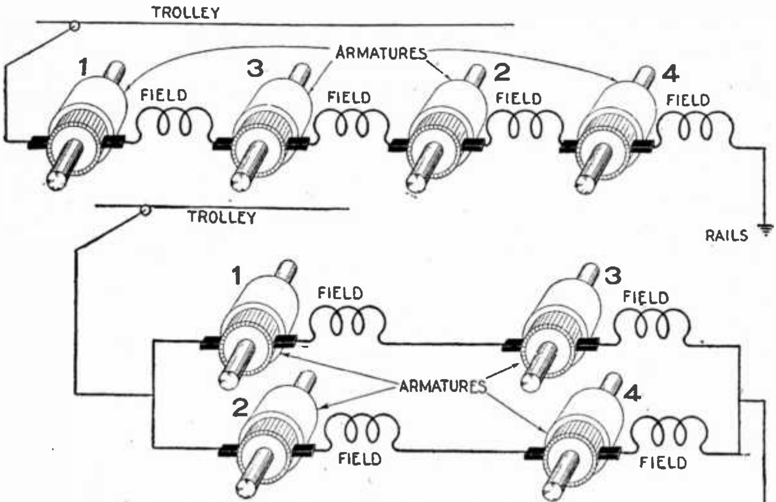
When two motors are in series each takes only half of the trolley voltage as explained in fig. 6,226.

In some few instances, further reduction in the resistance loss has been secured by using series, series parallel, or parallel connections as shown in figs. 6,227 to 6,229.

By this arrangement approximately one-half of the loss. VSS[1], of fig. 6,226 is saved and the total resistance loss is approximately three-fourths



FIGS. 6,222 and 6,223.—Series and parallel hook ups for 600 volt four motor equipment.



FIGS. 6,224 and 6,225.—Series, and parallel hook ups for 600 volt four motor equipment.

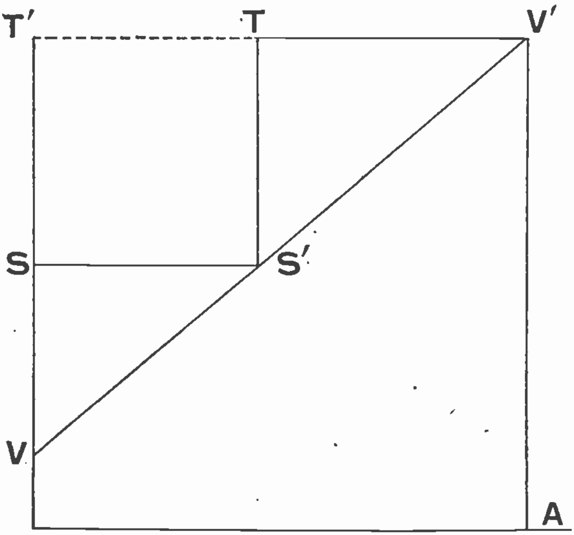
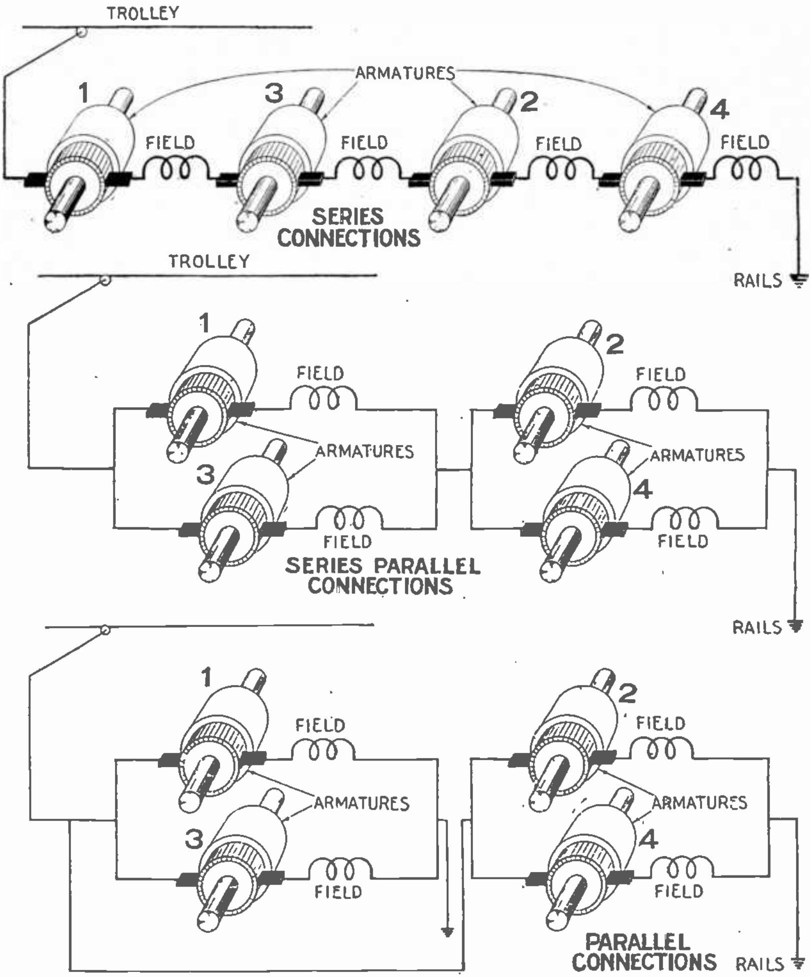


FIG. 6,226.—Diagram showing that the loss in resistors is approximately one-half the amount it would be without the series parallel connection. While in series the voltage for one motor and its resistor is only, SS^1, or half the trolley voltage, T^1TV^1. The energy delivered to the motor in either case is VS^1V^1A. With series parallel control, the resistance loss is $VSS^1 + TV^1S^1$, while with motors permanently in parallel, the loss is VT^1V, which is approximately twice as great.



FIGS. 6,227 to 6,229 —Series, series parallel and parallel hook ups for 600 volt four motor equipment.

of what it is with ordinary series parallel control, as shown in figs. 6,219, and 6,220 and figs. 6,222 to 6,226, or is approximately three-eighths of the amount it would be with the rheostatic control shown in figs. 6,218 and 6,221. However, it is an exceptional case where the reduction in resistance loss by using the connections of figs. 6,227 to 6,229 instead of those of figs. 6,222 and 6,223, justifies the additional complication in the control apparatus and wiring necessary to secure it. Therefore, series and parallel control as shown in figs. 6 222 to 6,225 is standard for car equipments.

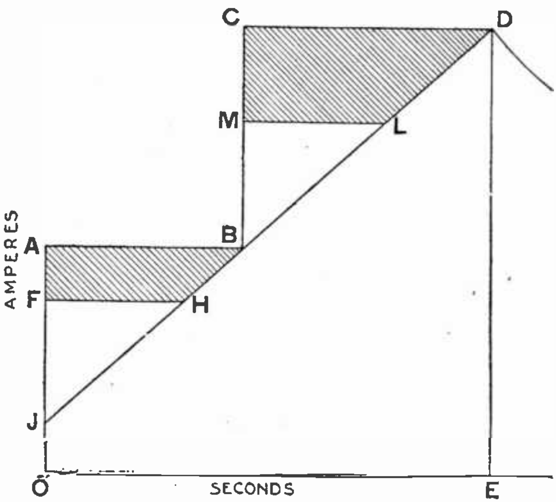
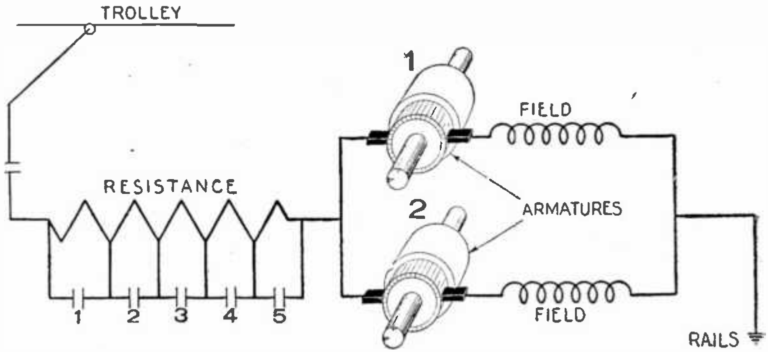


FIG. 6,230.—Field control diagram. In the diagram, AB and CD, indicate the currents per car taken from the trolley in series and parallel respectively, without field control. The area OABCDE, is a measure of the total energy taken from the trolley in starting, and the area, OJBDE, represents the actual input to the motors, while the areas, JAB, and BCD, show the rheostat losses. If field control be used, the currents are reduced to FH, and ML, with full field, but on the short field notches they are at B and D. The total energy from the trolley is represented by the area OFHBMLDE, while the energy delivered to the motors is the same as without field control, OJBDE, and the rheostatic losses are shown by the area, JFH, and BML.

Field Control Motors.—The use of field control motors increases the equipment efficiency in starting by reducing the resistance loss, as shown in fig. 6,230. From the explanation, it is evident that the rheostatic losses, and therefore the total energy taken by the car, are reduced by the amount indicated



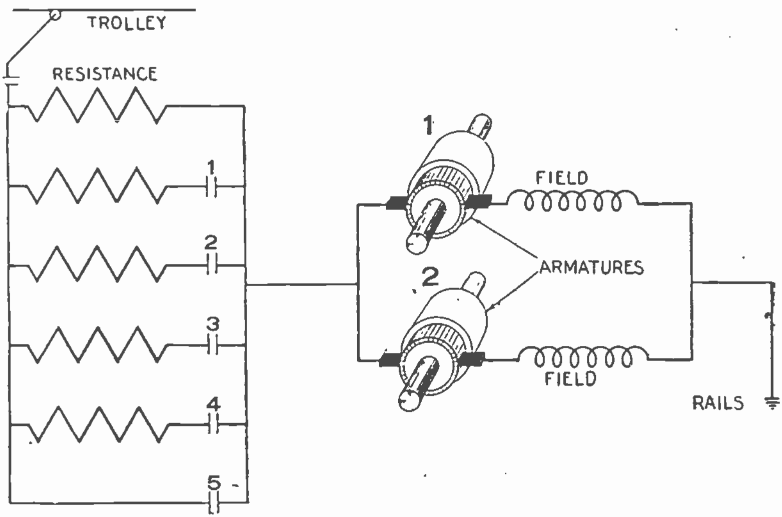


FIG. 6,231.—Diagram of two motor equipment showing series resistors used in starting. Switches for short circuiting the sections are indicated at 1, 2, 3, 4, and 5. When power is first applied all of these switches are open. They are closed consecutively in notching up the controller until all are closed. In this position the motors are running on full voltage without resistance in the circuit and this is an economical operating condition.

FIG. 6,232.—Diagram of two motor equipment showing parallel resistors used in starting. 1, 2, 3, 4, and 5 indicate switches which are all open at the start and are closed consecutively as the controller is operated. When switch 5 is closed the equipment is in an economical running connection.

by the areas FABH and MCDL. In various service tests, this reduction in energy consumption by the use of field control has been found to be from 5% to 17% of the total energy taken by the car.

Starting.—Three classes of resistor connections are used in starting.

With series resistors all of the resistance is in circuit at first and it is gradually short circuited by sections as shown in fig. 6,231.

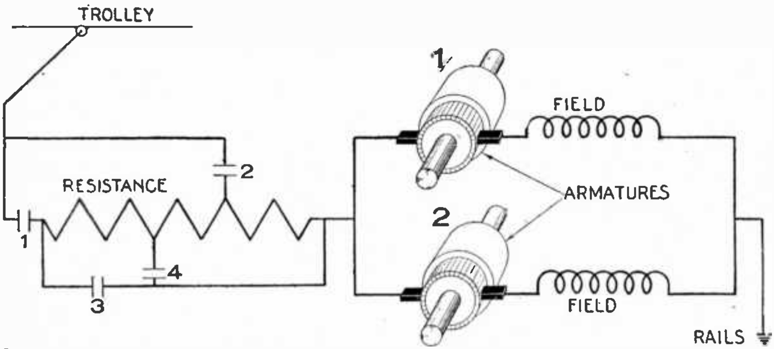


FIG. 6,233.—Diagram of two motor equipment showing series and parallel resistors. The sequence of operation of the switches in this case is indicated in fig. 6,234.

With "parallel resistors" only a part of the resistor is in circuit at starting and additional resistors are connected in parallel with the initial section by successive notches until finally the entire resistor is short circuited, as shown in fig. 6,232.

The third class of resistor includes those combinations using both series and parallel connections.

One such resistance is illustrated in fig. 6,233. The sequence of operation of the switches in this case is indicated by fig. 6,234, which shows by the circles which switches are closed on each controller point. Notch 5 is the running notch without resistance in circuit.

STEP	SWITCHES			
	1	2	3	4
1	●			
2		●		
3		●	●	
4		●		●
5	●	●	●	

FIG. 6,234.—Diagram showing sequence of operation of the switches in the hook up shown in fig. 6,233.

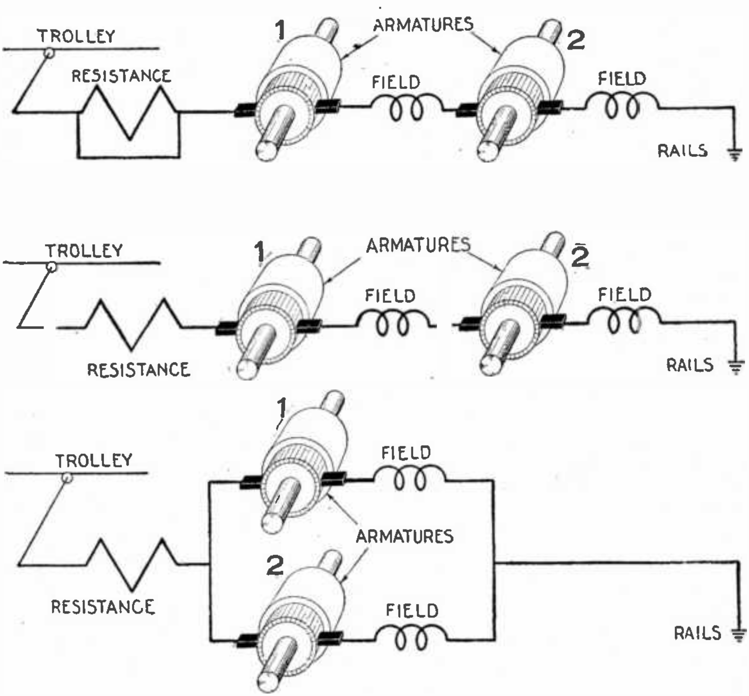
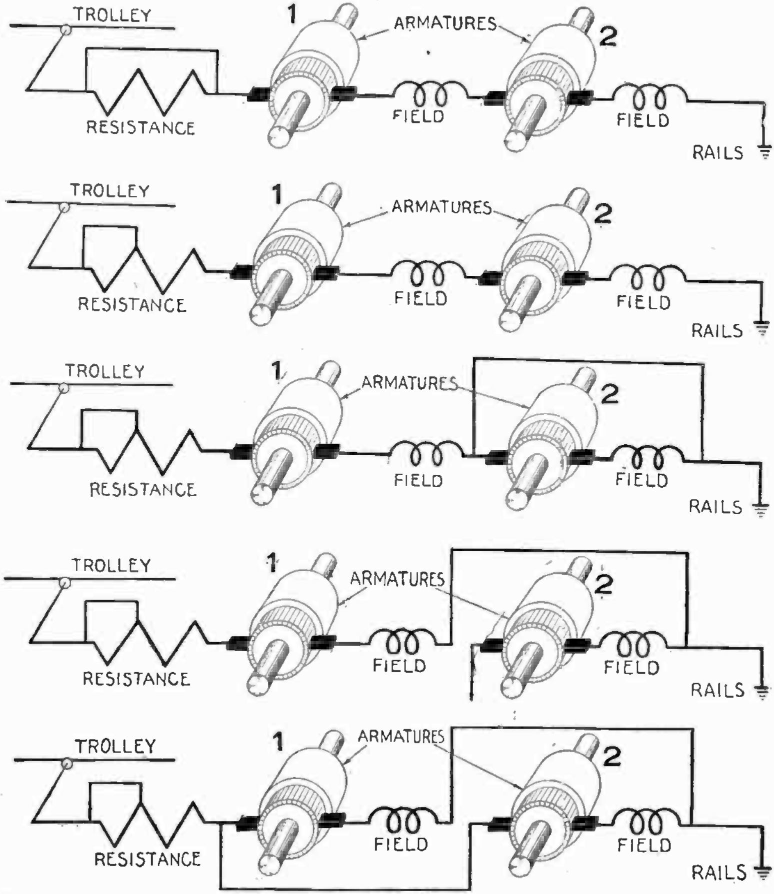


FIG. 6,235 to 6,237.—Diagrams of two motor equipment showing the connections for the last series, transition and first parallel points of the open circuit method.

Transition.—Three methods of making the transition from series to parallel connection of the motors are in use:

1. Open circuit;

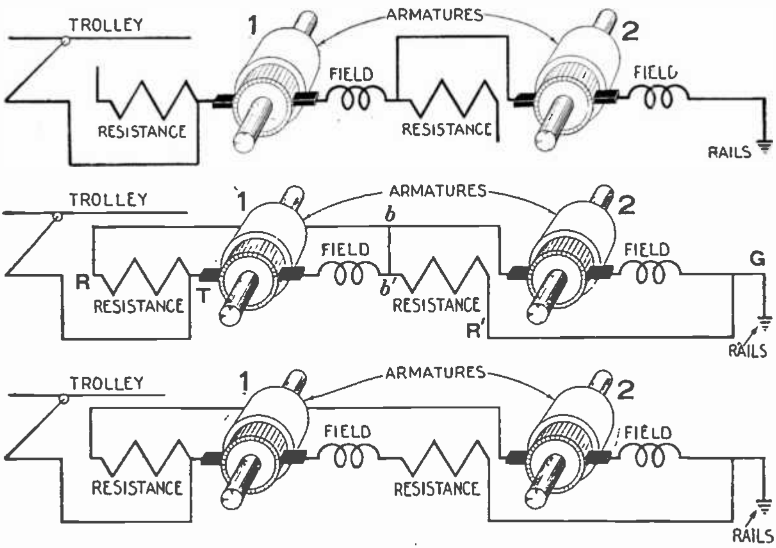


FIGS. 6,238 to 6,242.—Diagrams of two motor equipment illustrating the last series, transition and first parallel steps of the shunting method. Here there are three transition steps.

2. Shunting;
3. Bridging.

Open Circuit Method.—The connections for the last series transition and first parallel points of the open circuit method are shown in figs. 6,235 to 6,237. This is the method of series paralleling used with the L type of platform controllers most of which also use the method of parallel resistors.

These controllers were built only for large equipments, from 350 to 500 *h.p.* at 500 volts and since for equipments of such capacity it is now common



Figs. 6,243 to 6,245.—Diagrams of two motor equipments showing bridging method. Two resistors are used. On the transition step the motors in series are receiving full trolley voltage through the circuit Tb¹bG and the two resistors are in series with each other between trolley and rails thus forming a circuit TRbb¹R¹G in parallel with the motor circuit. A bridging connection bb¹, is made between the junction points of the two resistors and the junction point of the two motors and establishes two other parallel circuits, Tb¹R¹G and TRbG, each comprising one motor and one resistor in series. On the first parallel notch the bridge bb¹, is opened and the motors are in parallel with a resistor in series with each motor.

practice to use unit switch control, L type controllers may be considered as practically obsolete. Of course a number of L controllers which were installed in past years are still in successful operation.

Shunting Method.—The last series transition and first parallel steps of the shunting method of series paralleling the motors are shown in figs. 6,238 to 6,242. Here there are three transition steps:

1. First transition;
2. Second transition;
3. Third transition.

This method has an operating advantage as compared to the open circuit method in that only one-half of the torque is dropped during the transition instead of all torque being lost. Series paralleling by this method is used with most platform controllers of the K type, which also employ the method of series resistors, and with unit switch control except where automatic operation is required or the current handled is comparatively large.

Bridging Method.—This method is shown in figs. 6,243 to 6,245 from which it is seen that the last series transition and first parallel steps of the bridging method of series paralleling the motors are indicated.

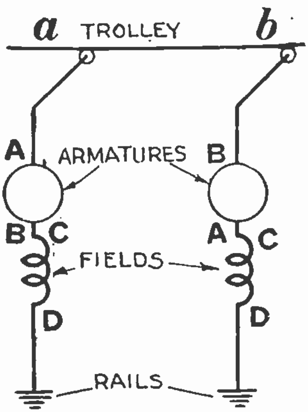
This method has an advantage over both of the other methods in that both motors are working all the time and none of the torque is dropped during the transition period. Bridging is used where automatic operation unit switch control is desired and with hand operated unit switch control, where heavy current is handled.

Reversing.—It is necessary to be able to run cars backward as well as forward. Since the driving motors are positively geared to the car axles, a change in the direction of motion of the car requires a change in the direction of rotation of the motor.

The direction of rotation of series motors *depends upon the relative directions of the current through the field and armature windings.*

If the direction of current through both field and armature be reversed, the direction of rotation will not be changed. A change in the relative directions of field and armature current, and therefore in direction of rotation, is made by reversing the connections of eithe- the field or armature in the circuit.

Example.—In fig. 6,246, if *a*, represent the connections to run the car forward, *b*, shows the connections for backward operation.



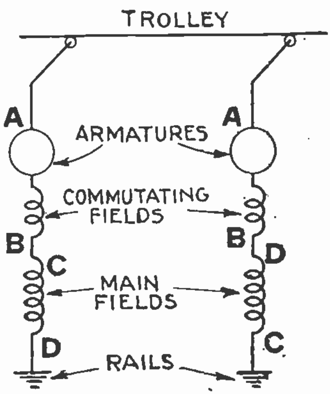


FIG. 6,246.—Diagram showing connections for forward and backward operation. At *a*, brush A, is connected to the trolley and brush B, to the positive side of the field. At b, the brush B, is connected to the trolley and A, to the positive side of the field. The negative side of the field is permanently connected to ground and the armature has been reversed. This is the standard method of reversing used with motors which do not have commutating poles.

FIG. 6,247.—Commutating pole motor hook up for reducing the voltage on the field coil insulation.

Commutating pole motors require that *the armature and commutating pole windings be connected so that the relative directions of current through them shall always be the same.*

It is further desirable that both the commutating and main field windings shall always be on the ground side of the armature on account of the reduced voltage strains on the field coil insulation. In order to secure these features, the commuting pole winding is permanently connected to the negative armature brush and the main field winding is reversed between the negative terminal of the commutating pole winding and the ground, as shown in fig. 6,247.

Electric Braking.—Track brakes are used to a limited extent with car equipments, in which case the controllers must be arranged to make the necessary connections. The energy for track brakes may be taken direct from the trolley or from the motors acting as dynamos driven by the stored energy in the car after the power is cut off.

For braking, *all the motors are in parallel and connected to the brake magnets through resistance which is varied as the car speed is reduced.*

In case of failure of the brakes, it is possible to brake the car by suitable manipulation of the controller and reverser, except where the equipment includes only a single motor or its equivalent of two motors permanently in series.

When a car is running without power there is a slight residual magnetism in the field poles although no current is flowing in the field coils and there is a tendency to generate voltage in the armature. With the reverser set for the direction in which the car is moving, this voltage is in such a direction that if it should produce a current through the field, this current would demagnetize the field which in turn would kill the voltage and current. Hence the motors will not pick up as series dynamos.

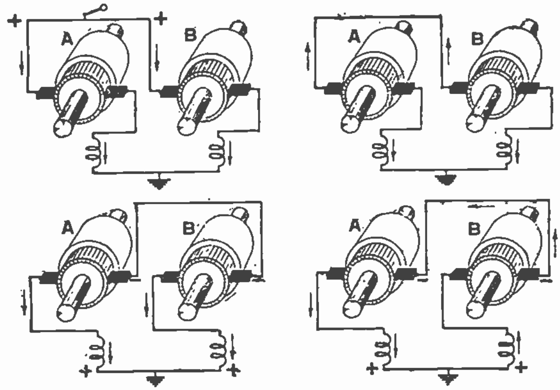
If, however, the car be moving forward and the reverser be thrown to its position for backward motion, the voltage set up in the armature by the residual magnetism tends to send a current through the field in such a direction that the field magnetism is increased which in turn builds up the armature voltage and current. In this way the motors are made to pick up as series dynamos.

An inherent characteristic of a series dynamo is that *it must be connected to a load in order to generate any voltage and the value of the voltage generated depends upon the amount of the load.*

If two motors be connected in parallel, with the reverser set for generation, both motors tend to generate in the same direction and therefore oppose each other.

In practically all cases one of the two motors is stronger than the other so that it "picks up" as a dynamo and the weaker motor runs from it as a motor tending to reverse the direction of motion of the car.

In fig. 6,248, is indicated by signs the voltage and by arrows the direction of current for two motors in parallel taking power from the trolley. In 6,249 the arrows show the tendency of armatures and fields to oppose each

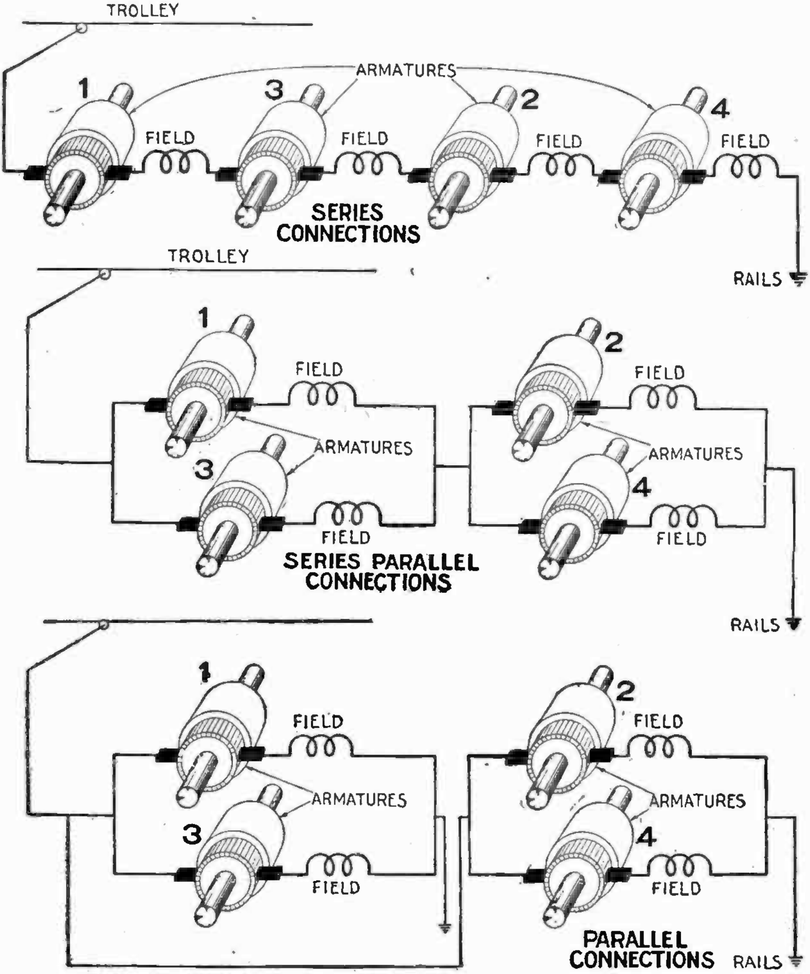


FIGS. 6,248 to 6,251.—Diagrams of two motors in parallel showing voltage and current conditions when taking current from the trolley, and when not taking current from the trolley.

other and maintain an electrical balance with no current flowing, which is the condition when the car is running without power. When the reverser is thrown to the backward position while the car is moving forward, the connections are as shown in fig. 6,250, and the signs and arrows respectively indicate the voltage and the direction in which current tends to flow initially.

If it were practicable to manufacture motors absolutely identical electrically and magnetically, a condition of balance would exist with two such motors connected as in fig. 6,250 and no current would flow.

Practically, however, one of the motors will always generate a higher voltage than the other and sufficient to drive current through it in the direction opposite to the voltage which it tends to generate.



Figs. 6,252 to 6,254.—Diagrams of four motor equipment arranged for three speed control.

In fig. 6,251 motor A, is operating as a dynamo driven by the momentum of the car, and is generating a higher voltage than motor B, thus furnishing power to operate B, as a motor tending to retard the car. This scheme is used only for emergency braking. When two motors are permanently in parallel, as with a 600 volt quadruple equipment, this emergency braking is secured by simply moving the controller to the off position and then throwing the reverser. With 600 volt double, 1,200 volt quadruple equipments, or 600 volt quadruple equipments arranged for three speed control, as in fig. 6,252, where all motors are in series at first, in order to secure emergency braking it is necessary to move the controller to the off position, throw the reverser, trip the circuit breaker, so that line power cannot be applied, and then move the controller up to the first notch on which motors are in parallel. This method of braking is equivalent to running one motor of a pair as a dynamo and the other as a load. It is also possible to use other apparatus for furnishing the load.

The two motors of a pair *may be operated as dynamos in either series or parallel and an external resistance connected in series with them for absorbing the energy which they generate.*

This is known as electric braking.

The external resistance may be replaced by the magnet coils of the track brakes which act on the track and wheels, and hence give effective braking with much less current through the motors than with electric braking through resistance.

With either electric braking or track brakes, it is necessary to reverse the motors to make them "pick up" as dynamos.

If the motors be in parallel when used for this purpose, it is also necessary to interchange the fields; that is, in fig. 6,252, connect the field of motor A, in series with the armature of motor B, and field B, in series with armature A, in order to secure equal voltages from the two motors and stability of the system. If this interchange of fields were not made, emergency braking would occur just as though no resistance or brake magnets were connected across the motor terminals.

Protection.—To furnish protection against too heavy overloads or grounds and short circuits which may occur in an equipment, an adjustable circuit breaker, as shown in fig. 6,257 is connected in the cable between the trolley and the controller.

Circuit breakers are rated according to the current which they will carry continuously and for any specific equipment, are selected so that the current rating of the breaker is approximately two-thirds of the nominal one hour current rating of one motor multiplied by the number of motors in parallel in the equipment.

The breaker is usually set to trip at a current 50% greater

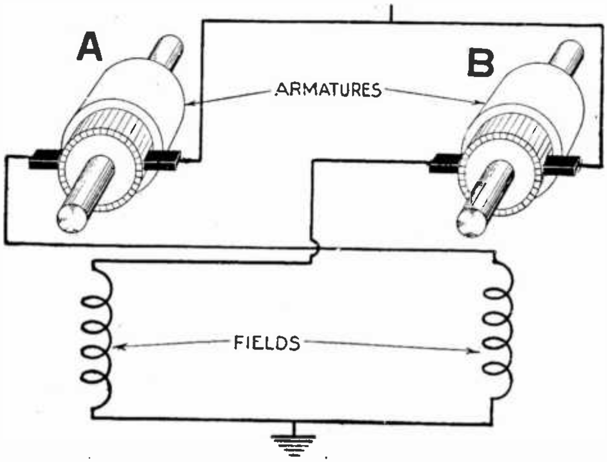


FIG. 6,255.—Two motor hook up to cause them to "pick up" as dynamos.

than the nominal current rating of one motor multiplied by the number of motors in parallel per equipment.

Example—A 600 volt car equipped with four motors, each rating 100 amperes for one hour, should have a circuit breaker with a continuous rating of $\frac{2}{3} \times 100 \times 4 = 267$ amperes. Ordinarily this breaker should be set to trip at $1.50 \times 100 \times 4 = 600$ amperes. On locomotives it is customary to set the breaker to trip at double full load on the motors. In the above case this would be $2 \times 100 \times 4 = 800$ amperes.

For protection against lightning and surges which occur in the contact line (trolley or third rail) *a lightning arrester is connected next to the collector and a choke coil is connected in the power circuit between the lightning arrester tap and the circuit breaker.*

If lightning or a line surge tend to produce an abnormal voltage at the car, which in turn tends to send a heavy rush of current through the equip ment, the choke coil limits the current rush and piles up the voltage next to

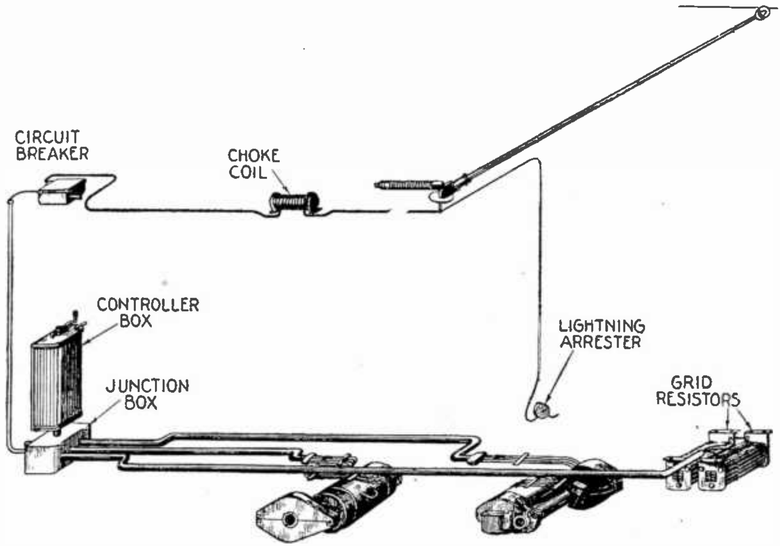


FIG. 6,256.—Westinghouse single end type K control equipment.

the arrester until the current finally jumps to ground through the arrester, the tension is relieved and normal conditions are re-established.

Fig. 6,256 shows in skeleton form the apparatus and connections for a single end car equipment employing two 600 volt commutating pole motors, platform type controller and auxiliary apparatus as described.

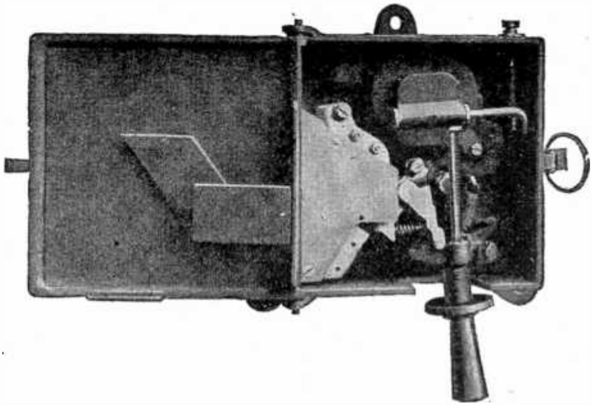


FIG. 6,257.—Westinghouse circuit breaker to furnish protection against too heavy overloads or grounds and short circuits which may occur in an equipment.

TEST QUESTIONS

1. *What are the functions of a control apparatus on a car?*

2. *What would result if full trolley voltage were applied to the motors of a car at standstill?*

3. *Name an important part of the control apparatus.*

4. *How are the various control connections made?*

5. *Does a controller increase the voltage by steps or uniformly?*

6. *Is an even or an odd number of motors used?*

7. *Describe the method of control with one and two motor equipment.*

8. *Describe the method of field control.*

9. *Name three classes of resistor connections used in starting.*

10. *Name three methods of making a transition from series to parallel connection of the motors.*

11. *Describe the open circuit method.*

12. *What connection is used in the shunting method?*

13. *Describe the bridging method.*

14. *Upon what does the direction of rotation of a series motor depend?*

15. *In reversing, what are the requirements of commutating pole motors?*

16. *What is understood by the term "electric braking"?*

17. *Describe the method of operating motors in electric braking.*

18. *What is necessary in electric braking to cause the motors to pick up as dynamos?*

19. *Describe the protective equipment.*

CHAPTER 136

Control Equipment

The type of apparatus described in this chapter is applied to cars and locomotives for 600 volt, 1,200 volt and 1,500 volt installation. The instructions and data covering this class of equipment apply in general to electro-pneumatic control equipment of special construction, such as would be required to multiple with other manufacturers' apparatus. Therefore, the information here given relating to individual pieces and parts of apparatus, such as controller boxes, switch groups, line switches, reversers, air cylinders, relays, etc., is practically the same regardless of special requirements.

For the benefit of platform operators, a general list of the apparatus involved is here given. The list of apparatus covers an equipment for four 65 *h.p.* 600 volt motors arranged for double end operation in trains on 600 volt trolley.

Main Circuit Apparatus

2 Trolleys.
1 Lightning arrester.
1 Main knife switch.
1 Main fuse box.
1 Control box.
1 Reverser (included in control box)
1 Main grid resistor.
1 Set insulating details.
1 Set pneumatic details.

Control Apparatus

2 Master controllers.
2 Control and reset switches.
1 Control resistor.
2 Train line junction boxes.
2 Train line receptacles.
1 Train line jumper

Trolleys collect the current from the overhead trolley wire usually by means of a revolving contact wheel.

Lightning arrester protects the control apparatus and main motors from lightning and other abnormal voltage surges.

Main knife switch, fig. 6,258, disconnects the main motor circuit from the trolley circuit so that the controlling apparatus may be operated independently of the main motors for inspection purposes.

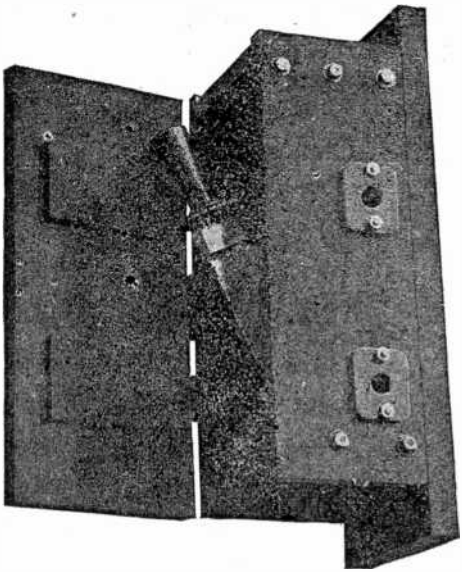


FIG. 6,258.—Westinghouse main switch. This is a knife switch for disconnecting the apparatus from the trolley circuit.

Main fuse box, fig. 6,259, provides ultimate protection to the equipment against sustained currents above the ratings of the apparatus, but below the setting of the overload trip protection.

NOTE.—The control equipment described and illustrated in the accompanying text is the Westinghouse type HL unit switch control equipment.

Control box and switch group, figs. 6,260 and 6,261. The main part of the equipment contains the resistance switches, the transition switches and where no separate circuit breaking line switch unit is used, the line switches. The difference between a control box and switch group is that the former includes the reverser mounted on one of the end plates, while a separate reverser is used with the latter.

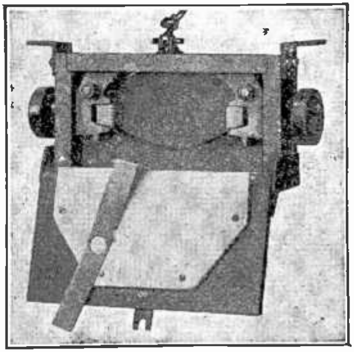


FIG. 6,259.—Westinghouse main fuse box to protect apparatus against excessive current.

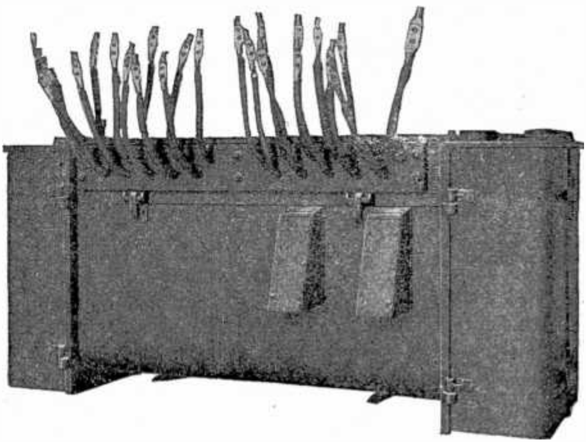


FIG. 6,260.—Westinghouse control box complete with covers.

Reverser, fig. 6,262, as its name implies, reverses the direction of current in the motor fields or armatures by interchanging the connections. This reversal of current in the field or armatures with relation to the armature or field current reverses the direction of running.

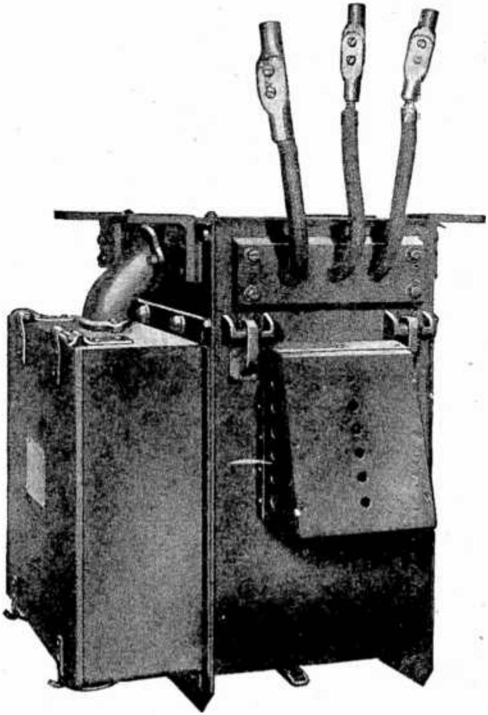


FIG 6,261.—Westinghouse line switch complete with covers.

Main grid resistor, fig. 6,263, limits the amount of current which flows and thus controls the torque developed by the motors. Notching of the master controller, which operates the switches in the control box or switch group, cuts out the resistance step by step, thereby permitting the motors to gradually speed up and hence the car to accelerate without excessive current and without undue discomfort to passengers.

Master controller, fig. 6,264, controls the starting and accelerating of the car. Closing and opening of main motor circuits are accomplished indirectly by the master controller energizing or de-energizing the control circuits of the switches in the control box or switch group.

Control and reset switch, figs. 6,265 and 6,266, energizes or cuts off power from the control circuit. It also resets the overload trip by energizing the reset coil.

Control resistor, fig. 6,267, provides relatively low voltages for the control circuits to the operating coils of the switches.

Train line junction boxes, fig. 6,268, are used to simplify the installation of control wiring and the inspection of equipments as a whole.

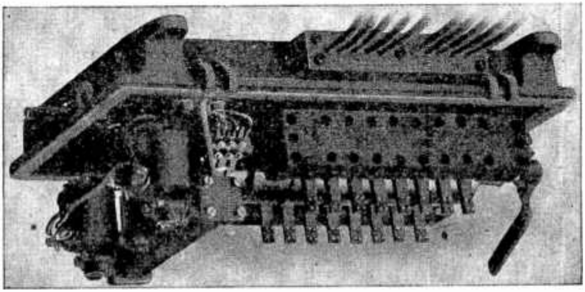


FIG. 6,262.—Westinghouse reverser for separate mounting.

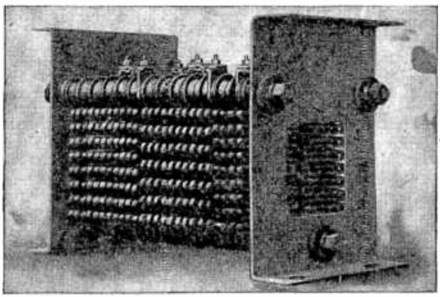
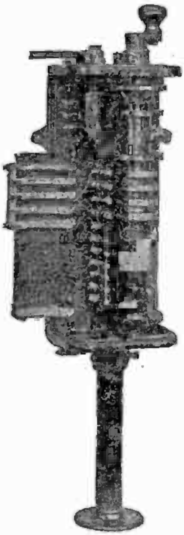


FIG. 6,263.—Westinghouse standard grid resistor for control circuits of motors. With all the resistance in, the amount of current the motors get is small and the car starts slowly; as the resistance is cut out, it gains speed.



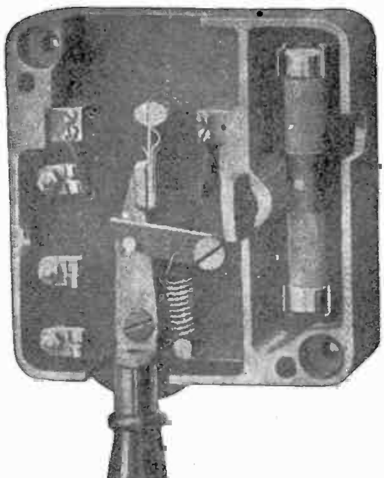


FIG. 6,264.—Westinghouse master controller shown without cover. ***It consists of*** a cylinder with contact rings, operated by the control handle, which open and close the circuits of the motor control switches, energizing and de-energizing their operating coils which cause air valves to admit air under pressure, into cylinders that control the moving parts of the switches.

FIGS. 6,265 and 6,266.—Westinghouse control and reset switch shown with and without cover.

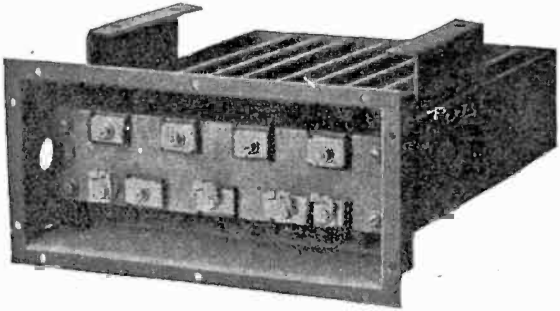


Fig. 6,267.—Westinghouse control resistor.

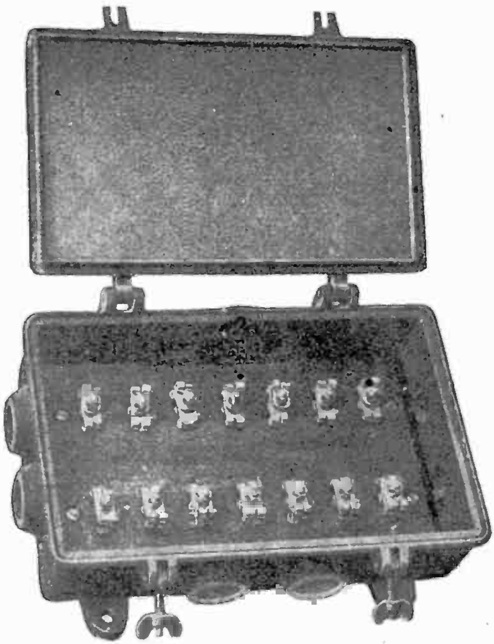
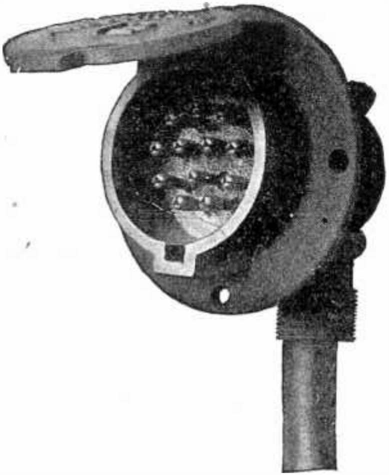


Fig. 6,268.—Westinghouse train line junction box open.



FIGS. 6,269 and 6,270.—Westinghouse train line receptacle and jumper for connecting the control wires of one car with those of another thereby enabling the motors of several cars to be controlled from one controller.

Train line receptacles, figs. 6,269 and 6,270, form control circuit terminals or extensions at the ends of car which in conjunction with the train line jumper completes the control circuits between adjacent cars of a train.

Insulating details are used to insulate the frame supports of the apparatus from ground to reduce voltage strains between parts of different voltages.

Pneumatic details provide means for cutting off the compressed air supply, for equalizing air pressures, and for cleansing the air. In some cases where air pressures above 75 lbs. are used a reducing valve for cutting down the pressure is supplied.

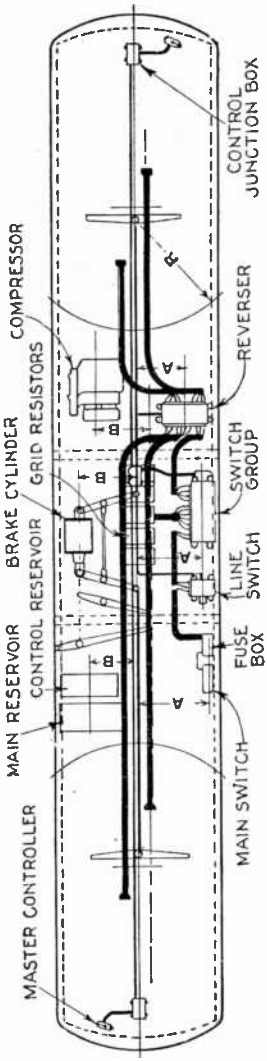


FIG. 6,271.—Typical car layout equipped with Westinghouse type HL unit switch control.

Operation

Single Car Operation. — *When taking charge of a car*, see that the main fuse is in place, the main switch and the pump switch are closed and the control air cut out cock is open. Be certain that all air tanks are drained of any moisture or sediment which may have collected in them.

If the trolley has been lowered or the pump switch opened, do not attempt to move the car until the main reservoir pressure has reached at least 60 lbs. pressure and the pump governor has cut out; then try the air brakes to see that they are operative before applying power to the car.

Place the controller handle in the "off" position and move the handle of control switch to the "reset" position momentarily to see that it shows a flash, thus indicating that the control fuse is intact and that power for operating the control and reset circuits is available. Then place the handle of the control switch in the "on" position.

Place reverse handle in forward or reverse position as desired, then move controller handle notch by notch in the usual manner. The last series and last parallel notches are the two running notches and give "half" and "full speed" respectively.

The main and reverse handles are so interlocked that the former cannot be moved unless the latter be in either the forward or the reverse position, and the latter cannot be moved unless the former be in the "off" position.

Merely moving the reverse handle does not throw the reverser. After putting the reverse handle in the desired position, the main handle must be put on the first notch in order to throw the reverser.

Should the reverser refuse to throw from the master controller for any reason, it can be moved by opening the cover and touching the pin on top of one or the other of the two magnet valves. In case the reverser fail to

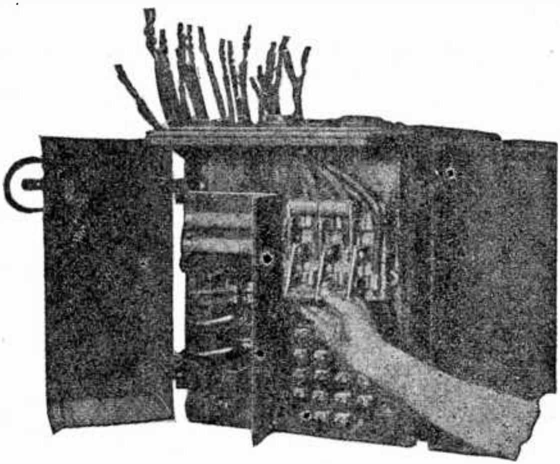


FIG. 6,272.—***Westinghouse control operation 1.*** Cutting out motors.

throw pneumatically it can be thrown by means of the hand lever, or, in case of the reversers mounted on the control box end plate, by inserting short piece of pipe over the lug provided for this purpose.

If the switches open, due to the operation of the overload trip return the controller handle to the "off" position and "reset" by momentarily closing the reset circuit by means of the control and reset switch. If, when the master controller is notched up, the overload trip again blow, the cause should be investigated. It is probable that either the master controller is being advanced too rapidly or there is a ground or "short" in the main circuits. If the difficulty be in one of the motors, the motor may be disconnected from the circuit by means of the motor cut out switch shown in fig. 6,272. If the car be otherwise disabled, the main circuit cut out switch should be opened. The car may then be operated in train as a trail car or withdrawn from service.

Motor cut out switches are either of the main circuit or control circuit type, and are usually mounted in one end of the switch group or control box, as in fig. 6,272. When a control circuit cut out switch is used, it is provided with a shaft having a squared end extension made to fit the master controller reverse handle.

Motors are numbered 1, 2, 3 and 4, starting from one end of the car. Since it is difficult to determine which is No. 1 motor, for example, and which is No. 4, particularly on a double end car, the cut out switches are arranged to cut out motors in pairs, No. 1 and No. 4 (the two outside motors) or No. 2 and No. 3 (the two inside motors).

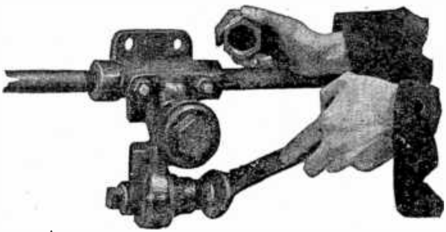


FIG. 6,273.—*Westinghouse control operation 2.* Adjusting reducing valve to change air pressure.

In case of damage to a motor, it is only necessary to determine whether it be an inside or an outside motor and open the corresponding switch.

With one pair of motors cut out of the circuit on four motor equipments, using main circuit motor cut out switches, manipulation of the master controller gives series parallel control of the remaining two motors.

Series parallel operation cannot be obtained with two motor equipments nor with four motor equipments using the control circuit type of cut out switch when one or a pair of motors is cut out. Normal operation of the master controller simply produces straight rheostatic acceleration.

If the unit switches fail to operate at any time, see that the fuse in the control and reset switch is in place. If it has blown, replace it. Before touching this fuse the trolley pole should be lowered, as this fuse is connected directly to the cable leading to the trolley. See that the control and reset switch makes contact, and that it shows a flash when opened with the controller on the first notch. Try the "reset;" if it do not show a flash when opened, try resetting by tripping the latch of the overload trip relay located on the end of the switch group or the line switch by hand.

If none of these tests show the cause of the trouble, remove master controller cover and observe whether the various fingers make contact on the drum segments, and whether a flash occurs when controller is moved from the first notch to the "off" position.

In case the controller show no flashing when moved from the "first" position to the "off" position, the trouble exists in the circuit from the trolley through the control resistor. The cover of the control resistor should be removed and connections examined. Trouble with control resistors is a rare experience.

Finally, with the trolley down and the main and control switches open. inspect the control box, switch group and line switch (if used) and the

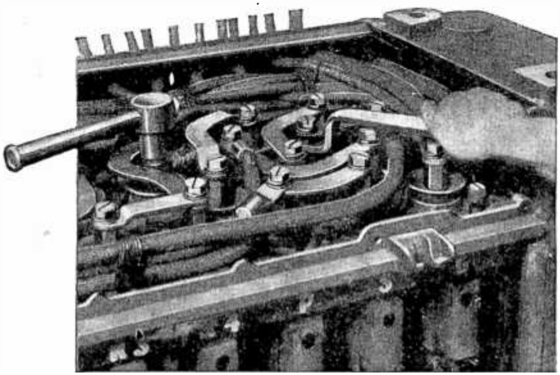


FIG. 6,274.—*Westinghouse control operation 3.* Tightening terminal bolts.

reverser and see that the interlock fingers are making contact with the plates against which they rest and that none of the small wires leading to them or to the magnet valves is broken or disconnected.

If, after making the above investigations, the trouble cannot be located the car should be reported as dead and removed to the car barn where a more thorough inspection can be made.

Emergency Braking.—*In case of extreme emergency only*, when the brakes have failed, a four motor equipment may be stopped by moving the reverse handle to the opposite running position and putting the main handle on the first notch. *After braking by this means has been set up the reverse handle must not be moved until the car has come to a dead stop.*

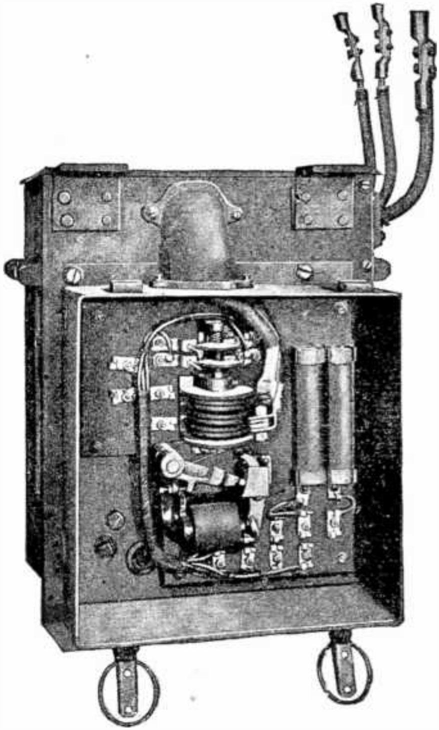


FIG. 6,275.—End view of Westinghouse line switch.

The braking effect produced is very severe, cannot be regulated, and should only be used when every other means of stopping the car has failed. This method of retarding the motion of the car is known as dynamic braking.

A two-motor equipment may be stopped under the same circumstances, by throwing the reverse handle to the opposite running position and then moving the main handle to any parallel notch.

The reverse handle must not be moved again until the car has come to a dead stop. Should the reverse handle be moved after the dynamic braking has once been set up, the heavy regenerated current will be broken at the reverser fingers and contacts, resulting in excessive burning of these parts.

Train Operation.—*Where two or more cars are to be operated as a train*, see that they are mechanically coupled and the air brake connections made. Then insert control train line jumpers in corresponding receptacles on each car.

The lid of the train line receptacles has a lug arranged to engage with a similar lug on the jumper head to hold it in place. Be sure these lugs properly engage each other when jumper heads are inserted.

Bus line receptacles and jumpers are similar in general construction to train line receptacles and jumpers, and should be handled in the same manner. Care should be taken *not to insert or withdraw them unless the trolleys on all cars are down or all bus line disconnecting switches are open. Only one pair of master controller handles* should be in place on the train, and these should, of course, be on the master controller at the head of the train.

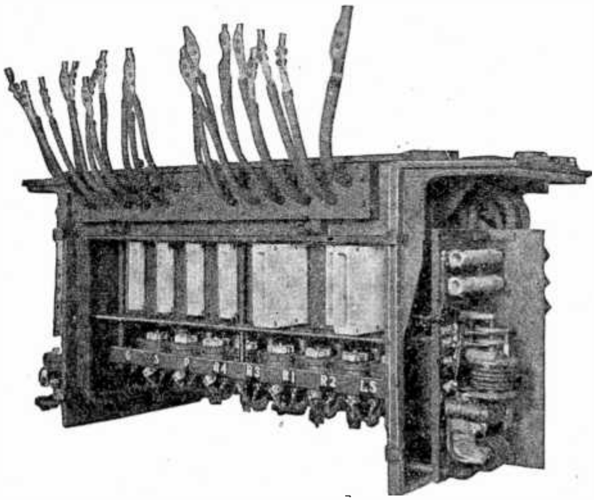


FIG. 6,276.—Westinghouse control box with covers removed showing overload trip relay and front side of switch group.

All control switches except the one at the operating master controller should be in the "off" position.

After the above precautions have been observed a train of two or more cars is then handled exactly as if it were a single car.

The operation of 1,200 *volt and* 1,500 *volt equipments is essentially the same as that of the* 600 *volt equipments*. They differ only in details of construction and in the arrangement of circuits.

Locomotives.—The type control here presented is used not only for the control of motor equipments on electric railway cars, but is extensively used where the heavy duty incident to electric locomotive service makes a reliable type of control necessary. The chief difference between car and locomotive equipments lies principally in method of mounting; for cars the main parts are mounted underneath the car body, while for

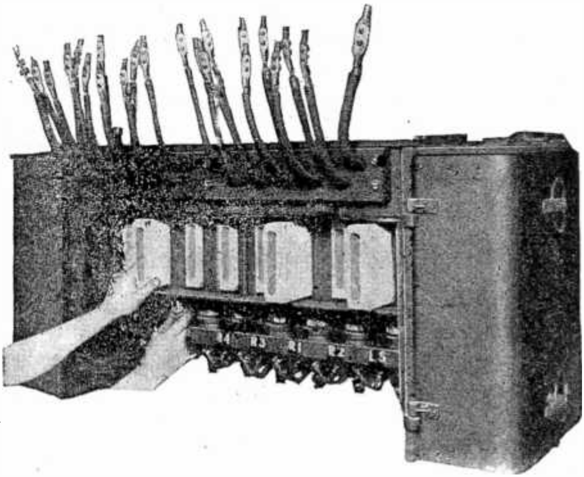


FIG. 6,277.—*Westinghouse control operation 4.* Removing arc boxes.

locomotives they are usually mounted on structural iron framing inside of the locomotive cab. The instructions herein apply equally to both locomotive equipments and car equipments.

Maintenance

General.—*Satisfactory operation* cannot be obtained from railway equipments of any sort, and failures on the road prevented, unless a careful and systematic inspection of the apparatus is made at regular intervals. *The work of maintaining* equipments is usually divided into three classes: light inspection, heavy inspection and overhauling.

The frequency of inspections necessary is usually set on a basis of car mileage and the work to be done, and depends very largely on local conditions. The following suggestions are based on average conditions, and will

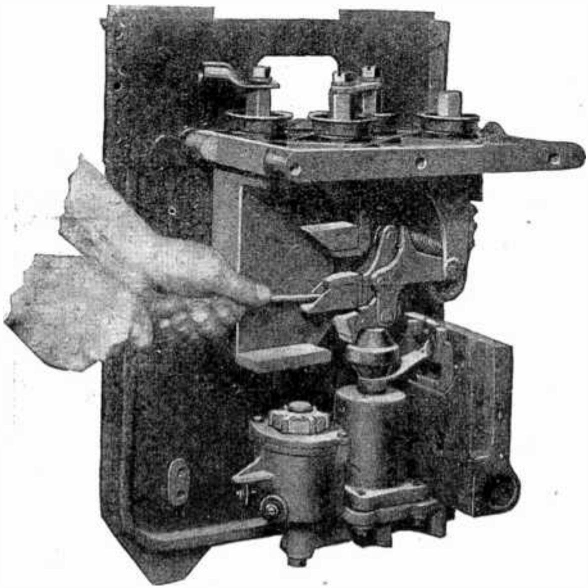


FIG. 6,278.—***Westinghouse contro. operation 5.*** Removing contact tips.

serve as a general guide until the particular modifications necessitated by local conditions, if there be any, can be determined. For example, it may be found that the work classed as heavy inspection can be taken care of partly during the light inspection and partly when overhauling.

Light Inspection.—Before any attempt is made to inspect the control box, switch group, line switch or reverser, the main switch should be opened to insure that the car cannot be accidently moved with anyone under it. Furthermore, the opening of the main switch will allow the operation of the control for inspection purposes.

The mileage which may be allowed between light inspections will depend on local conditions, and must be determined by trial. As a rule, city equipments should be inspected every 500 to 1,000 miles, while interurban equipments may be run from 1,000 to 2,000 miles between inspection periods which is the equivalent to about once a week for the two classes of equipment.

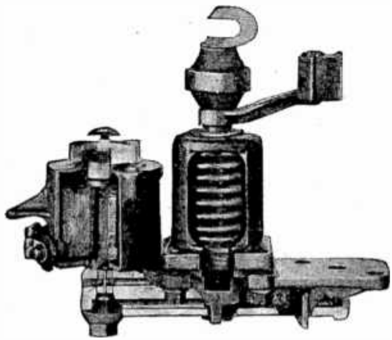


FIG. 6,279.—Westinghouse cylinder and magnet valve unit cut to show interior details.

The covers of each piece of apparatus, including control box or switch group, line switch, fuse box, reverser, changeover switch, master controllers and control switches, should be opened, the condition of the apparatus noted, and any necessary cleaning or light repairs made.

The arc horns, arc chutes, contact tips and switch shunts should be given particular attention and any horns that are burned off, chutes that are charred, burned through or nearly so, or shunts that show any indication of breaking, should be replaced. In case the arc chute of an important circuit breaking switch be in bad condition, and no spare arc boxes be at hand, they may be interchanged with those from a switch which merely cuts resistance in or out and is not subject to arcing duty. Should the contact tips become burned and rough they may be smoothed off with a file. Care should be taken to prevent arcing horns striking lower arcing blocks, as this causes the breaking of these horns.

The piston rod guides on every light inspection should each be given *one or two drops of oil*, by means of a can with a long spout. Care should be taken not to get any more oil than absolutely necessary in the cylinder, as oil is very injurious to the piston leathers. The cylinders should be lubricated only at heavy inspection periods.

Any air leaks from valves or cylinders should be corrected and any necessary small repairs made.

The interlocks on the switch group, line switch and reverser should be examined and cleaned if necessary.

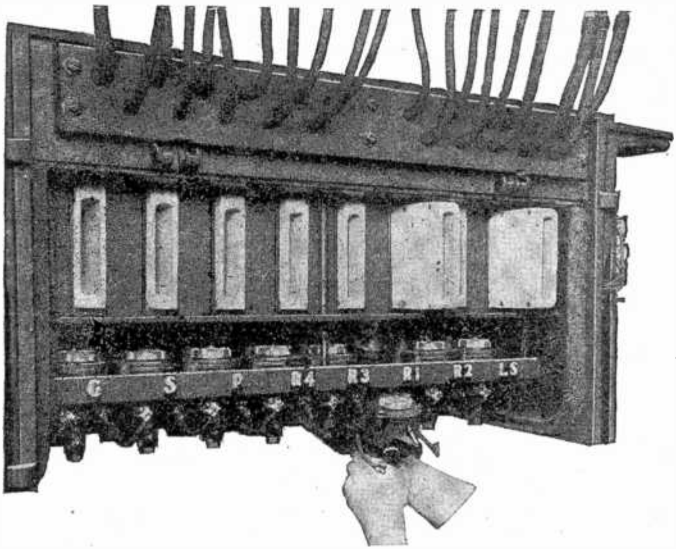


FIG. 6,280.—*Westinghouse control operation 6.* Taking out a cylinder and magnet valve.

The movement of each switch and that of the reverser should be noted by pressing the pins on the top of the magnet valves to be sure they work freely.

The switch group should be cleaned by blowing out the dirt with an air hose. This may be attached to the equalizing reservoir if no other source of air be available, but the moisture should first be drained from the tank before attaching hose. Blow from the interlock side.

Dirt, smoke or copper dust deposit on the piston insulators, valve magnets, or on the insulating surfaces of the control box should be removed with a

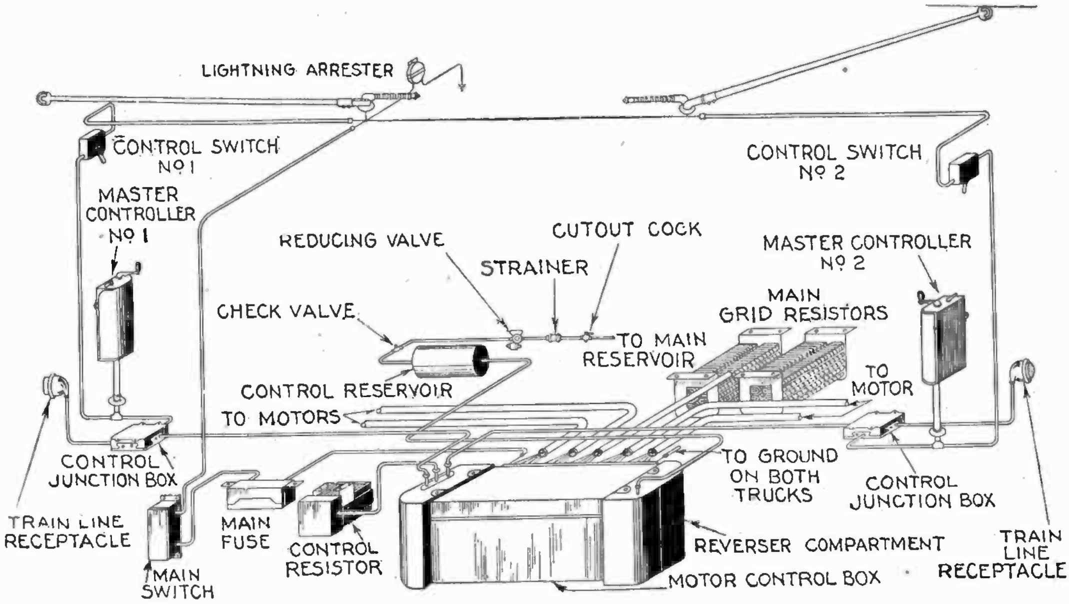


FIG. 6,281.—Isometric view of Westinghouse unit switch control equipment.

piece of cheese cloth. In using a cloth or waste for cleaning the controller parts, be careful so that the cloth or ravelings do not catch in the interlock fingers and pull them back far enough to give the spring a permanent set. Some types of fingers are provided with stops, which would prevent this injury, but there are other types where the movement is not definitely limited by a stop and which might be injured by the careless use of a cloth or waste.

The grid resistors should be examined to see that none of the grids is broken, and that the cables are tight in the terminals.

All air tanks should be thoroughly drained to get rid of any water and sediment that may be in them.

The switches and reverser should be operated through a complete cycle and the sequence checked after all the foregoing inspections and adjustments have been made.

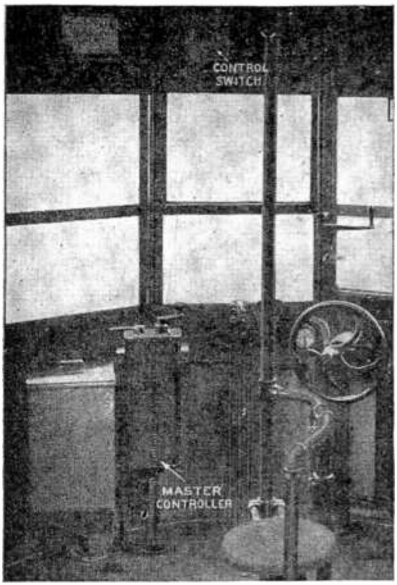


FIG. 6,282.—Interior of operator's cab showing Westinghouse master controller and control switch. The master control is for electro-pneumatic control of motors in modern heavy traction cars.

Heavy Inspection. — A heavy inspection in general should be made about every three to six months where cars are regularly in service.

All apparatus should be thoroughly cleaned and lubricated and all necessary repairs made, in addition to work ordinarily done at light inspections. *The air strainer* should be taken down and the curled hair which it contains washed in gasoline after the first three months' operation, and about every 12 months thereafter.

The reducing valve setting should be checked by screwing an inspector's gauge in the drain cock of the equalizing reservoir, to be sure that 70 lbs. pressure is secured on the control apparatus. At least every six months it should be taken apart, wiped thoroughly with a cloth free from lint, removing all oil from the piston. In reassembling, a good grade of dry graphite should be used sparingly on the slide valve *but no oil should be used on the piston.*

After setting or cleaning the reducing valve, the control should be operated up to full multiple about 10 or 12 times and the action of the gauge on the equalizing reservoir noted during operation. If the pressure drop more than three pounds during this process, the valve has not been properly assembled or cleaned and should be again taken apart and readjusted.

The insulating bolts and washers and the insulating pipe and conduit couplings on the control box or switch group, line switch, reverser and grid

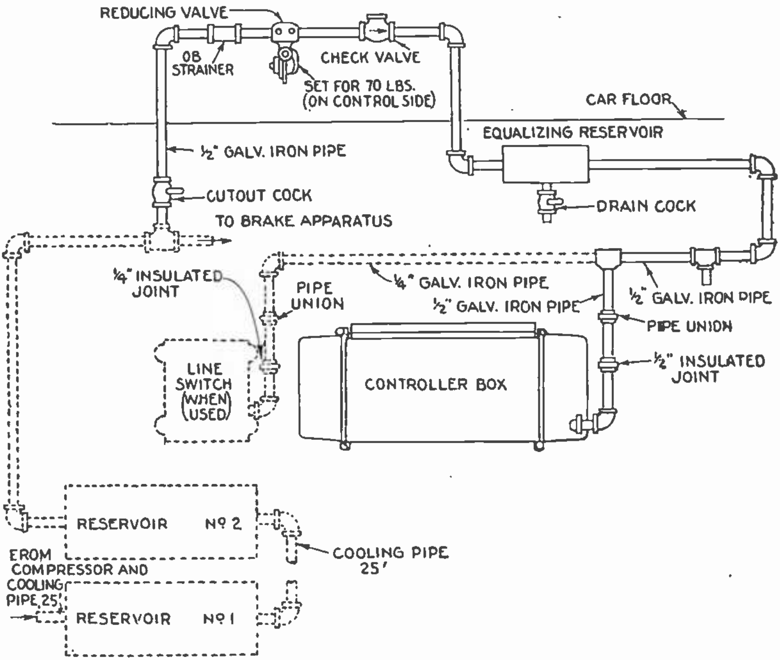
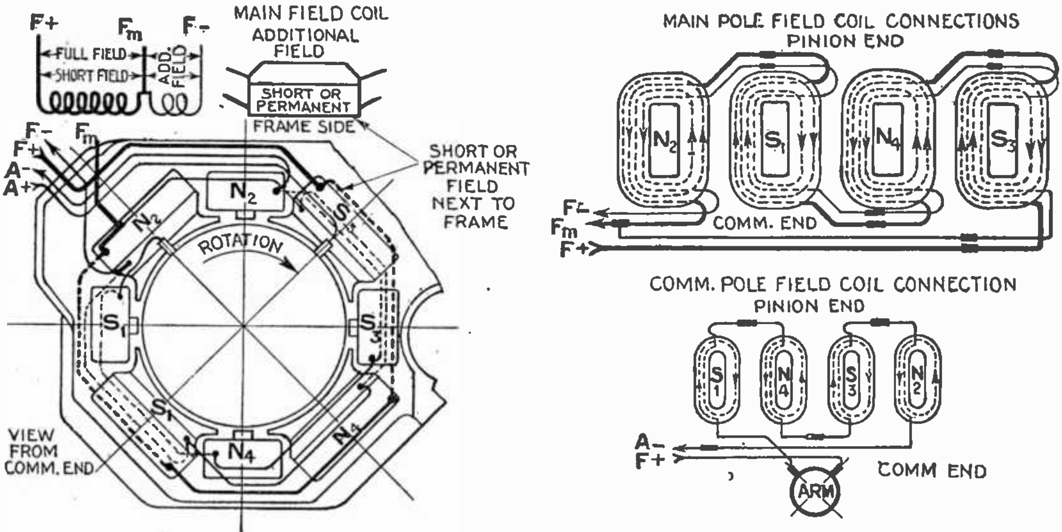


FIG. 6,283.—Westinghouse piping diagram of 600 volt installation showing pneumatic details.

resistors should be thoroughly cleaned, and if the surface be not smooth and shining a coat or two of thin shellac should be applied.

The nuts holding the grid resistor frames together should be inspected and tightened to take up any shrinkage which may have occurred.

The top covers of switch group and line switch should be removed and the copper bolts holding the switches and blowout coils tightened, if necessary,



FIGS. 6,284 to 6,288.—Westinghouse connection diagrams for field controlled motors. Motor leads are marked as here shown, which indicates by heavy and light lines the relative capacity of the winding sections. For four motor equipments (with motors connected in pairs) the resistance of the car leads connecting the F-leads of two motors of a pair to their common terminal in the control box should be the same. This is also true for the car leads connecting the Fm leads to their common terminal in the control box. ***Wiring precautions*** *with tapped field motors.*—When wiring cars equipped with tapped field motors it is necessary to take into consideration the resistance or balance of the motor circuit cables. The precaution just mentioned is not necessary for two motor, 600 volt equipments or 1,200 and 1,500 volt, two or four motor equipments. Frequently after all wiring connections have been made it is found that the motors are connected so as to oppose or buck each other, preventing the car starting under power. This indicates that the connections are not made to conform with the wiring diagram. Care should be taken to see that tapped field motors are connected in accordance with the official diagram because of the limited capacity of the added field section. In re-arranging connections between the motors and the car circuits, interchange of cable lead grouping should all be made on the leads from the car wiring. This will maintain all motors leads from the motors in the same position and therefore permit of a universal interchange of motors of the same type on any car. Dotted lines show connections at pinion ends.

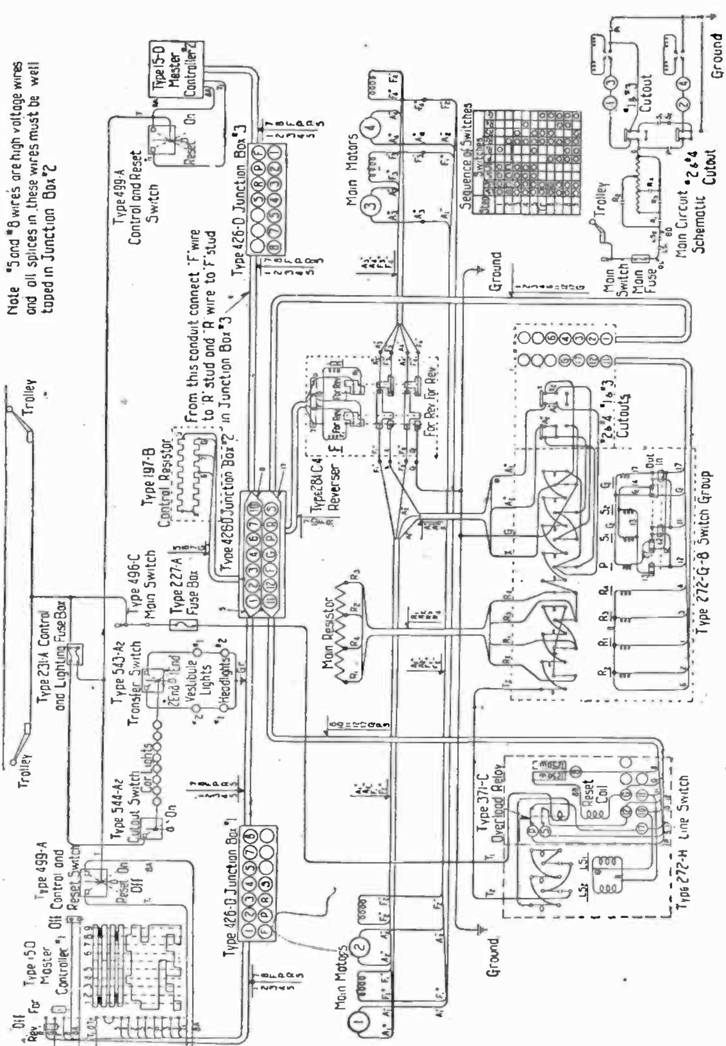
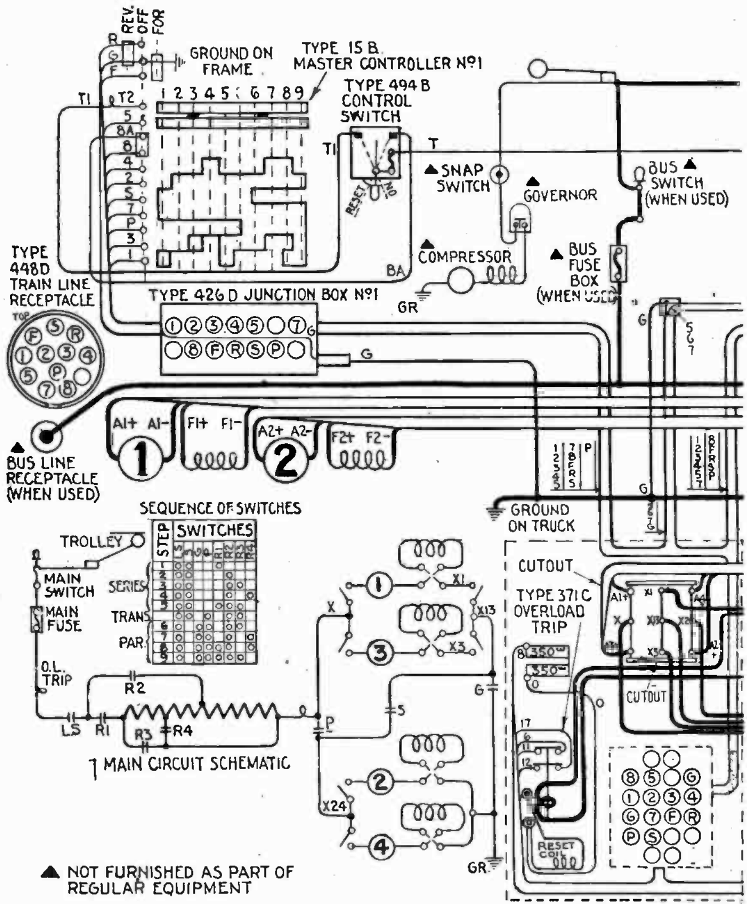
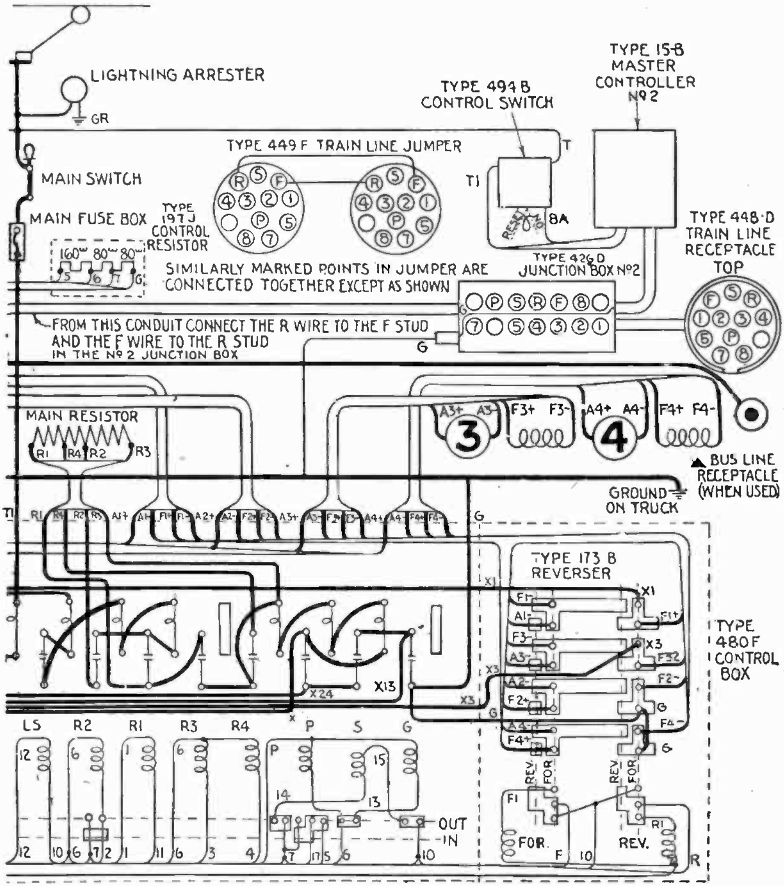


FIG. 6,289.—Wiring diagram for Westinghouse standard 1,200 volt type **HL** unit control equipment for four 50 *h.p.* 600 volt motors, connected two in series.



FIGS. 6,290 to 6,293.—Wiring diagram for Westinghouse standard 600 volt type HL unit



FIGS. 6,290 to 6,293.—*Text continued.*

control equipment for four 65 *h.p.* 600 volt motors.

by means of the special "goose neck" wrench as shown in fig. 6,274, supplied for this purpose with the equipment. The top bolts holding the strap connectors should first be loosened with the special socket wrench, also supplied as a part of the equipment. Caution must be taken not to stretch the bolts. Any dirt should be blown out of the top compartment with an air hose.

Any insulating surfaces which cannot be given a reasonably clean polished surface by wiping with cheese cloth should be given a coat or two of clean *thin* shellac. This should be thoroughly dry before the car is used. The various pivot pins of the switch arms, the contact fingers and the piston hooks should be lubricated with a drop or two of oil. The bolts holding the shunts should be tightened.

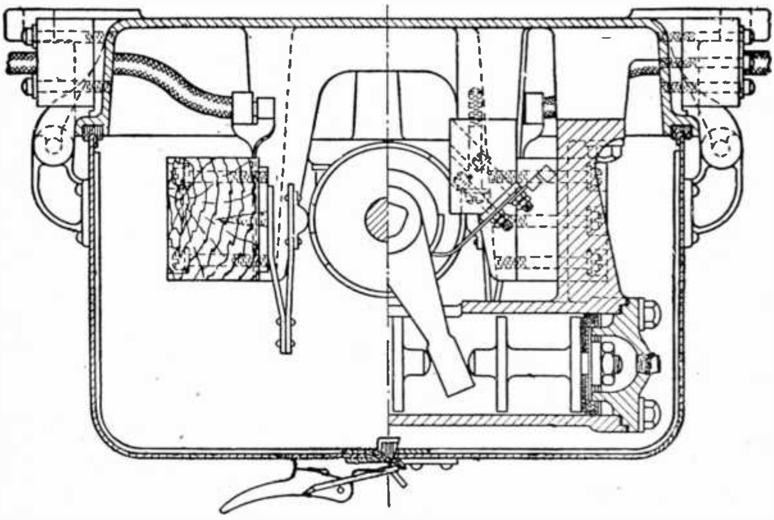


FIG. 6,294.—Westinghouse reverser. *Adjustments:* The portion of the finger which makes contact with the drum should be true so that when pressed against a flat surface it makes contact throughout its entire width. Adjustment of each finger may then be easily made by using a wrench where necessary to bend the finger spring to insure proper alignment. After adjustment spread grease on the drum segment and move the drum back and forth to thoroughly lubricate contact surfaces several times. Each main finger should be adjusted so that it drops from 1/16" to 1/8" below the surface of the drum segment when it is in the open or "off" position. If the finger drop too far there is danger that the drum segment will jam the finger. If the finger be not adjusted far enough below the surface of the drum segment there will not be sufficient pressure between the contacts to carry the current and overheating and welding of contacts may result.

If a switch become sluggish in its action at any time and cannot be brought to normal operating speed by oiling the piston rod guide, or by lubricating the piston with oil through the vent in the top of the cylinder, the cylinder should be taken apart and cleaned. It should be noted that the use of ordinary lubricating oil for lubricating the cylinder and piston leathers is entirely contrary to recommended practice. The oil specified by the manufacturers should be used.

The upper and lower valve stems of switches and reverser should be taken out and, if gummy, should be washed in gasoline and a little gasoline should be poured through the magnet core in order to wash the seats. When taking out the valves for this purpose, *each must be returned to its original position*, as each stem is ground in to fit its own seat.

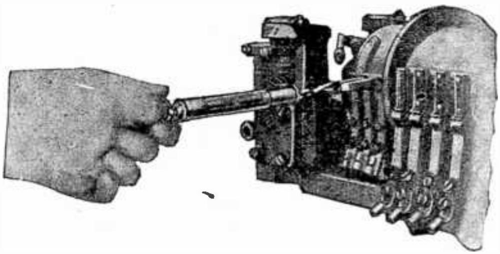


FIG. 6,295.—*Westinghouse control operation 7.* Checking control finger pressure.

The interlock contacts should be lubricated by wiping with a piece of cheese cloth, moistened with a thin lubricating oil. The finger tension should be tested and adjusted if necessary, as shown in fig. 6,295.

The covers of the control box or switch group and reverser should be examined to see that they fit tightly and that the felt which makes them dust tight, as well as the insulation on them is in place and in good condition.

The entire interior of the control box or switch group, line switch, reverser and changeover switch should be wiped clean, special attention being paid to the piston rod insulators. The covers should then be tightly closed.

Any dirt on the outside of control box, switch group, line switch, changeover switch or reverser, which has a tendency to fall inside when the covers are opened, should be cleaned off, and preferably, the entire outside should be cleaned.

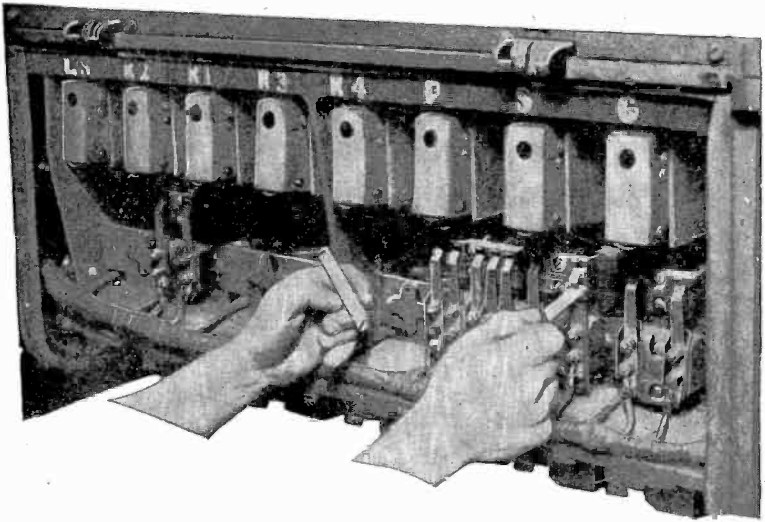


FIG. 6,296.—*Westinghouse control operation 8.* Adjusting interlock fingers.

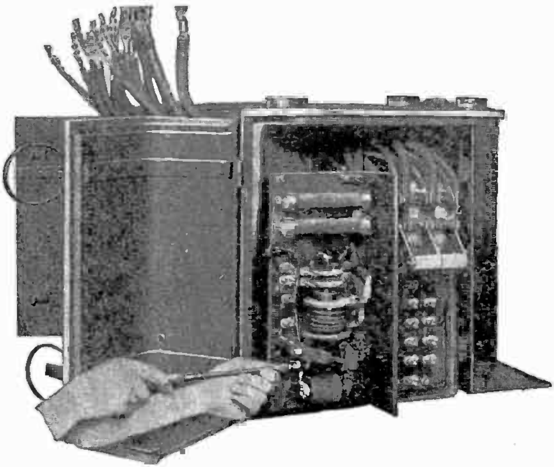


FIG. 6,297.—*Westinghouse control operation 9.* Adjusting type 371 overload relay.

The frames of the control box or switch group, line switch, reverser, and grid resistors *should be tested for ground* by means of a bank of lamps connected to the trolley. If found to be grounded, the cause should be located and corrected.

The screws through the insulating base on which the reverser fingers are mounted should be tightened, if necessary, to take up any shrinkage that may have occurred during service.

All junction boxes and terminal boards should be examined for dirt or loose connections.

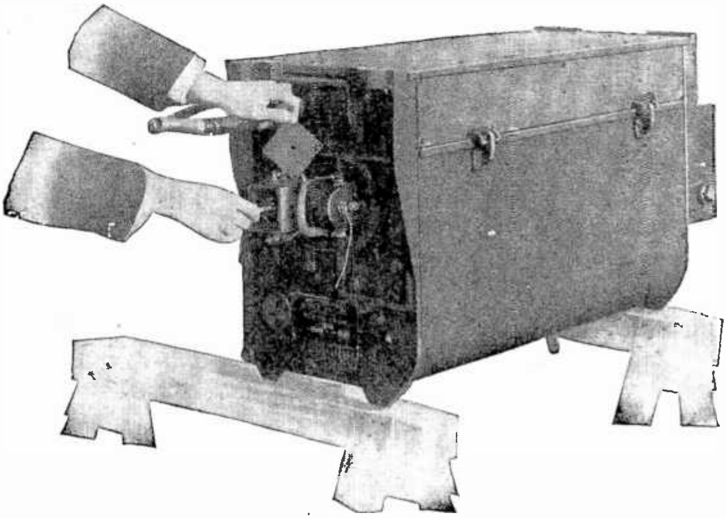


FIG. 6,298.—*Westinghouse control operation 10.* Adjusting type 392 overload trip.

The master controller fingers should be examined for wear, and if necessary, adjusted to have a lift of 1/16 inch, and to make good contact and then lubricated by wiping with a greasy cloth. Finger tension should be adjusted if necessary, as shown in fig. 6,295.

The master controller drum and reverser drum should be examined to see if there be any cutting of the contact surface by the fingers. If cutting be found, the drum and fingers should be smoothed up with fine emery cloth.

The parts of the interlocking and star wheel mechanisms of the master controller should be examined to see that they work freely and are in good order. They should be oiled when necessary. The handles should fit their respective positions properly.

Train line receptacles should be examined to see that the hinge joints and springs are in good condition, so that the covers automatically close when the jumper is removed and thus protect the contacts from the weather. The split contacts should be examined and if compressed should be adjusted to their original condition.

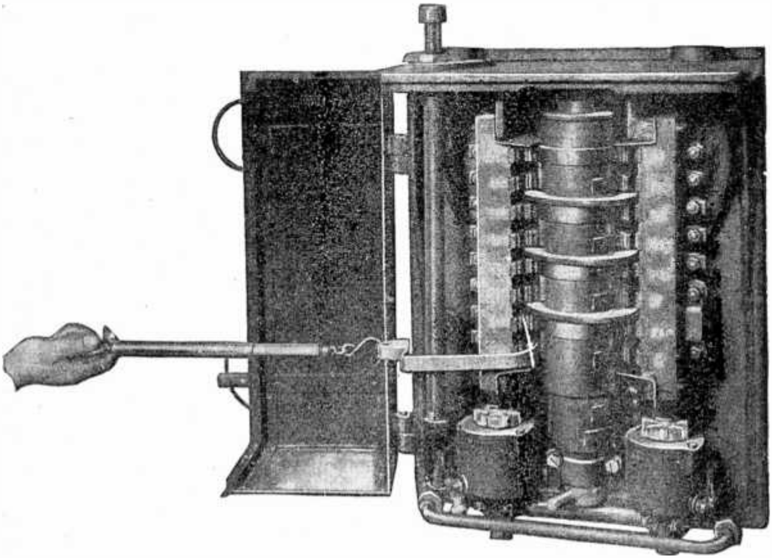


FIG. 6,299.—*Westinghouse control operation 11.* Reverser mounted on control box end plate.

TEST QUESTOINS

1. *Give a list of the apparatus used in general with electro-pneumatic control.*

2. *Describe the method of electric braking in case of extreme emergency.*

3. *What should be done before two or more cars are to be operated as a train?*

4. *Does the operation of* 1,200 and 1,500 *volt equipments differ from the* 600 *volt equipment?*

5. *What is the chief difference between car and locomotive equipments?*

6. *What is necessary for satisfactory train operation?*

7. *In how many classes is the work of equipments usually divided?*

8. *On what is the frequency of inspection based?*

9. *Describe the light inspection.*

10. *Upon what does the mileage between light inspections depend?*

11. *How is each piece of apparatus inspected?*

12. *Describe what attention should be given to the following: piston rod guides, air leaks, interlocks, switch groups, grid resistors.*

13. *How often is the heavy inspection made?*

14. *Describe the various operations of making a heavy inspection.*

CHAPTER 137

Air Brakes

In this type of brake which operates by the expansive property of compressed air, the air is compressed by a suitable pump located upon the engine and is stored until needed for use. When it is necessary to apply the brake, a portion of the stored air is allowed to pass into the brake cylinder. This cylinder is fitted with a piston which the escaping air moves outward. It is so connected with the brakes that its movement is communicated to the shoes and applies them.

To meet the needs of the various conditions of service, there are several types of air brake known as:

1. Straight air brake.
2. Emergency straight air brake.
3. Automatic air brake.
4. Automatic variable release air brake.
5. Quick acting automatic air brake.
6. Combined automatic and straight air brake.
7. Electro-pneumatic air brake.

Ques. For what service is the straight air brake adapted?

Ans. For moderate speed city surface line cars which are operated as single units.

Ques. How does the emergency air brake differ from the straight air brake?

Ans. It provides means to overcome the objectionable length of time required to apply the brakes, so that they may be applied quickly in case of emergency.

Ques. What is the meaning of the word "automatic" as applied to air brakes?

Ans. It denotes that in case of accident such as the parting of a train, bursting of an air pipe, etc., the brake is automatically applied.

Ques. For what service is the automatic variable release type air brake used?

Ans. For high speed interurban cars which are operated the greater part of the time in trains.

Ques. What is the feature of the automatic variable release type air brake?

Ans. This type of equipment provides a braking effect during retardation that can be maintained practically constant. The brakes may be quickly applied and released as frequently as desired, and can be partially released after an application has been made.

Ques. What is the adaptation of the quick acting automatic air brake?

Ans. For long trains to reduce the time required to apply the brakes.

Ques. How does the quick acting type differ from the variable release type?

Ans. It differs in that the triple valve is so designed as to feed both auxiliary reservoir and train line pressure into the brake cylinder.

This procedure not only causes each car to aid in quickly reducing the train line pressure throughout the train, but it decreases the drop in train line pressure which must be produced at the head car.

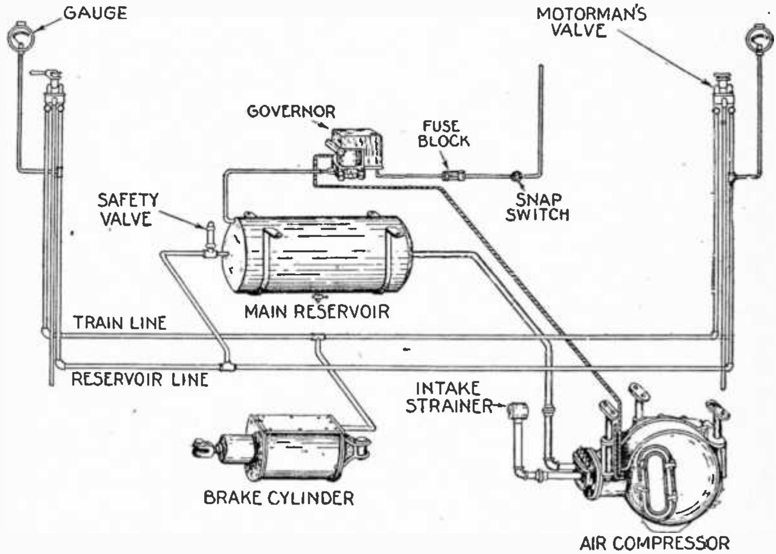


FIG. 6,300.—General Electric straight air brake equipment, showing the essential parts and pipe connections.

Ques. What is the object of the electro-pneumatic type of air brake?

Ans. It is designed for long trains.

Straight Air Brake.—In this type of air brake *the brake cylinder is connected directly to the motorman's valve which governs*

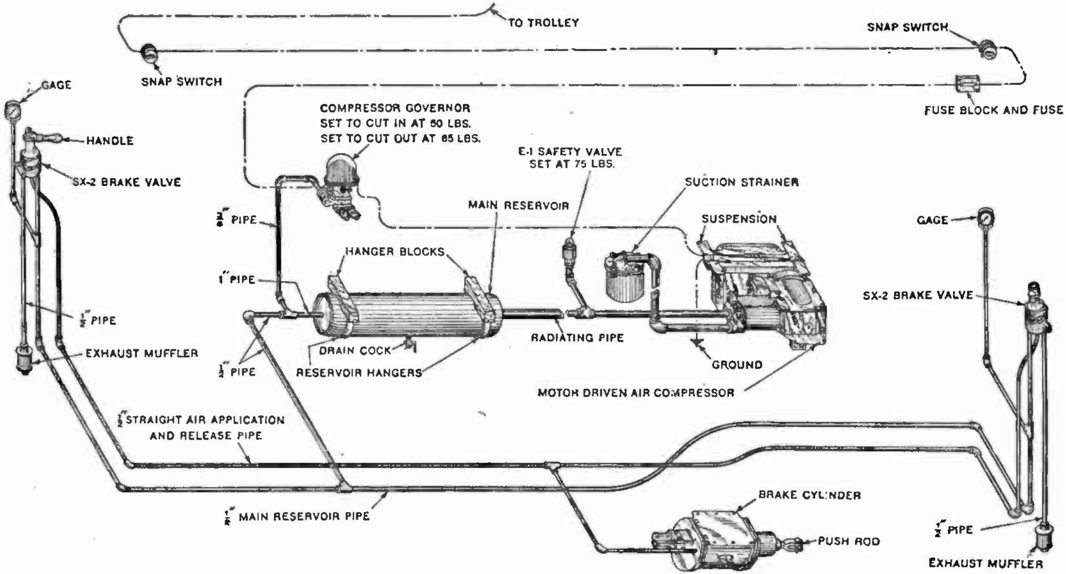


FIG. 6,301.—Westinghouse straight air brake equipment; pictorial view showing parts and pipe connections.

the admission of air to the brake cylinder and the exhaust of this air from the cylinder to atmosphere.

The brakes are applied by admitting air to the brake cylinder and are released when the air in the cylinder is exhausted to atmosphere. The general arrangement of this system is shown in fig. 6,301.

This type of equipment is composed of the minimum number of parts which can be installed and maintained at small cost and provides a means for controlling the speed of a car with a degree of flexibility.

A straight air brake equipment for a double end motor car consists of—

1. Compressor and auxiliaries:

a. Motor driven air compressor;

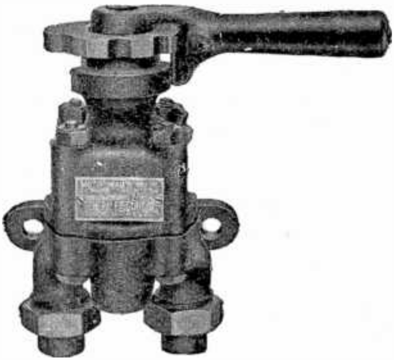


FIG. 6,302.—Motorman's valve for General Electric straight air brake system. This is a three way valve of the rotary type. The principal parts are the valve body, bonnet, valve stem and rotary valve. The rotary valve operates on a raised seat formed on the upper surface of the valve body. The ports of the rotary valve and valve body are machined accurately to size and position, and are located so as to perfectly balance the valve and reduce wear to a minimum. The stem is steel, case hardened, and is provided at the base with a ball seat which prevents leakage between the stem and bonnet. The bonnet is provided with a bushing of composition material which serves as a bearing for the stem and can be renewed when worn. The surface of the valve quadrant which is machined to indicate the operating positions, is case hardened to reduce wear. The bonnet is provided with a case hardened wearing pad which relieves the stem of strains due to the operator leaning on the handle.

b. Intake strainer;
c. Suspension set.

2. Pressure regulating equipment:

a. Air compressor governor;

b. Insulating connection;
c. ½ in. safety valve.

3. Cab equipment:

a. Motorman's valve;
b. Motorman's valve handle;
c. Single hand pressure gauges;
d. Snap switch;
e. Cutout with fuse.

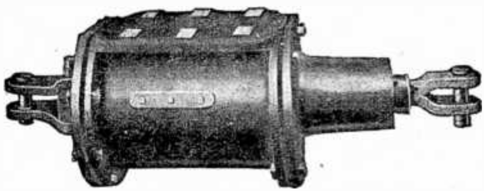


FIG. 6,303.—Brake cylinder for General Electric straight air brake system. *In construction,* the cylinder is fitted with a tubular piston rod which surrounds the push rod which attaches to the live cylinder lever. This construction permits of the brakes being applied by hand without moving the brake cylinder piston.

4. Brake details:

a. Straight air brake cylinder complete with push rod.

5. Main reservoir and accessories:

a. Main reservoir;
b. Reservoir hangers;
c. Drain cock.

The control of the brakes is by means of the motorman's valve, shown in figs. 6,300 and 6,302. This is a three way valve and the functions performed are:

1. Release position: Direct connection is made between the train line and exhaust through a large port.

2. Slow release and running position: Train line is connected to exhaust through a restricted port.

3. Lap position: All ports are blanked. This is the only position in which the handle can be removed.

4. Service application position: Connection is made between the main reservoir and train line through a series of small ports.

5. Emergency position: In this position the valve handle is at the extreme right and connection is made from the main reservoir to train line through a large port.

Rules for Operating a Straight Air Brake.—Before starting the air compressor see that the reservoir drain cocks are closed. Next, start the air compressor by turning the switch to the on position. When the gauge hand shows maximum main reservoir pressure, and before starting the car, make a service application of the brakes by moving the motorman's valve handle to the service application position to see that the brakes apply, which will be indicated by the brake cylinder piston moving out and forcing the shoes against the wheels. If the brakes apply properly with a service application, move the valve handle to the release position to see that they release properly, which will be indicated by the brake cylinder piston moving back in the cylinder and allowing the shoes to hang free of the wheels.

Running: Have the motorman's valve handle in the release position while running.

Service stops: In making ordinary service stops, place the motorman's valve handle in the service application position and leave it in that position until a sufficient amount of pressure has built up in the brake cylinder to give the retarding effect desired. The handle should then be moved to lap position. As the speed of the car is reduced, reduce the brake cylinder pressure in a series of steps by moving the valve handle from lap position to release position, and then back to lap position; repeat this movement until the stop is reached. At the point of stopping there should be only sufficient air in the brake cylinder to prevent the car rolling. It will be found that far better braking results will be obtained by making but one application as described above than by admitting only a small amount of air to the brake cylinder at the beginning of the stop, and increasing the pressure as the

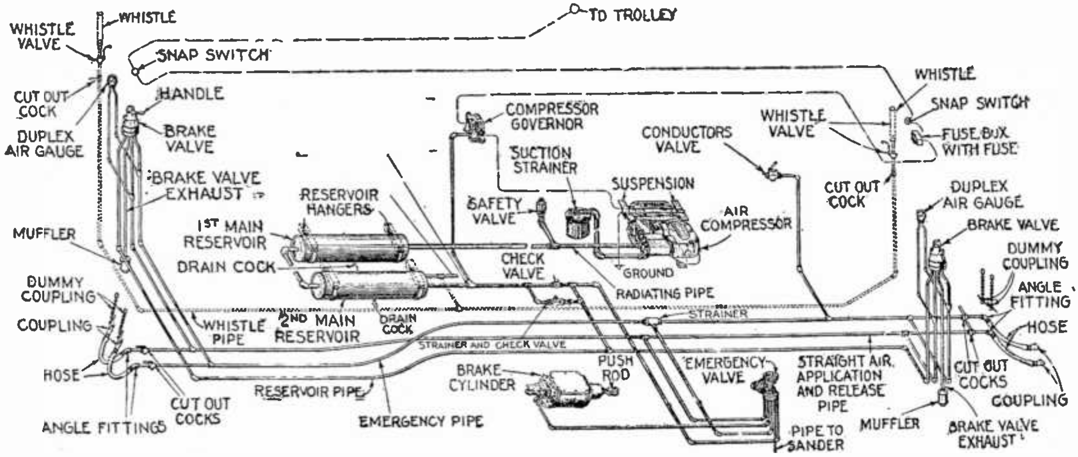


FIG. 6,304.—Westinghouse emergency straight air brake. Pictorial view showing parts and pipe connections.

speed of the car is decreased. The latter method usually results in rough stops, a waste of air and in many cases flat wheels. The practice of applying and releasing the brakes several times during a stop should be avoided.

Emergency stops: If it be desired to stop the car in the shortest possible distance, to avoid an accident, apply sand to the rails and at the same time move the motorman's valve handle to the emergency position and leave it in that position until the car comes to a stop or the danger be past.

Emergency Straight Air Brake.—An objection to the straight air brake is *the length of time required to apply the brakes owing to the relatively long pipe through which the air*

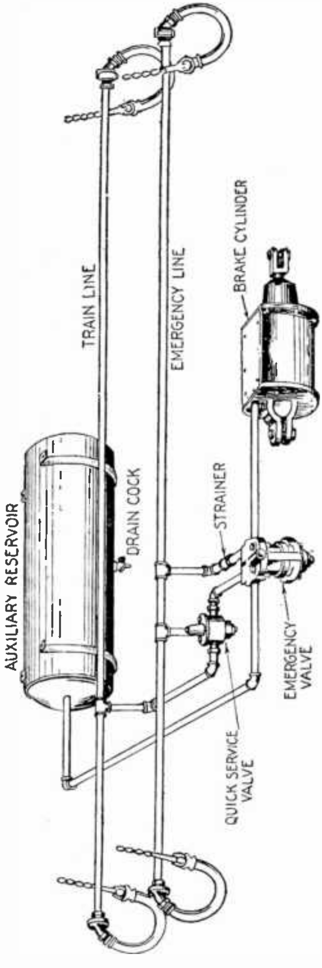


FIG. 6,305.—General Electric emergency straight air brake equipment for trail car.

must flow from the reservoir to the brake cylinder. This is especially objectionable when it is necessary to make a quick or emergency stop. A simple method of overcoming this defect is *by providing the straight air brake system with an emergency valve and an auxiliary reservoir pipe line.*

This arrangement is less complicated and costs less than the automatic system.

The various parts comprising the emergency straight air brake are shown with the pipe connections in fig. 6,304.

This equipment has been designed for cars which are normally operated as single units, but which under certain conditions are required to operate in short trains of two or more cars. These trains may consist of all motor cars or a combination of motor and trail cars. The equipment for a trail car is shown in fig. 6,305.

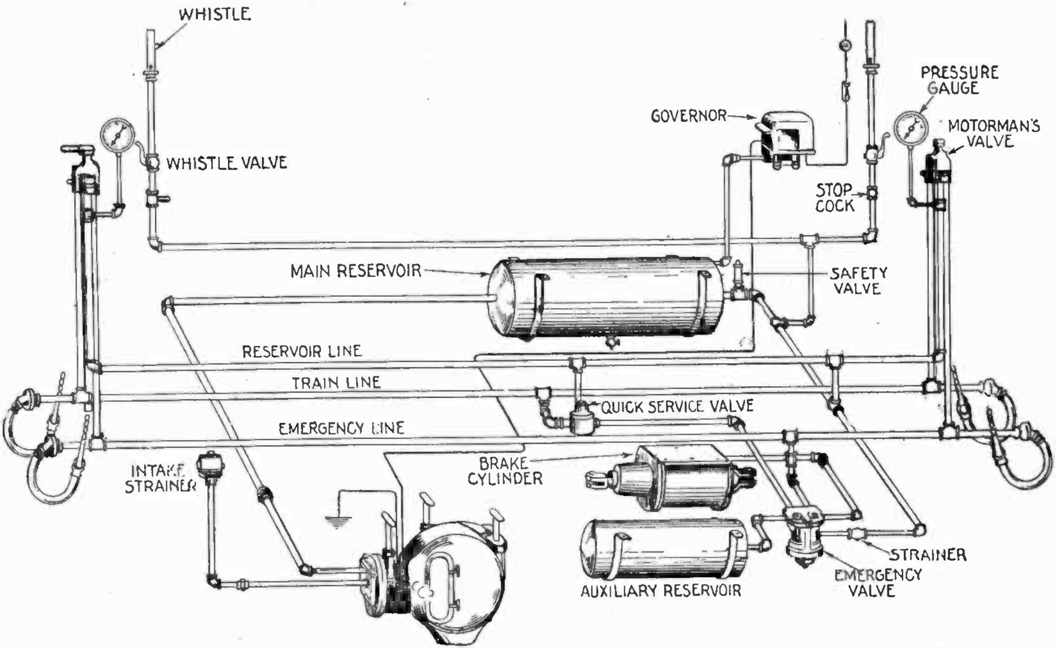


FIG. 6,306.—General Electric emergency straight air brake equipment for motor car. The emergency straight air brake equipment, as the name implies, is a combination of a straight air brake equipment and an automatic air brake equipment of the simplest form, the straight air brake equipment being used for service operation of the brakes and the automatic equipment for emergency operation. Two pipe lines, namely, the train line and the emergency line are installed the entire length of the train. The train line provides a direct connection from the motorman's valve to the brake cylinder on each car, thus serving the same purpose as

In operation when the valve is thrown into emergency position it allows the pressure of the reservoir line which is higher than that in the emergency valve to compress a spring in the latter and thereby allow a direct passage of reservoir air into the brake cylinder. Connections with the train line and reservoir lines are also simultaneously cut off. The application of the brakes on trailers is made possible by the addition of an auxiliary air reservoir, emergency valve, and reservoir line to the equipment necessary for "straight air" braking.

In order to release the brakes after an emergency application, the emergency valve must first be returned to its normal position by recharging the reservoir line to reservoir pressure, whereupon the brakes may be released as from a service application by exhausting the air from the train line.

Automatic Air Brake.—As previously mentioned the term automatic as applied to air brakes means that in case of accident such as the parting of a train, bursting of an air pipe, etc., the brake is automatically applied. To accomplish the automatic application of the brake in case of accident, it is necessary to provide on each car:

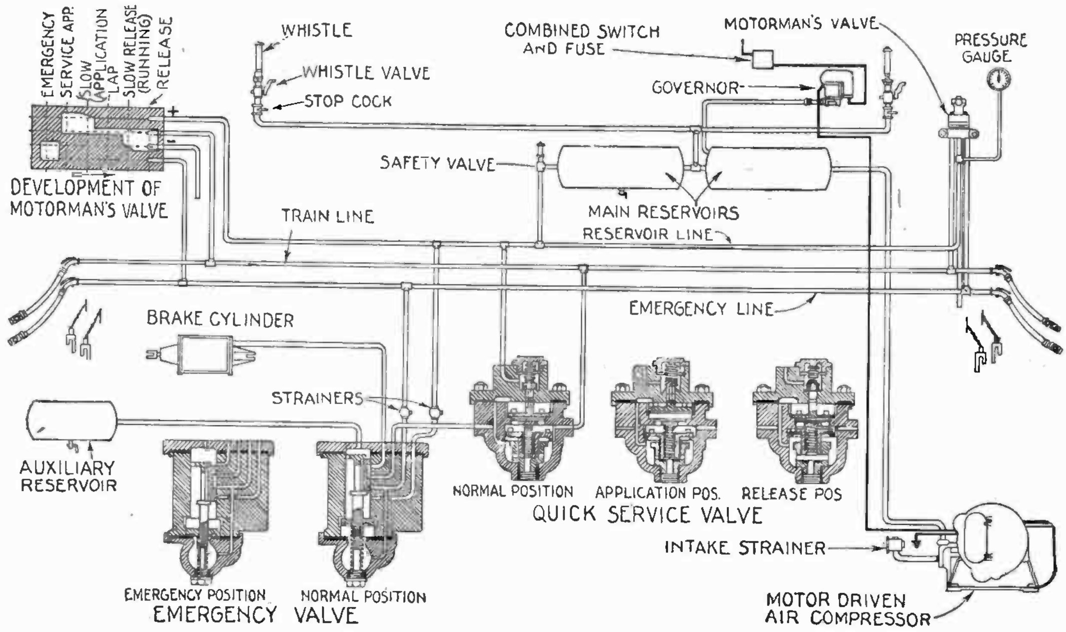
1. An auxiliary reservoir, and

2. A triple or distributing valve.

The functions of the triple valve are briefly:

1. When charging and maintaining the pressure in the brake system:

FIG. 6,306—*Text continued.* the train line in the straight air brake equipment. The emergency line normally carries air at reservoir pressure and connects together through the emergency valve the main reservoirs on the motor cars and the auxiliary reservoirs on the trail cars. Any sudden reduction of pressure in this emergency line applies the brakes automatically on each car of the train.



FIGS. 6,307 to 6,312.—Diagram showing General Electric emergency straight air brake. In this diagram, the actual construction of the motorman's valve at the left, the emergency valve and the quick service valve have been disregarded and these parts are shown diagrammatically, so that the passage of air through the same can be readily followed. The motorman's valve, although of rotary design, is shown at the left of the diagram, as a slide valve, so that the different positions and functions performed by the valve can be readily observed. It will be noted that in the *release position* of the valve, the train line is connected to atmosphere. In the *service application position*, the train line is connected to reservoir. In the *emergency position*, the emergency line is connected to atmosphere. The emergency valve is shown diagrammatically in the *normal position* and in the *emergency position*.

FIGS. 6,307 to 6,312.—*Text continued.*

It will be noted that, in the *normal position*, the train line is connected, through the quick service valve, by means of the cavity in the emergency valve slide valve, to the brake cylinder. Also the reservoir line is connected through the slide valve chamber to the auxiliary reservoir. In the *emergency position* of this valve, the auxiliary reservoir and brake cylinder are connected together and the train line and emergency line are connected together. The quick service valve is shown in three positions. In the *normal position*, the valve controlling the port from the train line to atmosphere is closed and the valve controlling the port from the reservoir to train line is closed. In the *application position*, the valve controlling the port from reservoir to train line, is open. In the *release position*, the valve controlling the port from train line to atmosphere is open. The operation is further described in the following notes.

NOTE.—***To make a service application*** of the brakes, the motorman's valve handle is moved to either the first or second *service application position*, depending on whether a quick or a graduated stop is desired. The valve handle is held in this position until the required brake cylinder pressure has been reached. It is then returned to the *lap position*. In the *service application position* air is admitted from the reservoir line by means of the motorman's valve to the train line raising the train line pressure. This causes the upper piston in the quick service valve to lift and the air from the train line then flows through leakage grooves past the piston through the cavity in the slide valve of the emergency valve to the brake cylinder. The movement of the piston of the quick service valve raises a lift valve from its seat which admits air direct from the reservoir line to the chamber above this piston, uniting with the train line air already flowing to the brake cylinder.

NOTE.—***To release the brakes*** after a service application, the motorman's valve is moved to the *release position*, thus connecting the train line to atmosphere as shown in the diagram. The reduction of train line pressure causes the lower piston with its direct connected valve in the quick service valve to raise, thus allowing the air from the brake cylinder to escape to atmosphere. Air from the brake cylinder also flows through the leakage grooves which are uncovered when this piston is raised, to the train line and through the motorman's valve to atmosphere. The passage of air through the quick service valve both in applying and releasing can be more clearly understood by referring to the *application* and *release position* of this valve shown in the diagram.

For an emergency application of the brakes, the motorman's valve is moved to the extreme right position which exhausts the air in the emergency line to atmosphere. This sudden reduction of pressure in the emergency line causes the piston in the emergency valve to move downward, due to the unbalanced pressure between the auxiliary reservoir and the emergency line until the lower edge of the piston makes an air tight joint on a leather gasket at the bottom of the piston chamber. This cuts off any flow of air from the auxiliary reservoir to the emergency line, and therefore prevents the auxiliary reservoir air escaping to atmosphere through an open emergency line. With the emergency valve in this position, communication is established between the auxiliary reservoir and brake cylinder. Connection is also made between the emergency line and the train line, the object being to afford an additional exhaust to atmosphere from the emergency line in case the train line is open between the cars. This connection between the emergency line and train line in the emergency position of the valve, provides a means for releasing the brakes after an emergency application has been made.

NOTE.—***To release the brakes*** after an emergency application, the motorman's valve is moved to the service application position, so that the emergency line will be charged through the train line and the slide valve in the emergency valve will be forced to its normal position. The motorman's valve is then moved to the release position which exhausts the brake cylinder to atmosphere.

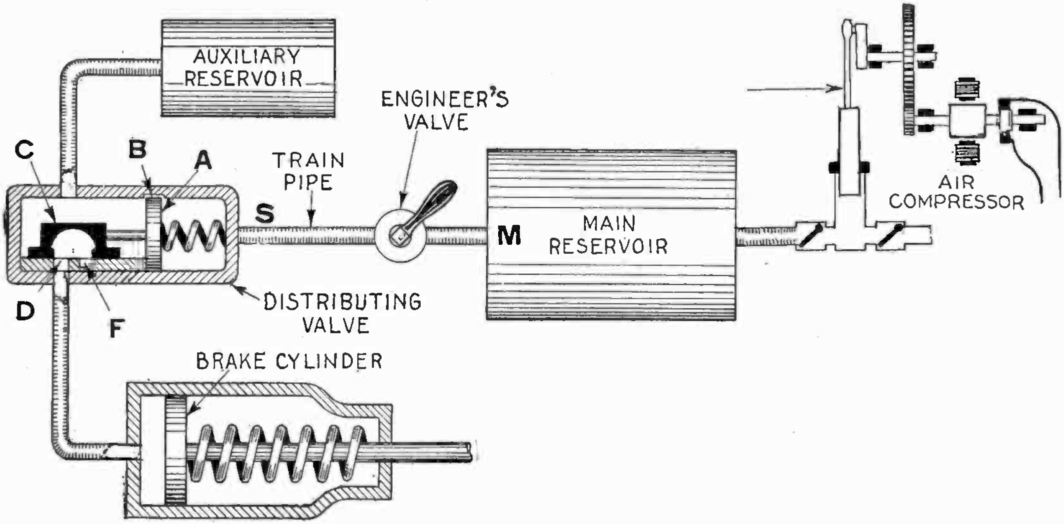


FIG. 6,313.—Elementary automatic air brake. The principles of operation are described in the accompanying text

a. To permit air to flow from the brake pipe to the auxiliary reservoir;

b. To prevent air flowing from the auxiliary reservoir to the brake cylinder;

c. To keep the brake cylinder open to the atmosphere.

2. When applying the brakes:

a. To close communication from the brake pipe to the auxiliary reservoir.

3. When holding the brakes applied:

a. To close all communication between the brake pipe, auxiliary reservoir, brake cylinder and atmosphere.

4. When releasing the brakes and recharging the system:

a. To open communication from the brake cylinder to the atmosphere;
b. To permit air to flow from the brake pipe to the auxiliary reservoir;
c. To prevent air flowing from auxiliary reservoir to the brake cylinder.

The operation of the system is best explained by first considering the elementary arrangement shown in fig. 6,313, illustrating the principles of operation.

Here, the air pump maintains a supply of compressed air in the main reservoir at a suitable pressure. The engineer's valve may be turned 1, so as to establish communication between the main reservoir and the train pipe; 2, this communication may be broken and the air locked in the two parts of the system; 3, the opening from the main reservoir may be closed and that from the train pipe opened into the atmosphere. Air passes through the distributing valve to the auxiliary reservoir placed under each car. The distributing valve also affords communication between the auxiliary reservoir and the brake cylinder when the brakes are to be applied.

In operation, the pump maintains a supply of compressed air of suitable pressure in the main reservoir. Opening the engineer's valve allows air to flow through train pipe, to distributing valve; entering this it comes in contact with piston A, and pushes it to the left end of its stroke. When in this position, one side of the piston is spanned by the groove B, in the casing, called the leakage groove. Air leaks through this groove into the space behind the piston and thence passes into the auxiliary reservoir.

When the pressure in auxiliary reservoir and train pipe becomes equalized, the apparatus is said to be charged and the brakes can be applied by turning the engineer's valve so that the flow from the main reservoir is stopped and the air in the train pipe is exhausted into the atmosphere; this causes excess pressure on left face of piston A. The air then starts to rush out from auxiliary reservoir through leakage groove, but as it cannot escape rapidly enough to supply the loss in D, the piston A, is moved to the right moving with it the attached slide valve C, which uncovers the port D, leading to the brake cylinder. This allows air to flow into the brake cylinder and apply the brake. Meanwhile the piston A, has traveled to the right, and beyond the end of the leakage groove B, stopping the flow of air from the auxiliary reservoir to the train pipe, thus setting the brakes; they will remain set until released.

To release brakes the engineer reestablishes communication between the main reservoir M and the train pipe S. Air again enters the triple valve. The piston A, is pushed to the left, thus C, is shifted so air flowing from

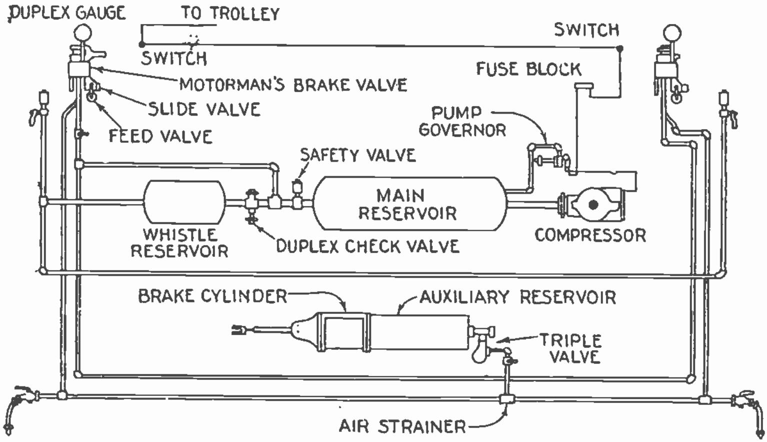


FIG. 6,314.—Automatic air brake system showing essential parts and pipe connection

auxiliary reservoir into the brake cylinder is stopped and the brake cylinder vented to atmosphere by means of the passage beneath valve which connects port D, and exhaust port F, the latter being open to the atmosphere.

The elementary principle here presented should be thoroughly understood before making a study of the actual apparatus.

The essential parts of the automatic air brake are shown with the pipe connection for a double ender installation in fig. 6,314.

Automatic Variable Release Air Brake.—This is a type of

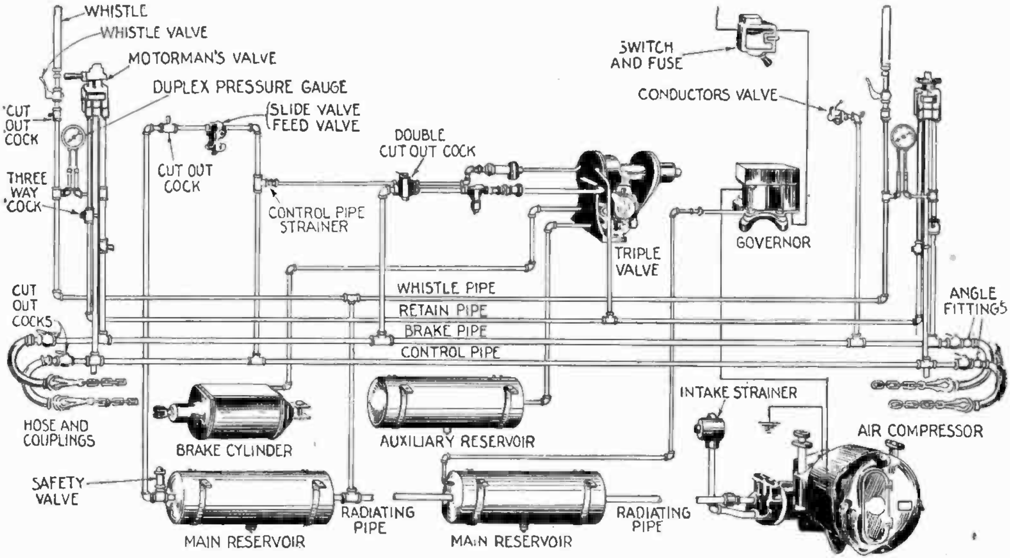


FIG. 6,315.—General Electric automatic variable release air brake equipment for motor car, showing parts and pipe connections.

automatic brake *provided with a triple valve designed to give a full or restricted release of the brakes as desired*. This feature is useful in obtaining the accurate stops so important in stations where individual cars are required to stop opposite certain definite points. Less air is also used, since it is necessary to make only one application when

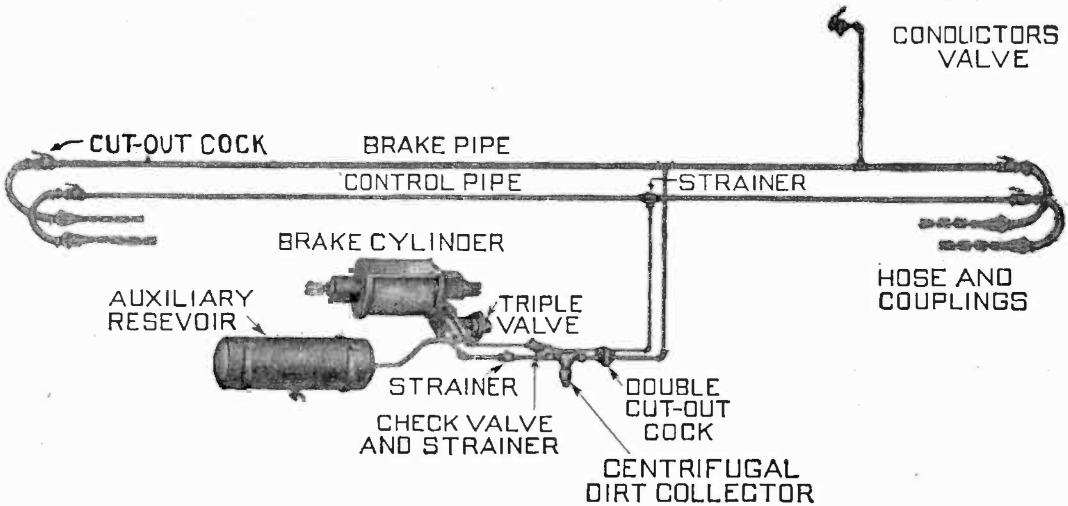


FIG. 6,316.—General Electric automatic variable release air brake equipment for trail car.

approaching a station, the brake cylinder pressure then being reduced in a series of steps as the speed of the train is decreased.

The general arrangement of the equipment is shown in fig. 6,315.

In operation the air from the main reservoir is admitted directly to the control pipe on each motor car, through a feed valve adjusted to reduce the reservoir pressure of 85 or 95 lbs. to the standard brake pipe pressure of 70 lbs. The excess pressure is thus confined to the main reservoir and the danger of overcharging the brake pipe and auxiliary reservoir is consequently eliminated.

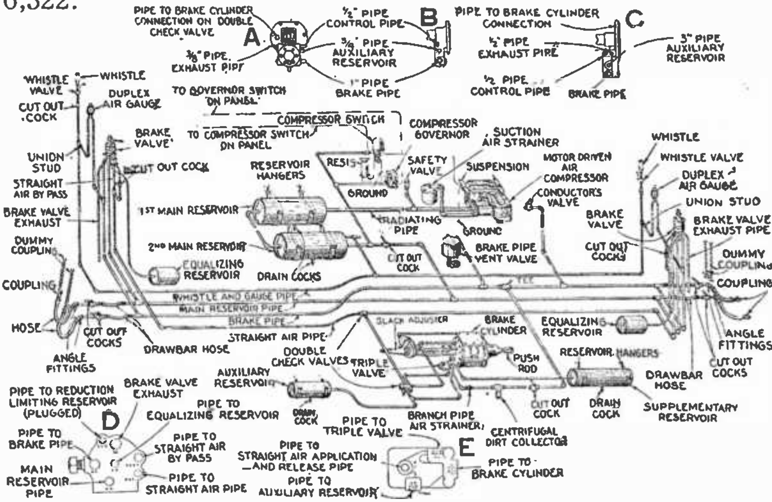
On account of the fact that the pressures above and below the rotary valve of the motorman's valve are equalized, when in the release and running positions the motorman's valve operates very easily, thus minimizing wear on the rotary valve and seat.

This arrangement has the further advantage of providing automatically for an even distribution of work between the several compressors on a train, without the use of special governing apparatus. The triple valve is of the quick acting, quick recharge, variable release type, which recharges the auxiliary reservoir directly from the control pipe on each car.

Quick Acting Automatic Air Brake.—This type of automatic air brake *is the same as the plain automatic but with the additional feature that the triple valve is so modified that when a relatively quick reduction in brake pipe pressure is made, it also opens a direct communication from the brake pipe through the triple valve to the brake cylinder*. This not only increases the brake cylinder pressure in proportion to the amount of air flowing into it from the brake pipe, but by venting air from the brake pipe locally on each car, hastens and increases the effect of the reduction made at the brake valve; the net result being to greatly shorten the time from the movement of the brake valve handle until a full brake application is obtained on the entire train, and to increase the total braking power obtainable by such operation (called an emergency application of the brakes), about 20 per cent over the maximum obtainable during ordinary operations (called service applications of the brake), or when using the plain automatic brake. This difference is due solely to the construction of the triple valves, which are called respectively the plain and quick action triple valve.

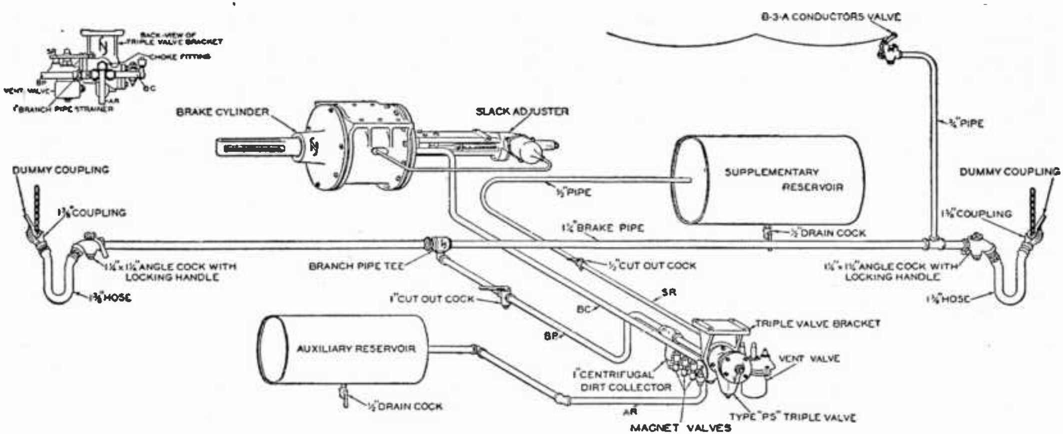
For all ordinary (service) applications of the brake, the operation of the two triple valves is identical.

Combined Automatic and Straight Air Brake.—This equipment is designed for use on electrically operated vehicles running in single car service or in trains. It is therefore especially adapted for both city and high speed interurban train service as well as for such service as is required of light electric locomotives or motor cars used for handling freight cars, switching, etc., since it provides for quick and flexible operation of the brakes on a single unit by straight air with the added facility of immediately changing to automatic operation when coupled to cars. This system as constructed, is shown in figs. 6,317 to 6,322.



Figs. 6,317 to 6,322.—Westinghouse combined automatic and straight air brake equipment diagrams showing parts and pipe connections. Figs. A, B, C, show pipe connections to brake cylinder pressure head; fig. D, pipe bracket of brake valve; fig. E, pipe double check valve.

Electro-pneumatic Air Brake.—On account of the changing conditions of railroad service such as longer trains, heavier cars, higher speed, greater frequency of trains, stops, etc., new functions and additional refinements are demanded of air brake equipments. To meet these exacting conditions the electro-pneumatic system of brake control has been developed. The operation of this system depends on *a triple valve so constructed*



Figs. 6,323 and 6,324.—New York electro-pneumatic air brake equipment showing parts and piping connection.

that the air distribution which causes it to operate may be controlled either pneumatically or electrically.

The Westinghouse electro-pneumatic brake equipment as applied to the Staten Island Rapid Transit Railway and the Philadelphia subway, and here described, illustrates electro-pneumatic control of brakes.

The equipment consists of the following parts: as shown in figs. 6,325 to 6,332.

1. *Motor driven air compressor.*

To compress the air.

2. *Electric compressor governor.*

This in conjunction with the *compressor switch*, automatically controls the operation of the compressor between predetermined minimum and maximum pressures.

3. *Two main reservoirs.*

These receive the compressed air from the air compressor for use in charging the brake system. They also supply air to the brake cylinder in emergency applications to produce a high emergency pressure.

4. *Safety valve.*

This connected to the main reservoir protects against excessive main reservoir pressure should the governor for any reason fail to operate properly.

5. *Auxiliary reservoir.*

This supplies air to the brake cylinder in service applications.

6. *Supplementary reservoir.*

This assists in obtaining graduated release of the brakes and prompt recharging of the equipment.

7. *Feed valve.*

This automatically maintains a predetermined normal pressure in the system.

8. *Two illuminated duplex air gauges.*

One connected to the piping near each brake valve, which shows by a red hand the pressure in the main reservoirs, and by a black hand the pressure of the brake pipe.

9. *Two brake valves.*

One at each end of the car by which the motorman by proper manipulation of the handle, can operate the brakes on each car.

10. *Two equalizing reservoirs.*

One at each end of the car, which are required for the operation of the equalizing piston of the brake valves.

11. *Universal valve.*

It corresponds in a general way to the triple valve in common use, operates to charge the reservoirs and to control the admission of air to, and exhaust from, the brake cylinder.

12. *Brake cylinder.*

This is provided with piston and rod so connected through the brake levers and rods to the brake shoes that when the piston is forced outward by the air pressure, this force is transmitted through the rods and levers to the brake shoes and applies them to the wheels.

13. Brake cylinder pressure limiting valve.

This is located in main reservoir pipe to limit brake cylinder pressure in emergency application to the valve's adjustment, in this case 60 lbs.

14. Conductor's valve.

Located inside each car, whereby the conductor may apply the brakes if necessary.

15. Combination double and single cut out cock.

Located in the brake pipe and main reservoir pipe branches with a connection to the brake cylinder and equipped with extension handles with which it is possible to open and close the cocks from the interior of the car.

16. Three plug switch.

Used to establish the electrical supply circuit to the operating brake valve.

17. Two air alarm whistles.

While not a part of the air brake apparatus proper, one of these whistles is placed at each end of the car with the necessary whistle valves and cut out cocks to be used as a warning of approach.

18. Various cut out cocks, air strainers, check valves, hose, switches, etc.

19. Automatic slack adjuster.

By means of this a predetermined piston travel and consequently a uniform cylinder pressure is constantly maintained, compelling the brakes on each car to do their full share of the work, thus securing the highest efficiency and reducing the danger of flat wheels which are likely to accompany a wide range of piston travel. This device establishes the running piston travel; that is, the piston travel, occurring when the brakes are applied while the car is in motion; and since this is the time during which the brakes perform their work, the running travel is most important.

With this equipment four lines of pipe are used: *feed valve pipe*, *feed valve control pipe*, *main reservoir pipe* and *brake pipe*, the main reservoir pipe and brake pipe being continuous throughout the train.

The *feed valve pipe* is always kept charged to the pressure, determined by the setting of the feed valve and furnishes the air supply to the controlling brake valve.

The *feed valve control pipe* connects brake pipe pressure through the brake valve to the feed valve so that the actual pressure of the brake pipe controls the opening and closing of the feed valve, thus assuring consistent operation of the feed valve to maintain a fully charged brake system.

The *main reservoir pipe* has a branch to the universal valve on each car through which main reservoir pressure is supplied to the brake cylinder in emergency application.

The *brake pipe* connects the controlling brake valve to the universal valves throughout the train and forms the means of communication by which the motorman by proper manipulation of the brake valve handle can operate the brakes on each car.

Rules for Operating Electro-pneumatic Air Brakes.—The following rules are intended to cover in a condensed form the important instructions to be observed in handling this equipment in service.

Charging.—Before starting the air compressor, *close* the drain cocks in the main, auxiliary and supplementary reservoirs, the brake pipe and main reservoir pipe cut out cocks at each end of the train (or car) and all whistle cut out cocks except the one in the operator's cab.

See that the following cocks are *open*: The main reservoir cut out cock between the main reservoir and feed valve, both cocks of the combined cut out cock, one of which is in the brake pipe branch pipe to the universal valve and the other in the main reservoir pipe branch pipe to the universal valve, all brake pipe and main reservoir pipe cut out cocks, between cars and the whistle cut out cock in the operator's cab.

See that all hand brakes are fully released.

The fuses in the compressor and battery circuits must be in place and *live*. Place a handle on the brake valve to be operated and move it to *release and running* position at the extreme left; also insert plug of three pole switch at the brake valve. Then close the snap switch in the battery circuit and start the compressor by closing the snap switches in the compressor circuits.

Do not attempt to move the train (or car) until the brake pipe gauge hand shows full brake pipe pressure.

Running.—Keep the brake valve handle in *release and running* position when not being used. In event of sudden danger, move the brake valve handle quickly to *emergency* position at the extreme right and leave it there until the train stops and the danger is past.

If the brakes apply while running over the road, due to the opening of the conductor's valve or rupture of the brake pipe, move the brake valve handle to *lap* position at once to prevent loss of main reservoir pressure. After the train stops, the cause of the application should be located and remedied before proceeding.

Service Application.—To apply the brakes for an ordinary stop, move the brake valve handle to *service* position. When the brake pipe gauge hand shows that a sufficient reduction in brake pipe pressure has been made to apply the brakes as required by the speed, condition of rail, grade, loading and kind of stop desired, move the handle back to *lap* or *holding* position, according to the results desired, as explained later, where it should remain until it be desired either to release the brakes or to apply them with greater force.

In the latter case move the handle again to *service* position, further reducing the brake pipe pressure until the desired result be obtained, then return it to *lap* or *holding* position.

The amount of brake pipe reduction necessary in any given case depends entirely on the conditions as stated above, a knowledge of which is soon acquired by practice. It should be especially borne in mind, however, that the retarding effect of any given reduction is relatively greater at low than at high speeds, other conditions being equal.

When making a pneumatic service application, it is useless to attempt a reduction below the equalizing point, at which the auxiliary reservoir and brake cylinder pressure become equal, as no further increase in brake cylinder pressure can be obtained. Furthermore, this results in a delayed release and a waste of air.

Under normal operating conditions an equalizing point corresponds to a reduction of 20 lbs. from 70 lbs. brake pipe pressure. The brake pipe reduction is automatically limited when operating electrically upon equalizing of the brake pipe and brake cylinder pressure.

The best possible stop will be made when the brakes are applied as hard, *at the very start*, as the conditions of speed, rail and comfort of passengers will permit, and then graduated off as the speed of the train is reduced, so that at the end of the stop little or no pressure remains in the brake cylinders.

Because the retarding effect of any given reduction is greater at low than at high speed, a heavy brake pipe reduction at low speeds will result in an abrupt stop, with perhaps discomfort to passengers or slid wheels. At high speeds a heavy initial reduction should be made in order to obtain the most effective reduction possible when the momentum of the train is greatest. If the brake cylinder pressure be very light at first and be increased as the speed of the train diminishes, it not only makes a longer stop but the high cylinder pressure at the end will be liable to produce a rough stop, perhaps slide the wheels and result in loss of time because of the necessity for waiting until this high cylinder pressure can exhaust before the train can proceed.

Holding the Brakes Applied.—After the reduction of brake pipe pressure has been made, the brake valve handle should be placed in lap position when operating *pneumatically* and left there until it be desired to make a further reduction or to release the brakes. When operating *electrically*, the brake valve handle should be placed in *holding* position if it be desired to recharge the system while holding the brakes applied.

Never allow the brake valve handle to remain in lap or holding position, except while bringing the train to a stop, and it should not be allowed to remain in this position for a sufficient length of time to permit the cylinder leakage to diminish the braking power materially.

Release.—*To fully release the brakes* after any application, move the brake handle to *release* and *running* position. The handle must be left in this position at all times when the brakes are not in use.

Electric. *To graduate or partially release the brakes*, move the brake valve handle to *release and running* position for a moment, then back to *holding* position; repeat this operation as may be necessary until the train is brought to rest with only enough pressure retained in the brake cylinders to prevent its rolling.

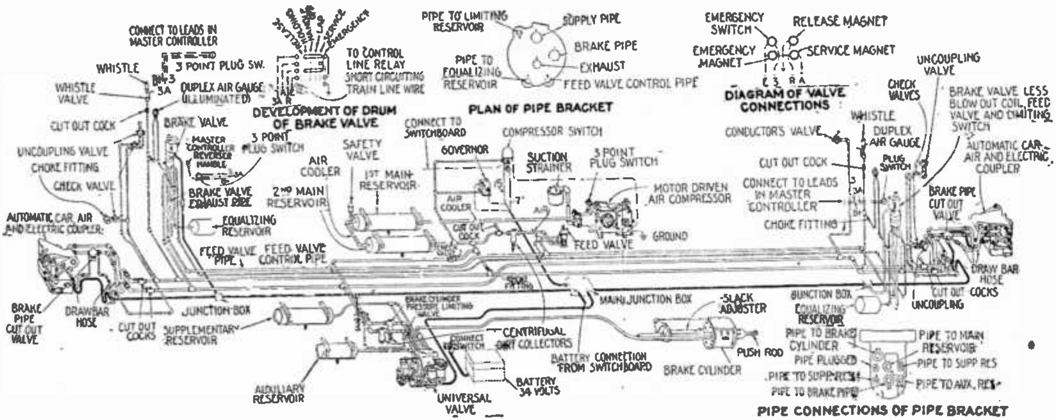
Pneumatic. *To graduate or partially release the brakes*, move the brake valve handle momentarily to *release and running* or to *holding* position, then back to *handle off* or *lap* position; repeat this operation as may be necessary until the train is brought to rest, only enough pressure being retained in the brake cylinders at the end of the stop to prevent the wheels rolling. With very little practice, the motorman will learn how long the handle should remain in *release and running* or *holding* position to produce the results desired. Obviously, this varies with the brake cylinder pressure, the amount of reduction in brake cylinder pressure desired and the length of train, etc.

When it be desired to release the brakes but slightly or when handling short trains, if the handle be moved to *release and running position*, the resulting increase in brake pipe pressure and the corresponding release of brake cylinder pressure is likely to be greater than is intended. For this reason it is usually best in such cases to move the handle from *lap* to *holding* instead of to *release* and *running position*. A few trials will enable the motorman to find out for himself which of the two positions he should use.

Emergency.—Should it become imperative to stop in the shortest possible time and distance, to save life or avoid accident, move the handle quickly from whatever position it may be in to *emergency position*, which is at the extreme right, and leave it there until the train stops and the danger is past.

Changing Ends.—When changing from one end of the train or car to the other, close the whistle cut out cock, remove the brake valve handle, withdraw plug of three pole switch and, after placing the handle on the brake valve at the other end and inserting the switch plug, move the handle to *release* and *running position* and open the whistle cut out cock in the operator's cab.

Synchronizing System.—The compressor governor, compressor switch and a wire, extending throughout the train, designated the synchronizing wire, comprise what is termed the synchronizing system, the purpose of which is to insure that all compressors in the train will start and stop at the same time, thus equally dividing compressor labor and eliminating overwork on the part of any single compressor.



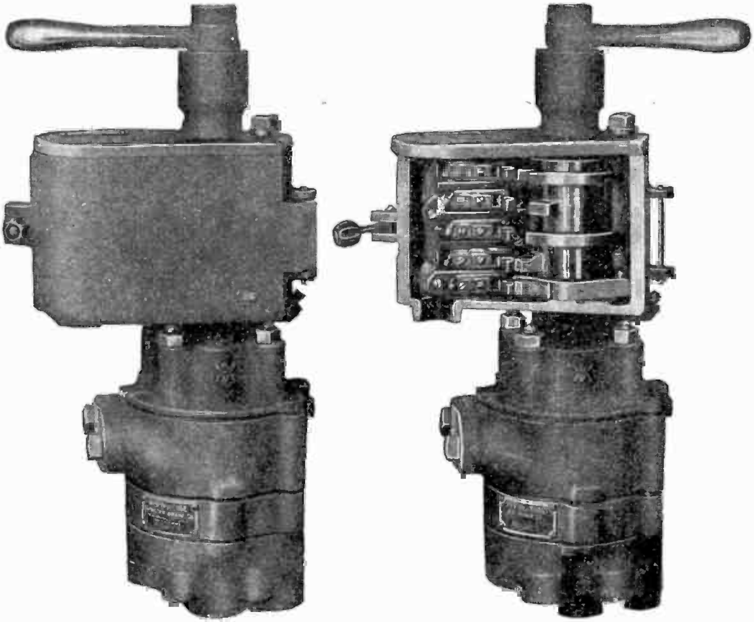
Figs. 6,325 to 6,332.—Piping and wiring diagrams of Westinghouse electro-pneumatic brake equipment as applied to the motor cars of the Staten Island Rapid Transit Railway Co. B+, + battery wire; 15, synchronizing wire; 3, emergency switch wire; R, release wire; A, application wire; E, emergency wire; 7, − battery wire.

All governor terminals are connected in parallel between the synchronizing wire and the positive side of the battery, all compressor switch magnet terminals between the synchronizing wire and the negative side of the battery, as shown in fig. 6,330.

When any master governor cuts in, the magnets of all compressor switches in the train are energized, the magnets in turn operating valves to cut in the switches thus completing the circuit from trolley to compressor on each car.

Electro-pneumatic brake valve handle positions.—The handle positions from left to right are

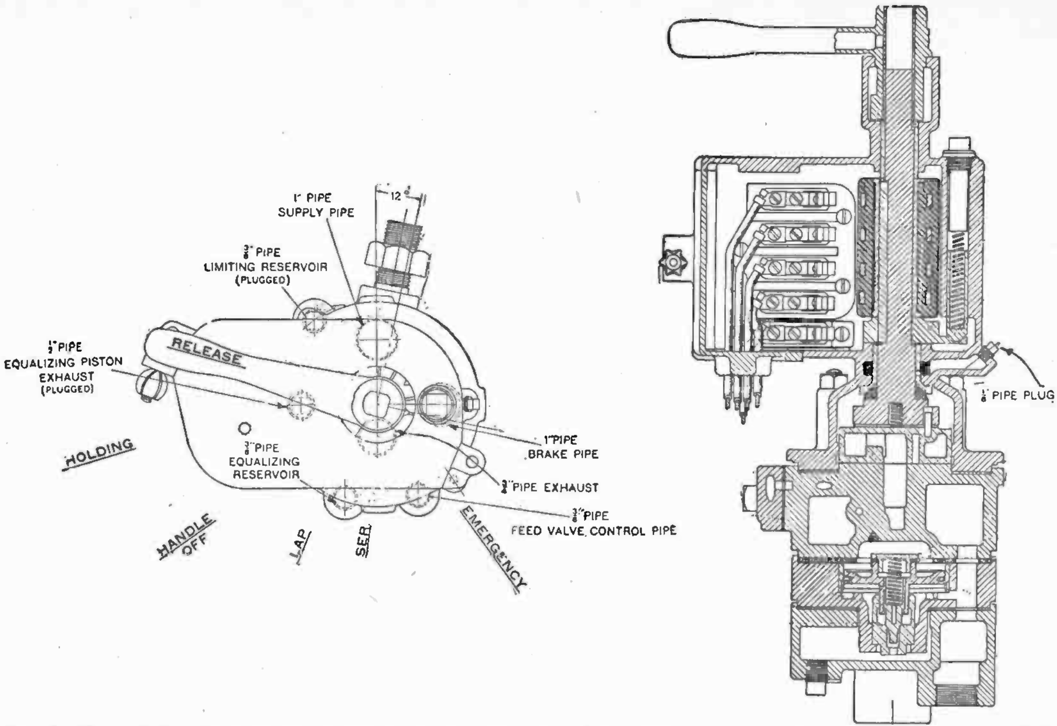
1. Release.
2. Electric holding.
3. Handle off.



FIGS. 6,333 and 6,334.—Westinghouse electro-pneumatic brake valve. Fig. 6,333, view with cover in place; fig. 6,334, view with cover removed showing electric portion.

4. Lap.
5. Service.
6. Emergency.

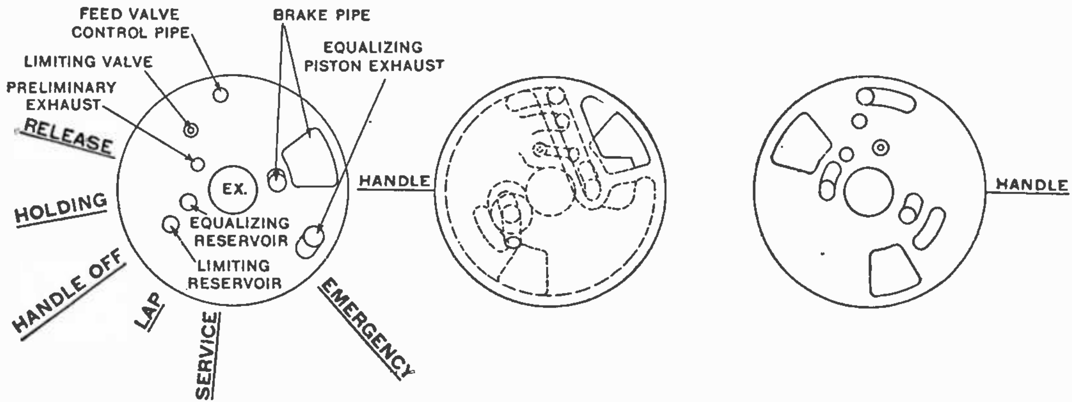
The pneumatic portion of the brake valve is shown diagrammatically in figs. 6,340 and 6,350. The electric portion is shown in fig. 6,334, and



FIGS. 6,335 and 6,336.—Westinghouse electro-pneumatic brake valve. Fig. 6,335, top view showing various positions; fig. 6,336, sectional view. ***In construction***. seven connections are provided on the bracket as follows: Supply pipe, brake pipe, feed valve control pipe, equalizing reservoir, brake valve exhaust, equalizing piston exhaust and limiting reservoir, the last two of which are

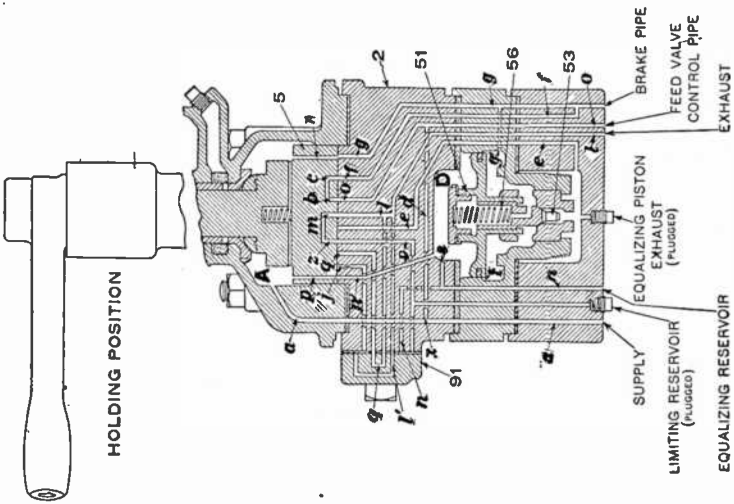
FIGS. 6,335 and 6,336.—*Text continued.*

not used and therefore are plugged. Raised letters are cast on the bottom of the pipe bracket to insure that proper connections are made. This brake valve is composed of two distinct parts, one pneumatic and the other electric. The electric portion is placed above the pneumatic and consists of a rotary drum with contacts attached to the same shaft as the rotary valve and corresponding fingers on the body of the valve. The upper finger is connected to the supply wire and to the emergency switch wire through the three pole switch, as shown in fig. 6,326, the second to the service magnet wire, the third to the release magnet wire, the fourth to the emergency magnet wire and the bottom one to the control line relay short circuiting train line wire. This last finger provides an emergency protection feature which is further described under the heading *emergency position*. The positions of the handle are identical for the electric and pneumatic release, service and emergency, consequently, if the electric control should fail, the pneumatic control will automatically function.



PLAN OF ROTARY VALVE SEAT PLAN OF ROTARY VALVE FACE OF ROTARY VALVE

FIGS. 6,337 to 6,339.—Westinghouse electro-pneumatic rotary valve and seat of the brake valve. Fig. 6,337, plan of rotary valve seat; fig. 6,338. plan of rotary valve; fig. 6,339, face of rotary valve.



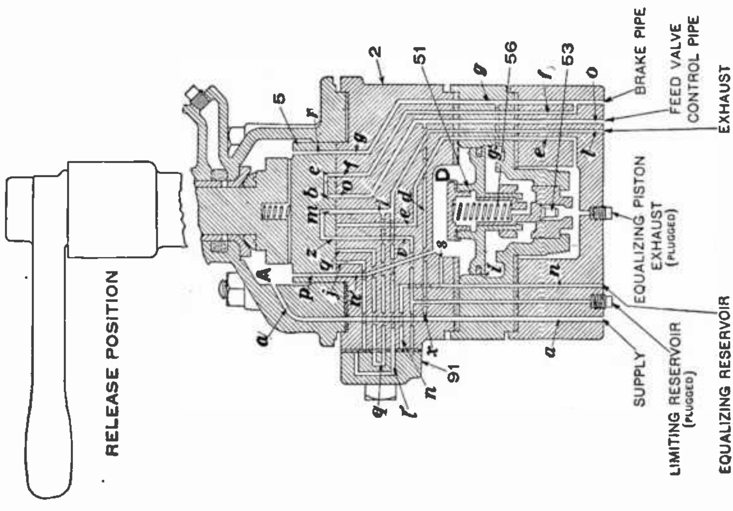


FIG. 6,340.—Westinghouse electro-pneumatic brake valve 1. Release position.
FIG. 6,341.—Westinghouse electro-pneumatic brake valve 2. Holding position.

diagrammatically in fig. 6,326. The operation of the brake valve in the various positions is as follows:

Release position.—Fig. 6,340. All brakes throughout the train are released and the system recharged. The feed valve pipe supplies feed valve pressure through passage *a*, to chamber *A*, above the rotary valve whence the pressure flow continues through port *r*, and passage *g*, to the brake pipe and through port *p*, and passage *b'*, to chamber *D*, and passage *S*, charging the brake pipe and equalizing reservoir to feed valve pressure. The chamber beneath the equalizing piston is charged through passage *g'*.

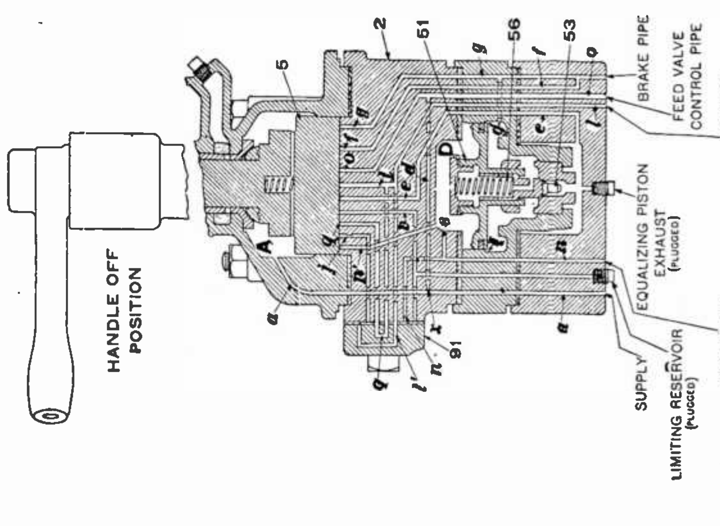
Ports *b*, and *c*, are connected, establishing communication between passages *f*, and *o*, allowing brake pipe pressure to flow from passage *g*, through the feed valve control pipe back to the diaphragm regulating chamber of the feed valve. No electrical connection is made in this position. Therefore, the release magnets on the universal valves are de-energized, permitting the escape of brake cylinder air to the atmosphere. The service and emergency magnets are held, closed by their respective springs.

Electric holding position.—In fig. 6,341, pneumatically the same operation takes place as in *release position*, except the recharge is slower due to the fact that port *r*, is not fully open.

Electrically, the release magnets are energized, thus preventing the exhaust of brake cylinder air. Therefore, in this position the brakes may be held applied while the brake pipe is being recharged or if desired, graduated off by movement of the brake valve handle between *release* and *holding positions*.

Handle off position.—Fig. 6,342. This position permits removal of the handle. The rotary valve blanks the ports and therefore the brakes are held applied as the brake pipe pressure has not been restored after the service reduction that should always precede removal of the handle.

Electrically, the release magnets are energized so that brake cylinder pressure will not be lost in case the brake valve handle be placed by mistake in this position when *lap* is intended or in passing from *lap* to *holding* as just before graduating the release. Restricted opening *x*, in passage *d*, of the rotary seat maintains communication between the feed valve supply, *a*, and the feed valve control passage *o*, so that when both brake valve handles on a car are in handle off position, at which time *f*, and *o*, will be blanked by the rotary valve, any leakage from the feed valve supply pipe will be reflected in the control pipe, which will cause the feed valve to open to maintain the pressure above the rotary valve, keeping the rotary valve on its seat and assuring a head pressure to effect a quick recharge on return of the handle to release.



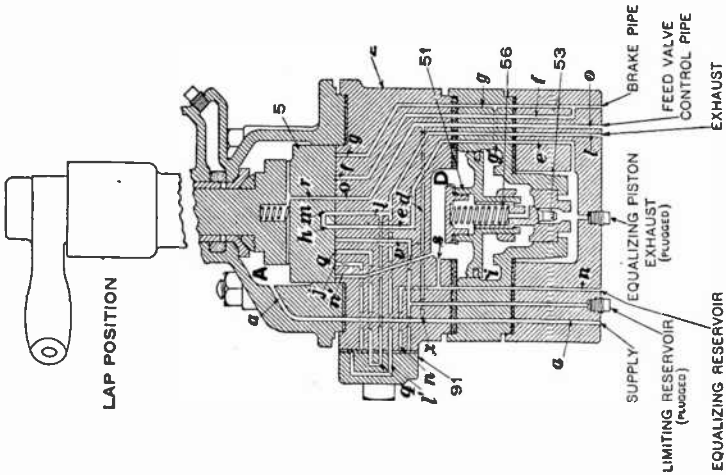
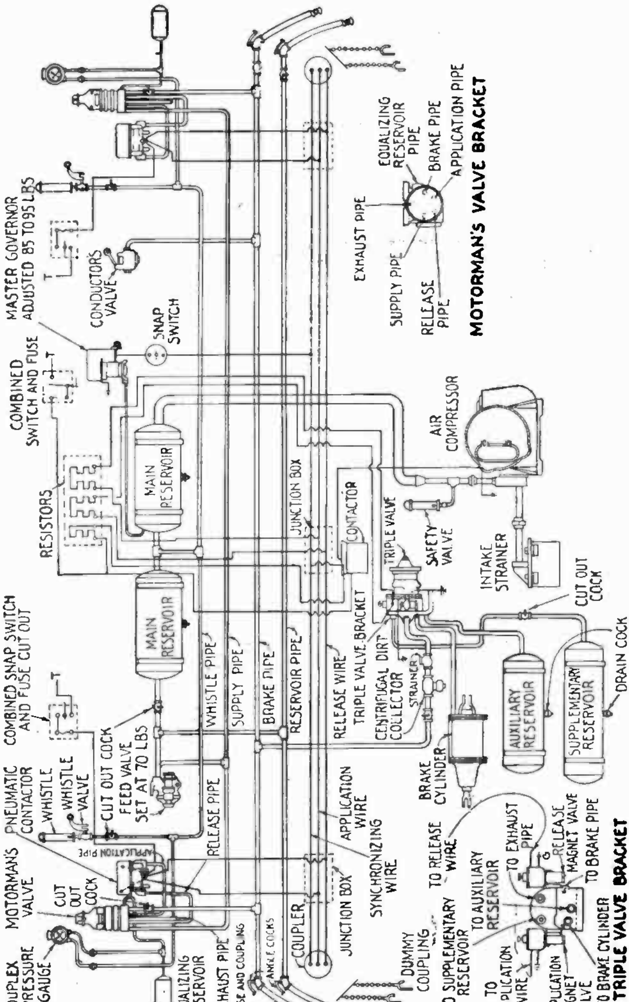
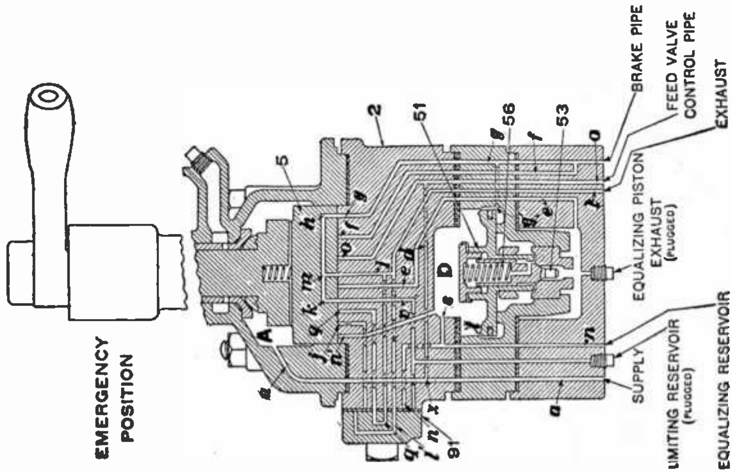


FIG. 6,342.—Westinghouse electro-pneumatic brake valve 3. Handle off position.
FIG. 6,343.—Westinghouse electro-pneumatic brake valve 4. Lap position.



FIGS. 6,344 to 6,348.—General Electric connections for electro-pneumatic motor car air brake equipment.



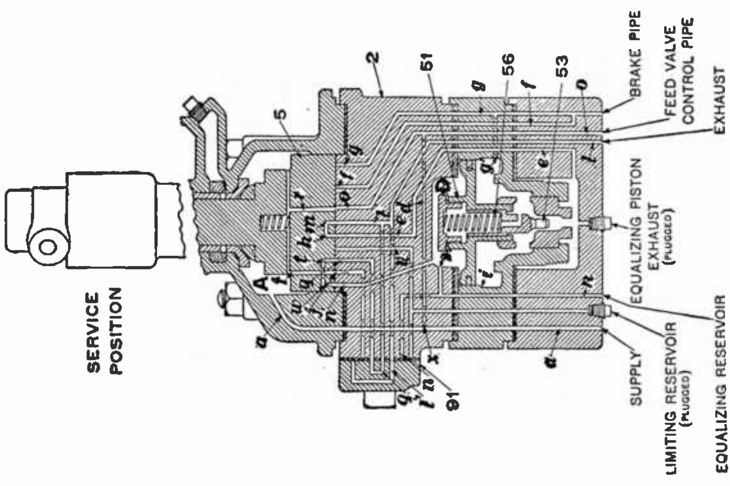


FIG. 6,349.—Westinghouse electro-pneumatic brake valve 5. Service position.
FIG. 6,350.—Westinghouse electro-pneumatic brake valve 6. Emergency position.

Lap position.—Fig. 6,343. This position is used to hold brake cylinder pressure and therefore all ports are closed except the equalizing discharge valve exhaust port *e*, which is connected to the exhaust port *l*, through ports *h* and *m*, in the rotary valve. Brake pipe exhaust from the equalizing discharge valve, 53, through passage *e*, therefore is open to the brake valve exhaust so that brake pipe pressure can be pulled down equal to the equalizing reservoir reduction of the preceding brake pipe reduction. Also, supply pressure in chamber *A*, is maintained to feed valve setting due to the control exercised by port *r*, communicating with the feed valve control pipe through passage *o*. Release magnets are energized to hold brake cylinder pressure.

Service position.—Fig. 6,349. All brakes are applied throughout the train. Pneumatically, ports *w*, and *t*, in the rotary valve register with ports *n'* and *q*, in the seat, allowing air from chamber *D*, and the equalizing reservoir to escape through passage *l*, to the atmosphere. The fall of pressure in chamber *D*, allows the brake pipe pressure under the equalizing piston 51, to raise it and unseat the discharge valve, 53, permitting brake pipe air to flow to atmosphere from passage *g*, through passage *g'*, past the discharge valve, through passage *e*, in the seat, ports *h* and *m*, in the rotary valve and *l*, in the seat to the brake valve exhaust. Also, port *r*, in the rotary valve is slightly open to permit communication between the control pipe and the supply pipe thereby maintaining supply pressure at the maximum.

When the pressure in chamber *D*, is reduced the desired amount, the handle is moved to *lap position*, thus stopping any further reduction from that chamber. Air will continue to discharge from the brake pipe past the discharge valve until the pressure has dropped to an amount slightly less than that retained in chamber *D*, when the piston will be forced downward gradually, the discharge valve seating and stopping the discharge of brake pipe air.

It will be apparent that the amount of reduction in the equalizing reservoir determines that in the brake pipe, regardless of the length of the train. The gradual reduction in brake pipe pressure is to prevent quick action. and the gradual stopping of discharge to prevent the pressures at the head end of the brake pipe being built up by air flowing from the rear which might cause some of the head brakes to *kick off*.

Electrically, the release magnets and service magnets throughout the train are energized, thereby closing brake cylinder exhaust and producing an electric service brake application.

Emergency position.—Fig. 6,350. All brakes are quickly and fully applied throughout the train. Pneumatically, the brake pipe passage *g*, is directly connected through fully opened ports, *h*, and *m*, in the rotary valve to the exhaust port *l*, a heavy reduction of brake pipe pressure thereby being quickly obtained.

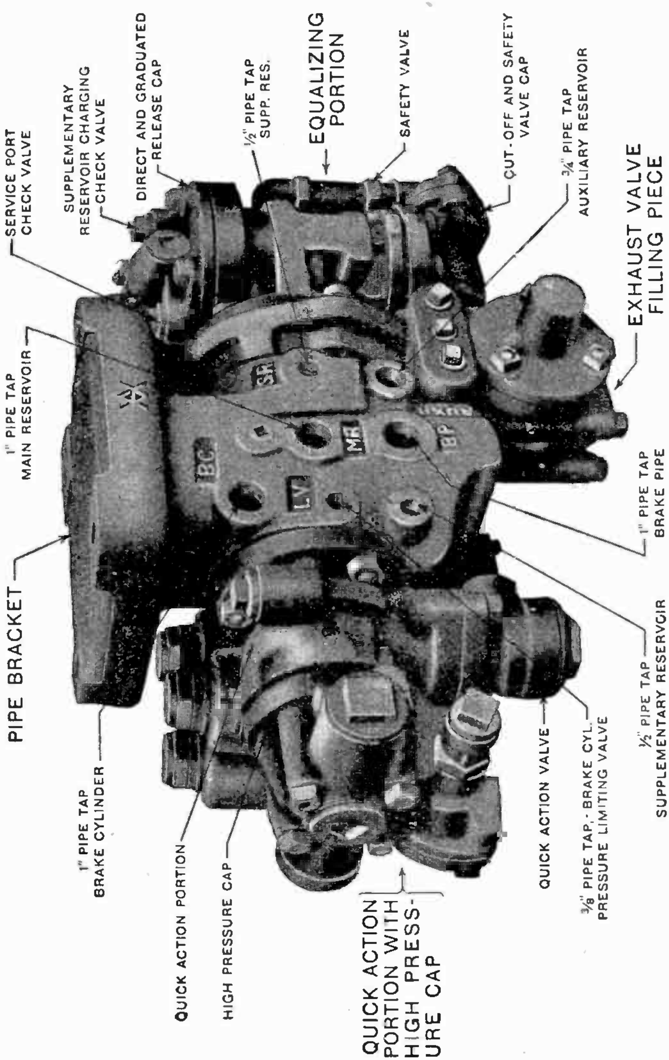


FIG. 6,351.—Westinghouse universal valve showing pipe bracket, equalizing portion, exhaust valve filling piece, quick action portion, etc.

Electrically, the emergency magnets are energized throughout the train resulting in an emergency application. Also in this position the bottom finger of the electrical portion of the brake valve contacts with the steel quadrant thereby grounding and short circuiting the line relays so that in the event of air brake failure the operator is able to reverse and buck the motors.

Universal valve.—The electro-pneumatic triple valve called by Westinghouse a *universal valve* is shown in figs. 6,351 and 6,352, and consists of the following portions.

Three face pipe bracket.—This is designated type C, to which are bolted the quick action, equalizing and electric portions and the exhaust valve filling piece, the latter being inserted between the equalizing portion and the pipe bracket. The bracket is bolted to the underframing of the car, all pipe connections being made permanently to this bracket, so that none need be disturbed in the removal or replacement of any one of the operating portions of the universal valve. This bracket contains two chambers, the quick action chamber and quick action closing chamber.

The equalizing portion.—This is similar in operation to the old style plain triple valve. It is this portion which is directly affected during pneumatic operation by differences in pressure between brake pipe and auxiliary reservoir, and it controls, either directly or indirectly through the medium of the other portions of the universal valve, the desired charging of the reservoirs, and when operating pneumatically, controls the application of the brake in service, and the release of the brakes. This portion has a direct and graduated release cap which may be set either for direct release or graduated release operation as desired.

The quick action portion.—This includes the various parts controlling the quick action and high pressure functions.

The exhaust valve filling piece.—This is inserted between the equalizing portion and the pipe bracket, which interlocks the electric and pneumatic features of the brake on a car so that if either the release or service magnets fail to operate as intended, the pneumatic application and release functions of the brake remain unimpaired.

When operating electrically, it also cuts off the auxiliary from the supplementary reservoir and closes the brake cylinder exhaust passage.

The electric portion.—This comprises the *service, emergency and release magnets and emergency switch*. The service and release magnets with their attached valves control the electric service applications and release of the brakes. The emergency magnet with its valve controls the operation of the emergency parts of the universal valve. The emergency switch closes the emergency magnet circuit during an emergency application.

The emergency switch and piston might be called the connecting link between the pneumatic and electric emergency functions of the equipment. It serves as a circuit closer to start the electric transmission of quick action throughout the train when originating pneumatically.

A magnet valve cut out cap, by means of which the service magnets as a unit may be cut out independent of the emergency magnet and vice versa or all may be cut out as may be necessary, is included in the electric portion.

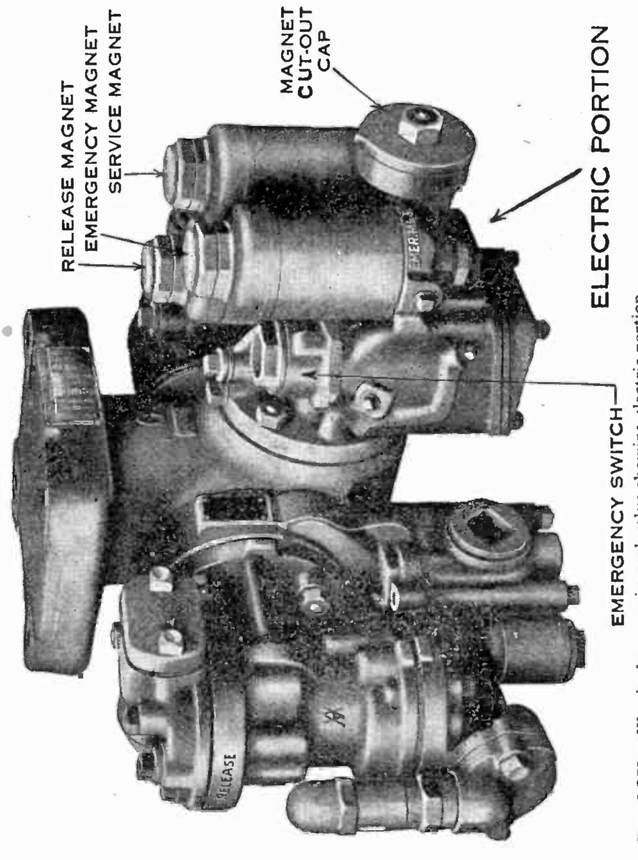


Fig. 6,352.—Westinghouse universal valve showing electric portion.

Hints to Motormen and Conductors.—These instructions will be found helpful in coping with various mishaps which sometimes occur in the operation of trains, fitted with electro-pneumatic brakes.

Cutting out brakes.—It is important not to cut out the brake on any car unless it be impossible to operate it. Small leaks are not sufficient cause for thus reducing the braking force on the train. After cutting out the brake on any car (by closing the cut out cocks in the branches from the main reservoir and brake pipes to the universal valve) release its brakes by opening the auxiliary reservoir and supplementary reservoir drain cocks and leave them open.

Unexpected brake applications.—Such applications may be due to the use of the conductor's valve, the train breaking in two, a bursted hose, or rupture in the piping. In such event the motorman should at once place the brake valve handle in *lap position*, and watch the gauge. If the black pointer fall, it indicates a leak in the brake pipe and if both pointers fall, it indicates that the train is broken in two or a leak in the main reservoir pipe. If this leak be found to be in the brake pipe, after securing the train with the hand brake, place the brake valve in *release position* and carrying handle return along side of train and locate leak.

Conductor's valve.—Should the conductor find it necessary to set the brakes from within any car, the cord or handle of the conductor's valve should be pulled down as far as possible. This valve must be closed, of course, before signalling the motorman to go ahead; otherwise brake pipe pressure will continue to escape and the brakes cannot be released.

Brake pipe rupture.—In event of a brake pipe hose bursting, or if the brake pipe be ruptured, close the cut out cocks in the brake pipe and main reservoir branch pipes to the universal valve and the brake pipe cut out cocks next ahead of and behind the point of rupture, and release the brake on the car thus cut out by bleeding the auxiliary and supplementary reservoirs. If this car be at or near the rear of the train, release the brakes on the rear cars by the nearest brake valve, leave the brake valve in *release* and operate from the head section. Whenever brake pipe cut out cocks have been closed, the train should be operated with caution from the longest section. All brakes will operate electrically except on the car cut out, but if the electric brake circuit fail, the pneumatic brakes can only be controlled to the point where the angle cock is closed.

Main reservoir pipe rupture.—Should a main reservoir pipe or hose burst, close both main reservoir and brake pipe cut out cocks, the cut out cock in the brake pipe branch pipe to the universal valve, and release the brakes by bleeding the auxiliary and supplementary reservoirs. Cut out the compressor switch and proceed the same as with a burst brake pipe.

Branch pipe rupture.—Should a brake pipe branch pipe break between the universal valve and the cut out cock, close the cut out cock and release the brake on that car by opening and leaving open the auxiliary and supplementary reservoir drain cocks, and proceed as usual. If the break occur between the cut out cock and the brake pipe, it is, in effect, a brake pipe rupture and the instructions given under that heading should be followed. If the main reservoir pipe branch pipe break between the cut out cock and the universal valve, close this cock and proceed as usual. If the main reservoir pipe branch pipe break between the cut out cock and the main reservoir pipe, it is, in effect, a main reservoir pipe rupture, and the instructions giver under that heading should be followed. After cutting out the brakes on a car charged with air for any of preceding troubles, before moving train make an emergency application of the brakes, then release brakes and proceed.

Overcharged brake pipe.—Should the brake pipe become temporarily overcharged, thereby preventing a proper release of the brakes, make successive applications of 20 lbs. and release, charging the brake pipe to within 5 lbs. of previous pressure after each release. Further overcharging may be prevented by placing the brake valve in handle off position. To prevent brake creeping on in case brake pipe is leaky, move brake valve handle to *release* momentarily, then back to *handle off position.*

Leaving cab.—Whenever the motorman leaves the cab, as in changing ends, etc., he should make a 20 lb. reduction and moving the handle to *lap*, remove the handle, leaving brakes set.

TEST QUESTIONS

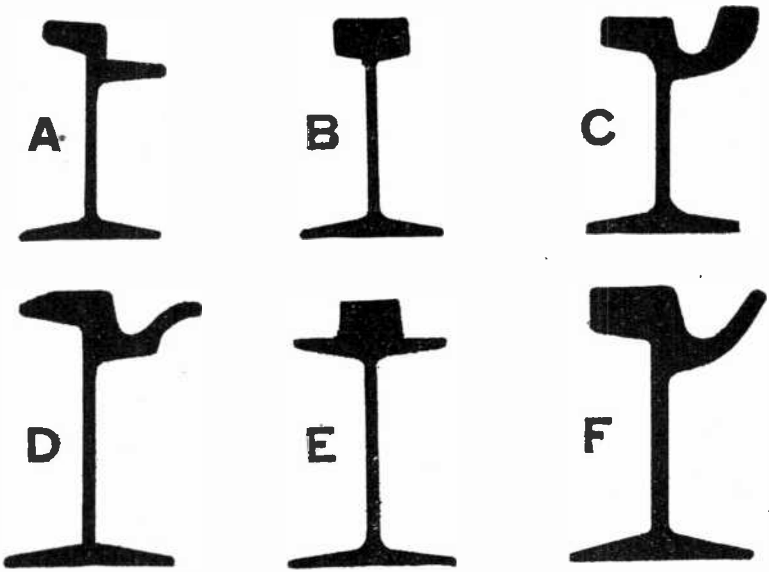
1. *Name the various kinds of air brakes.*
2. *How does the emergency air brake differ from the straight air brake?*
3. *What is the meaning of the word "automatic" as applied to air brakes?*
4. *For what service is the automatic variable release type air brake used?*
5. *What is the feature of the automatic variable release type air brake?*
6. *What is the adaptation of the quick acting automatic air brake?*
7. *How does the quick acting type differ from the variable release type?*
8. *What is the object of the electro-pneumatic type of air brake.*
9. *Describe the straight air brake.*
10. *Give rules for operating a straight air brake.*
11. *Name an objection to the straight air brake.*
12. *How is the objection in the previous question overcome?*
13. *Name the various parts of an emergency straight air brake.*
14. *Describe the operation of an emergency straight air brake.*
15. *What apparatus is necessary to accomplish the automatic application of the brake in case of accidents?*
16. *What are the functions of a triple valve used with the automatic air brake?*

17. *Describe the method of operating the automatic air brake.*
18. *How is the operation of the automatic air brake best explained?*
19. *What is an automatic variable release air brake?*
20. *How does the quick acting automatic air brake differ from the plain automatic brake?*
21. *For what service is the quick acting automatic air brake designed?*
22. *How is a triple valve modified for quick action?*
23. *For what service is the combined automatic and straight air brake designed?*
24. *Name the conditions for which the electro-pneumatic air brake is adapted.*
25. *Upon what does the operation of an electro-pneumatic brake depend?*
26. *Name the parts of the electro-pneumatic brake.*
27. *Give the rules for operating an electro-pneumatic brake.*

CHAPTER 138

Tracks

The distinction between the tracks for steam and electric railroads becomes less pronounced as the traffic conditions under which they operate tend to become similar. Figs. 6,353 to 6,358



FIGS. 6,353 to 6,358.—Various girder rail sections. **A,** plain girder rail; **B,** high tee, or Shanghai rail; **C,** grooved girder rail; **D,** Trilby girder rail: **E,** center bearing girder; **F,** deep flange girder show some familiar girder rail sections. Ordinary tee rails are to a large extent supplanting the girder and grooved sections in city streets.

Electric roads are extending into country districts over private right of way, permitting the use of steam railroad standards, both for road bed and equipment, so that many of the track structures used for steam roads are equally applicable to electric roads.

There is a small but appreciable mileage of tracks laid in paved streets where the use of standard split switches is not practicable and a double tongue switch or a tongue switch and mate, must be substituted for the former to insure proper provision of flangeways. While girder rail construction is desirable, provided the expense is justified, satisfactory results may be obtained from built up tee rails in places where the nature and depth of the paving permit of their use.

Track work involves in addition to the installation of the rails, such devices as guard rails, switches, frogs, cross overs, etc.

In order to understand clearly the explanations of this chapter, familiarity with the terms commonly used in track work is essential.

Definitions

Closure rail.—The length of rail necessary to connect the heel of switch with the toe of frog, either on the lead or on the lead curve.

Connecting track.—A track which differs from a cross-over in that the tracks between which it lies are either oblique to each other, or if parallel, are more remote than the track centers ordinarily employed.

Crossing.—A structure designed to permit one track to cross another at grade, usually made up of four connected frogs, one for each intersection.

Crossover.—A track made up of two turnouts, with the track between the frogs, so arranged as to form a continuous passage between two nearby and generally parallel tracks.

Double crossover.—A combination of two crossovers in opposite directions which intersect between the parallel tracks; also called scissors crossover.

Frog.—A device for use where two running rails intersect, it has provision of flangeways to permit wheel flanges traveling along either rail to cross the other.

Frog angle.—The angle formed by the intersecting gauge lines of a frog.

Frog number.—One-half the co-tangent of one-half the frog angle, and is the number of units of center line length in which the spread is one unit.

Guard rail.—A rail or other device laid parallel with the running rail opposite a frog to form a flangeway with this rail and hold the wheels of equipment to the proper alignment when passing the point of frog. The guard rail is also placed parallel with the running rail ahead of a split switch so as to form a flangeway with the rail to hold the wheels of equipment in proper alignment when approaching the switch.

Guard rail gauge.—The distance from the gauge line of the frog to the flange side of the guard rail, measured ⅝ in. below the top of the rail, and is always 4 ft. 6¾ in. whatever the track gauge may be.

Half-inch point of frog.—The point where the spread between the gauge lines is ½ in. Its distance in inches from the theoretical point, or the intersection of the gauge lines of the frog, measured toward the heel, is equal to one-half the frog number.

Heel end of frog.—The end farthest from the switch.

Heel length.—The distance between the heel end and the half-inch point of frog measured along the gauge lines.

Heel of switch.—The end opposite the tapered end of switch or point rails.

Heel spread.—The distance between the gauge lines at the heel of the switch, standardized at 6¼ in.

Knuckle rails.—Used in slip switches. Rails bent to an obtuse angle equal to the supplement of the angle of the slip switch crossing, against which the two pairs of tapered movable rails bear.

Ladder track.—A diagonal track from which several tracks diverge through separate turnouts.

Latches.—Latches and locks are used to secure the switch against improper movement.

Lead.—In a turnout the length between the actual point of switch and the half-inch point of frog measured along the main track.

Lead curve.—The curve interposed between the heel of switch and toe of frog.

Movable point frogs.—These consist of tapered rails lying against a knuckle rail and so connected that they provide passage on one or the other of the intersecting tracks.

Point of switch.—The tapered end of the switch or point rails.

Rail braces.—Stays used to prevent the rails pushing out or turning over.

Scissors crossover.—See double crossover.

Slip switch.—A combination of a right and a left hand switch in the case of a single slip, and of two right hand and two left hand switches in the case of a double slip, together with the track between them, placed within the limits of the crossing of one track by another and connecting the two intersecting tracks on one or both sides of the crossing, respectively, without the use of separate turnout frogs.

Split switch.—A device consisting of two tapered movable rails, with the necessary fixtures, which is designed to divert rolling stock from one track to another.

Switch angle.—The angle included between the gauge lines of the switch rail and stock rail.

Switch plates.—Used to support the point rails at the proper elevation and to maintain the stock rails in position.

Switch rods.—Braces to hold the switch rails the correct distance apart and to keep them from rising as well as to supply the means for connecting them with the switch stand.

Switch stand.—This provides the means for throwing a switch or movable point crossing, except when they are operated by a power device, as at an interlocking.

Target and lamp.—Used to indicate the position of the switch.

Throw of switch.—The distance through which the switch rails are moved sidewise, measured along the center line of the switch rod nearest the vertex, to bring either point against the stock rail. This distance has been standardized at 4¾ in.

Toe end of frog.—The end nearest the switch when the frog is in track.

Toe length.—The distance between the toe and the half-inch point of frog, measured along the gauge lines.

Toe spread.—The distance between the gauge lines at the toe end of the frog.

Turnout.—The connection of one track with another, consisting of a

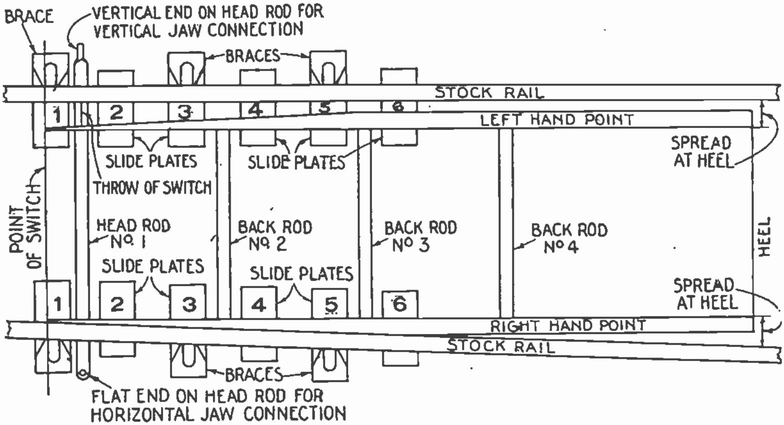


Fig. 6,359.—Diagram of split switch with names of parts.

switch, frog, two guard rails (except where the frog is self guarded), and the various connecting and operating parts.

Vertex.—This is the point where the gauge line of the switch rail, if produced, would intersect the gauge line of the stock rail, and is the point where the stock rail bend is introduced. Also called the theoretical point of switch.

Switches.—A switch is *a device for diverting rolling stock from one track to another*. There are several kinds of switch, classified as:

1. Split;
2. Three throw;
3. Derailing.

The split switch is the one mostly used. It consists essentially of *two switch or point rails, known as the right hand and left hand*

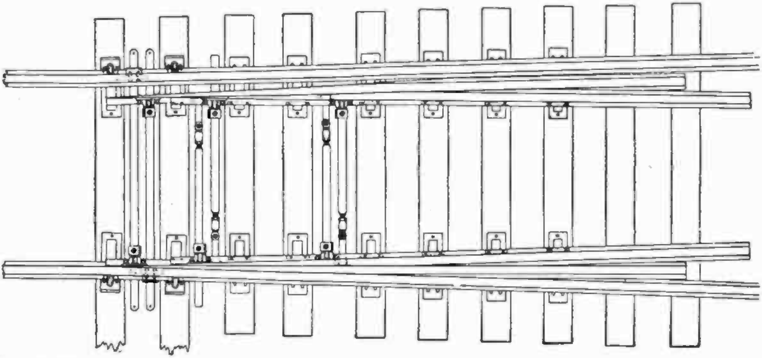


FIG. 6,360.—Racor three throw split switch with adjustable rods.

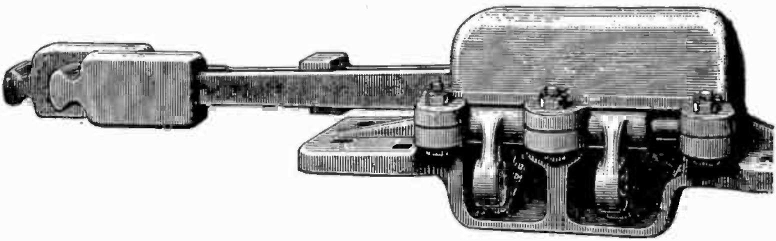


FIG. 6,361.—Racor three throw ground throw switch stand.

points; one or more rods to hold the switch rails in correct relation with each other and to keep them from rising; gauge and switch plates to elevate the switch rails to the required height with respect to the stock rails and to maintain the stock rails rigidly in position in conjunction with plain or adjustable braces; and auxiliary *devices for securing, adjusting, insulating or protecting the several parts of the structure.*

Fig. 6,359 illustrates a *split switch* giving names of parts. Switch rods are necessary to maintain the switch points the correct distance apart at the point end of the switch, as is done by the heel blocks or shoulder tie plates at the heel of the switch.

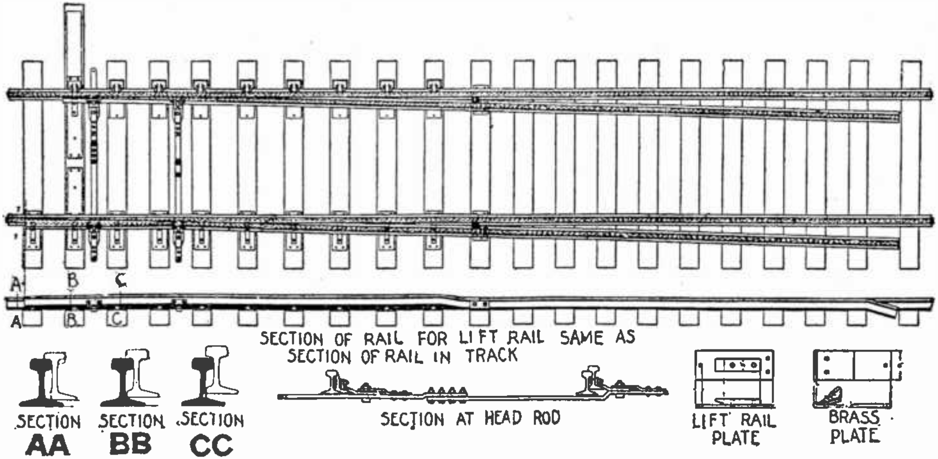
A *three throw switch* is used where two turnouts from the same side or from opposite sides of a parent track have their origin at a common point, so that one switch stand can operate the two switches.

The two switch points which heel on the middle one of the three tracks have their points approximately opposite each other, although connected to different operating rods, while the points which deflect the traffic to one or the other of the outside tracks are staggered with these at the point end and usually also at the heel end, approximately the distance between centers of ties. The respective staggered points are connected through special clips which permit of close engagement of the two switch rails when set for either outside track, so that the inner point backs rigidly against the outer point which in turn backs upon the stock rail. Fig. 6,360 illustrates a three throw split switch with adjustable rods, and fig. 6,361 the type of stand used for this switch.

Although *a derailing switch* is not favored in the main track, and a properly designed deflecting track is given preference, one or the other of these devices is a necessity for checking runaway trains on heavy grades.

The lifting derail, which provides for an unbroken main line when set for a clear track, is effective either as a switch derail or a switch connection for a deflecting track. It is made up of a standard switch point, which engages the wheels on one side to deflect the car, while a specially designed section of rail lifts the opposite wheels and permits their flanges to pass over and off the running rail upon the ties or into a parallel deflecting track.

Frogs.—A frog is *a device which is introduced at the intersection*



Figs. 6,362 to 6,369.—Racor lifting derail with overlapping one piece lifting rail.

of two running rails to permit the flanges of wheels moving along one of them to pass across the other.

The object of a frog is to support the wheels over the missing tread surface between the throat and half-inch point, and provide flangeways for aligning the wheels when passing over the point so that they will be afforded the maximum of bearing area.

Frogs are classified as:

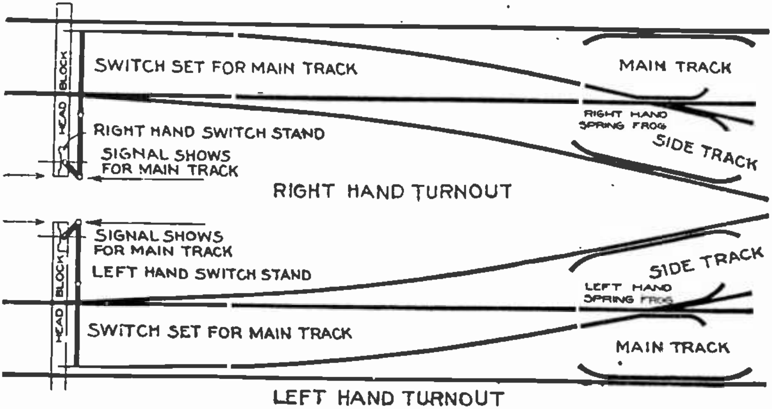
1. Rigid;

2. Spring rail;
3. Sliding.

Each type may be constructed in various ways depending on service desired and conditions under which used.

Frogs may be divided into two principal groups:

1. Turn out;
2. Crossing.



FIGS. 6,370 and 6,371.—Diagrams of right and left hand turn outs, right and left hand spring frogs and switch stands. Spring rail frogs must be used right hand or left hand for right or left hand turnouts as shown. Switch stands of the single throw type, without means for changing position of signal staff should be used right and left hand. Some types of stand are interchangeable for right or left hand turnouts.

These, however, overlap as when standard turnout frogs form the end frogs of a crossing, or a double pointed frog is required for a turnout from three rail combined standard and narrow gauge track.

Standard turnout frogs are generally in two principal classes:

Rigid frogs, which have no movable parts;

Movable wing frogs, in which one or both of the wings move outward to provide flangeways.

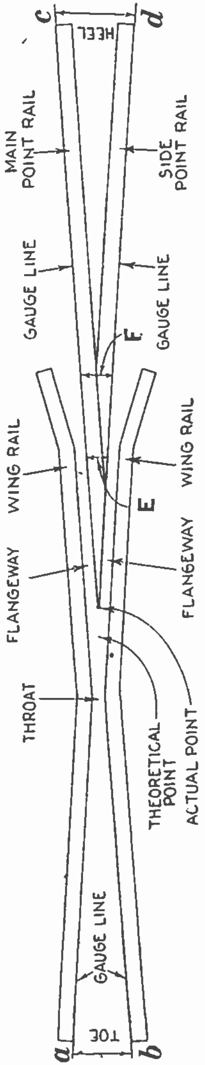


FIG. 6,372.—Parts of frog and simple rules for measuring angle. The angle or number of a frog can be obtained by dividing the total length in inches by the sum of *ab* and *cd* in inches. Another and simpler method: Mark point of frog where it is 2 inches wide at E. Mark also where 3 inches wide as at F. The distance between these two lines in inches is frog number.

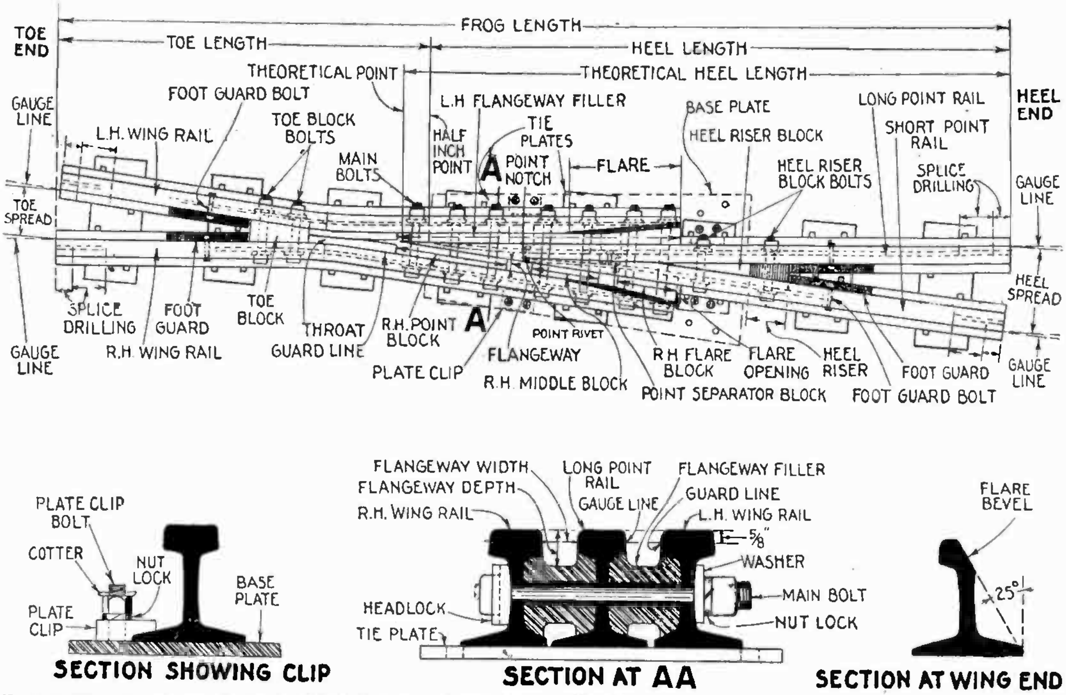
The rigid frogs include the bolted or clamped patterns, the manganese railbound, manganese solid and self-guarded frogs. The movable wing frogs include the spring rail frogs, these being right hand when the wing moves to the right, looking from the toe toward the point of frog, or left hand when the reverse is the case; and double spring rail frogs, in which the wing rails open both to the right and left. The rigid type of frog is commonly used where the traffic is approximately equal on both tracks, although rigid frogs of manganese railbound construction are extensively used at interlocking layouts regardless of the relative amounts of traffic.

The lighter types of rigid bolted and clamp frogs are more generally confined to yards and industrial tracks.

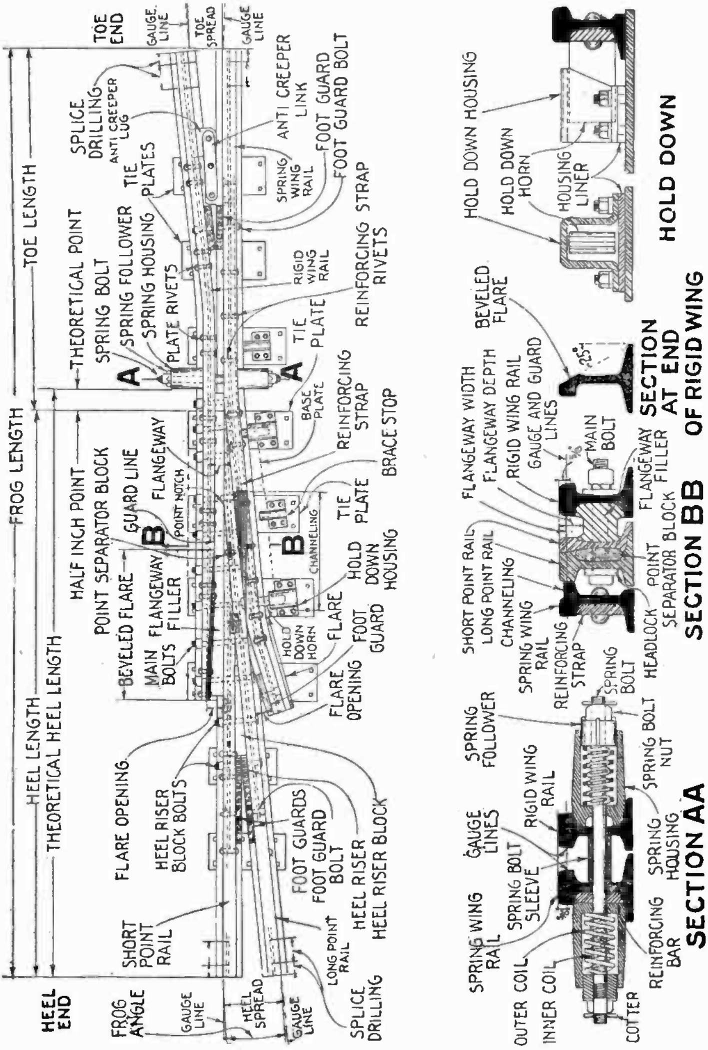
The spring rail frog is given preference over the rigid bolted frogs for main track turnouts other than at interlockings, although manganese railbound frogs are also much used in such places. The spring rail frog provides a practically continuous rail for the main track and is considered by many to afford easier riding and an increased life of the structure in the track.

The double spring rail frog is employed primarily where it is necessary to take care of narrow wheel treads occurring in a mixed traffic, as where operation is by both electric and steam trains.

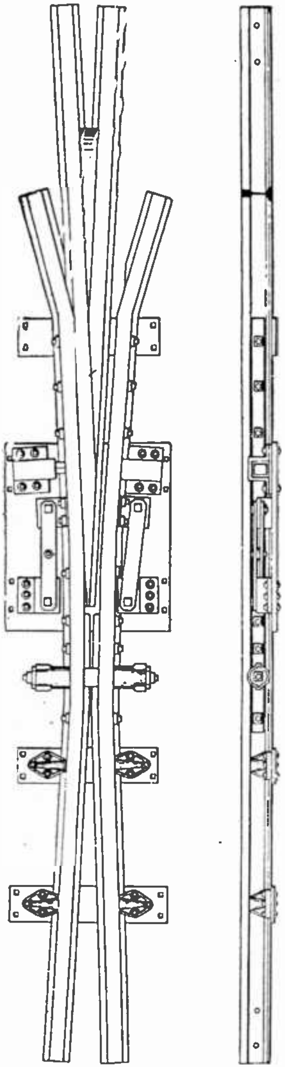
The parts of a frog and simple rules for measuring angle are



FIGS. 6,373 to 6,376.—*A. R. E. A.* preferred names of parts for bolted rigid frogs.



FIGS. 6,377 to 6,382.—*A. R. E. A.* preferred names of parts for spring rail frogs.



Figs. 6,383 and 6,384.—St. Louis sliding wing rail frog.

given in fig. 6,372. Figs. 6,373 to 6,376 show the construction of a rigid frog with names of parts.

Spring rail frogs differ from the rigid type in that they have *one or both of the wing rails held close to the point rails by means of a spring*, thus avoiding the flangeway opening and permitting the wheels to ride over the structure without the jar or pound that is so destructive to the rigid frog.

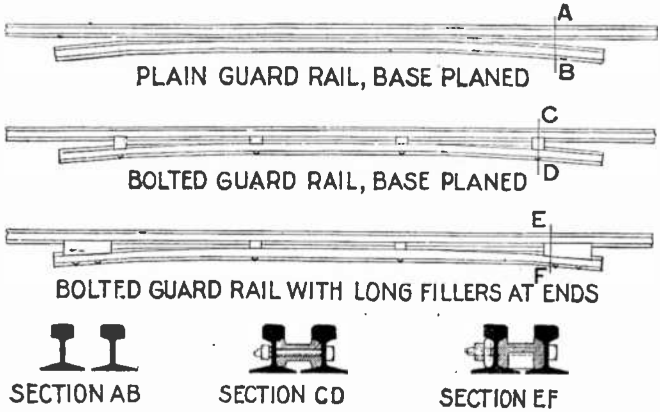
This also eliminates vibration to the rolling stock, on which account the spring frog has been generally used on main line turnouts where movement into sidings is infrequent. Figs. 6,377 to 6,382 show construction of a spring rail frog.

The action of the sliding rail frog is due to the car wheels in passing over the frog, the wheel flanges automatically moving the wing rails in passing over. Figs. 6,383 and 6,384 show the construction.

Guard Rails.—These are of three general classes:

1. Turn out;
2. Curve;
3. Bridge.

The turnout guard rail is designed to prevent the wheel flanges striking the points of frogs and switches, except where the frogs are self-guarded or the switches protected by a manganese steel flange.



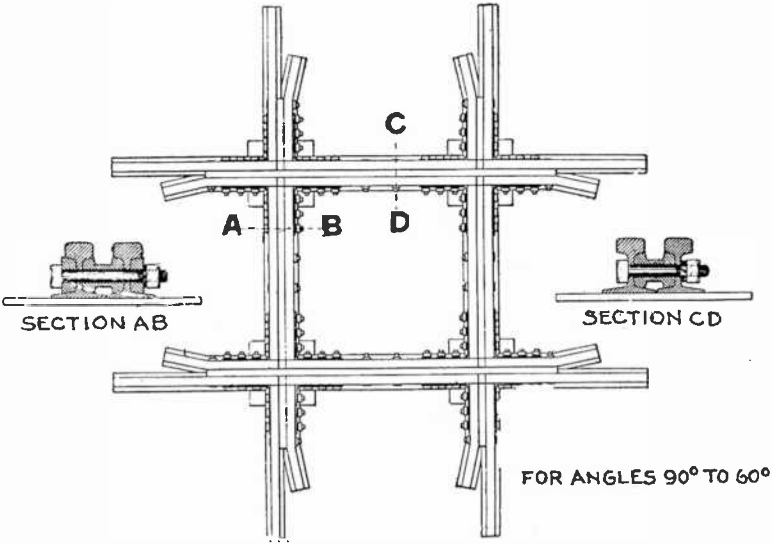
FIGS. 6,385 to 6,390.—St. Louis guard rails.

The curve guard rail is installed on the sharper curves to avoid derailment and to reduce side wear of rail and flanges. The bridge guard rail is intended to keep derailed wheels from running off the ties.

Guard rails are discussed herein principally as regards the turnout guard rail, although incidental mention is made of the curve guard rail, since its position in the track is based on somewhat the same mathematical principles and it employs similar auxiliary equipment.

While the ends of both turnout and curve guard rails are frequently cut square they may alternately be depressed or beveled as a provision against dragging parts of cars catching upon them. As a further precaution the ends of the guard rail are made to rest on a tie wherever practicable. Both types of guard rail also require flares at their ends, to align the wheels into their proper course without shock. The required width of flare opening is usually maintained by end blocks, which also serve as foot guards. All types of guard rails require an adequate means of bracing them against the side thrust of traffic.

Crossings.—The structure used at the intersection of two tracks, adapted for the passage of flanged wheels is termed a



FIGS. 6,391 to 6,393.—St. Louis crossing, two rail both tracks. Fig. 6,391, section AB; fig. 6,393, section CD.

crossing. Crossings are constructed to meet the conditions of service to which they are subjected. For those infrequently used or for light equipment, it is unnecessary to provide the substantial types that frequent trains, high speeds and heavy rolling stock would call for.

A crossing consists of *four frogs, one for each rail intersection, connected together and provided with arms at the four corners for attachment of the main rails.*

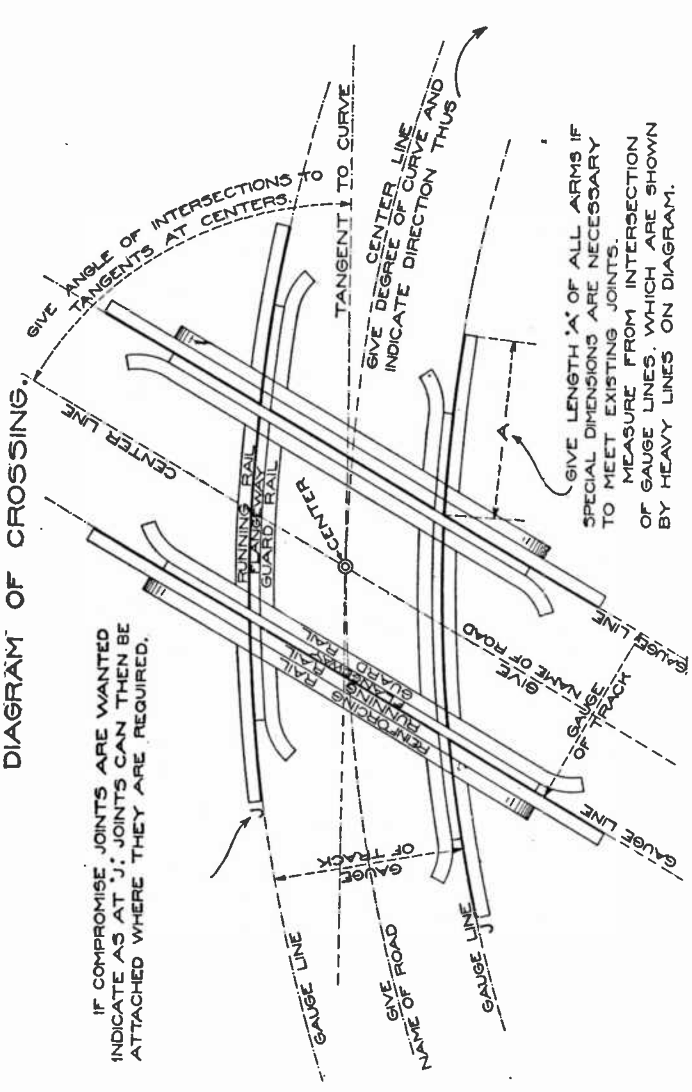
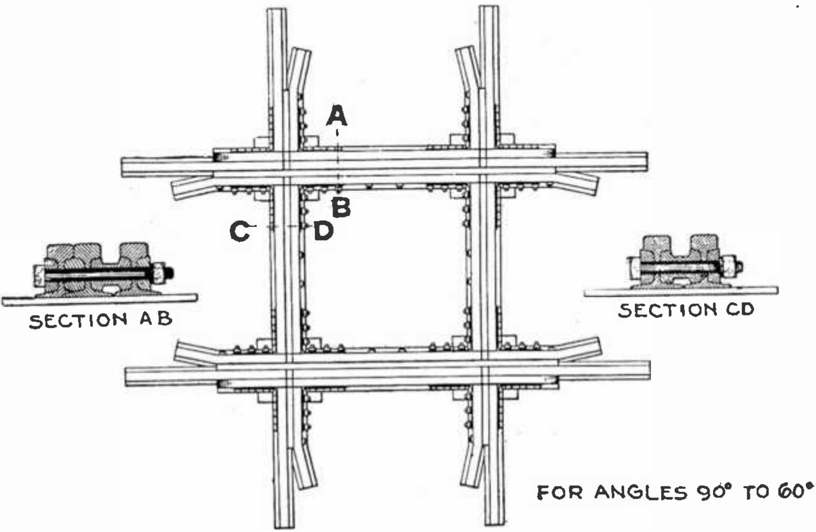


FIG. 6,394.—Diagram of crossing. *In specifying*, give angle of crossing preferably at the intersection of center lines though this may be taken at gauge line intersections if more convenient. If either track be curved, give the angle at intersection of tangents to curve and radius of degree of curvature. In the case of curved crossings, sketch must also indicate direction of curve.

The necessary protection of the points of the crossing, as well as the desirable provision of continuous flangeways, requires the addition of inner guard rails, extending also to the required distance beyond the intersections, except that in the simpler design for small angles the acute angle intersections may be protected by ordinary guard rails.

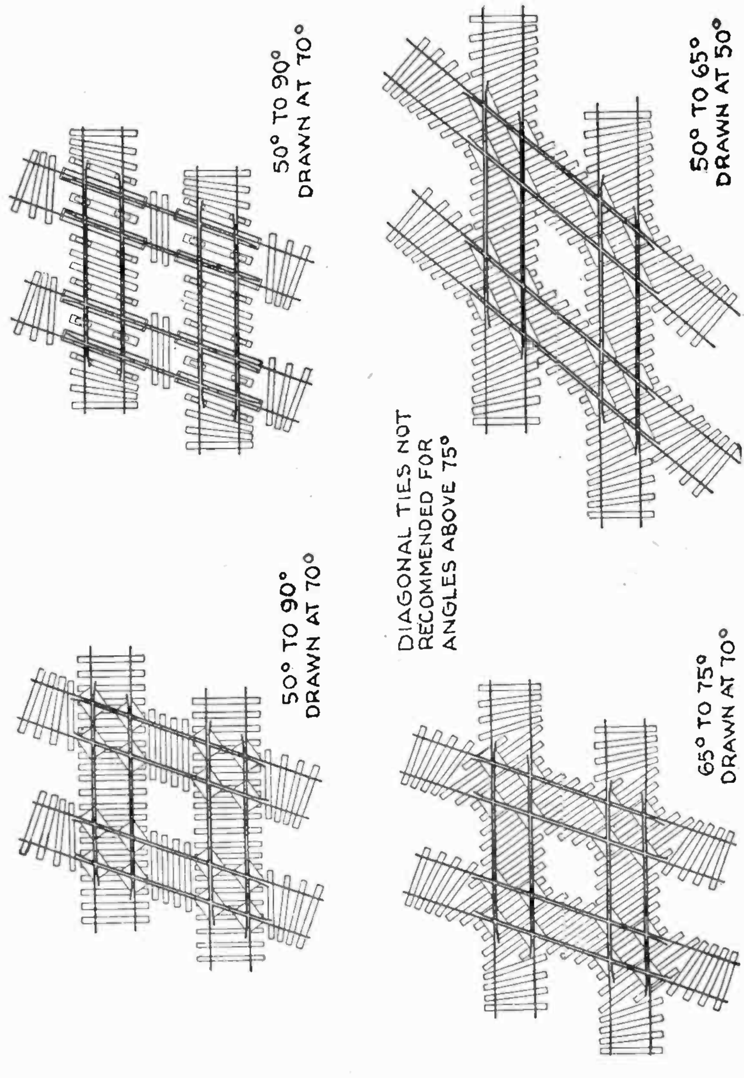
A third rail, known as easer rail or simply easer, is usually provided outside the running rails for reinforcement and to supply a bearing for the overhanging portion of hollowed out treads of wheels. The easer rails may be



Figs. 6,395 to 6,397.—St. Louis crossing, three rail one track. Fig. 6,395, section AB; fig. 6,397, section CD.

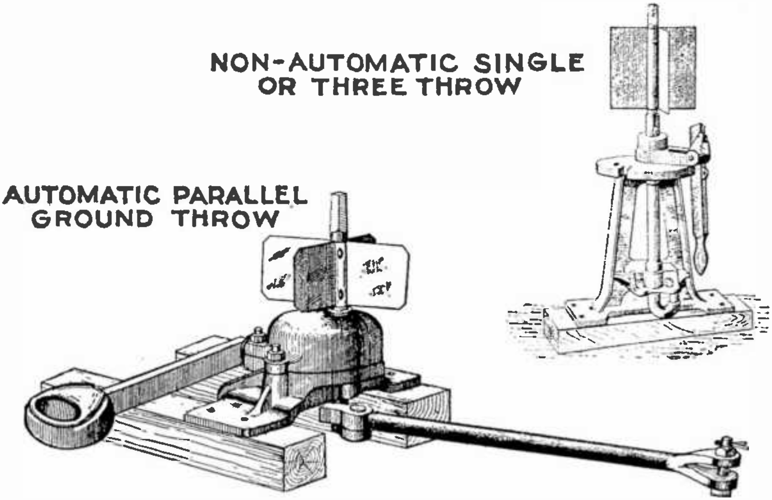
continuous throughout the crossing, or as is frequently the case for the smaller angles, of a length only sufficient to protect the immediate intersections.

When the angle at which the tracks intersect is other than 90° the two frogs at the acute angle intersections are called end frogs, and at the obtuse angle intersections, center frogs.



FIGS. 6,398 to 6,401.—*A. R. E. A.* tie layouts for railroad crossings.

End frogs as well as center frogs are double pointed except in the crossings of single rail design, sometimes used for angles below 25° in which the end frogs are standard turnout frogs protected by standard guard rails. The additional point in the end frogs is formed by the intersection of the guard rails of the crossing, while in the center frogs each of the two points is formed by the intersection of a running rail and a guard rail. The general layout of a crossing is shown in fig. 6,394.



FIGS. 6,402 and 6,403.—St. Louis switch stands. Fig. 6,402, non-automatic single or three throw, supported on one tie, safety bottom cap prevents removal of connecting rod, except by removal of stand or switch head rod; fig. 6,403, automatic parallel ground throw yard stand with movement of lever parallel with track. When used without latch the operation of this stand is automatic; that is, the lever will throw over in case switch is run through on a trailing movement. With latches, stand becomes positive and may be locked in either position.

Figs. 6,391 to 6,397 illustrate crossing construction and figs. 6,398 to 6,401 arrangement of cross ties at crossings.

Switch Stands.—The modern switch stand consists essentially of a base, a spindle and a throwing lever. The latter is moved through a part of a circle, either horizontally to impart directly a rotary motion to the spindle, or vertically, when some form of crank arm motion, or a mechanism of cams or beveled gears, is necessary to effect the rotation. A crank on the foot of the spindle serves to change the circular motion of the spindle into rectilinear motion to effect the throwing of the switch.

The manner in which the stands are thrown separates them into the two general classes:

1. Horizontal throw;
2. Vertical or ground throw.

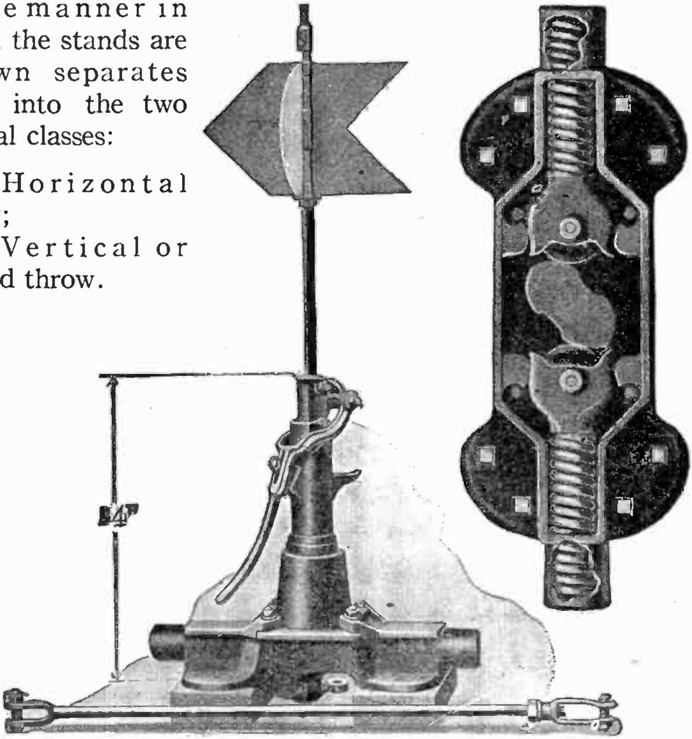


FIG. 6,404.—Ramapo automatic return switch stand designed principally for passing sidings on electric traction lines where it is desired that the switch after being run through shall be returned automatically to its original position. It may also be used similarly at special locations and in yards. The design of the stands is the same as in the automatic safety stands, except that the star piece is replaced by a lever arm with four curved faces. Two diametrically opposite faces are in contact with the roller plungers and compress the springs, which upon passage of the wheels rotate the spindle back to its normal position.
FIG. 6,405.—Ramapo automatic return switch stand, section of base.

Switch stands are further classified as:

1. Non-automatic (rigid throw);
2. Automatic;

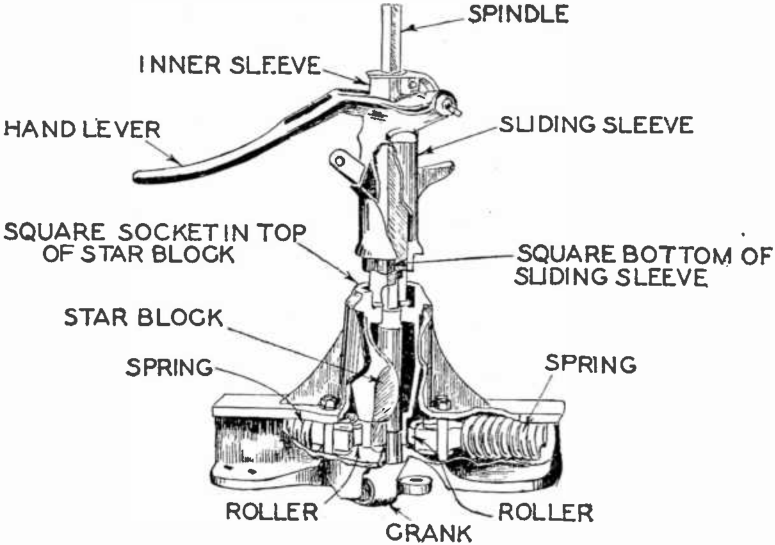
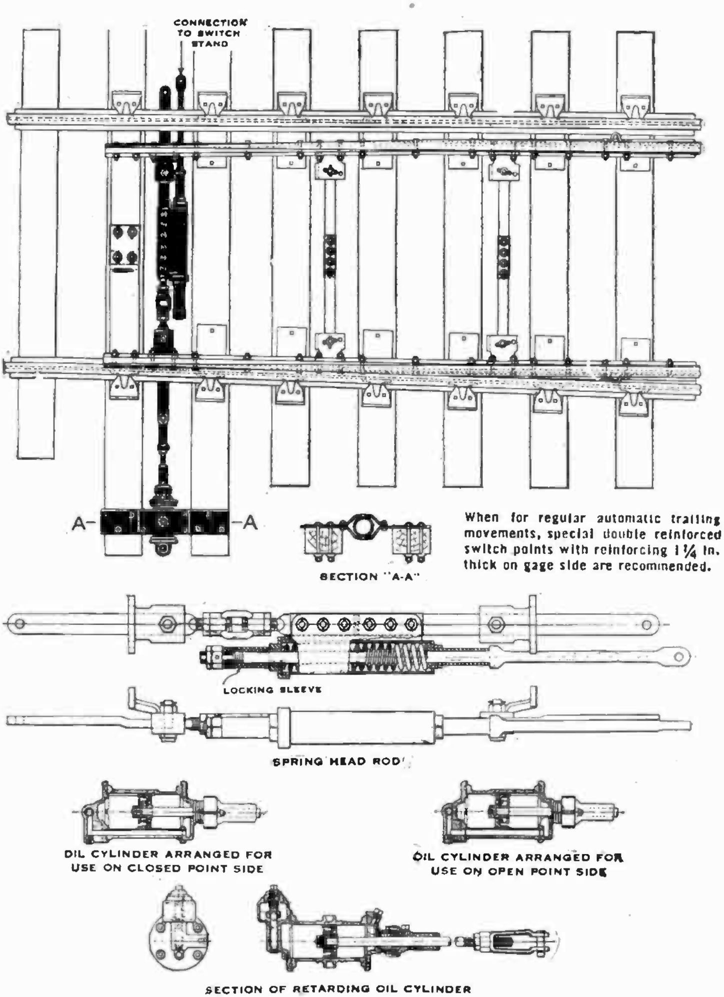


FIG. 6,406.—Ramapo automatic safety switch stand in hand operation. ***In hand operation,*** the hand lever is lifted, this action raising the sliding sleeve so as to disengage it from the star block, when the spindle, which is circular where it passes through the star block, will turn freely therein. When the switch is thrown the hand lever cannot be lowered and the sliding sleeve restored to engagement with the star block until the full movement of the switch has been completed, thus making operation by hand entirely positive. When engagement of the clutch has taken place the spindle is rigidly connected with the star block and is again in position for automatic operation or the switch stand may be operated by hand as before.

NOTE.—***Ramapo automatic safety switch stand.*** Explanation of automatic operation. ***In operation,*** when a switch is run through, the first pair of wheels forces the switch over and rotates the spindle connected to it through its crank and the switch connecting rod. The spindle, being rigidly connected with the star block through the clutch between it and the outer sleeve, also is rotated. The bottom of the star block is provided with a star member which is always in contact with roller plungers at the free ends of spiral springs, so that it can only rotate against the compression of the springs. When the star points pass the center line of the spring members the pressure of the springs forces the switch point against the opposite rail. Innumerable tests have shown that it is impossible for the switch points to remain partly open. The stand is left locked in either position ready for hand or automatic operation.



FIGS. 6,407 to 6,414.—Plan and sectional views of Racor retarding dash pot as installed on a spring switch connecting rod.

3. Automatic safety.

Fig. 6,402 represents a non-automatic stand and fig. 6,403 an automatic stand.

The automatic stand is simply a rigid throw stand with the means of automatic operation added.

The basic principles in the design of the automatic safety type are *positive throw for hand operation and automatic throw, with minimum friction and static resistance, when a switch, set wrong, is run through.*

The switch stand operates automatically whether the stand be locked or not; and since the spindle is rotated fully the target always indicates correctly the position of the switch points. These features not only contribute to the safety of operation, but insure longer life of the automatic stand, while avoiding damage to the switch points and their connecting parts. Fig. 6,406 illustrates the automatic safety type switch stand.

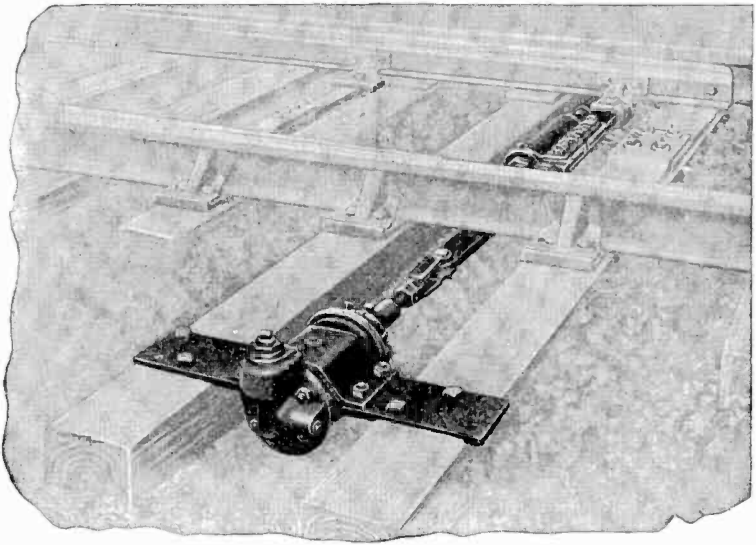


FIG. 6,415.—Racor retarding dash pot for use on spring switches. ***This device,*** working in non-freezing oil, retards the closing of switch points so that they will not snap shut between successive pairs of wheels when trailing through. Makes spring switches practical for steam roads, and is especially useful at passing sidings on electric railways. Saves wear and tear on switch points.

TEST QUESTIONS

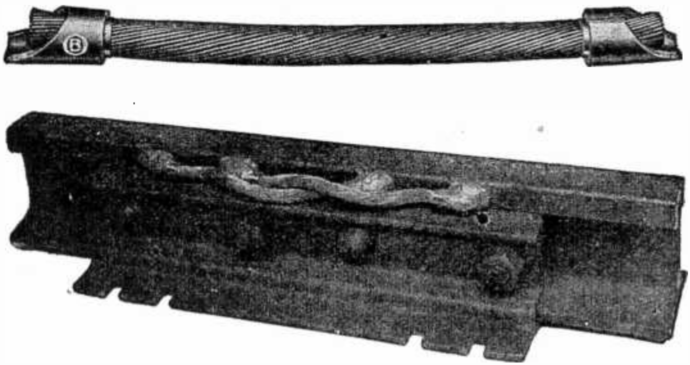
1. *How do electric railway tracks differ from steam railway tracks?*
2. *Of what does track work consist?*
3. *Give definitions of the various terms used in track work.*
4. *What is a switch?*
5. *Name the several classes of switch.*
6. *Describe the various classes of switch.*
7. *What is a frog?*
8. *Name the various classes of frog.*
9. *Into what two principal groups are frogs divided?*
10. *How do spring rail frogs differ from rigid frogs?*
11. *What is the purpose of a spring rail frog?*
12. *To what is the action of the sliding rail frog due?*
13. *Name three classes of guard rail.*
14. *What is the object of a turn out guard rail?*
15. *Define a crossing.*
16. *Of what does a crossing consist?*
17. *What is the object of the third rail or easer?*
18. *Describe a switch stand.*
19. *Name two classes of switch stand.*
20. *How are switch stands further classified?*
21. *Describe a non-automatic (rigid) throw stand.*
22. *How does an automatic stand operate?*
23. *What are the basic principles and design of the automatic safety stand?*

CHAPTER 139

Rail Bonding

Since the rails of an electric railway are used as the return portion of the circuit it must be evident that the joints between

FIG. 6,416.—Ohio compressed terminal rail bond intended for installing on web of rail under splice bar. Can be used singly to span one or more bolts or can be combined for double or quadruple bonding. This is a balanced bond, the two cables being of the same size.



FIGS. 6,417 and 6,418.—Ohio steel armored terminal rail bond for application by gas weld process and view of joint showing bonds welded. Strands are held in ⅛ in. steel terminals. Copper sleeve which distributes and damps vibration, protects the strands where they are held in the terminals. Especially suitable for rail joints where heavily ribbed splice plates are used. Applied by gas weld process which fuses ends of strands into the weld. Welding rod provides the metal for building up the terminal and contains the flux needed for the welding operation. About 20 lbs. of wire will be required for each 100 bonds.

the rails will offer more or less resistance especially because of corroded fish plates.

As rail lengths of 30 or 60 feet are used, there will be 88 to 176 joints per mile, and the resistance of these joints being in series the total resistance per mile of track will be considerable. In order to overcome this, adjacent rails are "bonded," that is joined by stranded copper bonds.

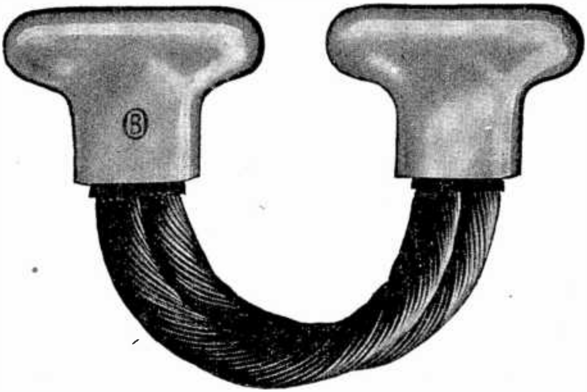


FIG. 6,419.—Ohio armored terminal rail bond adapted to steel metallic arc process. Can be used on rail of 50 lbs. per yard or heavier. Can be applied with any electric arc welding machine. Copper strands are welded to the heavy steel of the terminal. The wires are protected from welding heat by the steel armor. Copper sleeve which distributes and dampens vibration and adds to life of bond, surrounds the wire at the terminal. Operator welds steel to steel with steel. Terminal slopes slightly away from rail. In application there is plenty of room to weld in the angle where it does the most good. When completed the terminal is beveled from the rail. This reduces possibility of injury from car wheels, etc. Terminals are 2 ins. long. Soft steel welding rod is used. About 25 lbs. of rod will be required for each 100 bonds.

Ques. What are bonds?

Ans. Copper straps with terminals for carrying the current around the track joints.

Ques. How are they fastened?

Ans. By drilling holes in the rails and compressing the ends, or terminals, of these copper straps in them.

There are several classes of rail bonds, as:

1. Compressed terminal;
2. Welded terminal.

These types are shown in figs. 6,416 to 6,419.

The compressed terminal has ⅝ to 1 in. cylindrical heads which are forced into holes drilled in the abutting rails. The holes are drilled by a type

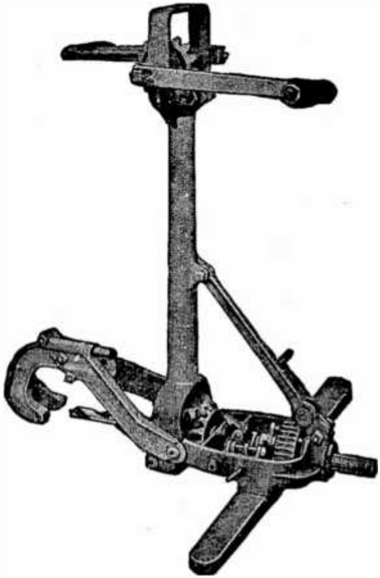


FIG. 6,420.—Moore track drill, for drilling holes in track rails, for bonds or splice plates. It is operated by worm gears and feeds the drill automatically; the advance of the drill being 1 in. for every 50 to 650 revolutions depending on the adjustment and the softness or hardness of the rail.

drill such as shown in fig. 6,420 and the terminal heads of the bond forced into the drilled holes by means of a clamp shown in fig. 6,421.

Various methods of welding are used, such as:

1. Gas;

2. Arc;
3. Cast;
4. Thermit.

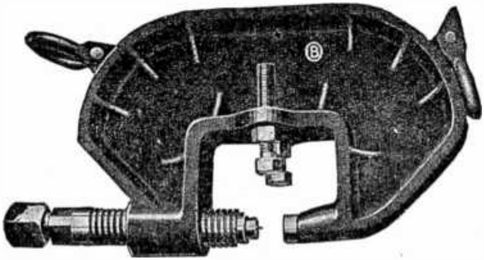
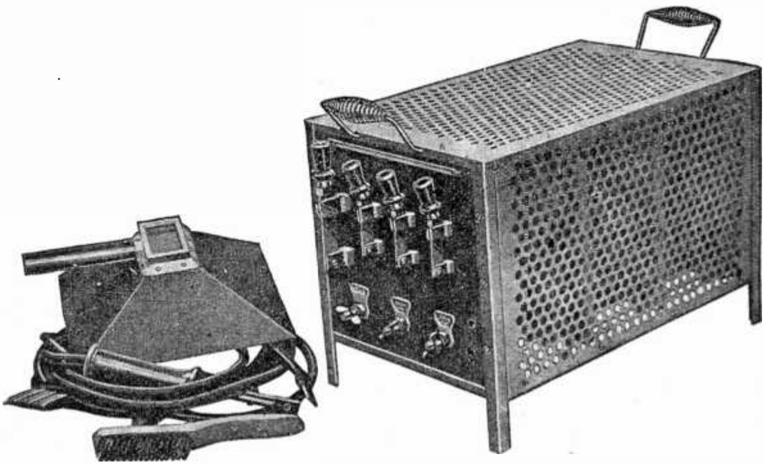


FIG. 6,421.—Ohio rail bond compresser for tee and girder rails.



FIGS. 6,422 and 6,423.—Ohio electric arc welding machine designed for portable *d.c.* railway welding service. The resistance consists of individual units, so designed as to afford support and protection to the coils. The output is adjustable in 30 ampere steps, from 30 to 120 amperes.

The electric arc is used very extensively for welding joints and has resulted in the development of rail bonds which can be applied with the electric arc in one form or another. One form of portable electric arc welding machine is shown in figs. 6,422 and 6,423.

Electric rail bond testing.—One of the best methods of finding the resistance of a bonded joint is to use two milli-volt meters

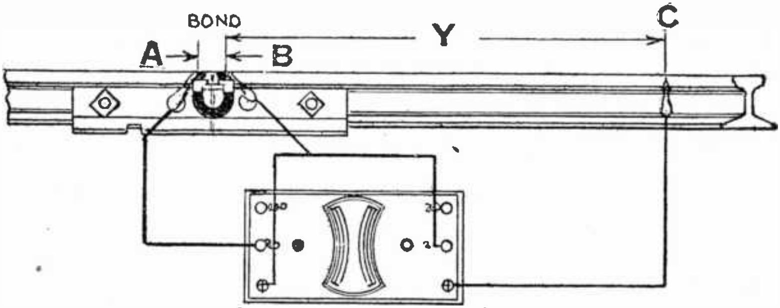


FIG. 6,424.—Diagram illustrating electrical rail bond testing.

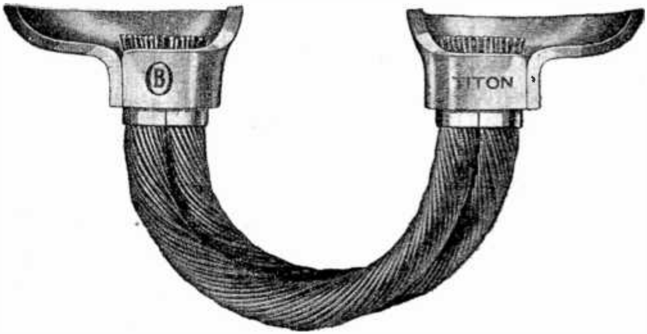


FIG. 6,425.—Ohio steel terminal rail bond adapted to copper metallic arc process. This bond is welded to the ball of the rail by electric arc using copper alloy electrode. Steel terminals catch and support the electrode metal and offer mechanical support for the copper cable. Electrode metal forms a fused connection of copper alloy of ample contact area between rail head, steel terminal and the copper strands, mechanically and electrically uniting each to the other. Copper sleeve which distributes and dampens vibration and adds to life of bond, surrounds the wire at the terminal. Special Titon copper alloy welding rod is used. About 25 lbs. of rod will be required for each 100 bonds.

and determine the number of feet of rail equivalent to the bonded joint. A duplex milli-volt meter is preferable to two separate instruments and should be connected as shown in fig. 6,424.

There must be sufficient current flowing in the rail to give a fair deflection on the instruments. Contacts A and B, should be placed on the rail head directly over the bond terminals. The contact C, should be moved along the rail until the two needles give the same reading. The drop along the joint is now equal to the drop along Y, feet of rail. As the current is the same in both sections the resistance of the bonded joint AB, equals the resistance of Y, feet of rail. The resistance of rail per foot is given in fig. 6,426.

The added resistance of the bonded joint is therefore equal to Y-AB feet of rail. Where the current flowing in the rail is not great enough to give good deflections on the milli-volt meter, it is customary to operate a line car close to the tester to produce the current flow.

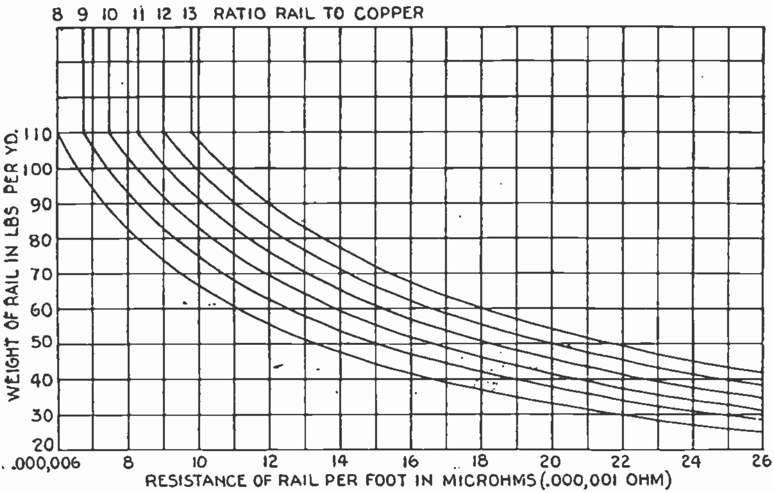


FIG. 6,426.—Chart showing resistance of steel rails; that is the resistance of 1 ft. length of rail in microhms (.000,001 ohm) for different weights of rail and ratios of rail to copper. *Example.*—What is the resistance per foot of a 70 lb. per yard rail for a ratio of 11 (rail to copper). Follow the horizontal line through 70, at the left, to the right until it intersects the curve marked 11, then follow the vertical line through the intersection downward and read .000,013 ohm per ft.

On alternating current systems, an independent direct current, furnished by a portable dynamo or storage battery, should be passed through the joint and section of rail Y, during the test.

It is highly important to know how much resistance is added to the joint in feet of rail equivalent when the bonding is in good condition.

The old rule that a joint should test three feet of rail or less has no significance and in many cases is entirely wrong.

Fig. 6,427 is a chart which gives the added resistance expressed in equivalent length of rail equal to the bonded joint for various capacities and lengths of bonds and weights of rail when the bond is in the best condition.

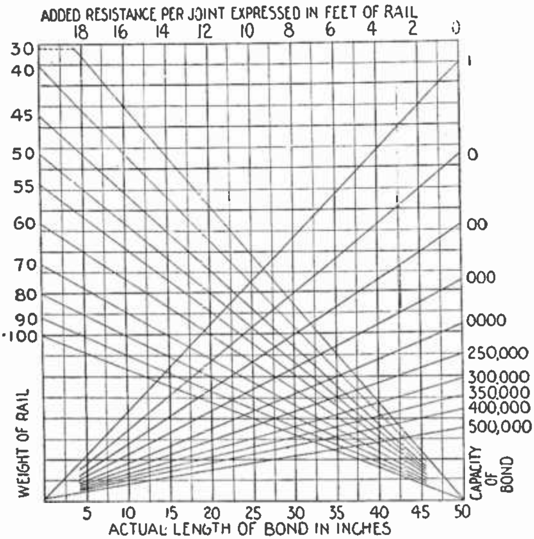


FIG. 6,427.—Chart showing bond resistance. The actual unformed length of the bond, the capacity of the bond and the weight of the rail per yard, must be known. Follow the vertical line through the actual length of the bond (shown at the bottom) until it intersects the diagonal representing the capacity of the bond (shown at the right). Follow the horizontal line through this intersection until it cuts the diagonal representing the weight of rail (shown at the left). Follow the vertical line through this point upward and read the added resistance per joint expressed in feet of rail (shown at top). This chart shows the standard for a given bonded joint with which its actual condition may be compared.

TEST QUESTIONS

1. *Define the term rail bonding.*
2. *Why is rail bonding necessary?*
3. *How are bonds fastened?*
4. *Describe an armored terminal rail bond.*
5. *How does a compressed terminal bond differ from a welded terminal bond?*
6. *Name the various methods of welding.*
7. *Describe the best method of testing rail bonds.*

CHAPTER 140

Subway and Tube Lighting

Lighting of subways differs in some respects from ordinary lighting. The line being underground or under rivers, the lights must be kept burning all the time. Consequently extraordinary precautions must be taken against failure. Emergency sources are arranged to act when the main source fails.

Ques. Does the main source depend on the operating source?

Ans. No. Power off the third rail or trains stopped, must in no way affect the lights.

Ques. Why is this important?

Ans. Should there be a tie up and passengers have to walk through the tunnel they will not have to grope in the dark.

Ques. Mention some typical methods of subway lighting?

Ans. 1. Direct lighting feeders from power houses or sub-stations of the traction company or of another traction company; 2, direct lighting feeders from power houses or sub-stations of electric light companies; 3, connections from both with interchange switches; 4, connections from third rails with interchange switches; 5, connections of separate groups of lights from separate sections of third rails or separate sources.

Ques. How may these be arranged?

Ans. In any combination or group of combinations.

Ques. Describe a typical modern method.

Ans. High tension, 11,000 volt cables run from the traction company's power houses or sub-stations to the subway stations.

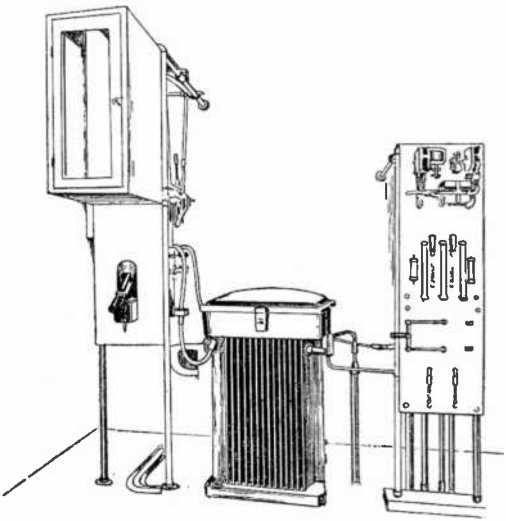
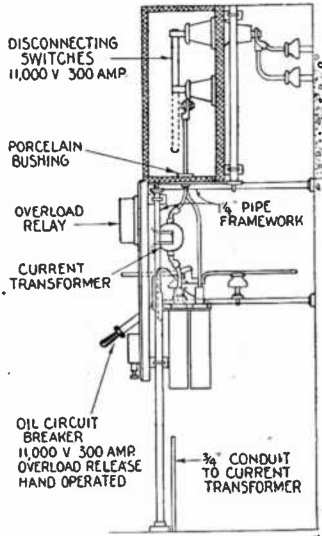


FIG. 6,428.—Transformer room of subway station. The room housing the apparatus for lighting the subway stations and tunnels contains the following: 1, high tension switches in the cabinet at the top of the high tension board; 2, transformer for reducing the 11,000 volts to 600 volts; 3, low tension switchboard for distribution.

NOTE.—Lighting cables for subways. Three conductor, 11,000 volt cables, paper insulated, lead covered, for furnishing the power for lighting the subways. These terminate in transformer rooms located at each subway station *and through switches* and panel boards furnish the power to the various sections. The current is transformed from 11,000 volts to 600 volts, and five lamps burn in series.

A transformer room is located at the end of each station platform. The current at 11,000 volts is transformed there to 600 volts and sent along the lines for lighting the stations and tunnels, as shown in figs. 6,431 and 6,432.

Ques. What apparatus is contained in the transformer room?



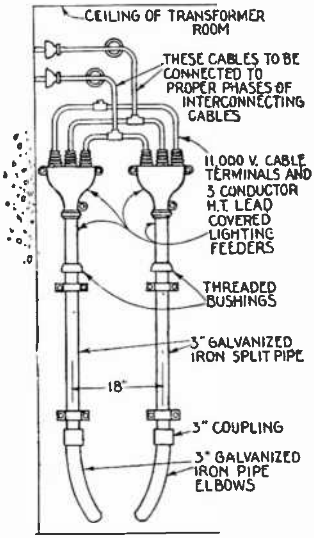


FIG. 6,429.—Subway lighting equipment. Side view of high tension switchboard showing cable connections to high tension knife switches, current transformer, oil circuit breaker, etc., and the mounting of the switchboard as related to the wall.

FIG. 6,430.—Subway lighting cables. The connections of the three conductors of high tension lighting cables and the taps taken off for transformer connection, showing method of fastening cables to wall.

Ans. A high tension switchboard, a transformer and a low tension switchboard.

Ques. What does the high tension switchboard consist of?

Ans. A cabinet containing two single pole 11,000 volt knife switches, to which the main cables connect, a panelboard and a current transformer, relay and oil circuit breaker for automatically opening the circuit in the event of a short circuit, ground or for repair or test.

Ques. What does the transformer do?

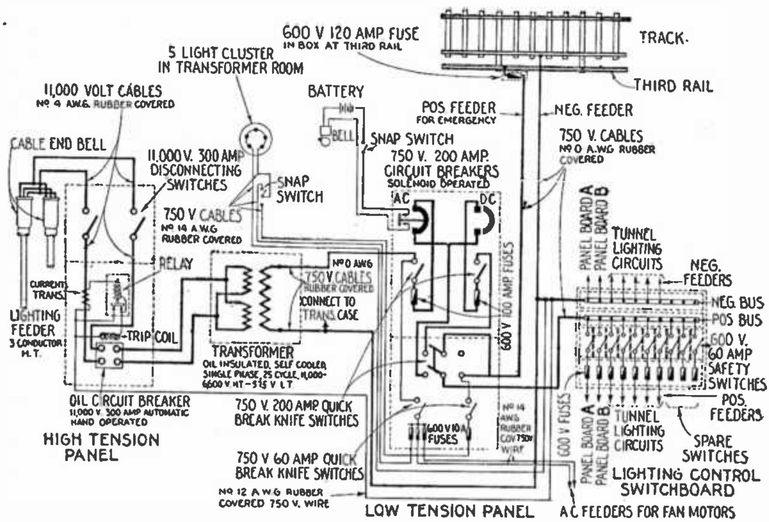


FIG. 6,431.—Wiring diagram of lighting equipment of subways. The current is transmitted from the power house or sub-station at 11,000 volts through high tension cables, goes through a transformer that reduces it to 600 volts, and through switches and circuit breakers to a distributing board which distributes it to smaller panelboards supplying various sections of stations and tunnels with current. On the low tension switchboard are two circuit breakers, so wired that they serve as change over switches in the event that the high tension current fails, the low tension current of the third rail automatically is thrown in and keeps the lights burning. Failure of the high tension current or the tripping of a circuit breaker causes an alarm to ring.

Ans. Reduces the high voltage of low amperage to low voltage of correspondingly higher amperage. In the case of the preceding answer, from 11,000 volts to 600 volts and the amperage correspondingly.

Ques. Why is 600 volts used for lighting?

Ans. Because it corresponds to the third rail voltage to which the lamps are often connected.

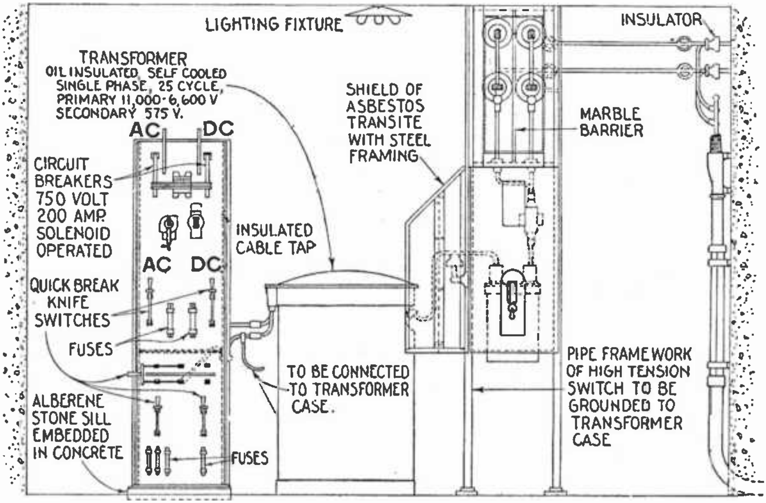


FIG. 6,432.—Subway lighting equipment showing the parts and the arrangement of the apparatus on the switchboards and the methods of connecting.

Ques. How are lamps connected for 600 volt operation?

Ans. Five in series.

Ques. What does the low tension switchboard consist of?

Ans. A panel containing two automatic circuit breakers, or change-over switches, one for *a.c.* and the other for *d.c.* and fuses and switches for controlling the various sections of lights.

The lamps are normally fed from the *a.c.* current of the transformer. A connection is also made to the third rail. The third rail current is *d.c.* If the *a.c.* fail, the *a.c.* circuit breaker opens, and automatically throws in the *d.c.* circuit breaker changing over the connections to the third rail or *d.c.*

To safeguard against the circuit breakers failing to operate, and leaving the station or tunnel in darkness, certain lights are connected directly to the third rails, some to local tracks and some to express tracks, and operate independently of the transformer room connections. Additional means may be provided, such as:

1. One high tension cable being thrown in when another fails;
2. One high tension source coming in when another fails;
3. One low tension source coming in when another fails;
4. Combination of the above.

In addition, lights are staggered and parallel lines are run so that should a wire burn out or a lamp burn out no portion of a station or tunnel will be in total darkness.

Safety Requirements for Handling Subway Lighting Equipment.—Safety is very important in handling subway lighting equipment and in making repairs or tests, as all circuits work on a grounded return and therefore the danger to shock must be eliminated. No circuit should be handled until the switches controlling that circuit be opened.

The high tension disconnect switches must not be touched until the oil circuit breaker is opened and the power house operator notified and he disconnects the cable from the bus.

As all cables, after operating, retain a static charge, a long stick with a chain connected thereto and to ground, is provided in each transformer room with which to take off the charge and to draw out the switches. These switches are normally enclosed in a glass door cabinet.

The panelboards on the station platforms, for controlling the various circuits, are usually of the safety switch type, and no switch can be removed for inspection until it is in the *open* position.

When working on the *d.c.* or third rail side, the fuse connecting the circuit with the third rail should be drawn. Safety must be practiced at all times and everything considered alive.

The concrete floor of platforms is not an insulator and one can get a shock. In the tunnels one must be especially careful as a shock may cause one to fall off a ladder and on to the tracks. The switch controlling the circuit should be opened before getting into the tunnel.

Railroad companies do not want accidents and do not send their employees out on hazardous jobs without precautions, and recklessness is not tolerated.

Requirements of Lighting Material for Subway Lighting.— All lighting material used in subways must be damp proof, dust proof and non-corrodible. The dampness existing underground and in the river tunnels would soon short circuit the apparatus and destroy the ordinary materials.

Conduits, outlet boxes, castings, supports, straps, etc., must be heavily galvanized and all joints well fitted. Rubber gaskets should be used at fixtures.

The fixtures on stations are usually of bronze and those in the tunnels of iron heavily galvanized. The shoe dust carried by trains, running back and forth, of the shoes sliding along the rails, would soon destroy the ordinary brass fixtures.

The wire used is a high grade rubber covered and braided, and passes a rigid inspection. Conduit must be free from burs and sharp edges. The fastenings must be secure to prevent conduit falling on to the tracks and across the third rail.

All wire joints must be soldered and well insulated with rubber tape. Installations, in general, must be made in such manner as will not cause disruption of service nor endanger passengers. Construction men must exercise individual care in working in subways or in under river tunnels.

TEST QUESTIONS

1. *Does the main source depend on the operating source?*
2. *Why is the item mentioned in the previous question important?*
3. *Mention some typical methods of subway lighting?*
4. *Describe a typical modern method.*
5. *What apparatus is contained in the transformer room?*
6. *What does the high tension switchboard consist of?*
7. *Why is 600 volts used for lighting?*
8. *How are lamps connected for 600 volt operation?*
9. *Of what does the low tension switchboard consist?*
10. *What provision is made to safeguard against the circuit breakers failing to operate?*
11. *Give safety requirements for handling subway lighting equipment.*
12. *What are the requirements of lighting material for subway lighting?*

CHAPTER 141

Electric R. R. Car Lighting

Electric cars are lighted usually by the electric current which supplies the power, whether it be overhead, trolley or third rail.

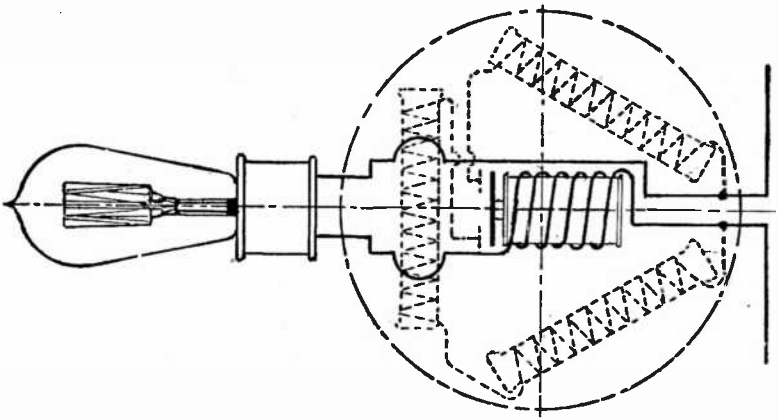


FIG. 6,433.—Lamp with compensating resistance relay. The line current goes through a solenoid which is in series with the lamp and energizes it and causes it to attract an armature. Removing the lamp or the lamp burning out, breaks the circuit and the armature drops onto two contacts, shunting the lamp and throwing its equivalent resistance into the circuit.

The lamps are usually connected in series, the number depending on the working voltage and resistance of the lamps. This series method of car lighting is dependent upon the trolley voltage which sometimes varies over a wide range, with more than proportional variation in light intensity.

The wiring is done in conduit and connections made to avoid jarring loose. Compensating resistances are often installed to prevent all the lights going out should one fail, as in some cases five lamps are connected in series. These compensating resistances are equivalent to the resistance of the lamp and are thrown in circuit by relays when a lamp fails.

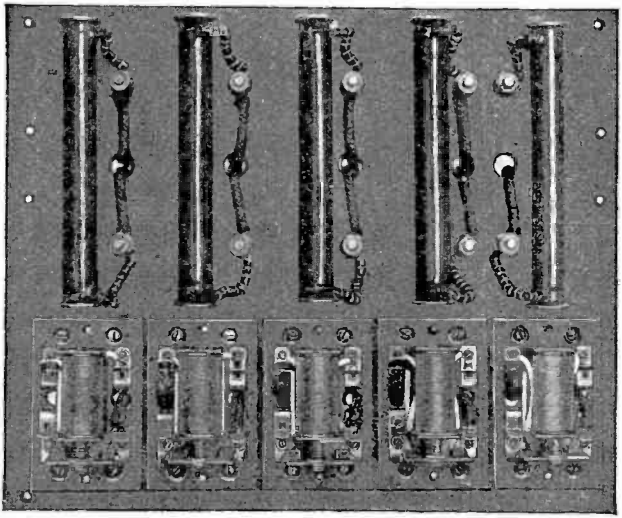


FIG. 6,434.—Electric Service Supplies automatic type compensating series lamp panel shown with cover removed. Compensating panels consist of separate relay and resistance unit for each circuit or lamp. The resistance units are mounted on insulating supports and arranged so that the unit may be readily renewed by the loosening of two nuts. They are supplied with pressed steel ventilated covers. Where the panel is designed for more than one circuit, all parts are mounted on a single insulating base, protected with one cover for the insulating units. The automatic relays have separate dust tight, solid cast iron covers for each individual relay.

Fig. 6,433 shows a lamp having a compensating resistance. Ordinarily the arrangement shown in fig. 6,433 is used, but under certain conditions, as, for instance, lack of head room, it is sometimes impossible to use the self contained fixture, in which case a 5 circuit panel may be placed at any convenient position in the car with wires run from each fixture to this panel.

Compensating panels are also used where one lamp of a circuit is to be divided into two smaller units, as, for instance, in car lighting where the main body of the car is lighted by means of 94 watt lamps, and platform and sign, each by a 46 watt lamp connected in multiple series.

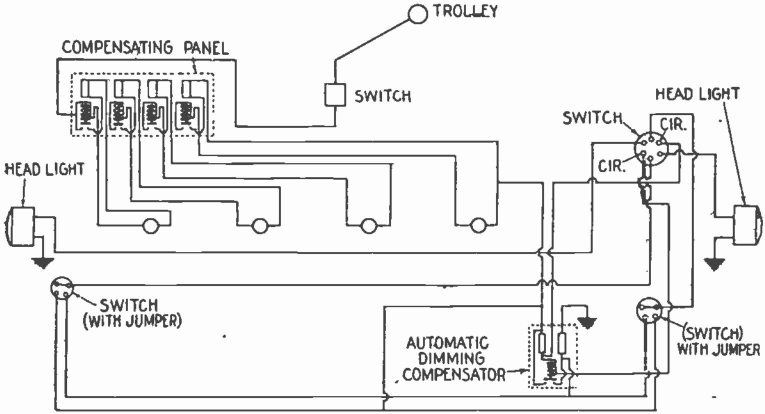


FIG. 6,435.—Diagram of series car lighting system showing hook up with automatic compensating panel. The diagram shows wiring connections for double end car equipped with two head-lights operated in series with one circuit of interior car lights, including automatic dimming, compensating resistance for both head-lights and four circuit compensating panel used in connection with car lights, thus offering a fully compensated single circuit with necessary switches, providing head-light and car illumination.

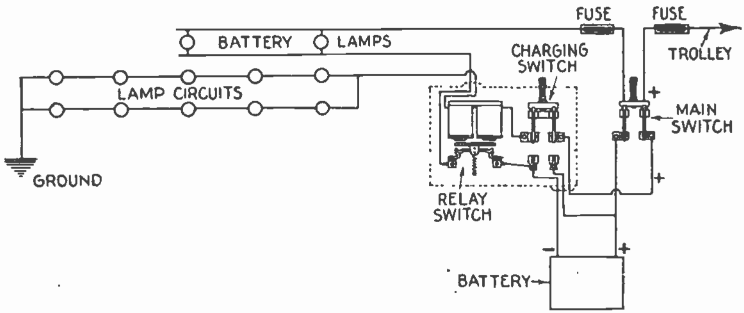


FIG. 6,436.—Diagram of storage battery emergency car lighting system.

As explained in fig. 6,433, the burning out or removal of a lamp in the circuit, due to the breakage of the lamp filament circuit, de-energizes a small solenoid which is in series with resistance units, the latter is substituted for the burned out lamp, and the placing of a good lamp in the socket automatically energizes the solenoid, disconnecting the resistance, and normal conditions are thus restored.

The method of wiring the lamps to a compensating panel is shown in fig. 6,435.

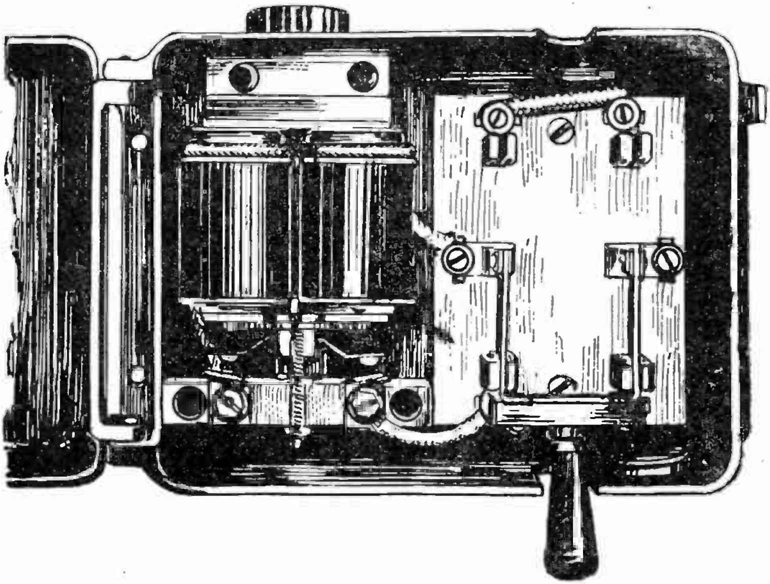
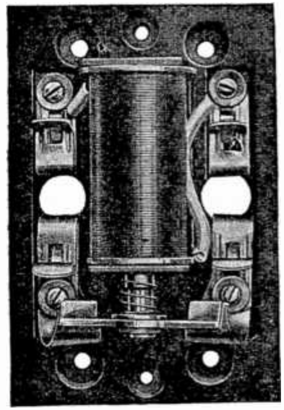


FIG. 6,437.—Consolidated relay and charging switch for emergency car lighting system. The relay and charging switch is for automatically charging auxiliary car lighting battery from trolley and for automatically cutting in a group of lamps on a battery circuit.

Emergency Car Lighting.—In subway cars and others where they may be stalled through the power going off, a device is necessary to give some illumination to the cars while such power is off.

Small storage battery lights are usually installed which are automatically thrown into circuit when the line current fails.



FIGS. 6,438 and 6,439.—Electric S. S. Co. emergency light relay. *It provides* an automatic means of cutting in an independent circuit of lamps, operated by a storage battery, in case of failure of the normal power supply. This enables the safe use of electric rear end signal or marker lamps, and in many cases a number of emergency lamps are also placed in the car body. The relays are placed in series with five lamps on the usual 500-600 volt *d. c.* circuit and to all practical purposes do not consume any current or cause any voltage drop. Under normal conditions, the relay is energized and the independent storage battery circuit kept open, but upon failure of the normal current, the armature drops and closes the battery circuit, thus lighting up the emergency lamps.

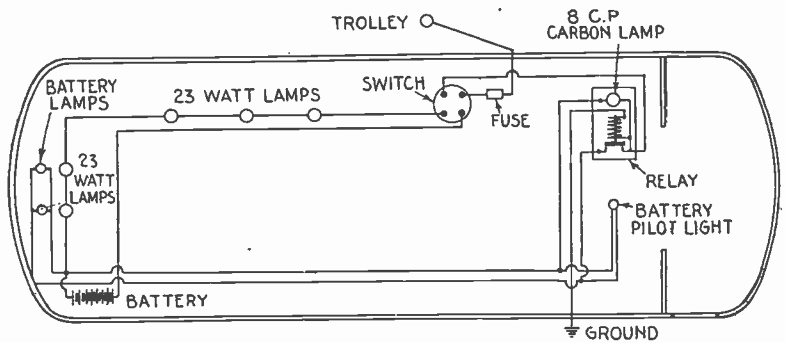


FIG. 6,440.—Electric S. S. Co. wiring diagram for single end car, using relay with pilot light, for operating two rear end signal lamps. Relay pilot light indicates disconnection or failure of battery.

These are operated by a solenoid in series with the line circuit and hold an armature suspended until such current fails, at which time the armature drops and throws the battery lights and current into circuit.

The wiring diagram, fig. 6,436, shows a storage battery system with relay switches and connections, and illustrates how the relay switch automatically throws the storage battery lights into circuit when current is no longer on the trolley. Under these conditions there is no flow of current through the magnet coils and the relay plate falls down upon the contacts

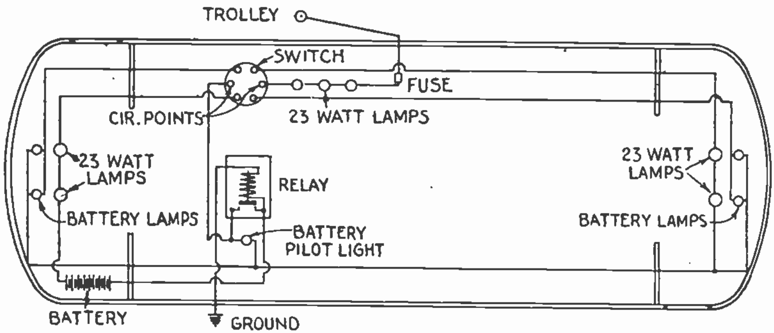


FIG. 6,441.—Electric S. S. Co. wiring diagram for double end car, using relay with emergency lighting circuit for operating two rear end signal lamps with proper switch connections for double end operation.

for the auxiliary lamp circuit, completing the battery circuit. Current flows from the positive terminal of the battery to the main switch, through the fuse to the battery lamps, through the relay plate to the negative terminal of the battery.

The double pole main switch is used to prevent the battery discharging when the cars are in the yard on a dead track, as the main lamps are always turned off in this case, and the battery circuit is therefore broken at this point.

The auxiliary or battery lamps are of six volt type the same as used for automobile lighting, and an ordinary ignition battery used. The operation of the relay and charging switch is shown in fig. 6,436. Here the current comes from the live trolley to the main switch and to the charging switch;

flowing through the magnet coils, the relay is attracted, and it continues to the lamps and to ground. In this position the storage battery is not in circuit. By throwing the switch to the lower position, as shown, current flows from the trolley through the main switch to the storage battery and then through the magnet coils to the trolley lamps and ground; this gives a one ampere flow through the battery; and as the battery is designed for 8 volts, it can be connected in series with the car lamp circuit without dimming the lamps materially. When the battery has been charged, the switch is thrown back to the upper position.

The accompanying diagrams show various hook ups for single and double end cars.

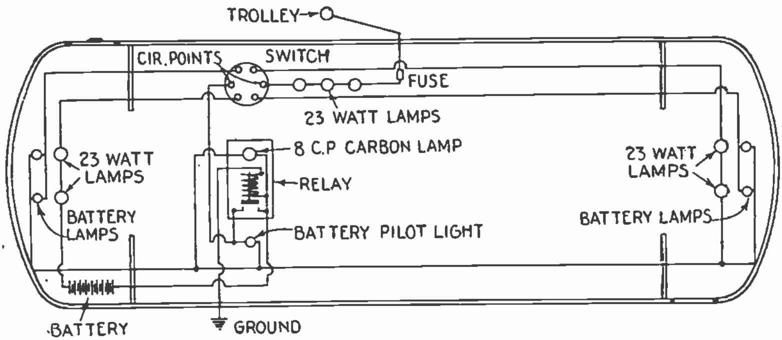


FIG. 6.442.—Electric S. S. Co. wiring diagram for double end car using relay having pilot light, indicating disconnection or failure of storage battery, for operating two rear end signal lamps with switch connections for double end operation.

TEST QUESTIONS

1. *What is the usual current source for the lighting of electric railroad cars?*
2. *How are the lamps generally connected?*

3. *What determines the number of lamps connected in series?*
4. *What is a compensating panel?*
5. *What system of wiring is used?*
6. *Why are compensating resistances used?*
7. *Describe the operation of a compensating resistance.*
8. *Describe the emergency system of car lighting.*
9. *Draw diagrams showing various hook-ups of single and double end cars.*

CHAPTER 142

Axle Lighting Systems

The term "axle" as popularly applied to car lighting systems includes such equipments as those *having a dynamo under each car belted to a pulley on one of the car wheel axles and wired to charge a storage battery.*

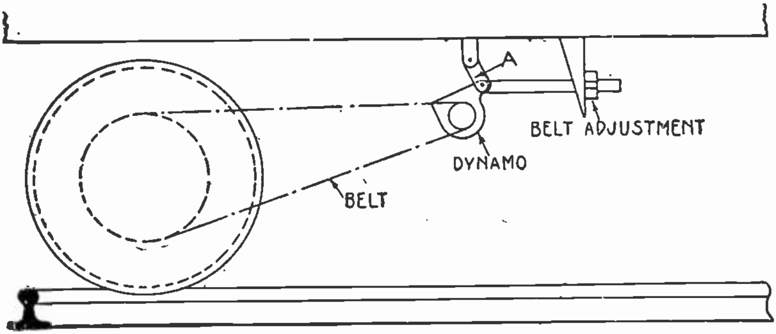


FIG. 6,444.—Essential features of one method of dynamo suspension in axle lighting system. *As shown,* the dynamo is supported at one corner of its frame by the adjustable link, A, in such a manner that it is free to swing toward or away from the driving axle. The suspending link is so placed that the belt draws the dynamo out of the diagonal position in which it would naturally hang, thus putting a definite tension on the belt, just sufficient to absorb the power required. It is obvious that when the pull on the belt exceeds that due to the offset suspension of the dynamo that the dynamo will be drawn toward the axle and the belt allowed to slip.

Accordingly the essential parts of such a system are:

1. Dynamo;

2. Axle pulley belt drive;
3. Storage battery;
4. Discriminating cut out, or reverse current circuit breaker;
5. Regulators;
6. Lighting fixtures;
7. Pole changer;
8. Switches, fuses, etc.

Dynamo.—This machine is mounted under the car body with

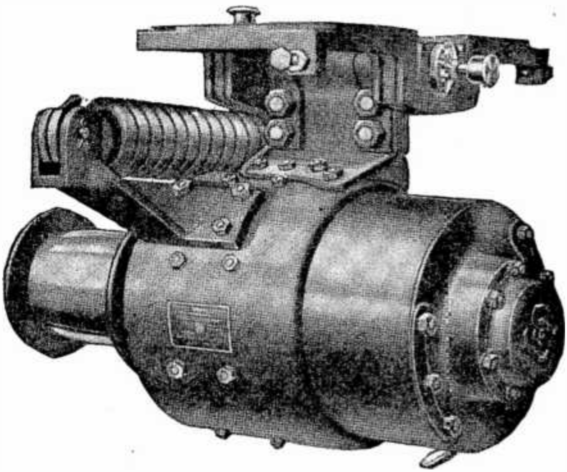


FIG. 6,445.—Safety C. H. & L. dynamo with tension spring.

belt drive as shown in fig. 6,444. Sometimes the dynamo is mounted on the truck frame.

When the dynamo is mounted on the car body, there must be included certain features for successful operation.

The drive must be so arranged that the belt tension device does not place an abnormal strain on the belt when the distance between the center of the driving pulley and the center of the driven pulley is increased by the car rounding a curve.

The dynamo is pivoted to the mounting foot and the belt held in tension by

1. Tension spring, or
2. Compression spring.

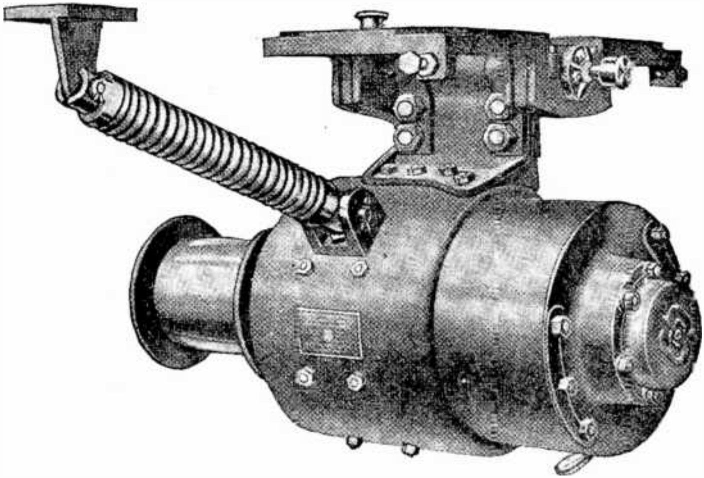


FIG. 6,446.—Safety C. H. & L. dynamo with compression spring.

These two arrangements are shown in figs. 6,445 and 6,446 and the belt tension is taken care of by an arrangement of spring which gives practically constant belt tension throughout any movement of the dynamo caused by belt stretch or the car rounding a curve.

Uniform belt tension is obtained by arranging the spring attachment to the dynamo so that when the belt pull occasioned by the weight of the dynamo increases, the belt pull caused by the spring decreases; the sum of the spring pull and the weight pull being constant.

The compression spring shown in fig. 6,446 is used only on suspensions where it is desired to have the center line of the pulley on the center line of the car.

The action of the uniform belt tension device is shown in figs. 6,447 to 6,450. Referring to these figures, the dynamo is hung from the shaft C.

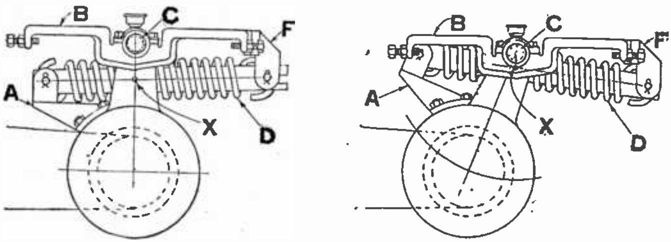


FIG. 6,447.—Position of dynamo with tension spring when distance between the axle pulley and suspension frame is shortened.

FIG. 6,448.—Position of dynamo with tension spring when distance between the axle pulley and suspension frame is lengthened.

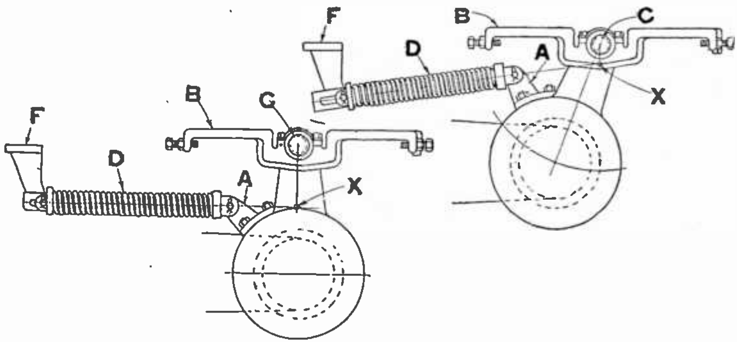


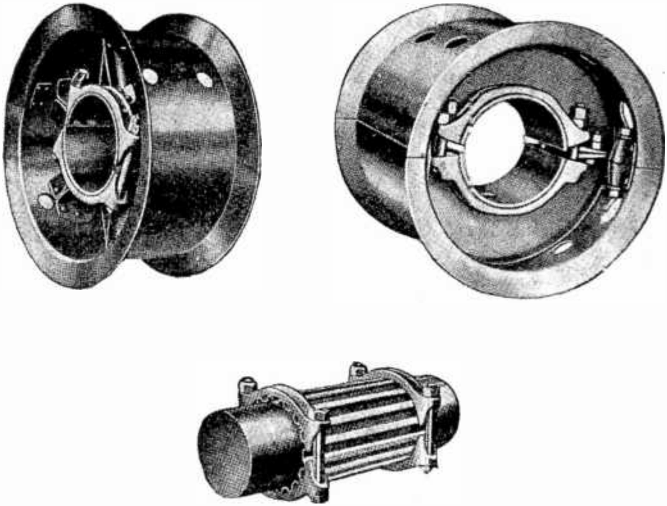
FIG. 6,449.—Position of dynamo with compression spring when distance between the axle pulley and suspension frame is shortened.

FIG. 6,450.—Position of dynamo with compression spring when distance between the axle pulley and suspension frame is lengthened.

To push the dynamo toward the truck requires more force the farther back the dynamo is pushed, as this action makes it necessary to raise the weight of the dynamo. If no spring be used, the belt tension would depend on the position of the dynamo, increasing as the dynamo is pulled by the belt toward the truck.

The same is true if an ordinary compression or tension spring be used, that is, as soon as the belt stretches or the distance between the dynamo and the axle varies, the pull of the spring changes the pull on the belt.

The spring is fastened at one end to the dynamo and at the other end is held stationary by a bracket F, attached to the suspension plate or to



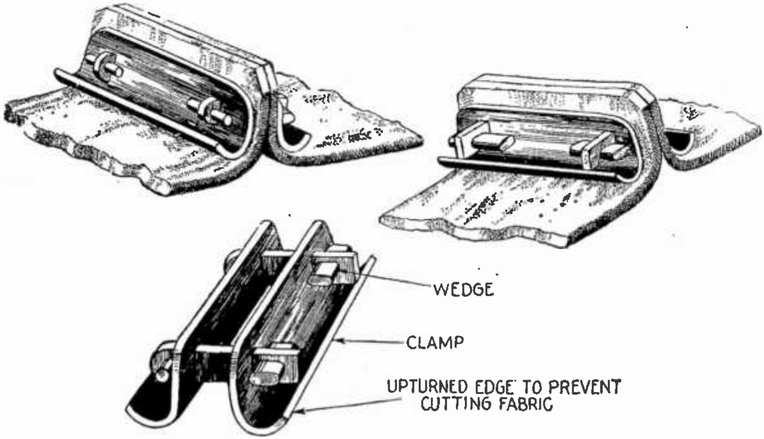
FIGS. 6,451 to 6,453.—"Underframe" pulley construction. Fig. 6,541, spoke type axle pulley; fig. 6,452, disc type axle pulley; fig. 6,453, axle pulley bushing.

the center sill of the car. This spring swings the dynamo away from the truck, as the suspension lugs on the dynamo act as a lever for the spring to revolve the center of the dynamo around the suspension shaft C.

The lever arm with which the spring pulls is the distance between the center of the shaft C, and the point X. When the dynamo hangs vertical as in figs. 6,447 and 6,449, this distance is comparatively large and the spring exerts considerable force.

When the dynamo swings toward the truck as in figs. 6,448 and 6,450, this distance between center of shaft C and X becomes smaller, and the force of the spring on the dynamo is less. In the latter position, however, the weight of the dynamo which is converted into belt pull has become greater.

The strength of the spring and its point of attachment to the dynamo are so selected that the increase in belt pull from the weight of the dynamo as it moves toward the truck, is counter-balanced by the decrease of the force of the spring as its point of application to the dynamo is changed relative to the center.

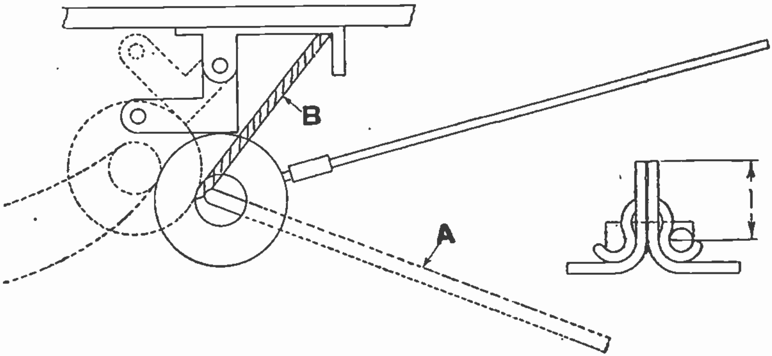


FIGS. 6,454 to 6,456.—Safety belt fastener and method of attaching. This fastener requires that the two ends of the belt be turned up perpendicular to the run of the belt, the ends being held firmly together by a plate on each side and two links extending through holes in the plate and punched holes in the belt. These links are held in place by wedges which are driven through slots in the links. The inclined surface of the wedge furnishes a means by which the side plates may he driven up tight against the belt under considerable variation in the belt thickness. A suitable clamping may be obtained for any thickness of belt by the use of one of three different lengths of link marked 4 ply, 4½ ply and 5 ply respectively. *To apply fastener*, cut the ends of the belt square across at the correct length. Draw lines square across the belt 1 inch from each end. Punch the holes for fasteners on these lines, using as a template, a fastener or template furnished with the belt cutter. A special belt punch should be used for making the holes the correct size and shape.

On railroads where there are a number of very sharp curves to contend with, it may be desirable to mount the dynamo so that the centers of the axle pulley and dynamo pulley are on the center line of the car.

This center line mounting is used to obtain the widest possible axle pulley; the use of a wide axle pulley may prevent the losing of the belt on very sharp yard curves.

The suspension arrangement shown in fig. 6,446 with the compression spring attached to the dynamo and to a bracket on the center sill is used where it is desirable to have a center line suspension.



FIGS. 6,457 and 6,458.—Method of pulling on belt. *To put on the belt*, swing the dynamo toward the truck, with the dynamo pry A, and block in upper position by wood piece B (20 ins. by 3 ins. by ⅞ ins. standard width).

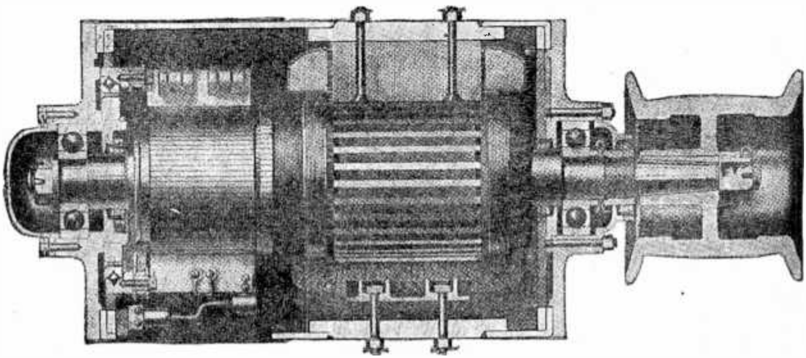


FIG. 6,459.—Safety C. H. & L. dynamo; sectional view showing construction.

Where this feature is not desired, the suspension is as shown in fig. 6,445, with tension spring attached to the dynamo and to the suspension plate. The dynamo is usually of the four pole shunt wound type as shown in fig. 6,459 connected as shown in fig. 6,461.

STORAGE BATTERY.—IT IS NOT NECESSARY HERE TO GO INTO THE DETAILS OF STORAGE BATTERY CONSTRUCTION AS THIS HAS BEEN COVERED AT GREAT LENGTH IN ANOTHER VOLUME OF THIS SERIES. The size of battery used depends upon the number and size of the lamps to be lighted, and usually

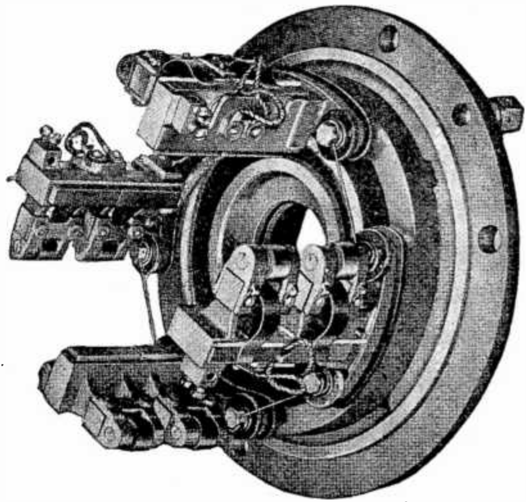


FIG. 6,460.—Safety C. H. & L. pole changer brush rigging. The direction of current from the dynamo is kept constant by rotating the brushes through an angle of 90° whenever the direction of rotation of the armature is changed. The pole changer may be taken off the head by springing out from its groove the snap ring which holds it on.

consisting of 16 to 20 cells arranged in groups of 2 or 4 for easy handling or removing.

A typical battery unit consists of two cells. These are combined into groups of 8 or 10 and connected in series and form the battery for car lighting.

Control and Regulating System.—There are numerous duties which have to be performed by automatic devices in the proper operation of a dynamo storage battery lighting plant, the devices which perform these operations being known as:

1. Pole changer;
2. Discriminating cut out or reverse current circuit breaker;
3. Dynamo regulator;
4. Lamp regulator.

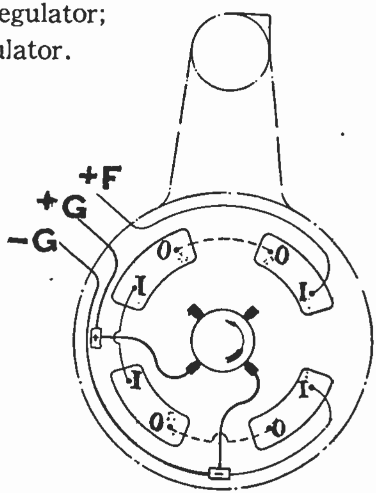


FIG. 6,461.—Diagram of field coil connections of safety C. H. & L. "axle" lighting system.

Pole Changer.—This device consists of a double pole double throw switch hinged in the center and thrown to one side or the other by a projection on a wheel mounted on the dynamo shaft. When the direction of the train reverses, the switch is thrown and keeps the direction of the current constant into the battery.

Discriminating Cut Out.—This is *an automatic switch for throwing the dynamo in and out of circuit*, as shown in fig. 6,462.

When the dynamo reaches the required speed and therefore attains the proper voltage, the iron core is drawn up into the coil and closes the switch causing the dynamo to supply the current.

When the train slows down a very marked degree or stops altogether, the magnetic coil becomes weakened and lets the iron core drop and it disconnects the dynamo and throws the battery into circuit.

Briefly, the discriminating cut out disconnects the dynamo from the battery when the voltage of the dynamo, by reason of decreasing speed, becomes lower than the voltage of the battery—otherwise the battery would discharge through the dynamo.

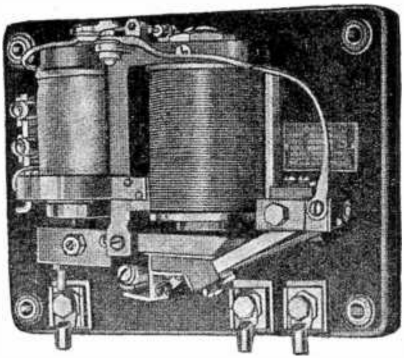


FIG. 6,462.—Safety C. H. & L. discriminating cut out or automatic switch. *It is* of the closed magnetic circuit type with pivoted armature. It has three voltage coils and one series coil, so arranged that when the dynamo voltage equals that of the battery the armature is lifted and the circuit closed.

Dynamo Regulator.—This consists of a pile of carbon blocks, or other arrangement, which offer a resistance, and are compressed or released, and either decrease or increase the resistance in the circuit by plungers controlled by the varying voltages caused by the carrying speeds of the train and in that way keep it constant. Figs. 6,464 and 6,465 show the construction of a dynamo regulator.

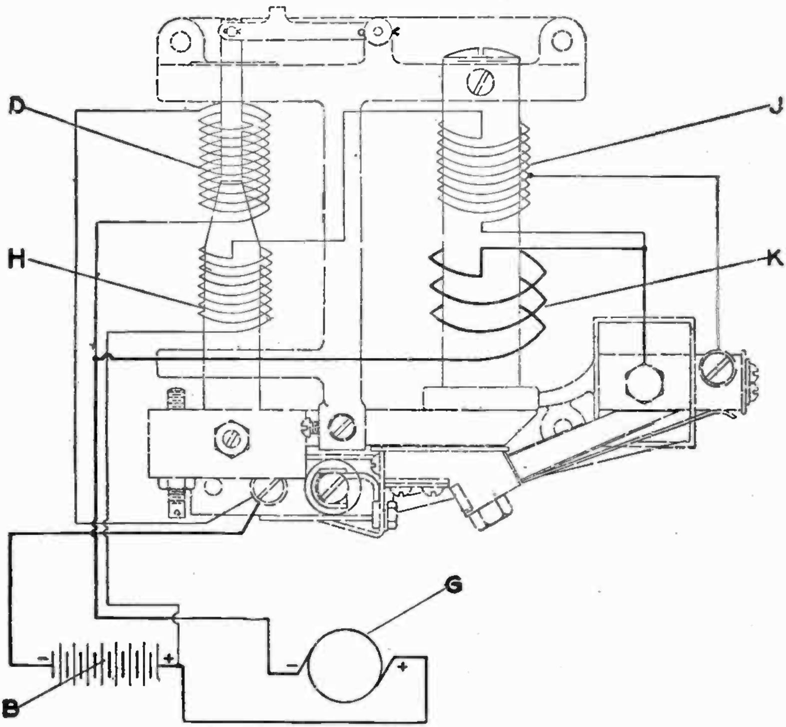
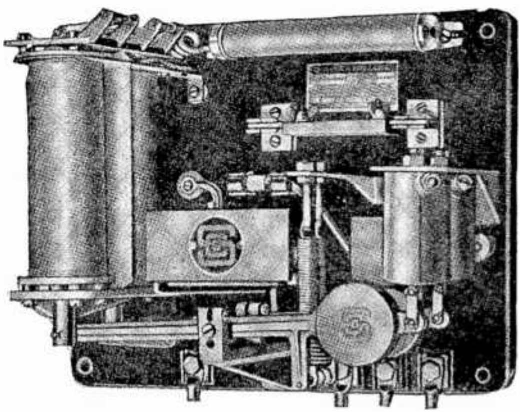
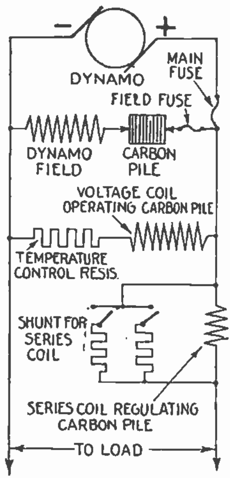


FIG. 6,463.—Diagram of Safety C. H. & L. discriminating cut out. The coil D, is connected across the contacts of the switch so that the voltage impressed across it is the difference between battery voltage and dynamo voltage, and if the dynamo be not operating, the full battery voltage is available. The pull of this coil on the auxiliary plunger locks the switch in an open position. At the same time the current from the battery which energizes this coil also serves to energize the field of the dynamo so that it will always build up in the proper direction. The coils J and H, are in series across the dynamo so that as the dynamo builds up, coil J, tends to close the switch while coil H, serves to replace coil D, which becomes inoperative as the dynamo voltage approaches that of the battery. The design of these coils is such that the correct balance is obtained at any battery voltage encountered in service. Consequently when the armature is set with the proper gap, the switch closes when the dynamo is charging the battery and also serves to neutralize coil J, when the battery attempts to discharge through the dynamo. The tap from coil J, brought out to the contact on the switch, serves to reduce the strength of coil J, so that a very small discharge from the battery will open the switch. It is thus possible to eliminate the carbon contacts formerly used. Due to the fact that the operation of this switch depends upon the balancing of the voltage coils D, H and J, the effects of temperature changes in the coils cancel each other. It is therefore not necessary to place resistances with zero temperature co-efficients in series with the coils to obtain the same operation under various changes in temperature.

Lamp Regulator.—The object of this regulator is *to maintain the lamp voltage constant with changes in the battery voltage.* With the battery run down, the lamps would burn dimly and with the battery fully charged perhaps burn the lamps out.

The regulator automatically varies the resistance in the circuit and





FIGS. 6,464 and 6,465.—Safety C. H. and L. dynamo regulator and wiring diagram. The dynamo is controlled to give the proper battery and lamp current through changes in speed and load by the amount supplied to the shunt field. This field current is controlled by the resistance of the carbon pile in series with the field. The resistance of this carbon pile is governed by the pressure exerted on it by levers which are operated by the plungers of current and voltage magnets. The windings of the series coil carry the total current output of the dynamo; if the current output tend to vary from that which the regulator is set to maintain during the early stage of battery charging, the plunger of the series coil through its lever, changes the pressure of the carbon pile, thereby reducing or increasing the field strength and holding the dynamo current to its proper value. If the voltage tend to rise above that for which the regulator is set to maintain, the plunger of the voltage coil through its lever, reduces the pressure on the carbon pile and holds the voltage to its proper value, thereby insuring reliable battery protection and adequate lamp supply. The series coil is set to hold the current value at the rated output of the dynamo. The voltage coil is set for a maximum voltage of 2.4 volts per cell, or 38.5 volts on a 16 cell equipment of lead batteries. With this as a maximum voltage, the voltage coil when effecting the regulation, prevents overcharging of the batteries, since the current to the batteries will then automatically taper down to a low value as the batteries become fully charged.

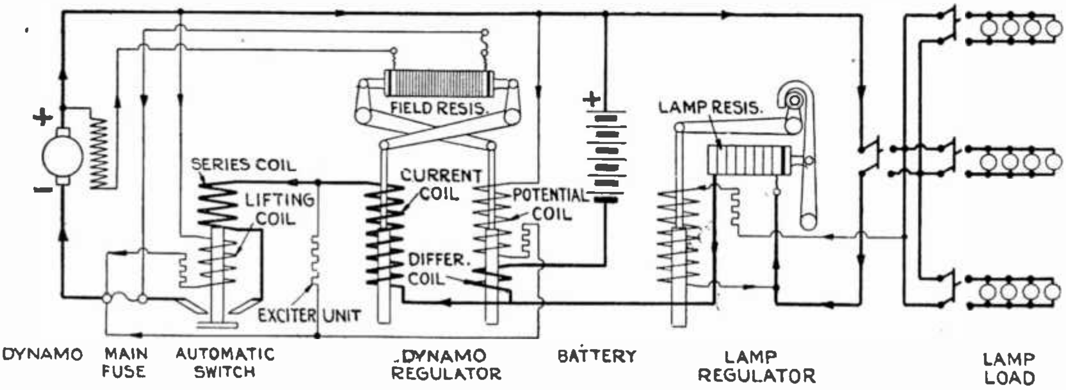


FIG. 6,466.—Wiring diagram of typical "axle" lighting system.

NOTE.—*Lamp regulator adjustments.* The only adjustments that can be made on lamp regulators are the pressure on the carbon pile, the spring tension and the air vent on the dashpot. To adjust the carbon pressure, have no current on the magnet, and disconnect the dashpot by removing the nut on the top, then pull down on the armature and screw up the knurled carbon adjusting nut on the left side of the regulator until the spring arm will just barely go back against its stop. Then loosen the carbon adjusting nut one half turn, which will allow the arm to go back freely against the stop. To adjust the spring tension, short circuit the carbon pile across 2 and 3, fig. 6,467. Have that voltage which it is desired to maintain across the lamp mains; that is, from 1 to 4. Usually this voltage will be either 30 or 40. Now adjust the spring tension by the spring adjusting screw until the armature will remain in any position throughout its stroke. Replace the dashpot and remove the short circuit from 2 and 3 and the regulator is ready to operate. No short circuiting device for the carbons is required. Special carbons are used which, when properly adjusted with a 30 volt equipment, give a total drop of less than 1½ volts at the maximum lamp load for the given regulator. If the drop be found to be greater than this, the knurled carbon adjusting nut should be tightened one or two notches more.

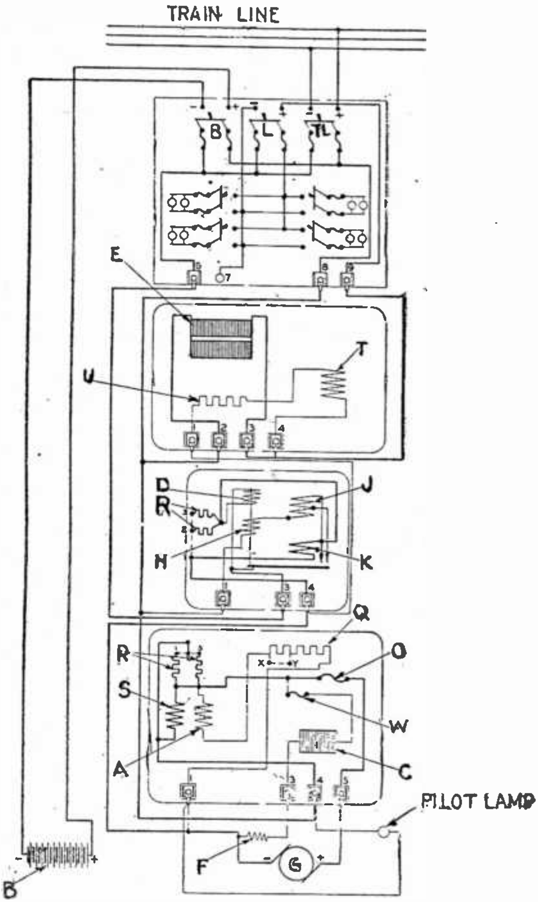


FIG. 6,467.—Wiring diagram of safety C. H. and L. regulator with main switch control of lamp regulator. *The parts are:* A, shunt regulating coil; B, battery; C, field resistance carbons; D, holding out coil for main switch; E, lamp resistance carbons; F, generator field; G, generating armature; H, balancing coil for main switch; J, lifting coil for main switch; K, series coil for main switch; L, main light switch; TL, train line switch; O, main fuse; Q, resistance for coil A; R, shunt resistance; S, series regulating coil; T, lamp regulating coil; U, resistance for T; W, field fuse. Note. Connect XY, to charge lead battery open for Edison battery.

keeps the lamps burning at proper brilliancy. Fig. 6,468 shows one form of lamp regulator.

The assembly, connection and operation of the various devices comprising the control and regulating system are shown in fig. 6,467.

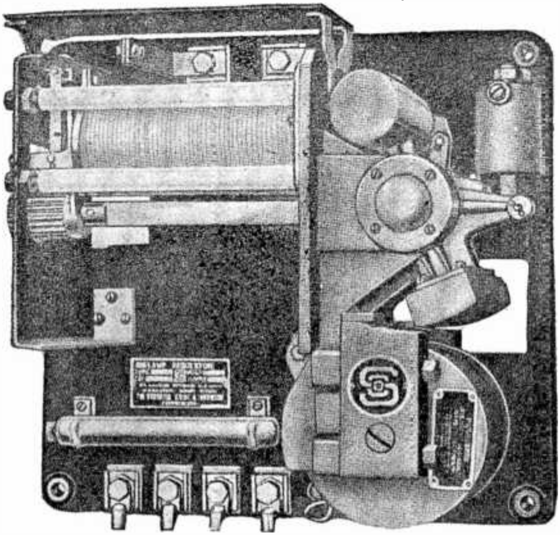


FIG. 6,468.—Safety C. H. & L. lamp regulator. *It consists of* one, two, or three piles of carbon discs in series with the lamps, the two or three piles being in parallel. The pressure on these carbons, and therefore their resistance, is governed by the armature of a magnet, the winding of which receives lamp voltage. The carbons are compressed by an adjustable spring connected to a link acting through a lever connection. The pull of the spring is opposed by the pull of the electro-magnet, which is connected directly across the lamp mains and is so designed that the armature will stay in any position throughout its stroke when the lamp voltage is right. When the lamp voltage is high, the magnet becomes stronger and pulls the armature down against the pull of the spring and reduces the pressure upon the carbons, increasing their resistance and bringing the lamp voltage back to normal. If the lamp voltage be low, the magnet becomes weakened, the spring pulls the armature back and, through the lever connection, exerts enough pressure on the carbon piles to decrease their resistance and bring the lamp voltage back to normal.

TEST QUESTIONS

1. *Define the term "axle" as popularly applied to car lighting systems.*
2. *Name the essential parts of an axle lighting system.*
3. *How is the dynamo mounted?*
4. *How is the dynamo drive arranged?*
5. *Name two ways in which the dynamo is pivoted.*
6. *How is uniform belt tension obtained?*
7. *Describe the method of attaching belt fasteners.*
8. *What is the best method of mounting the dynamo on railroads where there are a number of very sharp curves?*
9. *Name the devices used for the control and regulating system.*
10. *Describe a reverse current circuit breaker or discriminating cut-out.*
11. *Why is a discriminating cut-out necessary?*
12. *Of what does a dynamo regulator consist?*
13. *What is the object of a lamp regulator?*
14. *Describe the construction and operation of a lamp regulator.*

CHAPTER 143

Locomotive Head Light Systems

The problem of lighting electric trains does not involve the generation of the current as this is obtained from the third rail or overhead line. However, on steam roads, *there must be provided a current source.*

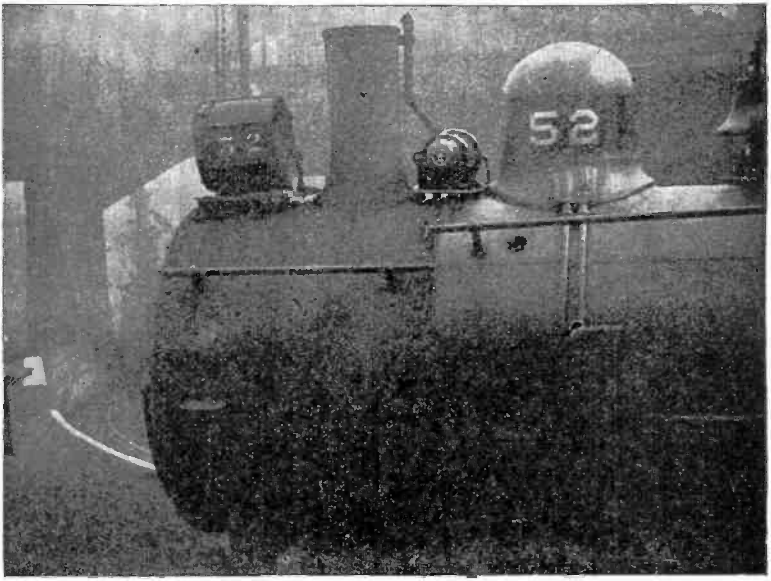
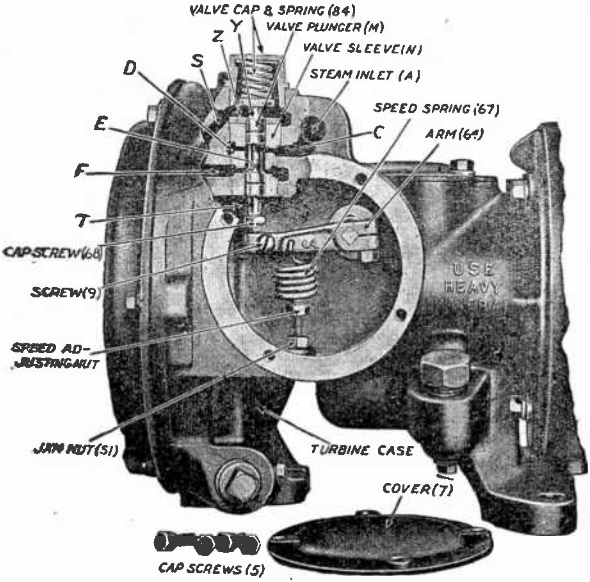


FIG. 6,469.—Westinghouse 500 watt head light unit installed in locomotive.

The current may be obtained either by the "axle system" described in the preceding chapter or from a turbine driven dynamo located on top of the locomotive boiler forward of the smoke stack. This arrangement, though originally intended only to furnish current for the head light. is now sometimes used to light the entire train.

The lighting of the entire train by a single turbine dynamo



FIGS. 6,470 to 6,472.—Keystone turbine with side cover and valve cap removed; turbine case broken away to show valve mechanism. *In operation*, steam enters at A, passes through the strainer B, into the passageway C, through the ports D, and travels between the valve plunger and the valve sleeve to the port opening E. The amount of steam passing through this port E, is regulated by the fly ball governor which controls the valve and thus automatically regulates the speed of the machine by proportioning the quantity and pressure admitted to the nozzle, etc., to keep uniform speed and voltage for any load. The valve is of the piston type. High pressure steam (boiler pressure) is maintained in the passageways C and D, and around the reduced central portion of the valve plunger M. The enlarged ends of this plunger are of equal diameter and area, and the slight leakage of steam between the plunger ends and the valve sleeve N, escapes into the cavities S and T, and into the turbine case where the steam pressure is slightly above that of the atmosphere. This leakage of steam tends to keep the valve plunger clean.

set has some advantages over the individual dynamos used in the axle drive system.

It provides greater dependability of operation, and because of its simplicity and higher efficiency, is more economical in first cost, operation and maintenance. In addition to lighting the entire train, the head end dynamo also furnishes current for locomotive lighting. Moreover the speed of the dynamo being maintained constant by the turbine governor, the lights burn at constant brilliancy regardless of the speed of the train.

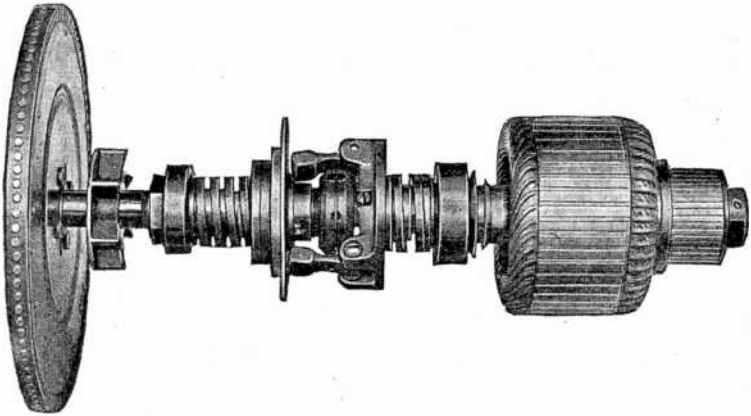


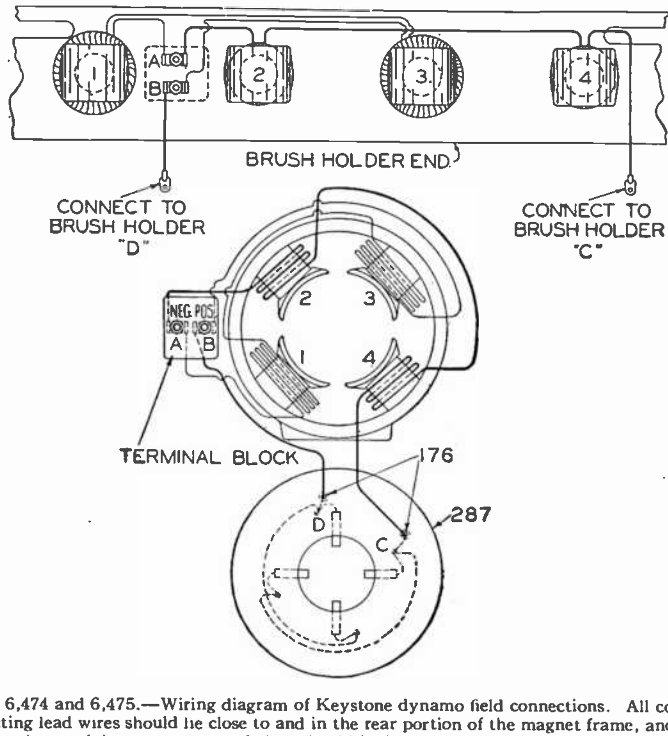
FIG. 6,473.—Keystone rotating element, showing wheel, baffle fan, governor, including oiling disc, safety spring, ball bearings and armature, mounted on the shaft.

In the axle system the voltage varies somewhat, resulting in dim periods of illumination and sometimes an objectionable flicker of the lights when the discriminating cut out or reverse current circuit breaker operates to disconnect the dynamo from the battery.

Train lighting systems of the locomotive head light type may be installed with or without batteries.

The simplest and least expensive installation is the non-battery system.

This consists of a single circuit running the length of the locomotive and train, with suitable flexible connectors between the locomotive and train, and between cars, together with control switches and fuses properly located to operate and protect the circuit. Two wire or three wire circuits may be used, depending on the length of the train. For short trains, a two wire circuit is satisfactory. For trains of greater length



FIGS. 6,474 and 6,475.—Wiring diagram of Keystone dynamo field connections. All coil connecting lead wires should lie close to and in the rear portion of the magnet frame, and away from the revolving armature, and they should be brought to the terminal block at the left side of the dynamo. The terminals are stamped shunt and series to facilitate proper connections. With the coils properly connected, as shown in the diagram, and then properly magnetized, opposite pole faces should have like polarity, and adjacent pole faces should have unlike polarity. If, for any reason, the above relation be not found, the following test will locate the trouble: With *d.c.* from an external and independent circuit of sufficient voltage to definitely influence a compass needle, and with external circuit wires connected to binding post B, and right hand brush holder C, the faces of poles No. 1 and No. 3 should indicate like polarity quite strongly. Shift external circuit connection from binding post B, to binding post A, leaving connection at C, as for previous test, thus causing current to flow in the series coils only; the faces of poles No. 2 and No. 4 should indicate like polarity quite strongly, and opposite to that shown by faces of poles No. 1 and No. 3 as just tested; thus pole faces should show alternately N and S, polarity.

than three or four cars, the three wire circuit is recommended, as it insures nearer uniform voltage throughout the length of the train.

The battery system, which provides a source of current when the locomotive is disconnected from the train, while more expensive in both installation and maintenance cost, provides the flexibility that is desirable and necessary for some installations.

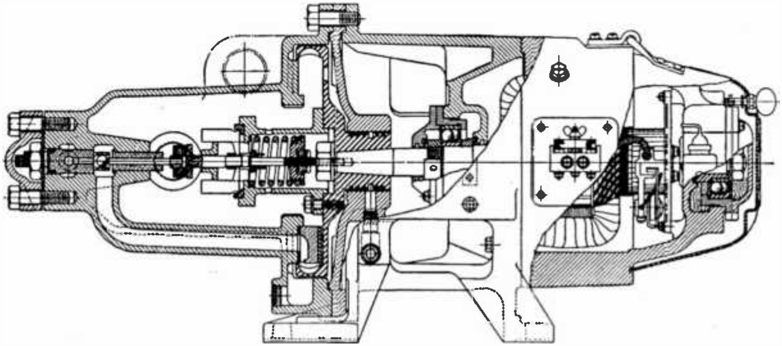


FIG. 6,476.—Westinghouse 32 volt, 500 watt locomotive head light unit; sectional view showing interior construction. The speed of the unit is controlled by a fly ball governor which is bolted to the turbine disc as a complete unit. This governor acts directly upon the governor valve stem without the use of any intermediate linkage. By means of this simple and reliable construction very close and stable regulation is obtained. The governor valve consists of a single seat against which a steel ball acts, the position ofwhich is fixed by the governor, thus, admitting the exact amount of steam required for the load. A metal labyrinth ring gland is used to seal the shaft where it enters the turbine cylinder. The rings are of the piston type and require no adjustment. The dynamo is wound to deliver 32 volts *d.c.* from no load to full load at approximately 4,000 *r.p.m.* and will carry its rated load of 500 watts continuously.

With the non-battery system, electric light will, of course, be provided only when the locomotive is connected to the train, while with the battery system light may be made available either for individual cars or for the entire train, for periods of five hours or so, when the locomotive is disconnected from the train.

The Power Plant.—The source of current as before mentioned consists of a turbine driven dynamo designed as a

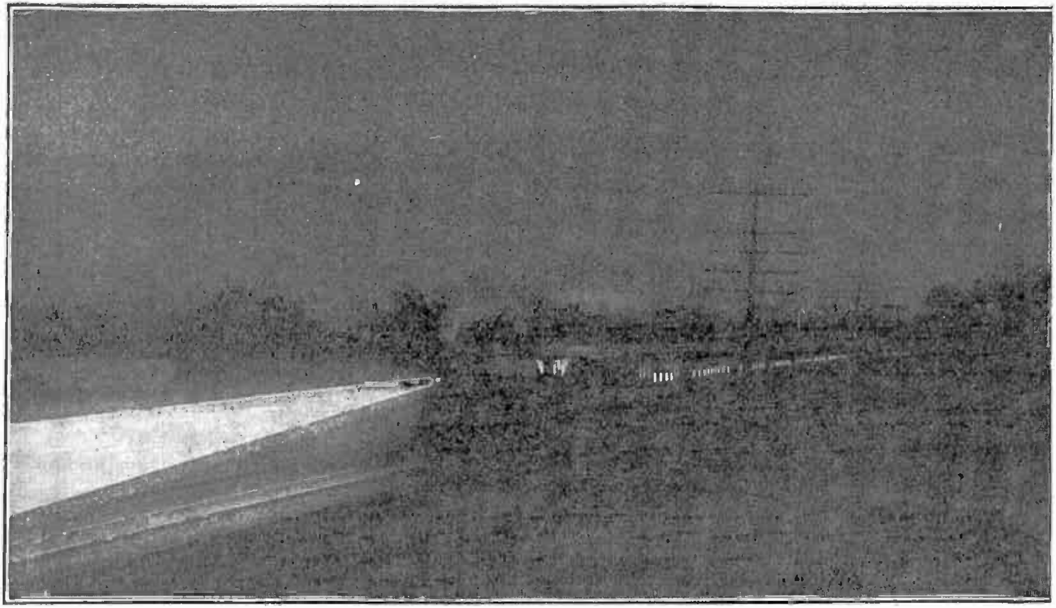


FIG. 6,477.—Entire train illuminated by "Sunbeam" turbine driven dynamo.

compact unit suitable for mounting on top of the locomotive boiler forward of the smoke stack. A typical set of this kind is shown in figs. 6,469 and 6,478.

Voltage regulation is accomplished by means of a centrifugal governor located in the body of the machine. It maintains turbine and dynamo speed practically constant, regardless of varying loads or steam pressures.

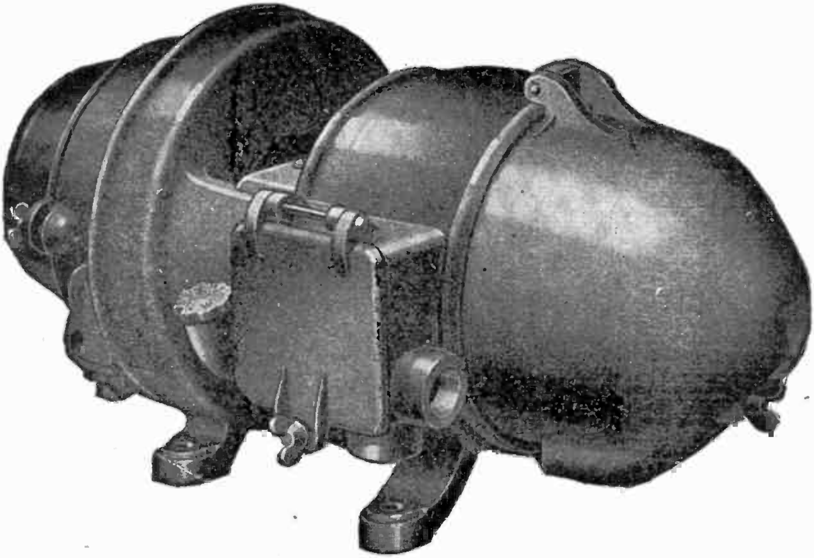


FIG. 6,478.—Sunbeam four pole turbine driven dynamo. It is a four pole, compound wound dynamo, having a capacity of 800 watts at 32 volts. This capacity is ample for automatic train control, head lights, cab lights, classification and marker lights. It operates at a speed of 2,800 *r.p.m.* In its design it complies in all respects with Association standards as a head light dynamo and train control dynamo. The armature and turbine wheel are carried on a single shaft, which rotates on ball bearings, one bearing between the turbine wheel and armature, and one at the armature end of the shaft. The dynamo frame, turbine case and supporting feet are cast in one piece, insuring rigidity and perfect bearing alignment. The turbine wheel is a steel disc with buckets welded on it. It can be safely run at the highest possible speed it can attain under any condition. It will deliver full output at uniform voltage, at from 100 lbs. to the highest boiler pressures now used. When in operation only sufficient steam is admitted by the governor valve to generate the electrical energy required. Steam consumption is in proportion to the load. It operates on a wide range of steam pressures.

Located at the top of the turbine body, the governor valve or main steam valve is mounted as a separate unit. It works in a renewable cage of nickel alloy.

The diagrams figs. 6,480 and 6,481 show arrangement of field coils for the 3 *kw*. and 4 *kw*. machines respectively.

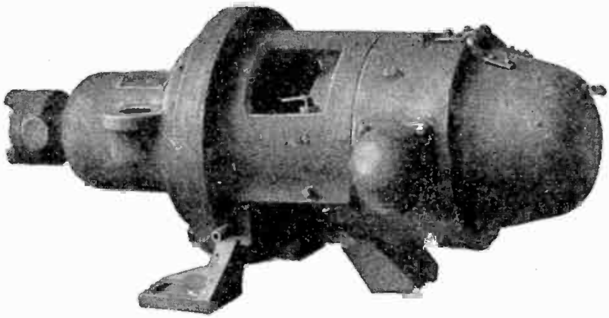
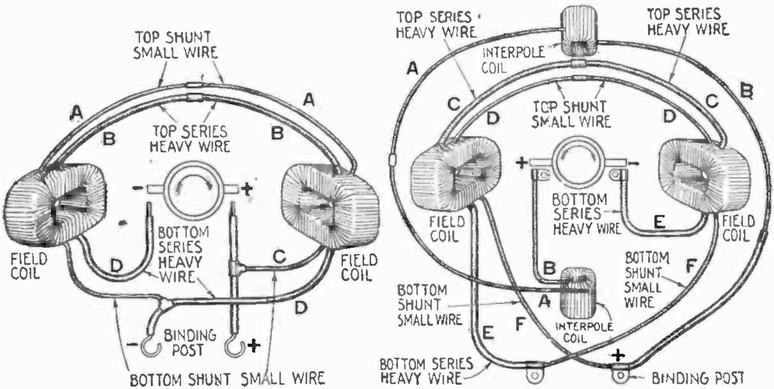


Fig. 6,479.—Westinghouse 32 volt, 500 watt locomotive head light unit. ***It consists of*** a single impulse steam turbine and an enclosed *d.c.* dynamo built together as a single unit. There are two self aligning ball bearings carried by the dynamo end brackets. The turbine rotor is mounted on the end of the dynamo shaft which is tapered and held in place by a lock nut and washer.



Figs. 6,480 and 6,481.—Field diagram of Sunbeam turbine driven dynamo sets. Fig. 6,480 3 *kw*.; fig. 6,481, 4 *kw*.

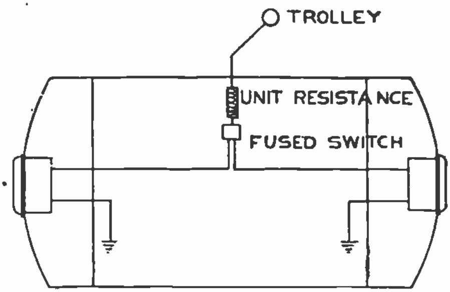


FIG. 6,482.—Head light wiring diagram for mine locomotives. 1, double end equipment, circuit voltage greater than head light lamp voltage; each lamp burns singly.

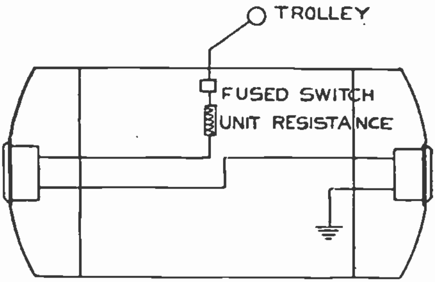


FIG. 6,483.—Head light wiring diagram for mine locomotives. 2, double end equipment, both head lights burn at same time, circuit voltage greater than that of combined lamps.

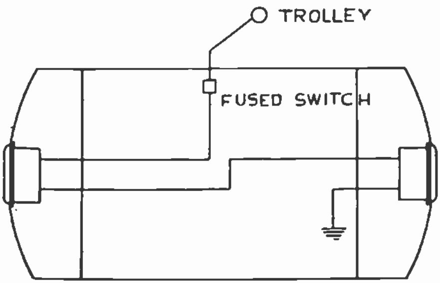


FIG. 6,484.—Head light wiring diagram for mine locomotives. 3, double end equipment, head light lamp voltage one-half that of circuit voltage; both lamps burn at same time.

TEST QUESTIONS

1. *Name two ways of obtaining the current used in a locomotive lighting system.*

2. *Give comparison of lighting entire train by single turbine dynamo or by individual axle drive dynamo:*

3. *Is the voltage constant in the axle system?*

4. *In what two ways may train lighting systems of the locomotive head light type be installed?*

5. *Where should two wire and three wire circuits be used?*

6. *What is the objection to the non-battery system?*

7. *How is the voltage regulation accomplished?*

8. *What is the usual voltage employed in locomotive lighting systems?*

CHAPTER 144

Car Heating

Electric cars are usually heated by electric heaters. These are made of coils of wire wound on porcelain spools placed in suitable containers and fastened under the seats.

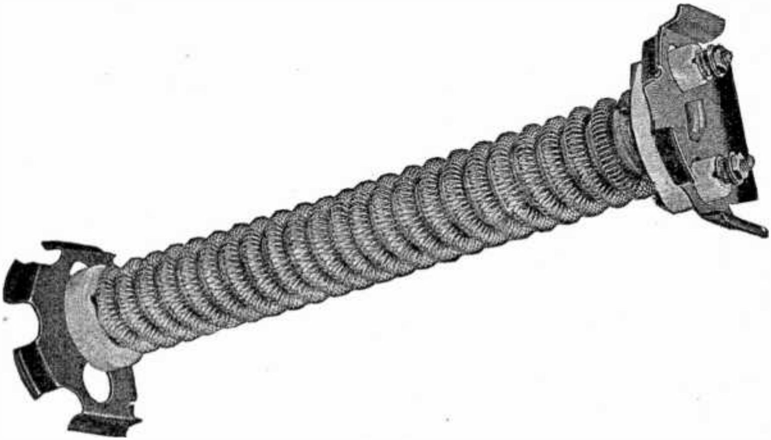


FIG. 6,485.—Consolidated heating unit for cross seat heater showing coil mounted upon porcelain spindle, the terminals for making connections and the steel end.

The wire *offers a resistance to the current and as the current is forced through the wire, it heats the wire and raises the temperature of the surrounding air.*

The amount of power consumed by electric heaters naturally varies with the climatic conditions, but for cars ranging from 24 to 34 feet in length the power consumption for average and severe weather conditions varies from 5 to 7 *kw*. respectively, so that the electric heater loads on both street railway and interurban systems compose a very large part of the total energy consumed. It is well known that on many well equipped electric railway systems, the amount of power consumed in heating and lighting the cars during very cold weather exceeds 20 per cent. of the power supplied to propel them. Both stove and hot water systems, however, possess several disadvantages. They occupy useful space, require special attention, and introduce dust, smoke and dirt into the car.

Construction of Heater Units.—Electric heater coils are made of special wire of such characteristics as are best for this purpose. The spindle supporting the coil consists of an iron

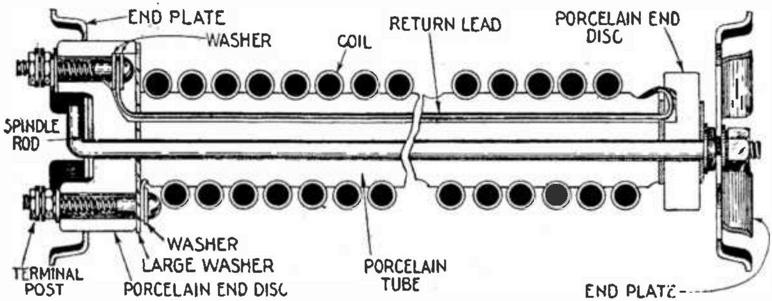


FIG. 6,486.—Sectional view of Consolidated heating unit for cross seat heater showing the return wire of the coil inside the porcelain spindle.

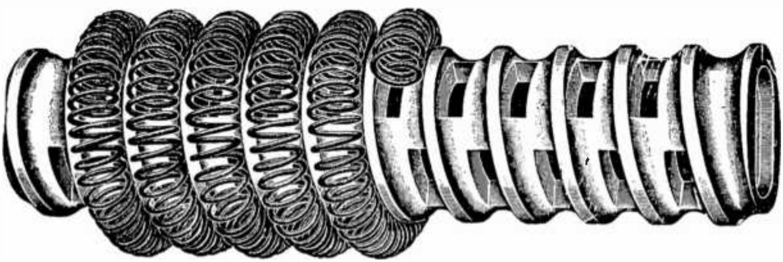
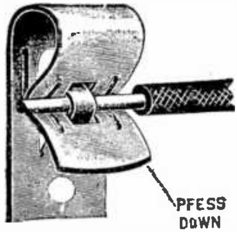


FIG. 6,487.—Ventilated porcelain core partially wound with resistance wire. The perforations in the porcelain core increase the radiating surface of the support, therefore the air passing through the supports and coils as well as around them give an efficiency not found where solid supports are employed.

rod, on which are strung porcelain tubes which are so designed and fitted that a helical groove extends from end to end.

Eccentric bushings are placed on both ends of the rod and passed through the heater end plates. The wire for the heater coil is wound in a close spiral spring, between the ridges on the porcelain spindle under suitable tension, and the coils are thus properly supported at every point, preventing vibration. Crystallization of the wire with consequent fracture due to vibration is therefore avoided.

It is well known that wire expands with heat and contraction takes place again when the current is cut off.



FIGS. 6,488 and 6,489.—Gold spring clip terminals. The object of the spring arrangement is to prevent vibration loosening the connections.

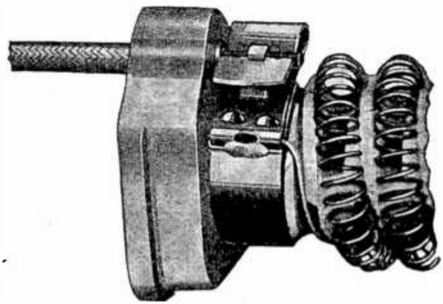


FIG. 6,490.—Gold two-end connection showing application of spring clip. With spring clip terminals there is a direct connection from the resistance coil to the lead or service wire and no amount of vibration will loosen the connection to open circuit and cause arcing, as has happened with the binding post type.

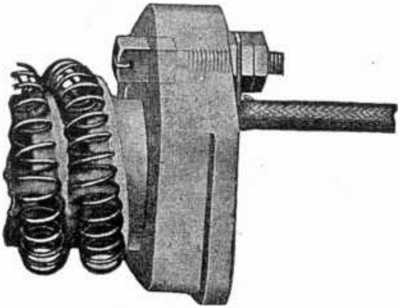
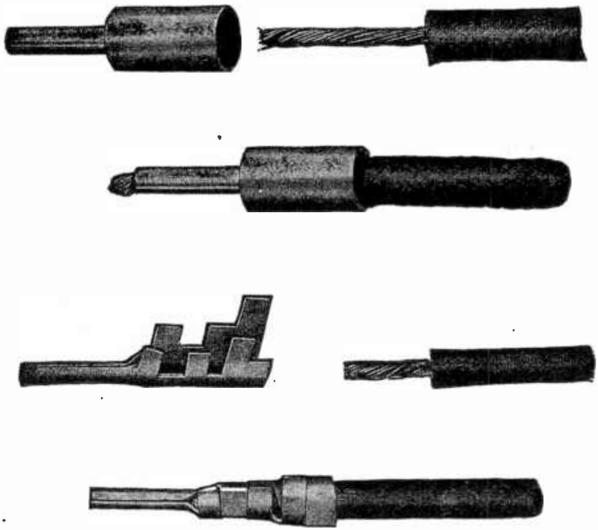


FIG. 6,491.—Gold binding post terminals. This manufacturer makes both kinds of terminal but recommends the use of spring clip terminals to prevent possibility of loosening by vibration.



FIGS. 6,492 to 6,497.—Gold service wire tips. These prevent the open circuiting of the wire at the terminals due to vibration at the point of contact; also eliminates frayed edges of the insulation. In attaching type shown in figs. 6,492 to 6,494, the wire is sweated into the ferrule, allowing about ⅛ inch of the bare wire to extend beyond the end of the tip, which end is dipped in solder, making a positive connection. Figs. 6,495 to 6,497 show the clamp type.

The spring of the coils not only holds them to the supporting insulator, but also takes up the expansion and contraction without disturbing the position of the coil on its support. Consequently, there is no danger of the wire breaking due to the strain of contraction as is the case where the resistance wire is wound straight around a bar or rod of insulation. This construction of the heating element allows the use of the maximum amount of wire in a given space and exposes every portion of the large surface presented, so that a large quantity of air comes freely into contact with it. The construction is shown in the accompanying illustrations.

Arrangement of Heating Circuits.—Heating equipments are usually arranged for three points of heat. The light coils are

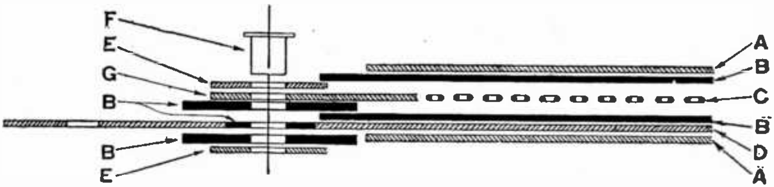


FIG. 6,498.—Gold enclosed type heating element. The object of this construction is to conduct the heat away from the wire as quickly as possible. *The parts are:* A, outside sheath; B, micanite plate insulation, double thick; C, heating resistance, nickel chromium alloy; D, supporting strip; E, terminal washer; F, ferrule; G, ribbon lead connection.

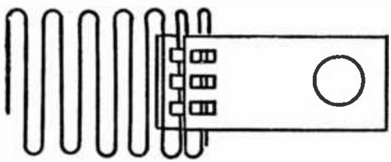
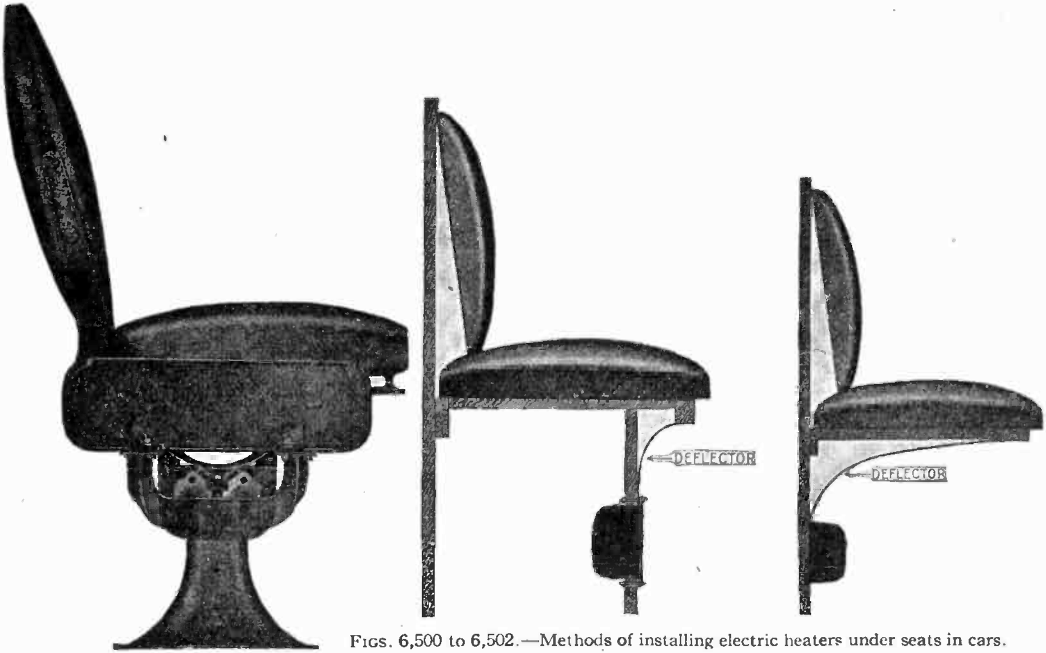


FIG. 6,499.—Section of Gold element showing lead and method of attaching. Terminals are frequently weak points on heaters. In the construction here shown an extra wide lead of nickel is employed and several turns of the resistance wire are laced into it, providing a good contact without brazing or welding. This terminal will operate at temperatures in excess of that obtained in street car service.

NOTE.—*The surface temperature* of the sheath of a car heater under normal rating is a little over 600 degrees Fahr. The minimum dehydration point of mica is from 1,200 degrees Fahr. (about the melting point of aluminum) to 1,800 degrees Fahr. A condition which never can be reached in car heating even though the heater should receive 100 % overload.



FIGS. 6,500 to 6,502.—Methods of installing electric heaters under seats in cars.

wired in series on each side of the car and connected to point 1 of the regulating switch. The heavy coils on each side are also wired in series and connected to point 2 of the regulating switch.

With No. 1 switch on and No. 2 off, one point of heat is obtained; with No. 2 on and No. 1 off, two points; and full heat is obtained with both switches on. Sometimes the heaters are made with all coils alike for two points of heat instead of three points. Where a single switch master is used ahead of the thermostatic control equipment, the heater fuses can either be contained within the safety switch or a separate fuse box can be used.

It is advisable to adhere to the arrangement providing for three different gradations of heat, where thermostatic control is used, as it makes possible the use of only one point of heat during rush hours, and thus the heater equipment is taking its minimum current at the time of the peak of the load.

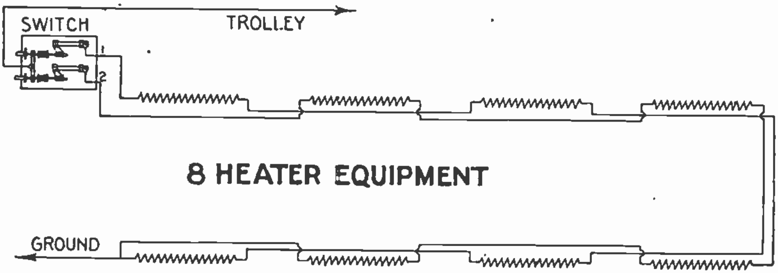


FIG. 6,503.—Connections of single unit heaters for seats running longitudinally in a car. Note staggered connections. Throwing in one switch sends current through one-half the number of heaters, but uniformly distributed.

Cross seat heaters are usually made with terminals at only one end. The return wires are carried in passageways in the porcelain tubes.

Wire Used in Heater Elements.—For several years there were a great many heaters constructed with resistance coils of galvanized iron wire, but there have been objections to the use of this wire because of its very high temperature co-efficient, its increased resistance under service and to its unreliable period of life, and it was found that the only point in its favor was the price, that made it possible for manufacturers using this grade of wire to sell electric heaters at what seemed to be a ridiculous price as compared to electric heaters made with other grades of resistance wire.

Location of Heaters.—Figs. 6,500 to 6,502 show three methods of installing electric heaters in cars. They are placed under the seats as shown in the illustrations.

The deflector is for the purpose of preventing the heat lodging in a pocket under the seat. It is usually a plate of thin sheet steel fastened to the seat and curved so as to deflect the heat outward.

Methods of Connecting Heaters.—Depending upon the size of the car to be heated various numbers of heater units are

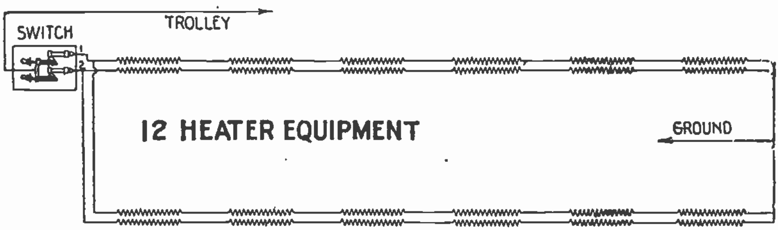


FIG. 6,504.—Connections of two unit heaters for seats running longitudinally in a car. Closing one switch sends current through one coil unit of each heater, closing both switches and full current is on.

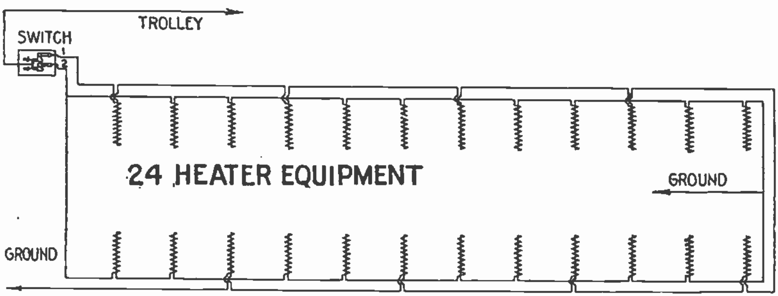


FIG. 6,505 —Diagram of connections for single unit cross seat car heaters.

used. The accompanying illustrations show installations ranging in size from 8 heater to 24 heater equipments.

Heat Control of Car Heaters.—In order to maintain the temperature at a desirable degree some means must be provided for controlling the heat given off by the heating elements. This may be done by

1. Manual control.
2. Automatic control.

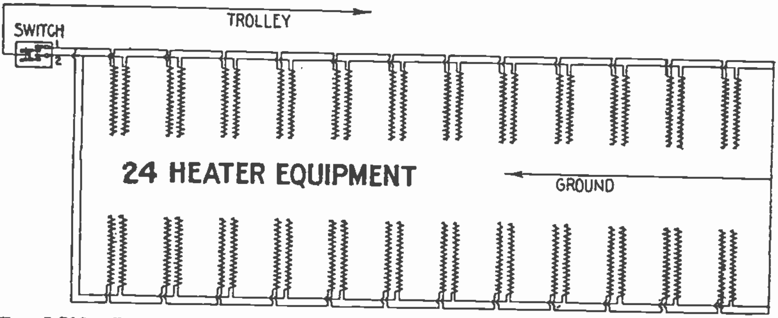


FIG. 6,506.—Diagram of connections for two unit cross seat car heaters.

Car Heating by Electricity

Test on Atlantic Avenue Railway, Brooklyn, N. Y.

Cars			Temperature F.		
Doors	Windows	Contents Cu. Ft.	Outside	Average in Car	Watts Consumed
2	12	850½	28	55	2,295
2	12	850½	7	39	2,325
2	12	808½	28	49	2,180
2	12	913½	35	52	2,745
4	16	1012	7	46	3,038
4	16	1012	28	54	3,160

FIG. 6.507.—Gold three degree reciprocating snap switch. Capacity 53 amperes; 600 volts.

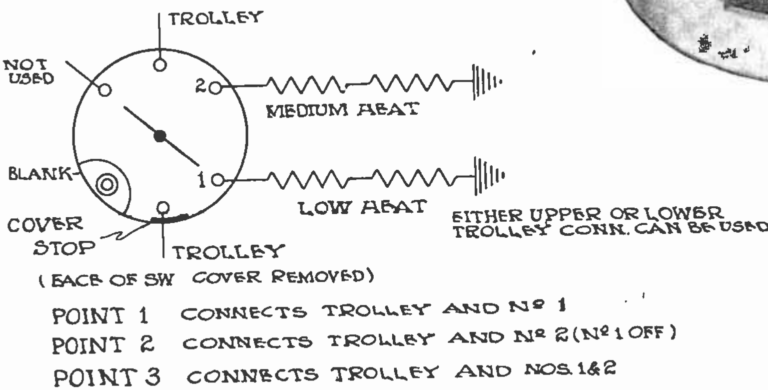
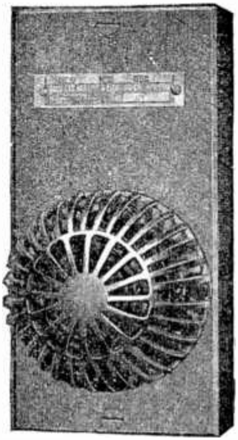


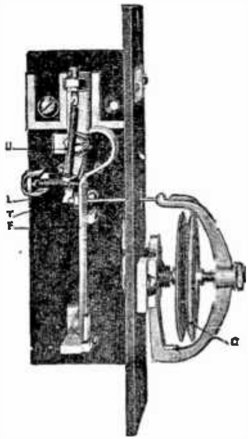
FIG. 6.508.—Wiring diagram showing hook up for Gold three degree reciprocating snap switch.

obtained respectively by means of:

1. Snap switch;
2. Thermostat.

Snap Switch Control.—Fig. 6,507 shows a type of snap switch which gives three degrees of heat, being shown in diagram in fig. 6,508. The switch can be snapped in either direction, therefore it is not necessary to pass from a low heat through a higher heat to open the circuit. The wiring diagram shows





Figs. 6,509 and 6,510.—Gold thermostat. Fig. 6,509, outside view; fig. 6,510, case and element guard removed.

the face of switch with cover removed. Note indications are different from those shown on cover.

Thermostat Control.—By definition a thermostat is an automatic device by which *an electric circuit is closed when a given low temperature is reached, and opened when a given high temperature is reached.* Accordingly the purpose of a thermostat of a type used with car heaters is *to automatically cut the current off the heating coils the moment a set car temperature is reached, and to cut it in when the temperature falls slightly below that point.*

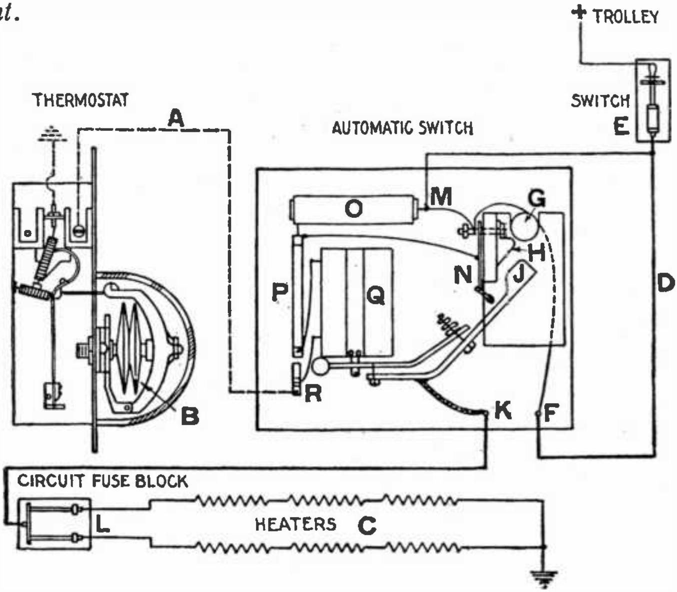


FIG. 6,511.—Wiring diagram of Gold thermostatic control. ***Method of operation:*** In the off position of the switch as shown, the thermostat having broken the circuit A, due to rise in temperature, thus expanding the diaphragm B, the electric heaters C, are of course cut out. When the diaphragm B, is contracted due to lowering of the temperature in the car a contact will be made in the thermostat, the current then passes from trolley through main switch E, through line D, to terminal F, on magnetic switch, through blow out coil G, to main contact H, through contactor J, to terminal K, through fuse block L, through heaters to ground. It will be noted that the positive pole of the line enters the magnetic switch at terminal F, and returns at terminal K. While it is preferable to wire the circuit as shown, no damage will result if the polarity be reversed and the switch will function equally as well. The thermostat receives its current from the main switch E, to terminal M, on magnetic switch and is shunted directly through fuse P, to main coil Q, to terminal R, through thermostat to ground. In the cut in position of the thermostat the current flowing directly through coil Q, which is energized draws up contactor arm J, closing the switch, using full line capacity of coil Q, in doing so. At N, is located a shunt switch, which when the switch is closing, opens the shunt around resistance O, placing this resistance in series with main coil Q, leaving just enough power in it to hold the switch closed, but reducing the voltage to such a degree that the arcing of the thermostat break is practically nil. With this method of wiring, the thermostat being grounded, it is impossible for any short circuit to occur at the thermostat.

In actual service the length of the cut out period is surprisingly long, aided partially by the action of the sun and again helped by the body heat from passengers at the crowded periods, allowing more current for the actual running of the cars when needed.

One construction of thermostat is shown in figs. 6,509 and 6,510.

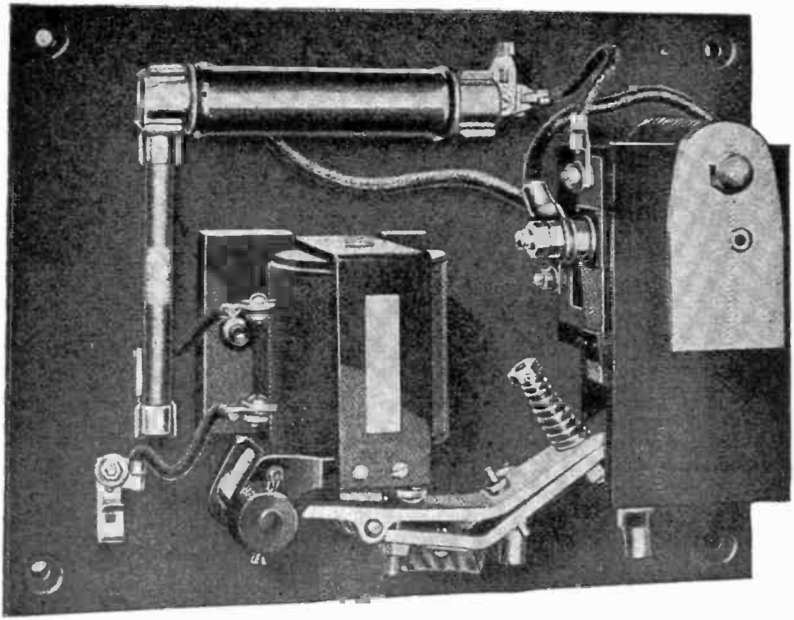


FIG. 6,512.—Gold automatic switch. It is magnetic and performs the two fold function of opening and closing the circuit through which the heating coils are supplied, and of controlling the circuit from the thermostat so as to enable the thermostat to operate without sparking or arcing.

The temperature sensitive element is the double diaphragm C, shown in fig. 6,510 containing a volatile liquid, the front wall transmitting its motion to lever arm F, lever arm F, operating a switching mechanism opening or closing the electric circuit. ***Example:*** as long as the diaphragm is expanded by any temperature above the critical point for which the thermostat is set, the contact arm L, will remain in the off position. When the temperature falls, allowing the diaphragm to contract gradually, the contact arm L, will continue to remain in the off position until the continued recession of the diaphragm overcomes the tension of the spring U. When this occurs the contact arm L, jumps to the live contact by a quick and positive movement of over a quarter of an inch, cutting in the main heater switch. In other words, the thermostat performs the function of an ordinary single pole switch actuated by temperature changes. The thermostat, which is a delicate instrument, acts to operate the switch which controls the current supply to the heaters. The wiring diagram fig. 6,511, shows plainly the thermostat and switch with connections.

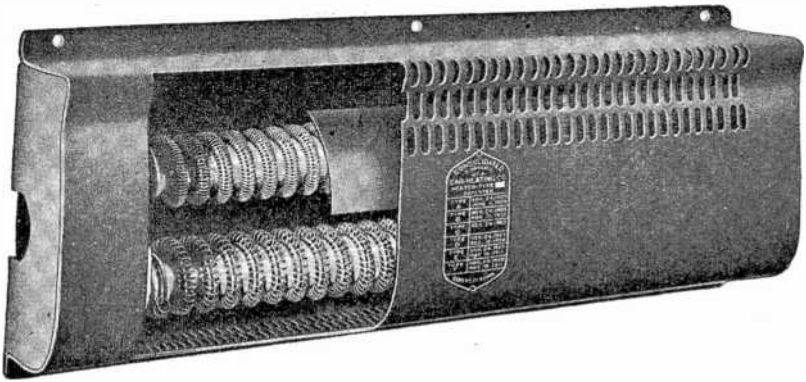


FIG. 6,513.—Consolidated double coil truss plank heater. *It was designed* for use on 1,200 to 1,800 volt circuit, as in the case of the single coil truss plank type. These heaters are used in a continuous row along the truss plank or side wall of the car. A deflector plate is provided which not only protects the coils against external injury, but also prevents the live parts of the heater being reached, so that it is impossible for passengers to receive a shock. The coils are secured to the spindles by means of an asbestos cord, thus they cannot, even if they become broken, come in contact with the heater case. The back is made of sheet steel lined with asbestos and is brought forward at the top of the heater forming a deflector to project the heat out into the car.

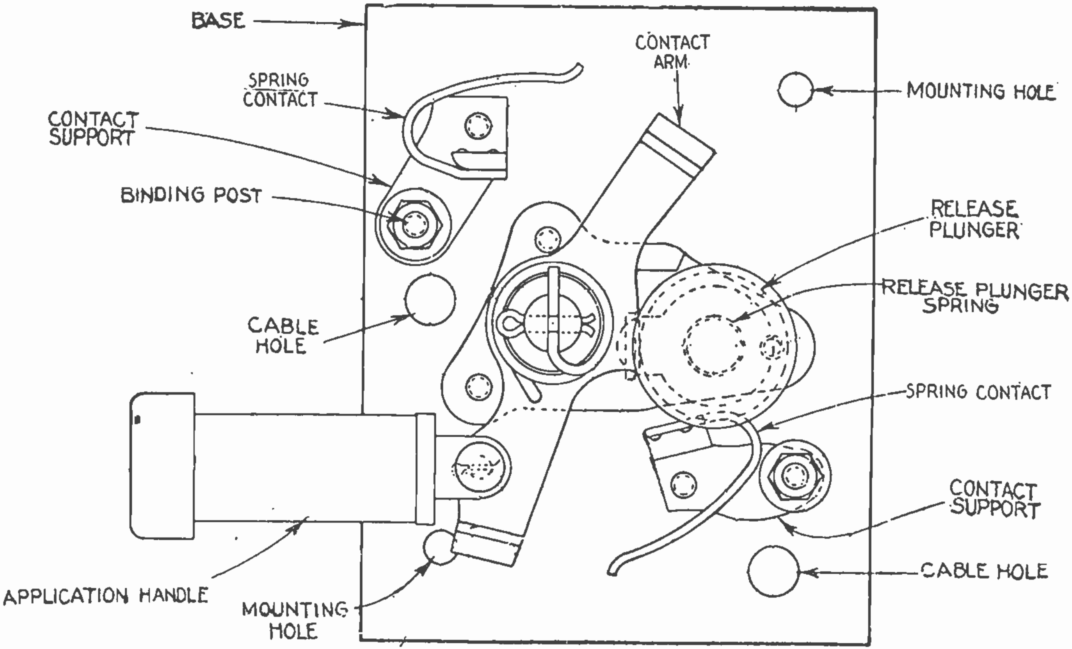


FIG. 6,514.—Gold door operated switch for vestibule heaters. This switch is used largely in vestibules of suburban, elevated and subway cars and is placed in a position so that when the motorman's cab is not in use and the door is folded back, it will press on the front plunger and cut the heat off the motorman's cab heater automatically. To obtain heat the left plunger is pushed in. Its use prevents the overheating of the small compartment when not in use.

TEST QUESTIONS

1. *How are electric cars usually heated?*
2. *How are the heating units made?*
3. *What kind of wire is used for the heating units?*
4. *How is the amount of power consumed by electric heaters varied?*
5. *What is the construction of a heater unit?*
6. *How many heating points are usually provided?*
7. *Draw diagrams showing arrangement of a heating circuit.*
8. *What two kinds of coil are used?*
9. *How is the heat controlled?*
10. *How are cross seat heaters usually made?*
11. *What are deflectors used for?*
12. *What is a thermostat?*
13. *How does a thermostat work?*
14. *Draw diagrams showing wiring of thermostats.*

CHAPTER 145

Railway Signals

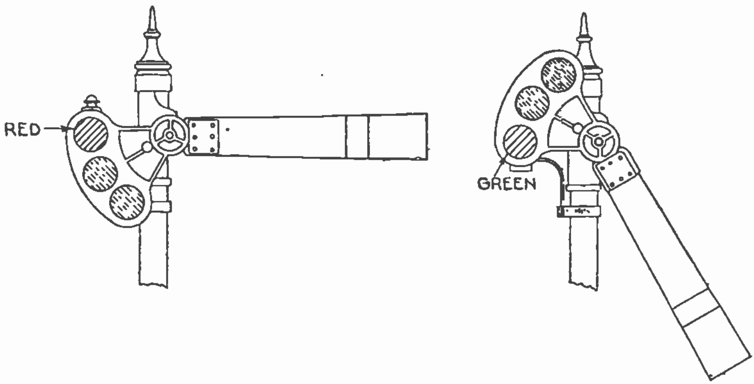
The author is indebted for able assistance in the preparation of Chapters 145 to 150 on the various systems of Railway Signaling to Mr. D. W. Van Gieson, Asst. Electrical Engineer (Railroad Signal Equipment), Board of Transportation, City of New York; one time Signal Engineer for New York State Transit Commission.

By definition a signal is *a means of conveying information to a train*—information necessary to the motorman or engineman in order that he may drive the train with safety, that is, properly directing its movement.

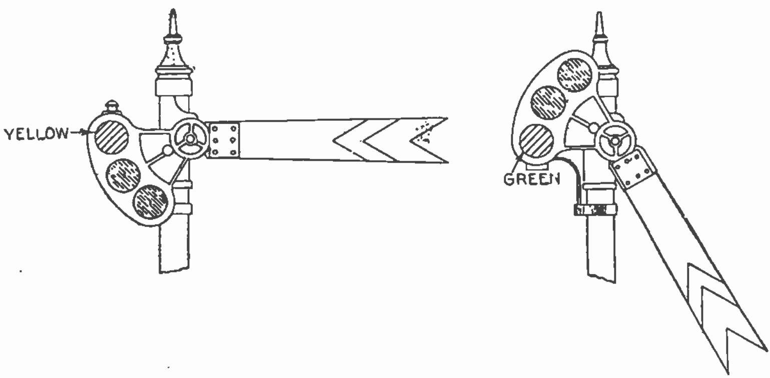
Signals may be classified:

1. With respect to size, as:
   a. High;
   b. Dwarf.
2. With respect to the signal proper, as:
   a. Semaphore;
   b. Color light;
   c. Position light;
   d. Disc.
3. With respect to operation, as:
   a. Automatic;
   b. Semi-automatic;
   c. Interlocking.
4. With respect to method of control, as:
   a. Manual;

b. Mechanical;
c. Electric;
d. Electro-pneumatic,



FIGS. 6,515 and 6,516.—Two position ***home*** signal. Note shape of arm or "blade." The front of it is usually painted red with a white stripe near its outer end and the back of it white with a black stripe near the end.



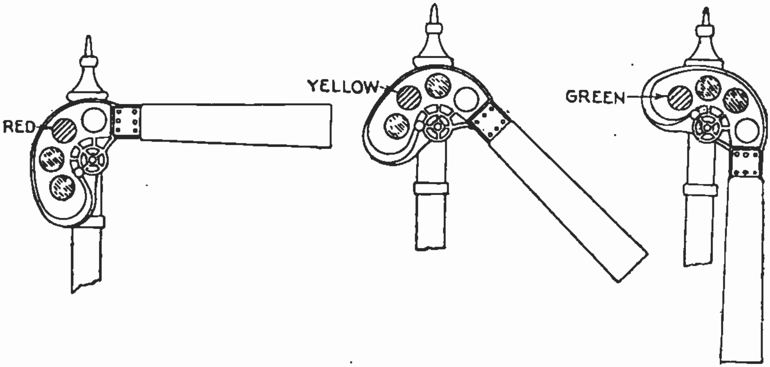
FIGS. 6,517 and 6,518.—Two position ***distant*** signal. The distant blade is made with a V shape or fish tail end. The front of it is generally painted yellow with a black stripe parallel with the end of the blade, or green with a white or red stripe. The back of the blade is painted white with a black stripe. A few roads that do not use this notation, paint the front of all blades yellow with a black stripe and the back black with or without a white stripe.

5. With respect to location, as:

   a. Block {home / distant}

   b. Take siding, etc.

Semaphore Signals.—This type of signal is one in which *the day indications are given by the positions of a movable arm, and the night indications by colored lights.*



Figs. 6,519 to 6,521.—Three position lower quadrant signal. The blades are made with square ends for interlocking purposes and with either square or pointed ends for block signaling. Where both square and pointed blades are used, the square end blades indicate stop and stay when the signal indicates stop.

They may be classed as:

1. Two position:

   a. Home;

   b. Distant.

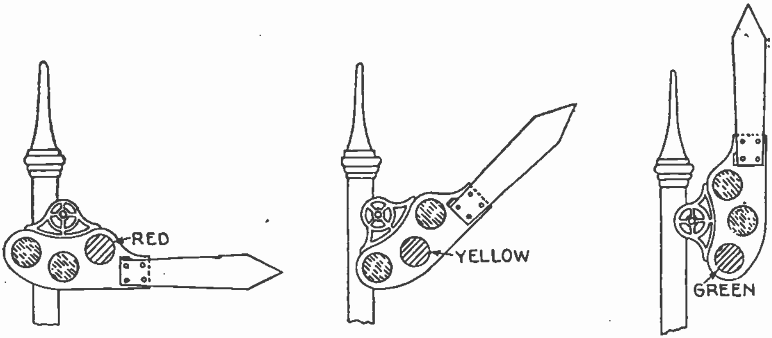
2. Three position:

   a. Upper quadrant;

   b. Lower quadrant.

Figs. 6,515 to 6,524 show the distinction between these two types.

Two position signal blades are often used in combination on the same signal post to give three indications. The home or top arm gives final authority to the engineman, the distant or lower arm merely repeating the indication of the home signal in advance; its function being purely cautionary.



FIGS. 6,522 to 6,524.—Three position upper quadrant signal. Where both square and pointed blades are used, the pointed end blades indicate stop and proceed at low speed when the signal indicates stop. Stop and stay is always the stop indication at interlocking plants. Three position blades have the front side painted red with a white stripe parallel with the end or yellow with a black stripe. The back side is painted white with a black stripe, or black with or without a white stripe.

Signal Indication.—Where lights are employed to give the indication, they are of two kinds:

a. Color—in Semaphore or Color Light Signals;

b. Position—in Position Light Signals.

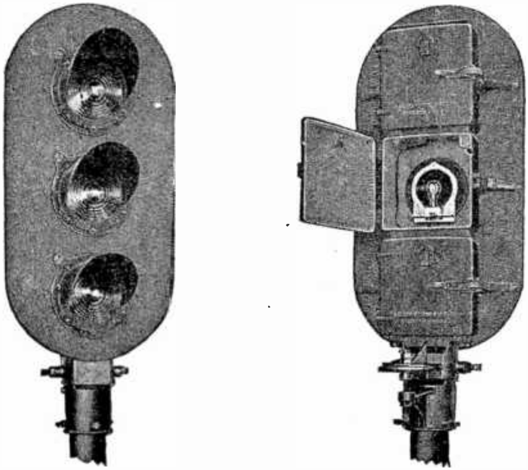
Color lights indicate by three colors, thus:

NOTE.—*The upper quadrant signal* is the latest type of arm indication and possesses some advantages over lower quadrant movements, chief among which is the fact that the arm does not require a counterweight to place it in the stop position. This is of considerable importance in case of failure of signal operating mechanisms. Should sleet collect on the blade it would tend to pull the upper quadrant signal to the stop position and to hold the lower quadrant signal in the proceed position. There is little doubt, too, but that the blade giving the proceed indication in the upper quadrant can be seen farther by enginemen than one giving the same indication in the lower quadrant.

1. *Green*—proceed;
2. *Yellow*—slow down prepared to stop;
3. *Red*—stop.

Position lights indicate by their position, thus:

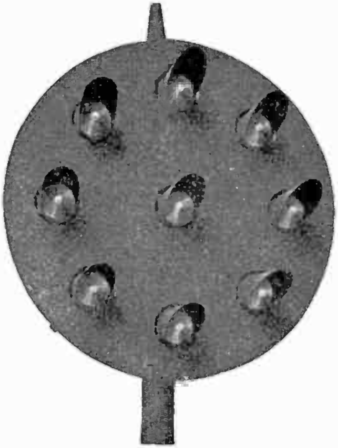
1. *Vertical*—proceed;
2. *Oblique*—slow down prepared to stop at the next signal;
3. *Horizontal*—stop.

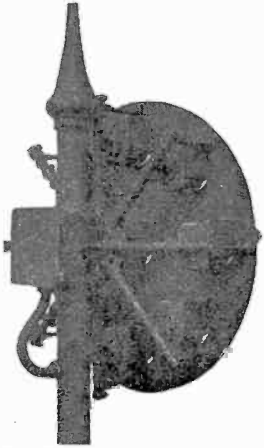


FIGS. 6,525 and 6,526.—GRS three indication color light signal unit; front and back views. The unit construction of this signal reduces to a minimum the number of parts necessary for a railroad to carry in stock and simplifies the matter of adding or changing indications after installation. For instance, a change from a system employing two indication signals to a system employing three indication signals is made by simply bolting on another case containing an additional light unit.

Figs. 6,527 to 6,529 show construction of a position light signal.

Semaphore arms operate the same as position lights. An engineman may pass a distant signal set at caution, but he must be prepared to stop at the home signal set at stop. In the case of interlocking, he must stop and stay, while in some cases in block signaling he may proceed after the stop. Figs. 6,515 to 6,518 show the ordinarv two position home and distant semaphore signals.





FIGS. 6,527 and 6,528.—GRS position light signal unit. This type is arranged to give four indications. ***It consists of*** nine lamps set around a cast iron hub bolted to a mast, and wired so that it can light three lamps in any one position. The lamps are 12 volt tungsten filament lamps and through the reflectors and lenses give a range of vision, in bright sunlight, of half to three quarters of a mile. The lamps are located on an 18 in. radius about the central lamp and the hoods and lenses project through a background attached to the pipe support by brackets. The wires leading to each lamp pass down the pipe supports to a central terminal box and from there, by flexible conduit down the mast to the source of current supply.

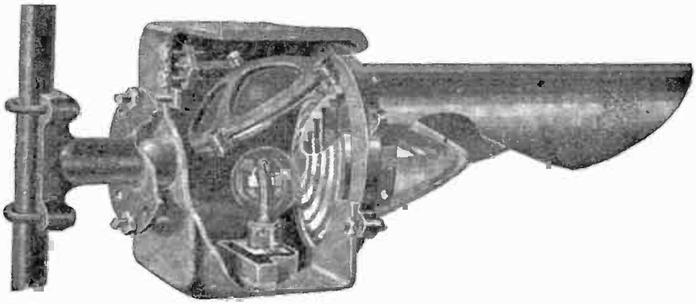


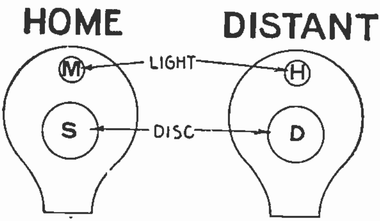
FIG. 6,529.—Position light signal lamp unit. ***It consists of*** a lamp, lamp receptacle, an inverted lens, a cover glass and a mirror reflector, contained in a cast iron case and a hood to keep reflection out. The lens is of clear glass with a focal length of 2¼ ins.; the cover glass is conical in shape, of amber tinted glass and has a frosted tip, the conical shape and frosted tip being to prevent reflection and sun glare, and the tinted glass gives a more penetrating beam for passing through fog. Further prevention of glare or reflection is procured by painting black the lower portion of the lens and having the lamp filament above the center of the lens. The mirror reflector adjusts for concentrating the beam.

Position-Light Signals		
Aspects High Signal		Indications
1		Proceed
2		Proceed prepared to stop at next signal
3		Proceed with caution prepared to stop short of train or obstruction
4		Stop
5		Stop and proceed as per rule
6	a b	Proceed prepared to pass next signal at medium speed
7	a b	Proceed at medium speed
8	a b	Proceed at restricted speed prepared to stop at next signal
9	a b	Proceed at low speed prepared to stop short of train or obstruction
Dwarf Signal		
10		Proceed at low speed
11		Proceed at low speed prepared to stop
12		Proceed at low speed prepared to stop short of train or obstruction
13		Stop
14		Take Siding

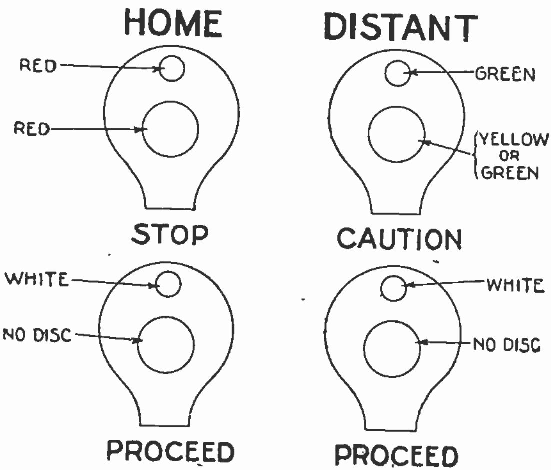
Figs. 6,530 to 6,548.—Various position light signals and their meaning, giving interpretation for three light high signals and also for two light dwarf signals.

Disc Signals.—These are in use to some extent. By definition, a disc signal is one in which *the day indications are given by the color, or by the absence or presence of discs.*

Figs. 6,549 and 6,550 show essential features of disc signals. The indications are given in figs. 6,551 to 6,554.



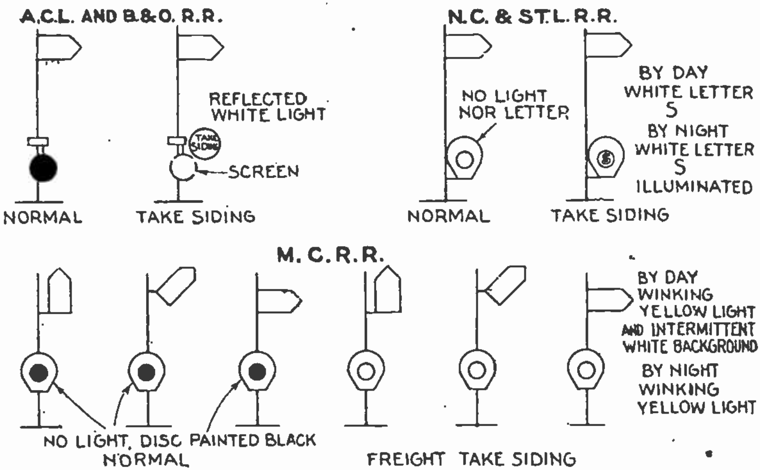
Figs. 6,549 and 6,550.—Essential features of disc signals. *For day indication* there is a large circular opening S, in which a red disc can swing into view, the home signal has a red disc, and *for night indication*, there is a light M, just above the disc opening. The distant signal has an opening D, for a yellow or green disc and a light H, just above.



Figs. 6,551 to 6,554.—Indications of disc signals.

Take Siding Signals.—The object of this class of signal is *to notify the engineer or motorman without the use of train orders, to take siding at non-interlocked switches, especially where located at some distance from operating towers.*

One form or another of the types of signal are used for this purpose, one example being a two blade signal in which the lower blade is operated at the oblique position in the upper quadrant and is marked with the words *take siding*, and illuminated at night. Various other methods are used to indicate siding orders.



FIGS. 6,555 to 6,564.—Take siding indicators as used by various railroads. 1.

Conclusions on Light Signals.—The following conclusions concerning the use of light signals are given in the 1917 volume of the Proceedings of the Railway Signal Association:

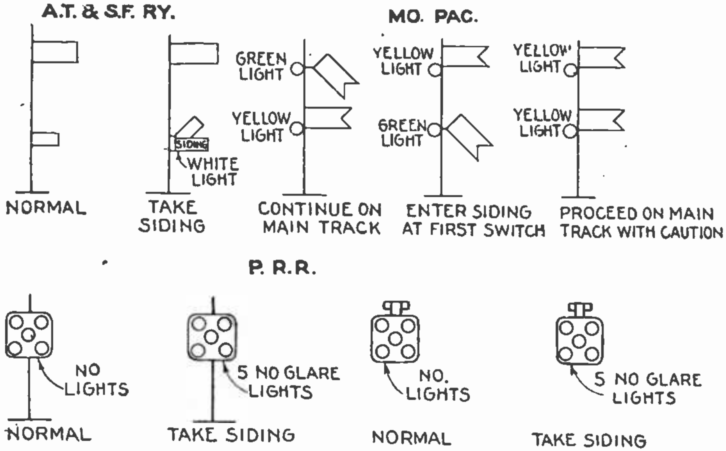
1. Colored and position light signals, for day and night use, by elimination of all moving parts except the control relays, reduce the number of failures.

2. Light signal aspects have greater visibility and range under adverse

weather and background conditions than the semaphore, while the close indications compare favorably.

3. Light signals give uniform indications at all times. Other types of signals give the indication by position in daylight, by color at night, and by both during transition periods. The various aspects of the position light signal are equal in intensity, range and visibility.

4. In general practice, the number of aspects of any one arm of a semaphore is limited to three. With the position light signal, four distinctive positions may be used, while the number of indications given by colored light signals is limited only by the colors available.



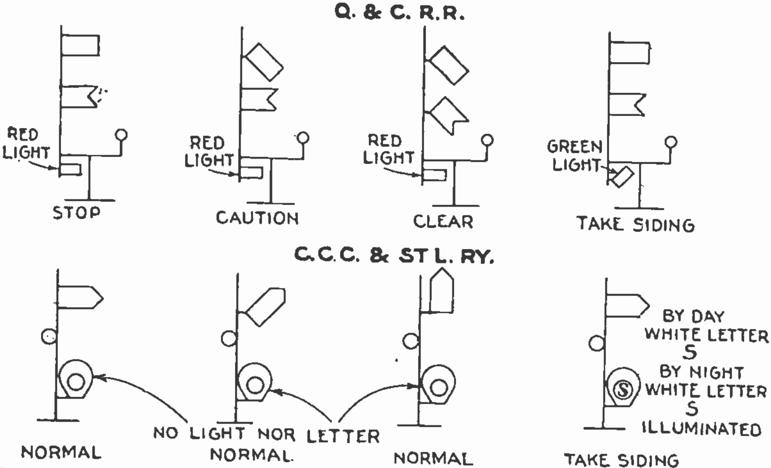
FIGS. 6,565 to 6,573.—Take siding indicators as used by various railroads. 2.

5. Where power is available, the cost of operating light signals is less than for operating motor signals.

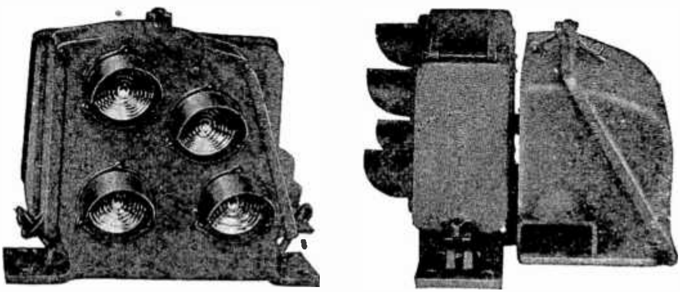
6. Current consumption under normal automatic signal conditions.—Position light signals: Four 5 watt lamps—20 watts. One colored light: 35 to 50 watts. For interlocking signals, consumption is increased depending upon the number of light displayed, but the ratio holds.

7. Cost of maintenance of light signals is considerably less than that of motor signals, and as the colored light signal has fewer lights to renew, it has an advantage in this respect over the position light signal.

8. The field for the economical use of light signals is limited, as noted above, to points where power is available. In this field, the light signals have advantages over other types. The position light signal can be installed at any location where clearance will permit the present standard semaphore to be erected. The colored light signal can be used in more restricted clearances.



FIGS. 6,574 to 6,581.—Take siding indicators as used by various railroads. 3.



FIGS. 6,582 and 6,583.—GRS position light dwarf signal unit.This type is designed for short range and its construction is different from the other types. The case containing the lamps is cast in one piece with a door on either side and is so arranged that a small cast iron relay box may be bolted on the back. The lamps are the type used in automobile head lights.

TEST QUESTIONS

1. *What is a railway signal?*
2. *Give classification of railway signals.*
3. *What is a semaphore signal?*
4. *Name several classes of semaphore signals.*
5. *Explain the difference between home and distant signals.*
6. *Is an upper quadrant signal more desirable than a lower quadrant?*
7. *What are the two kinds of signal indication where lights are employed?*
8. *How many colors are used in color light signals?*
9. *What do the different colors mean?*
10. *In position lights give the indications of the various positions.*
11. *What is the construction of a position light signal?*
12. *What is a disc signal?*
13. *Are disc signals used extensively?*
14. *What are the essential parts of disc signals?*
15. *How does a disc signal work?*
16. *What is the object of take siding signals?*
17. *What types of signals are used for take siding signals?*
18. *Give the conclusions on light signals according to the proceedings of the railway signal association.**

*NOTE.—The Railway Signal Association is no longer existent. It is now the Signal Section of the American Railway Association.

CHAPTER 146

Automatic Block Signals

The primary purpose of automatic block signals is the spacing of trains *a safe distance apart*, and the transmission of information to the engineman as to the presence of other trains which are about to interfere with his speed or movement.

There are some secondary advantages which are of much value, such as the detection of the position of switches, broken rails, etc. The important action of automatic signaling is that the passage of a train controls and actuates the operation of the signals, dispensing with the human agency, and providing for the protection of trains from following ones.

Block.—Automatic block signaling is accomplished by the placing of fixed signals along the trackway, each of which being so controlled as to indicate to the engineman the presence of an obstruction within a pre-determined section of trackway ahead of the signal. This section of trackway is called a *block*.

Home and Distant Signals.—A signal which gives indications for the block *immediately ahead* of the signal is called a *home signal*, that is, a home signal is located *at the entering end of the block for which it gives indication*. In fig. 6,584 A, is a home signal protecting block BC.

D is another signal which repeats signal A, by giving two distinctive indications dependent upon the indication of signal

A, and is known as a *caution* or *distant signal*. Signal D, may also be arranged to indicate the condition of block EB, as a home signal and thus become a combination home and distant signal.

A home signal shows the condition of the block directly in front of a moving train; and a distant signal the condition of the second block in front, or the block in the rear of the home block. An advance signal shows the condition of a block in conjunction with the home signal of that block. It is placed in advance of the home signal

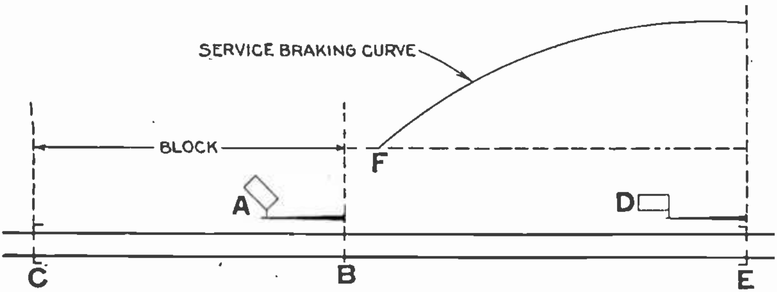


FIG. 6,584.—Diagram of block, illustrating home and distant signals.

It will be noted that the home signal *marks the entrance to the zone protected by the signal*, and, therefore, in case of an obstruction in this zone the signal may be of little or no value unless the train approaches it under full control.

The distant signal is designed *to afford advance information to enable the engineman to bring his train under control before reaching the home signal.*

It will be apparent that the distance between the home and distant signals should not be greatly in excess of the service braking distance for maximum speed, this in order to afford maximum facility and not require the engineman to carry the indication of the distant signal in his mind for a time after passing it before acting upon it.

Referring again to fig. 6,584, FE, is service braking distance for maximum speed and FB, is a reasonable margin of safety. It should be noted, however, that it is not by any means always practical to locate signals in accordance with these ideal principles. The distances, however, should never be less than those just indicated and it will be apparent that the value of the distant signal decreases as these distances increase.

Single Track Signaling.—This differs essentially from double track signaling in that *it must afford protection for train movements in either direction*, whereas double track signaling presupposes all train movements to take place only in a predetermined direction on a given section of track.

Thus, in fig. 6,584 a train after accepting signal A, at clear may expect to find block BC, clear. However, if trains were operated in both directions as on single track, another train moving from left to right might pass C, after the first mentioned train had accepted signal A.

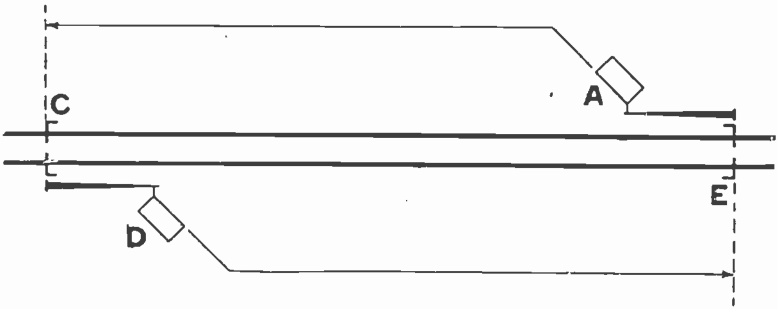


FIG. 6,585.—Signal arrangement which will afford certain protection for following movements, but not for opposing movements.

By providing another signal D, located at C, in fig. 6,585, to govern movements from left to right, and have signal A, control only to C, and signal D, to E, certain protection will be afforded for following movements, but is of little value to protect against opposing movements, as two opposing trains may pass signals A and D, respectively, at the same moment, both being clear, and meet in the middle of the block.

By providing an additional track circuit CE, and extending the control of signal A, to E, as in fig. 6,586, complete protection is afforded for opposing trains between B, and C, as a train moving from left to right will have caused signal A, to assume the stop position before it reaches signal D. It should be noted, however, that the extending of the control of signal A.

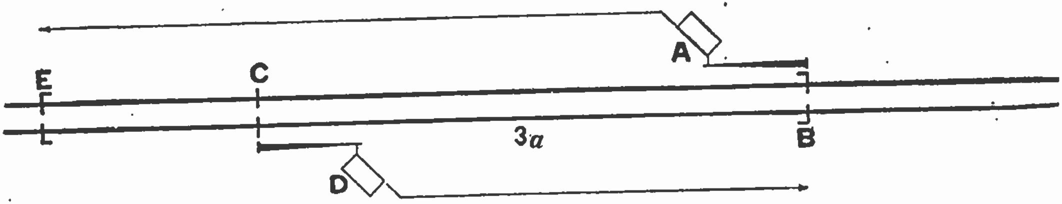


FIG. 6,586.—Signal arrangement with additional track circuit CE, and control extension of signal A, to E.

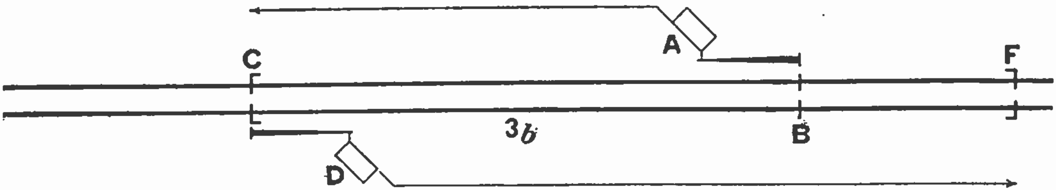


FIG. 6,587.—Signal arrangement giving protection for opposing movements by extending the control of signal D, to F.

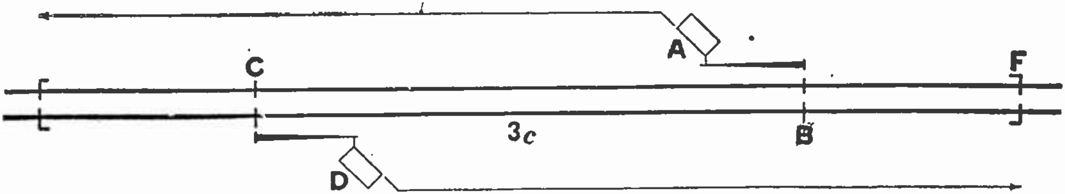


FIG. 6,588.—Signal arrangement giving complete protection by providing overlaps.

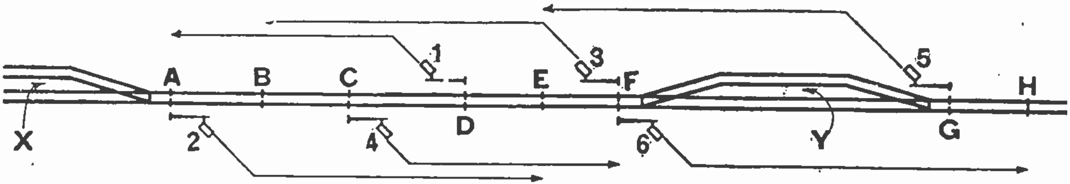


Fig. 6,589.—Early single track signal arrangements; X and Y, are adjacent passing sidings; signals 2 and 3, are starting or leaving signals; signals 1 and 4, are intermediate signals; signals 6 and 5, are siding signals.

may reduce facility as far as following movements are concerned, as the arrangement of signals may be such that a train moving from right to left need not have the protection of signal A, after it has passed C. This extension of the control of signal A, from C, to E, is called an *opposing overlap*.

The same degree of protection for opposing movements could be accomplished quite as well by extending the control of signal D, to F, as in fig. 6,587. The only difference is that preference would then be given to movements from right to left, while the arrangement shown in fig. 6,586, favors movements from left to right. Accordingly, complete protection is afforded by providing overlaps at both ends as shown in fig. 6,588. Earlier forms of single track signaling are based upon the principles just set forth and more or less literally applied.

Fig. 6,589 shows, as far as essential principles are concerned, the arrangement of signals and limits of control of the earlier forms of single track signaling. It will be seen that the arrangement affords complete protection in so far as it prevents one train colliding with another, either opposing or moving in same direction, so long as the signal indications are obeyed. There are, however, weaknesses in the system as follows:

1. Following trains are held apart farther than necessary. For instance, signal 2, must control to some point beyond signal 1, whereas from a standpoint of following protection this control need not go beyond signal 4.

2. With the controls as shown, after a train accepts signal 2, it will move to B, before placing signal 3, to the stop position. Meanwhile an opposing train can accept signal 3. Of course these trains will be held apart by signals 1 and 4, but delay and inconvenience will result. It is to be admitted that this condition can only exist as a result of error in, or disobedience to orders, but it is also good practice to make the signals prevent such a condition so far as it can be done without sacrificing other facility or protection.

3. Distant signals become of questionable value, as a train may get a clear distant indication and find the home signal at stop due to an opposing train having in the interim entered the block of the home signal. For example, if a distant signal be provided for signal 6, a train may find this signal clear and find signal 6, at stop due to an opposing train having entered the block of signal 6. Furthermore, it will be seen that this is not an unusual

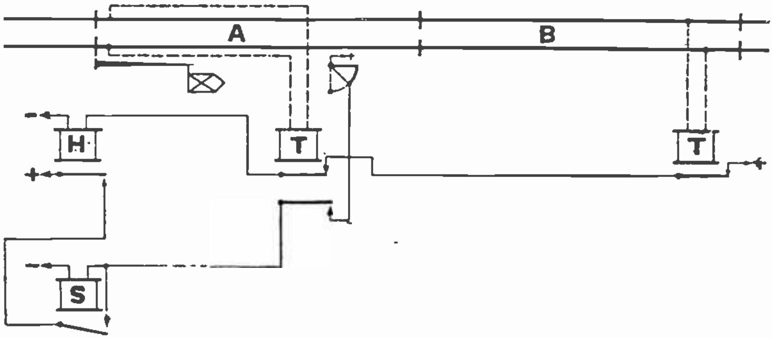


FIG. 6,590.—Absolute permissive block system circuits showing variable control by *stick relay*. H, is the control relay for the signal and is controlled by two track relays A, and B. S, is the stick relay. It will be noted that the pick up of the stick relay is through a back contact of relay of track circuit A, and a contact operated by the signal, which is closed say from 45° to 90°. The holding circuit for the stick relay is through a front contact of the stick relay itself, and a back contact of the signal control relay. It will therefore be seen that when a train passes the signal moving from left to right, it first drops relay for track circuit A, and the signal being clear, the pick up circuit is thus made. That is to say, the signal will remain clear for a sufficient length of time to pick up the stick relay and the stick relay will remain picked up as long as the signal control relay remains de-energized. It should be noted that the contact operated by the signal can be closed at any part of the stroke except that it must be open when the signal is at stop and must be closed for a long enough period after passing below the 45° position to allow sufficient time for the stick relay to pick up. It will furthermore be seen that a train moving from right to left will not pick up the stick relay, as the de-energization of track circuit B, will have caused the signal to assume the stop position before the train has reached track circuit A. Therefore, the pickup circuit will not have been made at any time.

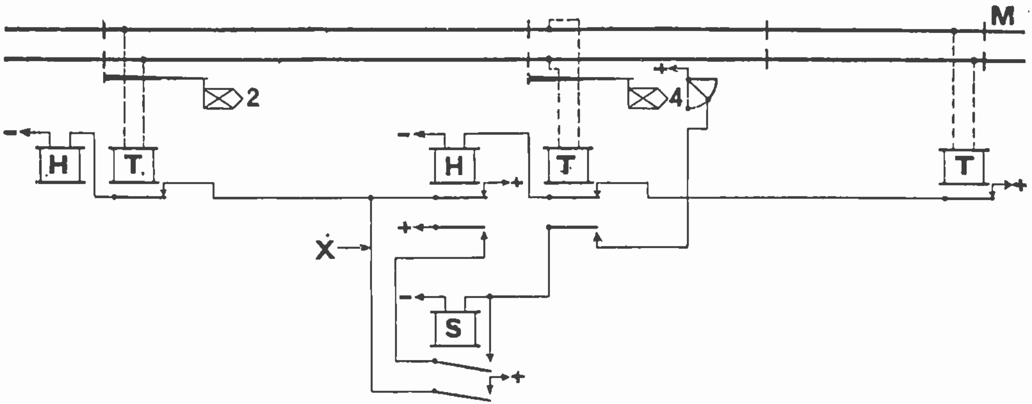


FIG. 6,591.—Absolute permissive block system circuits showing essential means of detecting traffic direction on single tracks. *In the diagram,* signal 4, controls to M. Also if wire X, be disregarded signal 2, will control to M, as the control for signal 2, is broken through the control relay for signal 4. It will be seen that wire X, feeds energy to the control wire for signal 2, when the stick relay is picked up even though the control relay for signal 4, is de-energized. Therefore, a train moving from left to right will allow signal 2, to clear as soon as it passes signal 4, as the stick relay will be picked up as long as the train is in the block of signal 4. However, in the case of a train moving from right to left both signals 2 and 4, will be caused to assume the stop position as soon as the train passes M, as the stick relay will not pick up for this movement. In other words, signal 2, has an overlap for opposing movements but not for following.

condition, but on the contrary, it is entirely regular when two opposing trains are approaching a siding for a meet and both are on time.

For a long time a considerable number of signal engineers questioned the advisability of automatic block signals on single track on account of these seemingly inherent shortcomings, and in order to overcome these defects a system known as the *absolute permissive block system* has been developed.

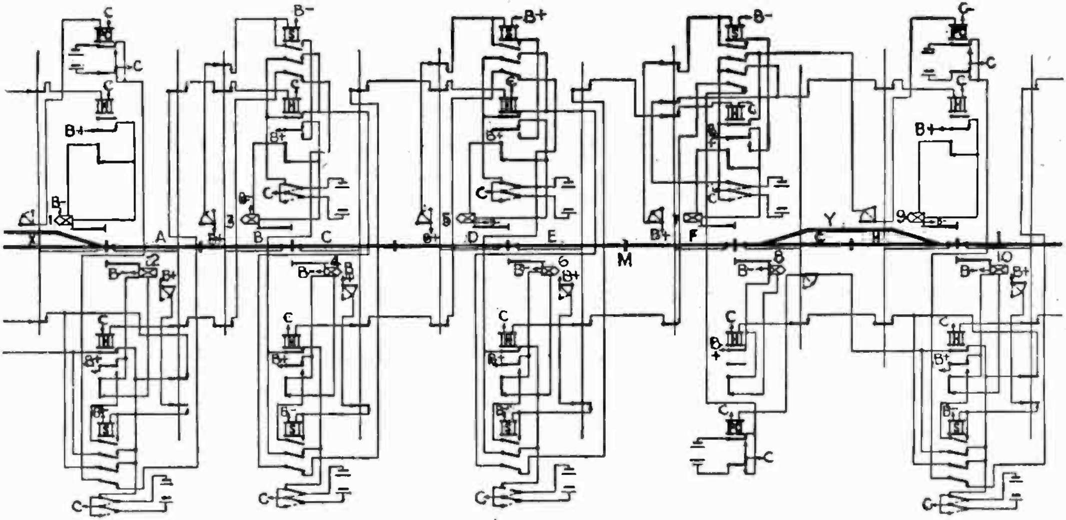


FIG. 6,592.—Absolute permissive block system circuit showing the arrangement of signals and circuits as usually employed. ***The diagram shows*** two simple sidings X, and Y, with the usual two signals at each end and with two pairs of intermediate signals. In this case both pairs of intermediate signals are shown opposite. However, the general scheme is not affected in the case of staggered intermediate signals. It will be seen that the control wire for signal 2, is carried forward and broken through front contacts of the control and stick relays at signal 4. Likewise the control of signal 4, is carried forward to signal 6. Signal 6, however, only controls to signal 8, or the end of the signal track block. Signals 7, 5 and 3, are controlled exactly the same as 2, 4 and 6. Therefore, a train moving from right to left upon passing signal 7, will cause signals 6, 4 and 2, to assume the stop position, as the stick relays at signals 4 and 6, will be de-energized. Thus, a long overlap is provided for opposing movements, to the next siding in each instance, and this is not objectionable in the case of following movements, as these overlaps are then cut off by the stick relays in a manner already explained. Furthermore, the siding signals have a varying control depending upon direction. For example, signal 9, controls to M, for opposing movements, but only to signal 7, for following. The net result is complete overlap protection from siding to siding for opposing movements, and signal to signal protection for following movements the same as on double track.

Absolute Permissive Block System.—This system is designed to afford: 1, Full overlap protection for opposing movements, and 2, Protection same as on double track for following movements.

This involves that the extent of control of a signal must be variable and depend upon the direction of traffic. For instance, in fig. 6,589, signal 2, must control at least to some point E, for opposing movements and preferably to signal 3, as the chances of opposing trains entering the single track between sidings X and Y, are thereby greatly reduced. Signal 2, however, for following movements needs only control to signal 4. The means for providing this variable control is an ingeniously arranged stick relay as shown in fig. 6,590. Thus, according to fig. 6,590, means are provided for detecting the direction of traffic, that is, a relay energized during the time a train is moving through a block in one direction and de-energized during the same period if moving in the other direction. An essential way, in which this means of detecting traffic direction applied to single track signaling, is shown in fig. 6,591.

The application of the principle shown in fig. 6,591, to actual single track conditions is shown in fig. 6,592.

It should be noted that in practice general modifications are made due to local conditions and general standards. For instance, siding arrangements and their relative positions vary; some roads want polar line circuits, while others insist upon neutral; some employ 3 position signaling, others 2 position; some use one battery for line and motor control, others use separate batteries. While the system as illustrated in fig. 6,592 is essentially the same as first conceived, it has fulfilled all the requirements.

NOTE.—Early in the development of the absolute permissive block system, certain protective features not heretofore described were recognized as necessary or advisable. For instance, the question was asked as to the result cf a stick relay remained picked up as might be the case if the control relay failed to pick up after the train had cleared its block. For example, if stick relay at signal 4 (fig. 6,592) be improperly picked up for any cause, signal 2, would then be at 45° even with an opposing train between signals 4 and 7. To protect against such a condition it will be noted that for instance the control for signal 5, is broken through a back contact of the stick relay for signal 4. Therefore, after a train has passed signal 4, moving from left to right the stick relay for signal 4, must again drop before either signals 5 or 7 can clear for an opposing movement. A careful study of the whole arrangement will disclose the fact that after a train movement has established traffic in one direction, the signals will not permit a reversal of traffic until the stick relays have been restored to normal or de-energized position.*

*NOTE.—In order to overcome the difficulties in connection with the distant signal, before referred to, it will be noted that the 90° position of signals governing the approach to sidings

D. C. Track Circuits.—The track circuit is the fundamental basis upon which the automatic signal has been developed. The simplest form of track circuit is the *d.c.* battery fed circuit as used on steam roads. This type of track circuit is shown in fig. 6,593.

Normally Closed and Normally Open Track Circuits.—The track circuit described in figs. 6,593 and 6,594 is of the normally

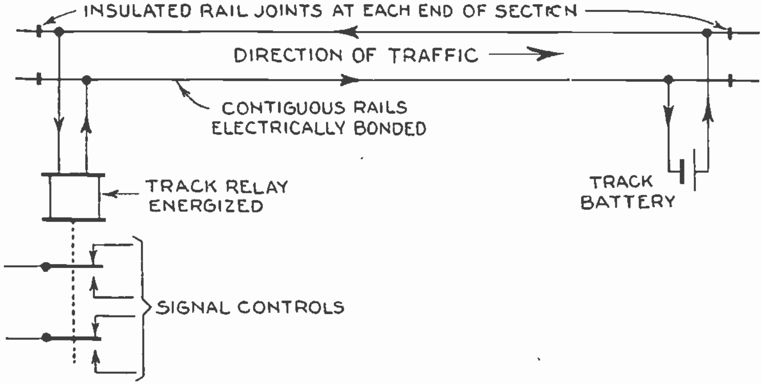


FIG. 6,593.—*D.C.* battery fed track circuit. The track relay is usually connected across the rails at the entering end of the section and the battery is connected across the rails at the leaving end, the rails forming part of the completed circuit. Contiguous rails of each section of track are electrically connected to each other with bond wires, and insulated rail joints are placed in both rails at each end of the section, insulating one section from the adjacent sections. The path of the current can be traced along the direction shown by arrows from the positive terminal of battery along one set of rails to the relay, passing through its coils, and returning along the other set of rails to the negative terminal of the battery.

NOTE.—*Continued.*

has been given a varying control depending upon direction. For instance, the 90° position of signal 6, depends always upon the position of signal 8, and upon signal 10, for opposing movements only. In other words, signal 6, will assume the 45°, as will also signal 8, as soon as a train, moving from right to left, leaves the siding next to the right of siding Y. However, this distant indication for following movements is the same as on double track. The great value of this feature will be apparent. The advantages are: 1. It prevents a condition in which a train passes a full clear signal and finds the next signal at stop and occupied by an opposing train. 2. It insures that a train will always get a caution signal when approaching a meeting point unless the opposing train has not left the next adjacent passing siding.

closed type since the circuit is complete through the relay when the track section is normal and unoccupied. The normally open type of track circuit is shown in fig. 6,595.

Basic Principle of Signaling.—Signal apparatus, controlling circuits, etc., must be so designed, installed and maintained that, so far as may be fairly practicable, *the derangement of any*

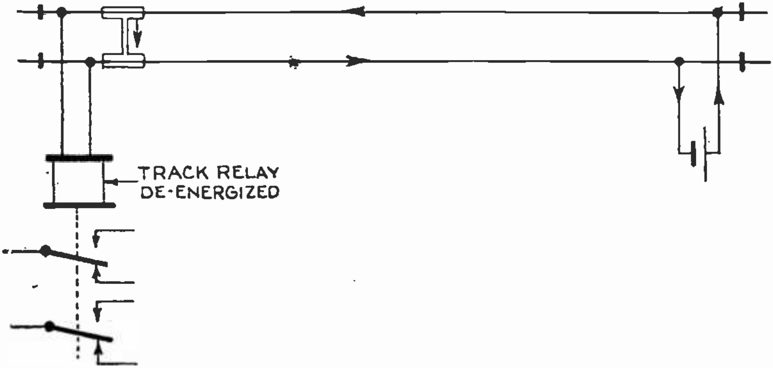


FIG. 6,594.—Diagram showing effect of a train in the block. This causes the current to be shunted through the low resistance return path offered by the pair, or pairs of wheels and axles of the train, and consequently there is little or no current flowing through the track relay. The relay is, therefore, de-energized during a train's occupancy of the section and the relay contacts are changed in position. Thus it is that the response of track relay to train movement through a section provides the means of automatically setting up circuit control conditions to supply or remove energy for any operated function, whether it be a line relay, signal light, signal motor, or other device. Thus is the means provided to control a signal to assume an aspect of color or position in the rear of a train which will indicate stop, or other less restrictive indication.

part, or failure of a part to perform its function, will react safely in its effect upon train movement.

This means that operations must rather be prevented at a time when they would be safe, than left free, by derangement, to be performed under unsafe conditions.

End Fed and Center Fed Track Circuits.—The track circuits shown in figs. 6,593 to 6,595, are of the end fed type. Fig. 6,596 shows a center fed track circuit where the track battery is located at the center of the block, and feeds both ways to relays at both ends. The presence of a train in this section de-energizes both relays.

While this type of track circuit requires the use of two track relays, it is employed to advantage on very long track sections where the use of end

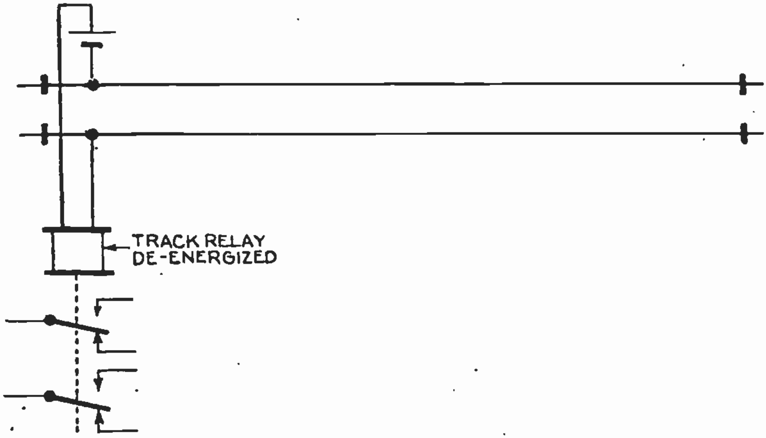


FIG. 6,595.—Normally open type, battery fed track circuit. In this type of circuit the presence of a train in the block completes the circuit through the track relay. While this type of circuit is economical in that it saves battery current, it has serious disadvantages and is used to a very limited extent. Its principal disadvantage is the uncertainty of the relay picking up. Any failures of the apparatus, such as a broken rail, exhaustion or breakage of the battery cell, or the breakage of any of the wires will render the apparatus inoperative. The detection of failures is not provided since the apparatus is maintained normal in the event of failure.

fed circuits would require a higher voltage to overcome the greater resistance of the long rail sections forming part of the circuit.

A. C. Track Circuits.—Alternating current track circuits and signaling are gradually superseding other systems. Being immune from the dangerous effect of extraneous direct current; being capable of selection between signaling current and the *a.c.* or *d.c.* propulsion current and giving more economical operation where *a.c.* power is obtainable, the *a.c.* track circuit is being used almost universally on electrified railroads.

Where the traction current is *a.c.* the signaling current is of a different frequency. The principle of *a.c.* track circuits is similar to that of *d.c.* circuits. The high tension signal voltage is stepped down from the signal mains by means of transformers to the required working pressure for the track circuits. *A.c.* track circuits for use on electric lines are divided into two classes, viz. single rail and double rail.

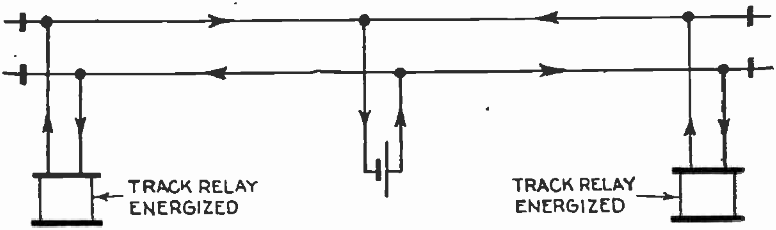


FIG. 6,596.—Center fed track circuit.

Single Rail Track Circuit.—When one rail provides sufficient conductivity for the negative return traction current, and where complete broken rail protection is not a requirement, the single rail track circuit is employed.

On account of its comparative simplicity, it is also used in yards or other complicated sections of special track work where the use of impedance bonds required in connection with double rail track circuits would be difficult of installation. Fig. 6,597 shows a typical *a.c.* track circuit.

Double Rail A.C. Track Circuit.—Where both rails must be retained to provide sufficient conductivity for the negative return traction current, or where broken rail protection is a requisite, the double rail track circuit must be employed. In this type of track circuit both rails are also used for the signaling current. A typical double rail *a.c.* track circuit is shown in fig. 6,598.

Impedance Bond.—This usually consists of a laminated iron structure in which is placed a coil of a few turns of heavy copper conductor.

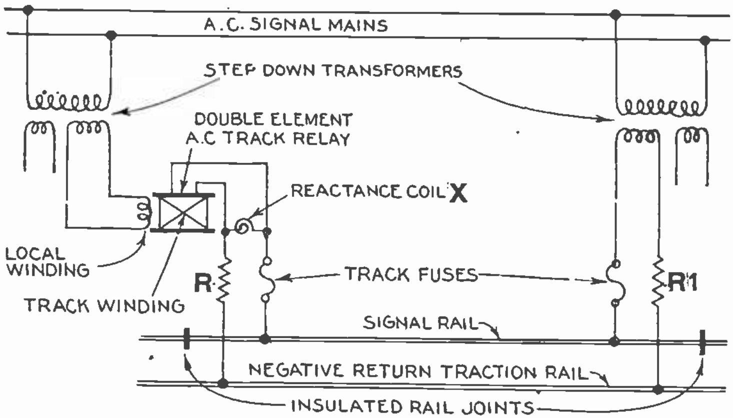


FIG. 6,597.—Single rail *a.c.* track circuit. *In this type* of track circuit only one rail, the signal rail, is insulated at either end of the block. The other rail is used jointly for the signal current and the traction current. The double element relay shown in the diagram permits of a low voltage being employed for the track circuit, which is advantageous. This voltage must be low or the circuit becomes supersensitive to leakage variation between rails. The reactance coil X, is shunted across the track relay where traction current is *d.c.* to limit or by-pass the *d.c.* which would otherwise flow through the relay, as inter-rail voltage exists on single rail circuits. The reactance coil is designed to impede the flow of *a.c.* and to offer low ohmic resistance to the flow of *d.c.* The resistance R, also limits the flow of *d.c.* to relay. The resistance R1, limits the *d.c.* to the transformer and also limits the flow of short circuited *a.c.* from the transformer when a train is in the block. While the *a.c.* track relay will not respond to *d.c.* its efficiency is lowered by the flow of *d.c.* through its windings.

NOTE.—*Another point* in connection with *a.c.* track circuits is that adjacent track sections are always fed with alternate polarities from the transformers. This provides for the detection of broken down insulated joints. With the type of double element track relay shown, that is with one winding fed from the track and the other winding fed from a local source of energy, the relay will operate in one direction with a given polarity, and will operate in the other direction if the polarity be reversed. Therefore, if either of the insulated joints should break down, the energy from the transformer passing across the broken down insulation would cause the relay of the adjacent track circuit to open positively thus setting the proper signals at stop and caution. With relays which take all their energy from the track this will not hold true.

The coil and laminations are enclosed in a waterproof iron case. The ends of the coil and a tap from the middle of the coil are brought out through the sides of the case and are provided with suitable terminals so that connections can be made to the rails and between the bonds with heavy copper cable.

Impedance bonds are located in the middle of the track between the traffic rails and are set down in the ballast between the ties so that the cover of the

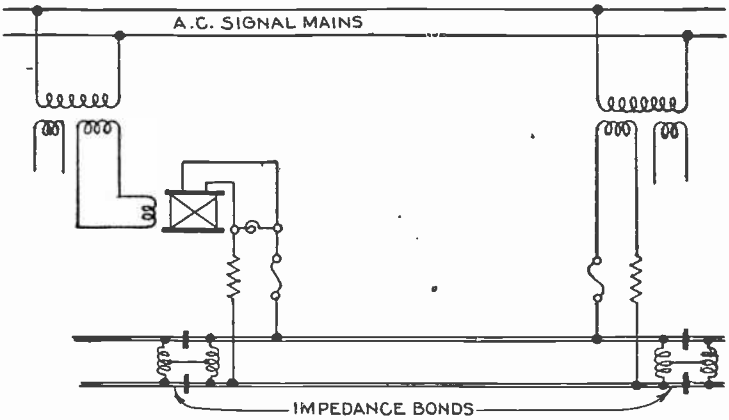


FIG. 6,598.—Double rail *a.c.* track circuit. This differs from the single rail track circuit in that both rails are insulated at either end of the block and that impedance bonds are used. The function of the impedance bond is to keep the rails electrically continuous for the traction currents and at the same time electrically separated for the signaling current. It can be seen from the method of connection of these bonds to the rails that if it were not for the impeding or choking effect of the bond, a short circuit between the rails would ensue. ***In operation*** direct currents flowing into a bond from the two rails toward the middle point of the bond are in opposite directions and the ampere turns due to each half of the coil tend to neutralize each other so that when the same amount of current flows in the bond from each rail the resultant ampere turns are zero. The *d.c.* traction current, therefore has no magnetic effect on the bond unless more current flows in one rail than in the other. in which case it would have a magnetizing tendency, which if too great, would lower the reactance of the bond, changing its resistance to alternating currents, and lowering the voltage available for the operation of the track relay. As this difference of current in the rails, called unbalancing, is likely to occur due to poor rail bonding connections in either rail, the impedance bonds are designed with an air gap in the magnetic circuit which makes them less sensitive to unbalancing. The reason for the impedance bond's high resistance to the flow of *a.c.* is as follows: Whenever a current is caused to flow through a coil, especially when wound on an iron core, a strong magnetic field is produced which in becoming established produces a counter electromotive force which opposes the impressed voltage and delays the building up of the current. If now, the current be caused to alternate many times a second, it will never be permitted to build up to its full value, that is, as represented by a constant voltage divided by the ohmic resistance.

case is just above the top of the ties. The method of connecting impedance bonds and their operation is shown in figs. 6,598 to 6,600.

D. C. Track Relays.—These instruments are usually of the tractive type or motor type. Figs. 6,601 and 6,602 illustrate the two types of relay.

A. C. Track Relays.—There are three important types of *a.c.* track relays known as

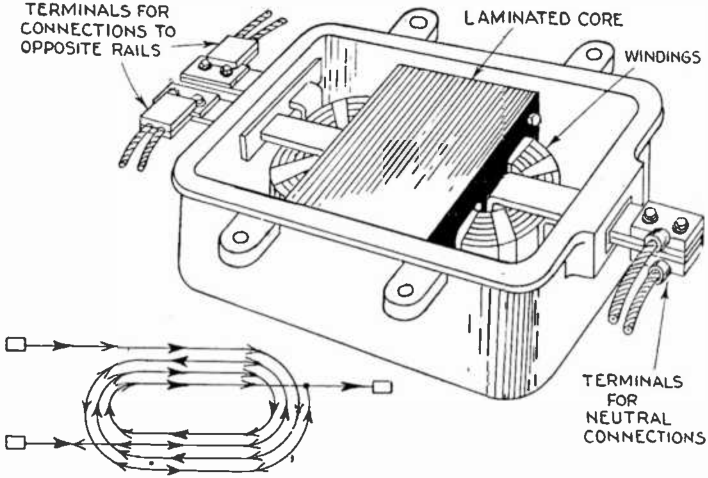


FIG. 6,599.—Impedance bond with cover removed.

FIG. 6,600.—Diagram of current in impedance bond. Heavy arrows indicate parallel paths of *d.c.* Light arrows indicate impeded *a.c.*

1. Galvanometer relay;
   - *a*. Ironless.
   - *b*. Iron.
2. Vane relay;
   - *a*. Single element.
   - *b*. Double element.
3. Polyphase relay.

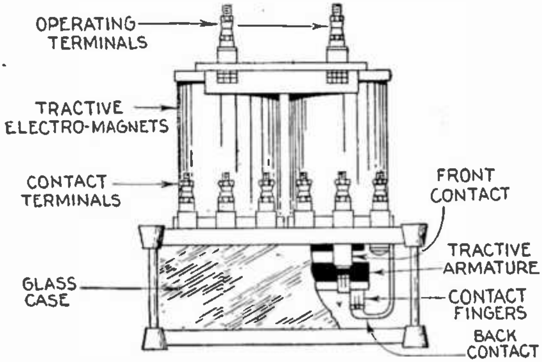


FIG. 6,601.—*D.c.* tractive type track relay. ***The operation*** for the changing of contact positions depends upon the principle of electro-magnetic attraction. The electro-magnets when energized attract an armature which actuates the mechanical movement of the relay contacts, picking them up. The de-energization of the relay allows the armature and contacts to drop away by gravity.

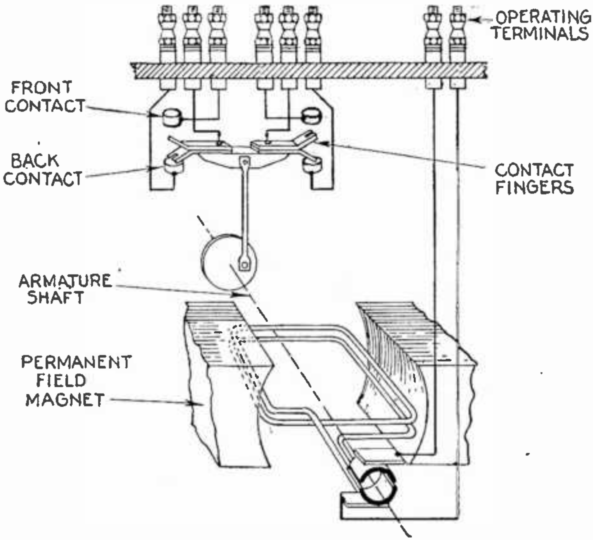


FIG. 6,602.—*D.c.* motor type track relay. ***The operating mechanism*** usually consists of a small *d.c.* motor having powerful permanent magnet fields. The contacts are moved from the de-energized to the energized position by rotary motion of the motor armature, the movement of which is transmitted to the contacts by suitable link arrangement.

Galvanometer Relay.—The ironless galvanometer relay is of the two element type, having *two separate windings and operating as its name implies, on the galvanometer principle.* Fig. 6,603 illustrates this relay.

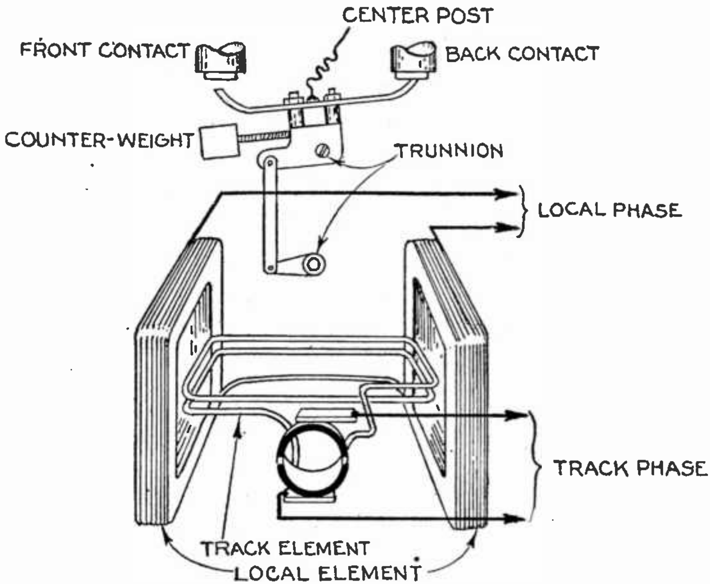


FIG. 6,603.—Ironless galvanometer relay. ***The essential parts*** are the local coils and the armature or track element swinging in the center of the local coils. The armature consists of a comparatively few turns of heavy wire formed and clamped to, but insulated from, a swinging frame attached to the armature shaft. With current supplied to both windings the necessary torque is produced in the armature, rotating the shaft, and operating a contecting link which actuates a pivoted bar carrying the contact fingers. When current ceases to flow in the armature, the torque is no longer existent, and a counter-weight is acted upon by gravity to restore contacts to original position. This relay operates most economically and effectively when its track and local elements are exactly in phase or 180° out of phase.

Another important type is the iron galvanometer relay shown in fig. 6,604.

Single Element Vane Relay.—This is an early type, being the first *a.c.* relay used for signaling purposes. Its construction and operation are shown in figs. 6,605 and 6,606.

Double Element Vane Relay.—This is one of the most efficient *a.c.* relays used in track circuit work. Unlike the single element relay, it is well adapted for operation on long track circuits. It is shown in figs. 6,607 to 6,609.

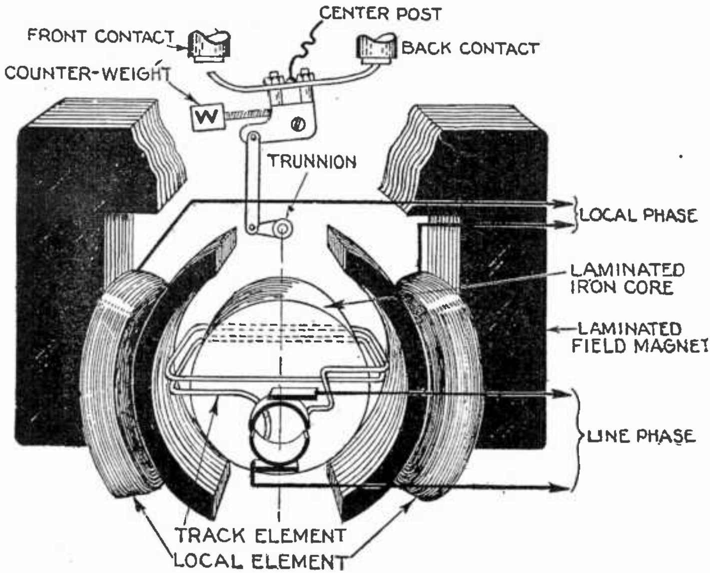
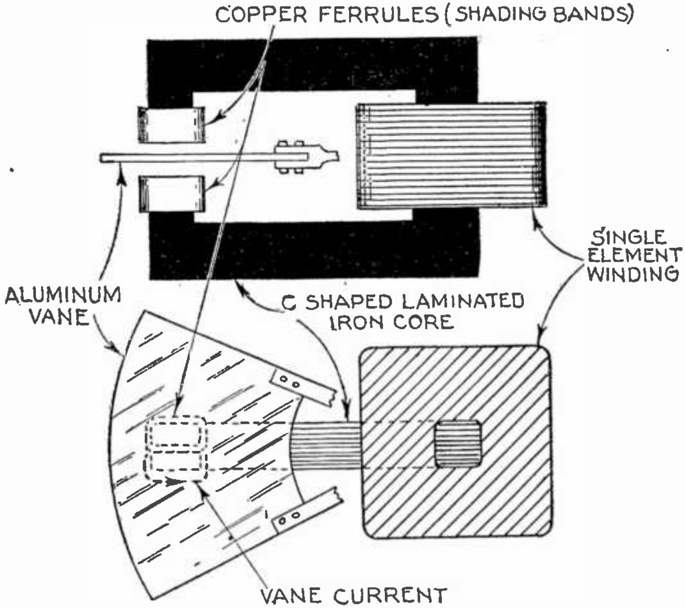


FIG. 6,604.—Iron galvanometer relay. This relay is the same in principle as the ironless galvanometer relay and the constructive design of the two relays would be very much the same, if it were not that an iron magnetic circuit is employed in the iron galvanometer relay. Iron field cores are used to make the relay more economical from the standpoint of power consumption. A strong magnetic field can be produced with a small energization of the local magnetizing coil when an iron core is used. As with the ironless galvanometer relay, this relay operates best when its track and local elements are exactly in phase or 180° out of phase.

Polyphase Relay.—This relay is generally looked upon as being the most economical for track circuit work and it is well adapted for use on long track circuits. This is a double element relay and as shown in fig. 6,610, is operated by a polyphase motor which consists of a non-magnetic rotating shell or rotor and fixed inner and outer cores, the outer core being the stator on which the windings are placed.

Electric Automatic Train Stop.—On railroads where a close headway between trains must be maintained with a maximum of safety, such as on rapid transit roads, the automatic train



Figs. 6,605 and 6,606.—Single element vane relay. It has an aluminum vane pivoted and moving vertically between the poles of a C-shaped laminated magnet core. The relay depends upon electro-magnetic induction for its operation. When the coils are sufficiently energized, the vane is caused to move upward between the pole faces of the electro-magnet, the upper halves of which are equipped with shading bands, which in combination with the *a.c.* supplied, give rise to a continuously shifting magnetic flux, producing a continuous torque in the vane. The movement of the vane, by a simple link arrangement, causes the contact shaft on which the contact fingers are mounted to be moved so as to change the contact positions. When the relay is de-energized, the vane which is counter weighted, drops by gravity on to a small fibre roller which acts to bring the vane to rest without shock or rebound. The single element vane relay, from the standpoint of power economy, is not well suited for use on very long track circuits, because the single element winding must receive all its power over the rails, and cannot, consequently, equal the power economy of two element relays on long track circuits, particularly where the ballast is poor.

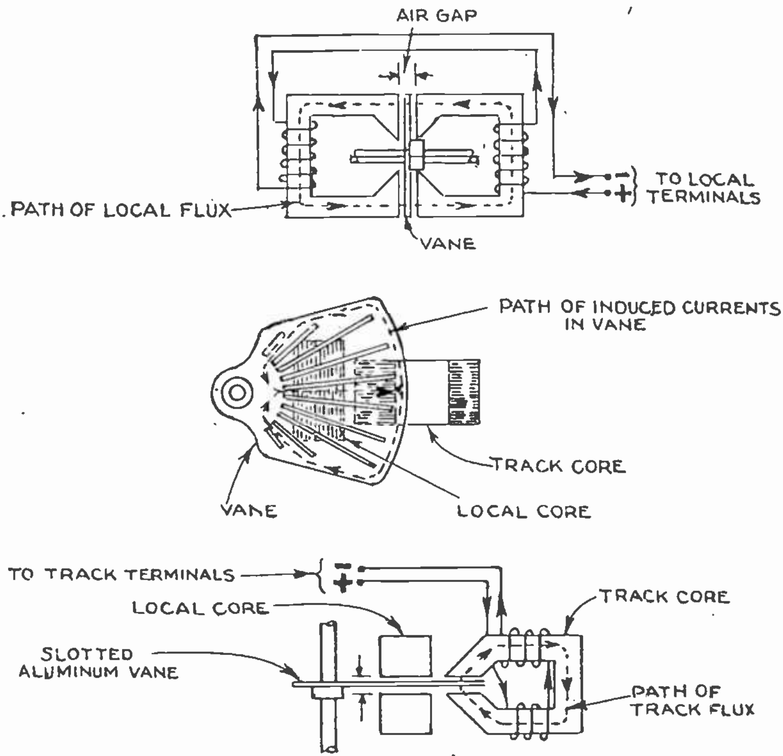


FIG. 6,607 to 6,609.—Double element vane relay. *It has* two local iron cores, one on each side of the vane; one track core which has a pole on each side of the vane at its outer radius. The local and track iron cores are fixed at right angles to each other. A vertical slot is formed by the two U-shaped local cores, and in this the vane is placed so that all the local flux passes twice through the vane but in opposite directions. The result of this flux cutting the aluminum conductors formed by radial slots in the vane is that currents are induced in the vane and are compelled to travel along the paths between the slots. The currents thus induced pass in a horizontal direction between the poles of the track core and lag 90° behind the local flux. When a current is sent through the track winding, it induces a flux across the vane which produces a force on the conductors of the vane at right angles to the direction of the currents. This tends to move the vane in a vertical direction, either upward or downward according to the direction of the currents in the track winding relative to the local current. Unlike the galvanometer relay, the double element vane relay should be supplied with current to its track element as nearly as possible in quadrature, 90° out of phase, with the current in the local element, for most efficient operation.

stop is an essential element which operates in conjunction with the signal to enforce obedience upon the part of motormen to the information conveyed by the signal.

The train stop *assumes that position which would trip and apply the emergency braking system on a train at such times*

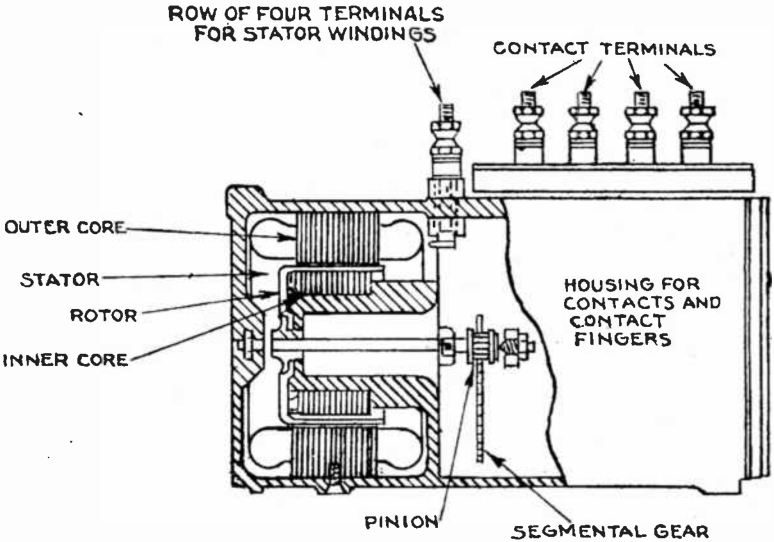


FIG. 6,610.—Polyphase relay. The motor windings are designed and connected so as to produce, with *a.c.* applied, a rotating magnetic field, which in turn induces currents in the non-magnetic rotor causing it to operate. The rotor is ordinarily connected to operate the contact fingers through the medium of a pinion and sector arrangement, thereby multiplying the effect of the rotor and permitting the operation of a large number of contacts with a very small amount of energy applied.

when the signal is indicating stop. One type of electric automatic train stop is shown in fig. 6,611.

Electro-Pneumatic, Automatic Train Stop.—This type of train stop is controlled electrically, but operated by compressed air. Its essential features and operation are shown in fig. 6,612.

A more recent development of the electro-pneumatic automatic train stop is the rack and pinion type.

In this type the mechanism has been designed along more compact lines. The piston transmits motion to a rack which rotates a pinion on the stop arm shaft, bringing the stop arm to the lowered or clear position. Upon the removal of energy and the consequent release of air pressure from piston,

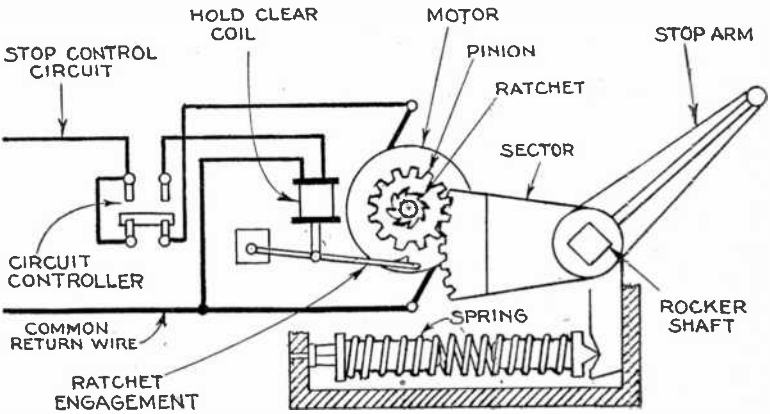


Fig. 6,611.—Electric automatic train stop. It consists of a motor operated pinion and sector mechanism which rotates a shaft to which is attached a stop arm so located with relation to the track and trains as to engage with a tripping device on the train when the train stop is in the stop position. Engagement of the stop arm with the tripping device on the train operates to automatically apply the air braking system on the train. In order to clear the stop and retain it in the clear position, energy must be supplied from the stop control circuit. The motor then operates the geared mechanism which rotates the shaft against the action of a helical spring in such a direction as to lower the stop arm to the clear position. The motor also operates a circuit controller which opens the motor circuit after the stop arm is lowered, and transfers energy to a hold clear coil. The hold clear coil which is in the form of a solenoid operates a device which engages with a ratchet on the motor shaft thus retaining the stop arm n the lowered or clear position, with little current consumption, until such time as electric energy is removed, when spring action restores the motor armature, geared mechanism, circuit controller and stop arm to the original stop position. The stop being held in the clear position only at such times as electric energy is applied is along the lines of safety since with this arrangement a broken wire would remove energy and cause the stop to assume the stop position. The arrangement is therefore consistent with the basic principle of signaling which requires that the failure of an essential part will cause the signal and its stop to assume their most restrictive positions.

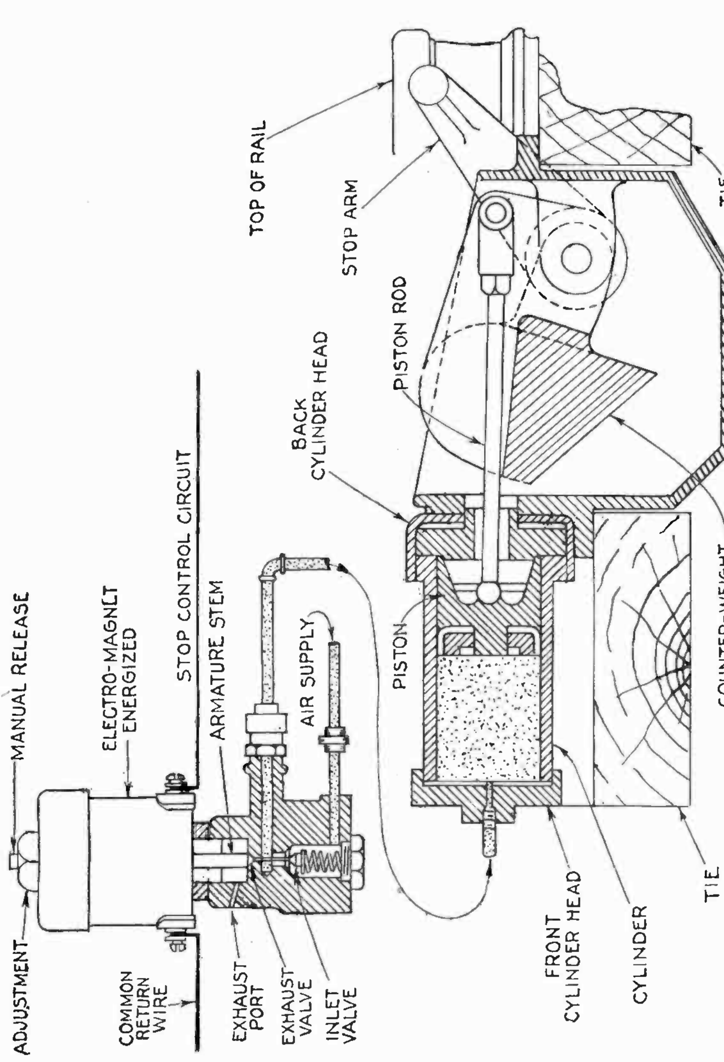


FIG. 6,612.—Electro-pneumatic automatic train stop. ***In operation,*** the energization and de-energization of an *a.c.* electro-magnet operates a pin valve governing the admission to, and release of compressed air from, an air cylinder with piston for the

FIG. 6,612.—*Text continued.*
mechanical movement of the stop arm. With magnet energized, armature and armature stem are drawn down, closing exhaust valve and opening inlet valve. Path of compressed air is then from air supply line, through inlet valve, through piping to air cylinder on stop mechanism. Piston in stop cylinder is moved to the right against back cylinder head. Movement of piston is transmitted along piston rod rotating counter-weight upward against gravity, and stop arm to clear position. When magnet is de-energized armature and armature stem are sprung up, closing inlet valve, thereby shutting off air supply. Exhaust port in magnet valve is open permitting air to exhaust from air cylinder at stop mechanism, through piping, through exhaust valve, through exhaust port to atmosphere. Counter-weight is acted upon by gravity and rotated to low position, bringing stop arm to upright or engaging position. It will be noted from the foregoing that a broken stop control wire or a break at any point in the air line would permit counter-weight to be acted upon by gravity to place stop arm in the engaging position to trip a train, also setting the signal at stop indication since the red light at signal receives energy direct through closed contact on stop circuit controller when the stop arm is in the tripping position. The circuit controller operates to change its contact positions with the positions of the stop arm.

the rack is moved back by the action of the helical spring under compression, and the pinion on stop arm shaft is rotated in such direction as to bring the stop arm to the engaging position for tripping a train.

Typical Automatic Block Signal Circuit.—The circuit diagram shown in fig. 6,613, is fairly typical of complete electrical controls for an automatic block signal and train stop as used in the New York subways where the overlap system of signal control is a necessary feature and where color light signals are used. This circuit has been chosen as presenting most in the way of signal control principles.

An understanding of the principles involved will therefore cover the necessary part of their application to less complicated conditions such as would be encountered on steam railroads. It should be remembered that signal control circuit design is subject to many ramifications, depending upon the conditions to be met and the degree of safety to be provided.

Signal Overlap Control.—This form of signal control is essential *to maintain the proper spacing of trains running on a close interval.*

It provides for overlapping the line control of a signal into the block section beyond the immediate or home block into which the signal governs train movement.

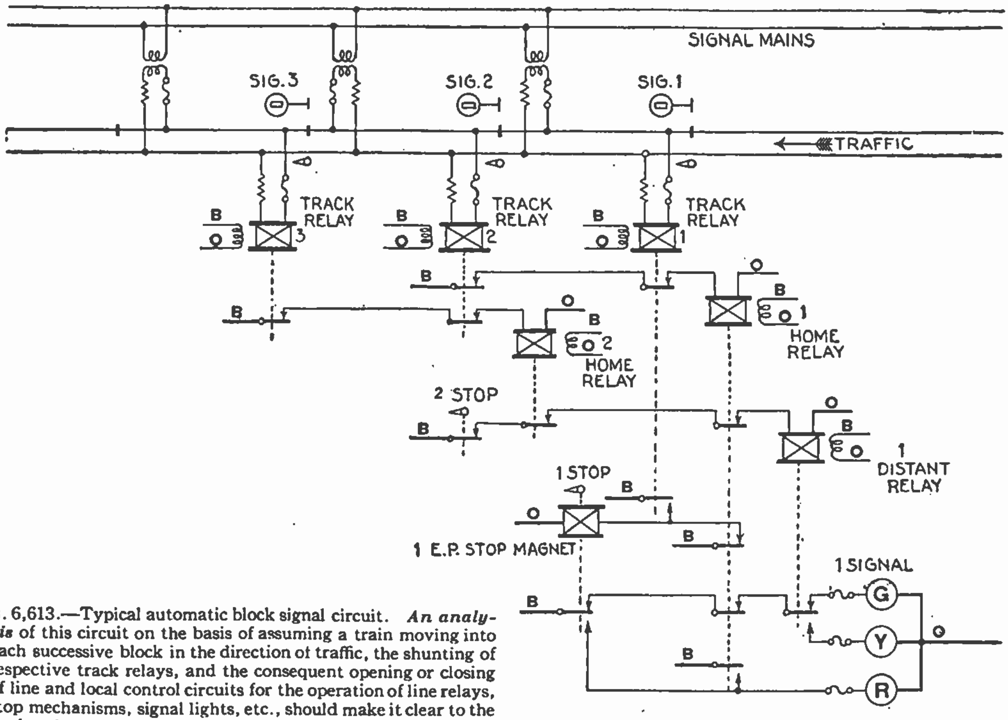


FIG. 6,613.—Typical automatic block signal circuit. *An analysis* of this circuit on the basis of assuming a train moving into each successive block in the direction of traffic, the shunting of respective track relays, and the consequent opening or closing of line and local control circuits for the operation of line relays, stop mechanisms, signal lights, etc., should make it clear to the reader that the signal indications in the rear of a train are such as to provide complete overlap protection, and that the co-ordination of stop arm position with signal indication is such as to trip a train should the information which signal conveys be disregarded. The reader is referred to "Signal Indications" covered in Chapter 145 on Railway Signals.

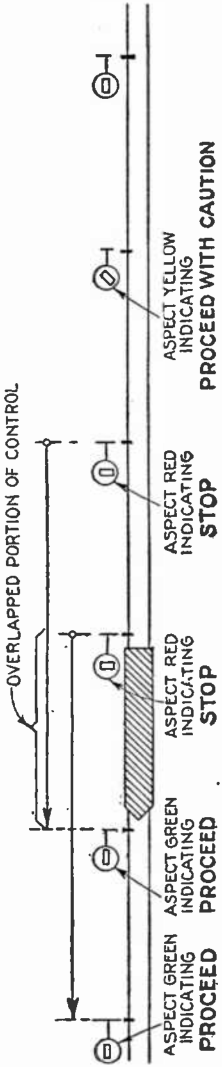


FIG. 6,614.—Signal overlap control.

As will be seen from fig. 6,614, there are always two signals displaying the stop indication in the rear of a train. Since the signals are located so as to provide braking distance for maximum speed of trains, plus a factor of safety, between each two signals, the system provides for a safe spacing of trains.

Scientific Location of Signals.—Signaling of a railroad is based on space intervals determined by time and not by distance.

Knowing the maximum number of trains per hour or the shortest time interval between trains, it is possible to signal a length of track which will keep trains moving without any check or stop, other than those required at stations.

On suburban lines, or where the traffic is light, the spacing between signals may be of considerable length and is subject to some latitude; but on congested lines and on rapid transit railways, the spacing of the signals is close and their location has become an exact science.

The location of automatic block as well as interlocking signals on railroads of this character can only be determined with careful consideration being given to the following elements:

1. Headway of trains and length of time of station stops.

2. Physical characteristics of the line. This includes such factors as grade and alignment of tracks, locations of switches, stations, etc.

3. Average and greatest length of train.

4. Permissible and possible speeds of trains over the sections to be signaled.

5. Operating characteristics of signal apparatus.

6. Motor and braking characteristics of car equipment.

This includes acceleration rates as well as deceleration rates for both emergency and service braking of loaded trains on level track and various grades.

7. The system of train operation, and required train movements at interlockings.

These elements enter into the basic design of the signal system and most of them can be set down at fairly definite values, and the usual practice is to combine the known quantities in proper relationship, in the form of operating curves, these curves being plotted for the entire length of each track.

By placing side by side the curves of two consecutive trains operating on the required schedule, the locations of signals between the two curves may be scientifically determined so as to meet the operating requirements.

In locating the signals, however, allowance must be made for the indefinite elements in the problem, and for the deficiencies in the car and roadway equipment. These curves represent the probable operating speed of the trains, on the required headway, which takes care of the capacity element of the problem, but the signal locations must also take care of the safety element, and the length of control of each signal spotted between the two operating curves must be such as to provide braking distance at maximum speed. A system of signaling laid out in this way will make for an equable movement of trains with a maximum of safety.

Speed Control of Signals.—This system of signal control *finds its greatest usefulness on rapid transit railroads.*

Perhaps the most important use of the speed control signal is *for closing in trains at busy stations where the duration of station stop is greater than at other stations of the line.*

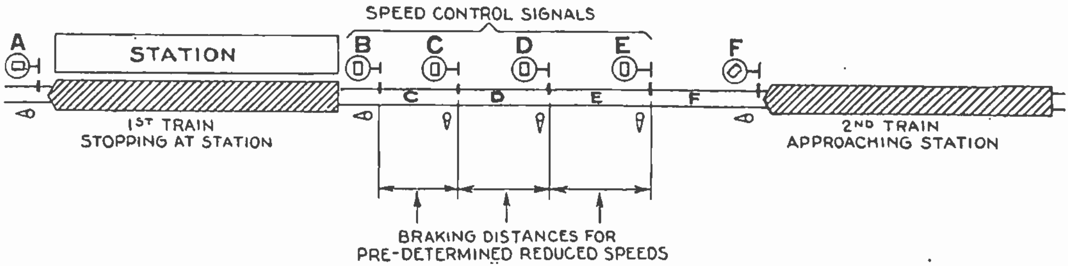


FIG. 6,615.—Speed control of signals. *In operation* a second train upon entering a signal block F, sets in motion a time element relay. Through the contacts of this relay the control circuits for signal E, are carried in such manner as to hold this signal and its automatic train stop at danger. The time element relay operates to pick up on a time interval. That is, upon receiving energy with the passage of second train into signal block F, the relay will operate to change the position of its contacts after a certain fixed interval of time has elapsed. This time interval is pre-determined depending on the speed at which it is necessary to hold trains, and relay is set accordingly. With a train moving through this block at prescribed speed, time element relay will operate to clear signal E. This process is repeated on train's approach to signal D, and so on. If train should exceed speed limit in any block, it will have arrived at speed control signal before the time element relay has operated to clear signal, hence train will be tripped. With no trains stopping at station, circuits are so arranged that speed control signals do not function as such, but give clear indications, allowing train to pull into station without reduction in speed.

This long station stop is a limiting factor to headway and while everything is done to reduce its duration there is a fixed minimum under which there can be no further reduction. The speed signal in this case operates to allow a train to approach close to the station at reduced speed when the station track is already occupied by a train. This reduction of approaching train's speed lessens the braking distance required between the train in station and approaching train, hence there is no sacrifice of safety. The consequent reduction of the distance between train about to depart from station and train about to enter station saves time in the operation proportionately as this distance is reduced. This reduction of time between trains passing through a station increases the number of trains that can be operated through the station per unit time, hence shortens headway or increases carrying capacity. How this closing in of trains to station at reduced speed is accomplished is shown in fig. 6,615.

Not only does the speed control signal save time when closing in trains at stations, but its tendency is *to keep trains moving*.

This is a decided advantage, from the standpoint of power consumed in starting trains.

The speed control signal may also be used to advantage to compel a pre-determined reduced speed on curved sections of track and on long steep down grades where safety may require a check on train speed, and over slow speed switch layouts.

In such cases, where the regulation of train speed is required, at all times, the circuits are arranged so that the speed control signals are normally at danger and clear always on a time interval with the approach of a train.

In other respects the process of governing the speed of the train is similar to that already described.

Speed control signals are most effective when the signal blocks through which the speed of trains are controlled are comparatively short, say 200 feet, approximately. This arrangement removes the possibility of a motorman moving his train at very slow speed in the forward part of the block and accelerating beyond unsafe limits in the remaining portion.

TEST QUESTIONS

1. *What is the primary purpose of automatic block signals?*
2. *What is a block?*
3. *Define home and distant signals.*
4. *How does single track signaling differ from double track signaling?*
5. *Describe at length the method of single track signaling.*
6. *What is the object of the absolute permissive block system?*
7. *What is the principle of* d.c. *track circuits?*
8. *How does the normally closed track circuit differ from the normally open track circuit?*
9. *Describe a* d.c. *battery fed track circuit.*
10. *Explain at length the basic principle of signaling.*
11. *Draw a diagram showing effect of a train in the block.*
12. *What determines the choice between end fed and center fed circuits?*
13. *Draw a diagram of a normally open type battery fed track circuit.*
14. *What are the advantages of an* a.c. *track circuit?*
15. *Describe a single rail track circuit.*
16. *Where should a double rail* a.c. *track circuit be used?*
17. *What is an impedance bond?*
18. *Draw a diagram of a single rail track circuit.*
19. *Describe the various types of relays.*

20. *What is an electric automatic train stop?*
21. *Describe the electro-pneumatic automatic train stop.*
22. *Draw a diagram illustrating single overlap control.*
23. *For what service is speed control of signals used?*

CHAPTER 147

Interlocking

By definition interlocking is *the operation of a system of switch, lock and signal apparatus so inter-connected that the movements of all members of the system must succeed each other in a predetermined order.*

Interlocking governs the movement of trains over conflicting routes, as distinguished from block signaling which governs the movements of following or opposing trains over the same route.

Interlocked switch and signal appliances were first devised and used at junctions and terminal points for the purpose of reducing the number of men employed to go from switch to switch, throw them by hand and then give a hand signal for the train to proceed over the route thus lined up. It was soon found that operating the switches and signals from a central point under the control of the levers in an interlocking machine greatly expedited the handling of traffic. By far the greatest accomplishment of interlocking, however, was the addition to train operation of an enormous factor of safety at such points.

Four distinct systems of interlocking have long been known and are in wide use:

1. Mechanical;
2. Electro-mechanical;
3. Electric;
4. Electro-pneumatic.

The last three are classed as power systems as distinguished from the mode of operation of the first which is by hand.

Each of these four systems is more suitable than any of the others for use in some places and under some conditions. It is often the case, that the decision which system to use, is obvious; but it is also often the case that the decision is close and calls for much study and for sound judgment, the latter presupposing accurate knowledge of many facts.

Power interlocking, like power signaling, had its origin and its engineering and commercial development in the United States.

This relates to the art as actually applied on a large scale to practical use. There were European inventors early in the field, but their inventions were not of real importance until long after the electro-pneumatic interlocking had become in the United States a well known and highly developed means of safety and economy. Interlocking is an example of the use of machinery in place of men.

An interlocking plant consists of *a group of levers concentrated at a central point for operating certain switches and signals, and so arranged as to interlock such levers and make it impossible to give clear signals for conflicting routes*. The advantages derived therefrom are safety, facility of operation and saving in cost of manual labor employed.

Distinction is made between several kinds of locking, classed as:

1. Section locking;
2. Sectional route locking;
3. Approach locking;
4. Stick locking;
5. Check locking.

Section Locking.—Section or detector locking consists of *the control of switches by track sections which may form a part or all of a route and of which the switches protected are a part.*

Sectional Route Locking.—It is desirable to prevent the manipulation of any switch after a train has passed a signal governing movement over that switch, no matter how remotely the signal may be located from the switch in question. This leads to the control of a switch by more than one track section, or route locking.

Where traffic is heavy it is also desirable that the switches be released as quickly as practicable after a train has passed over them. That is, the switches in one section may be released while those in another section of the same route are still electrically locked, for traffic in a certain direction. This is a question of expeditious handling of traffic and not of safety and is called sectional route locking.

Approach Locking.—In the early days of interlocking, some assurance of protection against a switch being changed in position, after a train had accepted and passed a clear signal, was provided by the introduction of a time element between the return of the signal to stop and the movement of the switch points. This was called time locking. It is evident that under certain operating conditions complete reliance for safety cannot be placed upon a time interval, so that in most power interlockings to-day what is called approach locking has superseded time locking for high and medium speed routes.

Approach locking provides that *while a train is approaching an interlocking signal which indicates proceed, the switches over which this signal governs train movement cannot be changed in position.*

The leverman always has the ability to cause signals to assume their most restrictive positions, as it may become necessary for him to stop a train after he has once cleared the signal for it to proceed. Approach locking provides that he cannot, even after restoring the home signal to a stop position, immediately change position of any switch which might affect the route for train movement. A provision to take care of an emergency requirement is made by the use of a clockwork time release not mechanically connected to the lever.

Ordinarily approach locking circuits are made effective as soon as a train enters the track circuit approaching the distant signal, so that if the distant signal indicates proceed the train is protected long before reaching the home signal near the derails and switches.

Stick Locking.—This is another form of approach locking, being different in that it becomes effective upon the reversal of the home signal lever and does not further depend on the approach of a train.

Check Locking.—This consists of *the intercontrol between levers in separate interlocking machines.* This is ordinarily required when provision must be made for reversing the normal direction of traffic between two interlocking plants.

It is accomplished electrically by means of lever locks which are similar to those used in connection with approach, route and section locking There must be cooperation between levermen before a signal can be cleared for train movement onto the track protected.

The methods of accomplishing the various kinds of locking are explained in later chapters.

TEST QUESTIONS

1. *Define the term "interlocking."*
2. *Name four distinct systems of interlocking.*
3. *Of what does an interlocking plant consist?*
4. *Explain briefly:* 1, *section locking;* 2, *sectional route locking;* 3, *approach locking;* 4, *stick locking;* 5, *check locking.*

CHAPTER 148

Electric Interlocking

Briefly, electric interlocking is that method of interlocking in which the operated units *are operated and controlled by electricity.*

The elements comprising an electric interlocking system are:

1. A source of power serving as a central energy supply for the entire interlocking.
2. A means of distributing energy to the various units for control, operation and indication.
3. The interlocking machine which places all units within the limits of the plant under the control of a leverman.
4. Motor operated switch and lock mechanisms for unlocking, throwing, locking and indicating the positions of various switches.
5. Mechanisms for clearing signal blades in response to lever movements.
6. Auxiliary devices such as tower indicators, track model, time releases, etc.
7. Automatic electric control exercised through the agency of track circuits, approach, route and detector locking.

Power Supply.—Either *d.c.* or *a.c.* may be used to operate an electric interlocking system. The *d.c.* type will first be described in detail. An essential requirement as to power is that there be no interruption of traffic so that either the source of power must be infallible or arrangement be made for emergency supply.

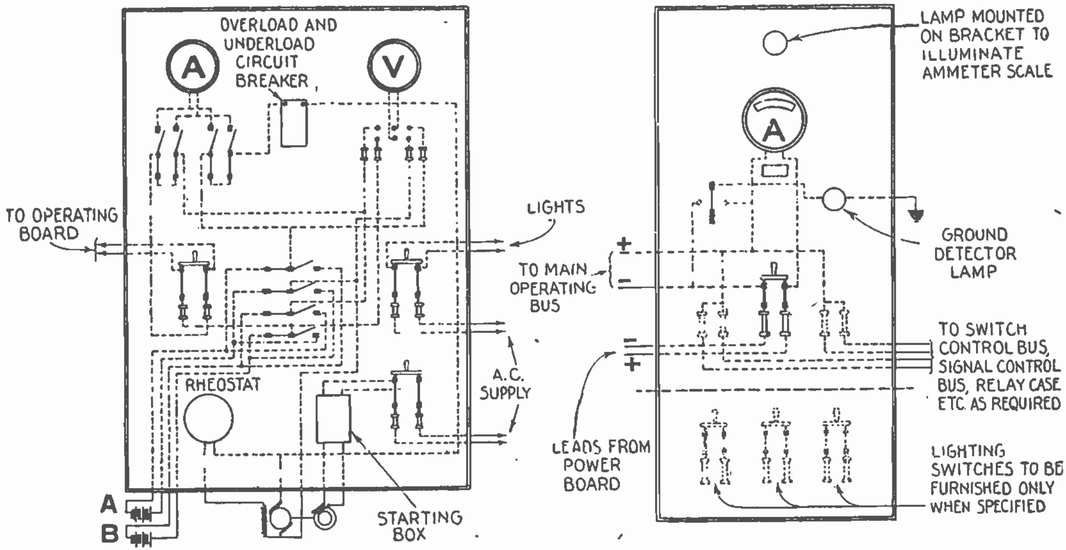


FIG. 6,616.—Power switchboard. Ordinarily located adjacent to dynamo or converting equipment and battery.

FIG. 6,617.—Operating switchboard. Located in the operating room where it can be observed by the leverman. The power and operating boards are ordinarily of one small panel each.

Energy may be obtained from a commercial source or may be generated at the interlocking plant. The former constitutes the usual practice. When commercial power is not available, either steam or gas engine driven *d.c.* dynamos may be used. For an average plant, the dynamo will be from 2 to 3.5*k.w.* the exact capacity depending upon the storage battery used. Power obtained from a commercial source is nearly always in the form of alternating current.

On *a.c.* electric roads, a line transformer will reduce the transmission voltage to either 110 or 220 at the interlocking tower. *A.c.* at this voltage can be readily converted to *d.c.* by means of either a motor generator or a rectifier.

An average plant will require either 55 cells of lead type battery or 90 cells of nickel iron alkaline battery, the capacities varying from 120 to 200 ampere hours in either case. The generating equipment and battery are ordinarily housed in the lower story of the tower.

Power Distribution.—The greater part of the energy is distributed by means of bus mains which extend throughout the plant. These are of heavy wire of low resistance, providing practically normal voltage for the operation of each unit, no matter how remotely located.

The bus mains supply current for the operation of both switches and signals of the electric interlocking, and if desired, for signal lighting.

Switch and Signal Operation.—This constitutes by far the heaviest momentary load on the interlocking battery. A 110 volt *d.c.* switch motor requires from 3 to 4 amperes for 2 to 3 seconds per switch movement.

A signal motor takes less than 1 ampere for 5 seconds to clear the signal.

It is essential *that there be no very great drop in voltage from the tower to the unit during its operation;* the bus main multiple supply system insures this.

An interlocking plant generally includes switches and signals distributed in such a way as to provide maximum facility in handling traffic, and with obviously no regard to their concentration in such a manner as to secure the same drop in voltage during the operation of one unit as another.

Signal Lighting.—Power for signal lighting is ordinarily supplied by separate lines leading from the operating switch board, but if desired, signals can be lighted from the bus mains.

Electric Locking.—Modern interlocking incorporates *all the*

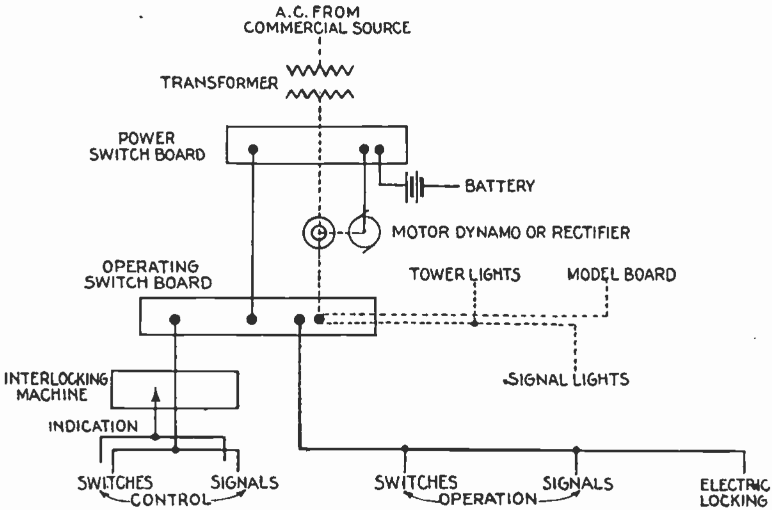


FIG. 6,618.—Diagram of power supply *d.c.* interlocking.

safeguards in the form of electric locking that are necessary to insure the safe passage of trains at such speed as the physical condition of the track will allow. Approach, route or sectional route, and section locking provide this. Most of the electric locking relays receive their energy from the bus mains.

Relays of 1,000 ohm resistance are connected in series with 9,000 ohm resistors to the 110 volt wires. Although the power requirement per unit is not of material consequence, the total energy taken is a considerable portion of that required for the entire interlocking.

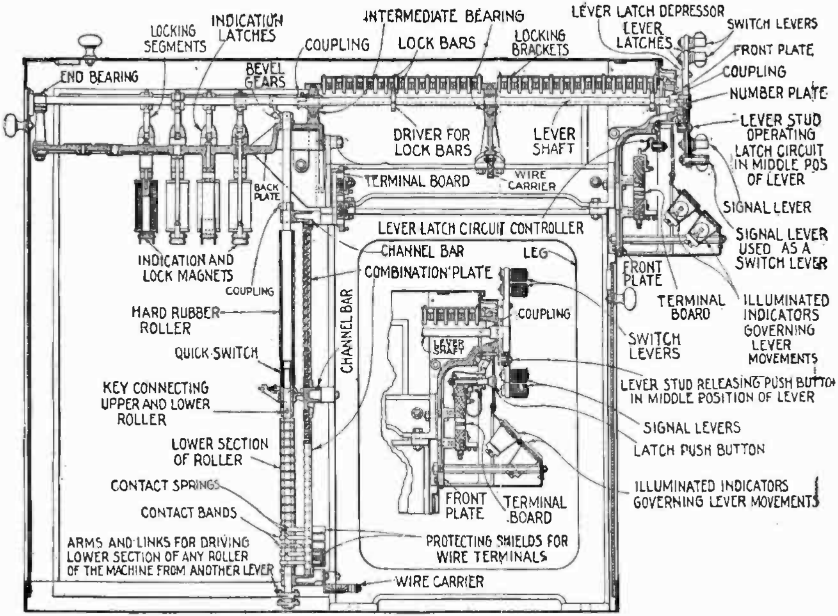


Fig. 6,619.—Union S. and S. Co. power interlocking machine, end view.

Track Circuits.—*A.c.* track circuits are often installed at *d.c.* interlocking plants.

The Interlocking Machine.—The principle of interlocking requires that *before a signal can be cleared for the movement of a train, all switches, derails and frog points, over*

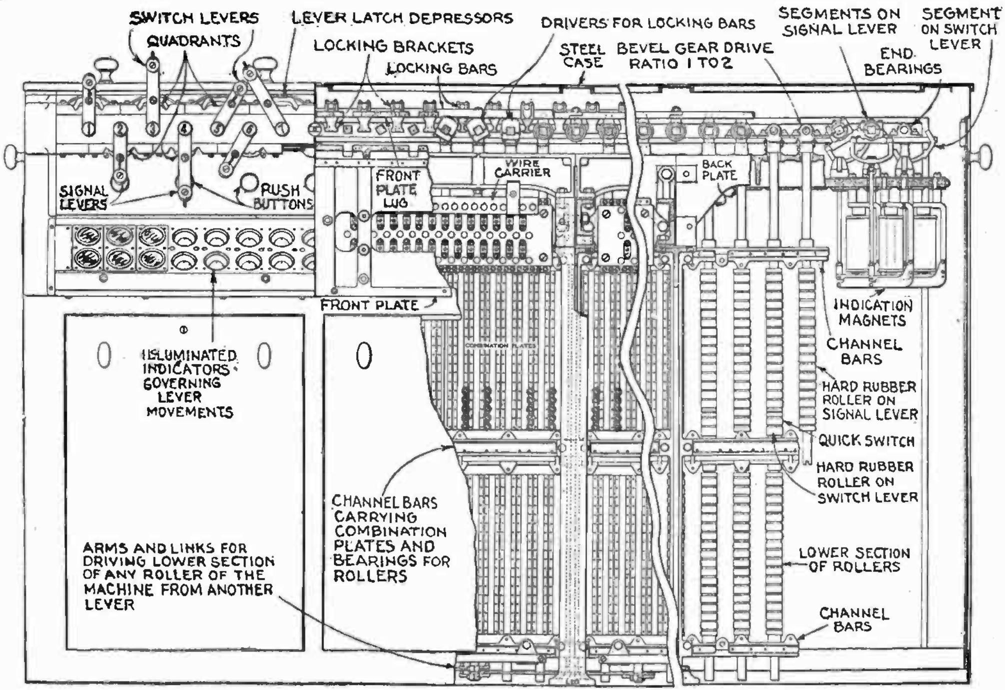


FIG. 6,620.—Union S. and S. Co. power interlocking machine; front view. This machine provides for the control of as many switches or as many signals by a single lever as is practical without limiting possible simultaneous traffic movements. *Example:* both ends of a cross over are controlled by a single lever, also opposing signals, only one of which can be cleared at a time, may be controlled by the same lever. Safety as well as simplicity is secured by a single lever controlling conflicting signals, as the interlocking of these is obtained directly through lever movement and not by means of the dogs and locking [illegible] lever used for each signal.

which the signal governs train movement, shall be in proper position and locked. To secure such protection for train movement it is desirable to concentrate the control of the various switches and signals at one point. The mechanism in which this concentration of control is secured is called an interlocking machine, as shown in figs. 6,619 and 6,620.

The machine consists of small hand thrown levers, compactly located in a frame and arranged for the operation of circuit controllers, but restricted in their movement by both mechanical locking and electric locks.

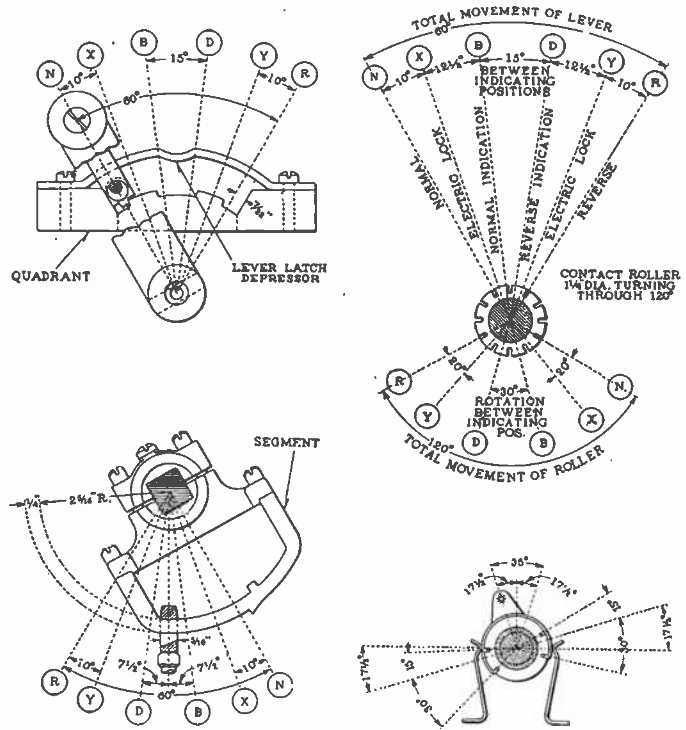
Lever Manipulation.—The multiple control of either switches or signals from single levers naturally results in a considerable reduction in the size of the machine and consequently the tower space required.

As indicated in figs. 6,621 to 6,624, each lever rotates through a 60° angle in a plane parallel with the machine. Thus a leverman may operate two widely separated levers at one time, pulling them toward his body or thrusting them away as required. The complete operation of a track switch from either of its two positions is effected by a partial movement of its lever, the complete movement being impossible until the switch responds to the partial movement.

Two circuits are employed before the lever movement can be completed, one for effecting the switch operation, and one for releasing the lever for its final movement, the latter being the switch indication circuit.

The complete operation of a signal from stop to proceed is secured by a continuous, complete lever movement, but its release from proceed to stop necessitates a preliminary lever movement for interrupting the power supply, and a final movement that can be made only after the signal has returned fully to the stop position.

The operation of switches and signals thus involves the opening and closing of contacts in electric circuits during and at definite points of lever movement. The restraint of lever movement by the switches or signals is accomplished by means of electric locks according to the energized or deenergized state of their magnets. The control of these electric locks is not restricted solely to switch and signal operation, train location being at times a factor in it. The accompanying illustrations show details of the switch lever.



Figs. 6,621 to 6,624.—Diagrams of switch lever. Fig. 6,621, represents the several positions of a switch lever during the operation of a switch, and shows the formation of the quadrant secured to the front of the machine frame and that of the lever latch carried by the lever. These are involved in restricting lever movements. This figure also illustrates means for forcing the lever latch into engagement with the quadrant at mid-stroke, so that this quadrant and not the segments of the electric locks will receive the impact of the lever's arrested movement, thus insuring entire freedom of action for the latches of the electric locks when these are lifted by the magnet to release the segment for final lever movement after the indication has been received. Incorporated in this figure is the stud or pin which co-acts with the latch to open and to maintain open a set of contacts for certain positions of the latch and lever in order to avoid useless consumption of energy from the battery. Fig. 6,623, shows one of the two segments and latches of a switch lever that are employed jointly for switch indication and section circuit locking. Fig. 6,622, shows diagrammatically the several positions occupied by a switch lever, as previously mentioned, and the angle of rotation that the lever movement imparts to the contact roller of the machine. The rollers move through double the angle through which the levers turn. Fig. 6,624 shows a section of the roller that is not continuously movable with the shaft, being restrained from following it during preliminary lever movement by a spring actuated toggle and until the

Checks on Lever Movement.—Considering first mechanical locking, in order that a signal may not be cleared until every switch, derail, and movable point frog over which it governs is in the proper position and locked, it is necessary that the movement of the levers in the interlocking machine be made in proper sequence. This is the function of the mechanical locking, and it is accomplished by: First, the release of one lever for operation only after another has been fully operated; and, second, by the locking of one lever against operation by movement of another before this movement has advanced sufficiently to cause any change in the position of the switch or signal which it controls.

It will be seen from fig. 6,625 that the movement of each switch lever is governed by two magnets together with their latches and segments. These serve not only as indication locks for restraining final movement of the lever until the switch has responded, but also as detector or track circuit locks, preventing the preliminary movement of the lever in case the track is occupied.

Prior to the movement of the lever to change the position of the switch from normal to reverse, the normal indication magnet must be energized, and this is possible only when the track section in which the switch is located is unoccupied. Correspondingly, before the lever can be moved from its reverse position, the reverse indication magnet must be energized, this also being possible only when the track section is unoccupied.

Assuming that the lever has been moved from its normal position to the reverse indication position D, fig. 6,623, the reverse indication magnet must become energized before the lever stroke can be completed. This energization is possible only when the switch has assumed its reverse position and allowed current to flow to the corresponding indication relay. Before the lever can be returned to its normal position the normal indication magnet must be energized, this showing that the switch has again completed an operation in co-ordination with the lever movement.

While one magnet thus permits the start of the lever to effect switch operation, the other insures that before the lever stroke can be completed the switch shall have responded to the lever movement and has been locked in its corresponding position.

FIGS. 6,621 to 6,624.—*Continued*.
final movement of the lever occurs after the indication has been received. This device functions as a part of the indicating system and is known as the *quick switch*.

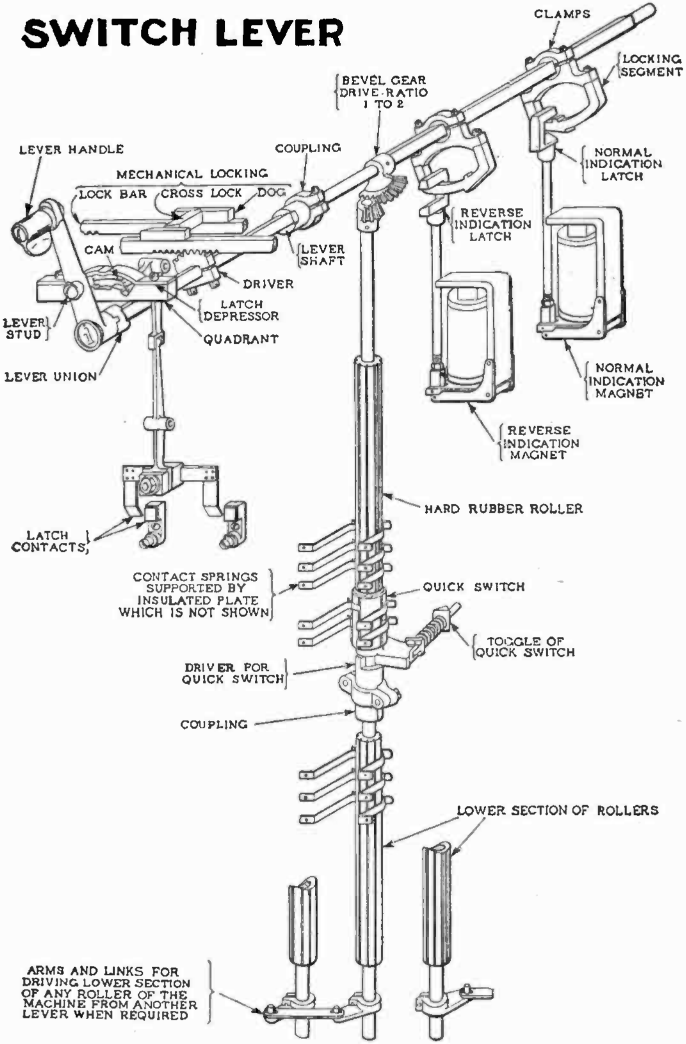
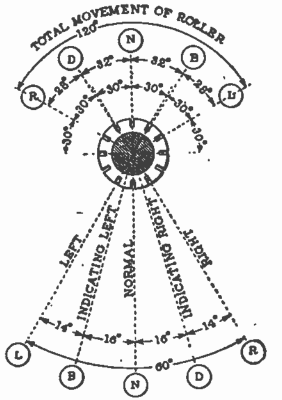
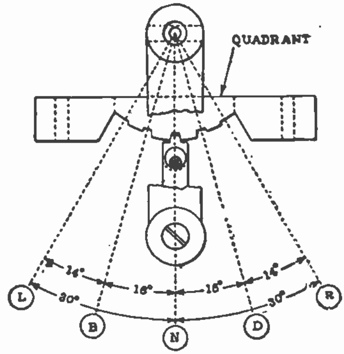
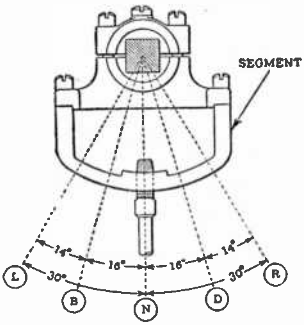


FIG. 6,625.—Perspective diagram of switch lever unit and its relative parts.







The final movement of the lever transfers the magnet which permitted such movement to the duty of locking the lever in its new position automatically when the track is occupied. Simultaneously with this action the other magnet is withdrawn from its section locking service and transferred to the indicating function required for the next operation of the switch.

Figs. 6,626 to 6,628.—Diagrams of signal lever. The signal levers occupy five distinct positions as shown in the diagrams, when used to their full capacity. By full capacity is meant the use of a lever movement to the right for the operation of one signal or set of signals and to the left for another signal or set of signals, the two sets necessarily conflicting with each other in respect to the route or routes governed. The signal levers normally occupy a central or vertical position. When thrown to the extreme right the signal cleared allows traffic movement over a given track in one direction, and when thrown to the left another signal will clear, allowing traffic over the same track, but in an opposite direction. The signal lever cannot be returned to its central position from either extreme until all signals affected by its movement in either direction are in their most restrictive positions. A partial movement of the signal lever from either of its extreme positions causes a break in the signal holding circuit previously supplied with current, thus allowing the signal blade to assume a restrictive position. Positions B, and D, represent those assumed by the signal lever when moved from either extreme position, represented by lines L, and R, to restore the signal to its stop position, and beyond which the lever cannot be moved toward its central, normal position until the signal has assumed its restrictive aspect.

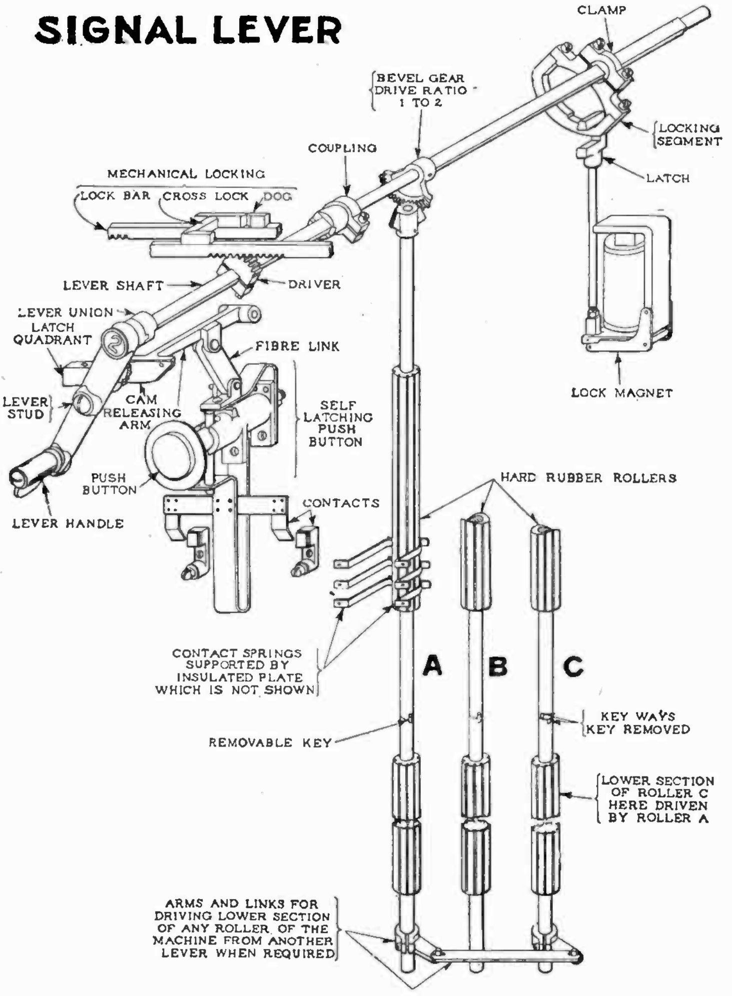


FIG. 6,629.—Perspective diagram of signal lever showing relation of the various parts of a complete signal lever unit. The push button shown immediately under the lever handle provides for the operation of calling on signals.

This transfer of the magnets from one field of usefulness to another occurs only at the completion of each full lever operation, and is performed jointly by what is termed the quick switch, and by what are designated as X and Y, springs of the contacting system.

The signal section symbols for the springs last mentioned are NX, and RY.

Only one electric lock magnet is required for the signal lever, as it is necessary in case of signals to indicate only the return of the signal blade to its most restrictive position, at which time the lock will become energized and the latch lifted, so that the lever stroke may be continued from either extreme position to the normal position which is central. This will be noted by reference to figs. 6,626 to 6 628.

Contact System.—The contact rollers are mounted with their axes vertical. The contact springs are mounted upon a panel or plate of moulded insulation which also supports the terminal binding posts to which outside connections are made.

Lever Lights.—The front plate of the interlocking machine is constructed with a recess under the levers so that lever lights or push buttons may be installed where required.

The former may be made to repeat the positions of either switches or signals or to show the track occupancy which may affect the movement of any switch.

On many roads the stop position of a signal is repeated by a red lever light indication, released when the lever is put normal. The push buttons are used for calling on arms and may be applied in connection with either electrical or mechanical stick control.

Switch Movements.—The operation of switches, derails, and movable point frogs is one of the most important functions as well as constituting the greatest load, of an interlocking plant.

Safety demands that the switch shall be finally locked in position when a train is passing; economy in handling traffic demands that there shall be no unnecessary loss of time in effecting the change of a switch from one position to the other.

The mechanism which meets these conditions must do its work in the following sequence:

1. Unlock;
2. Throw;
3. Lock switch points;
4. Indicate.

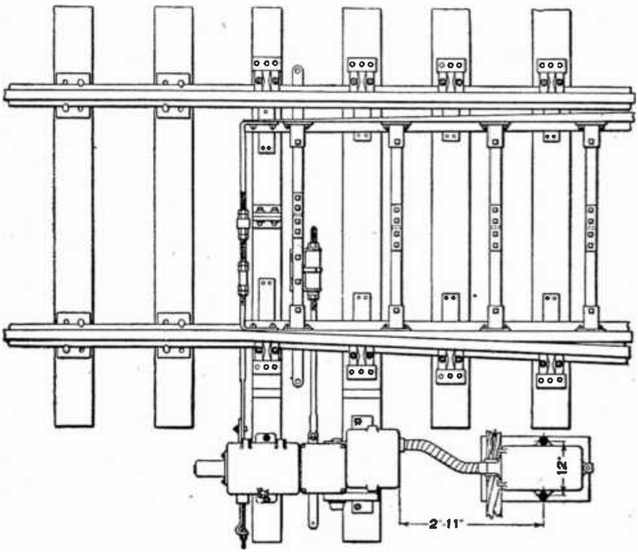


FIG. 6,630.—Single switch layout.

Fig. 6,630 shows an application of the single switch movement wherein it will be noted that the mechanism case is provided with four lugs for fastening it to two ties. The frog movement as shown in fig. 6,631 is slightly longer because of the extension necessary to take in the additional lock rod, and is arranged with six lugs for mounting on three ties.

Switch Control.—Fig. 6,632 shows the switch control circuit between the interlocking machine bus and the controller which is located adjacent to the switch movement.

Controller.—This is housed in a cast iron box mounted on a concrete foundation adjacent to the switch and lock movement, but independent of the track. Therefore, it is not integral with the switch and lock mechanism which, of necessity, is directly connected to the rails and ties.

The controller for *d.c.* interlocking is normally de-energized; that is, it requires current only when changing from one position to the other, and this

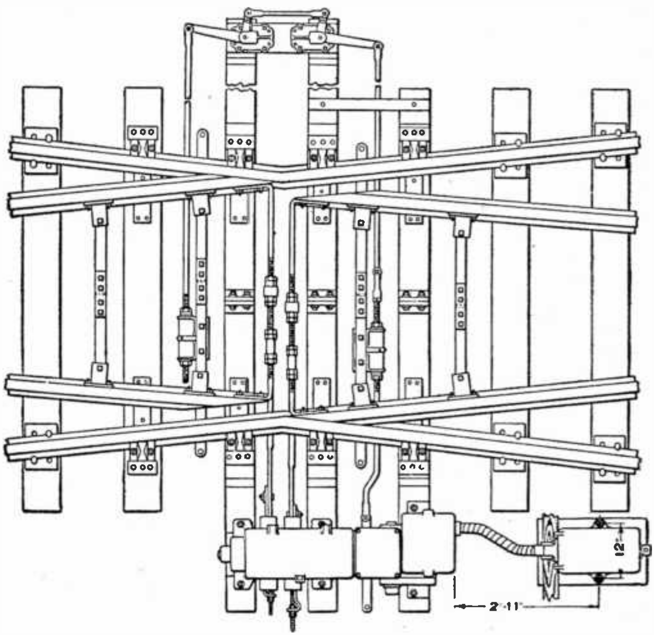


FIG. 6,631.—Frog layout. One pair of the frog points is operated directly from the movement, motion being transmitted to the other set of points through a combination of two crank arms. A pair of short arm cranks are recommended, rather than a single straight arm crank.

is accomplished in less than a second. The controller is illustrated in figs. 6,632 to 6,635.

The operation of the controller will be more clearly understood by following through a description of what happens when the interlocking switch lever is thrown from normal to reverse, and, after the switch movement has operated and indicated, returned to its normal position. See figs. 6,634 and 6,635.

When lever L, is reversed, positive battery from the machine bus will be connected to wire 1RW, and current will flow through wire 1RW, contact X, wire W5, to neutral magnet N. Magnet N, is permanently connected to negative bus wire CH.

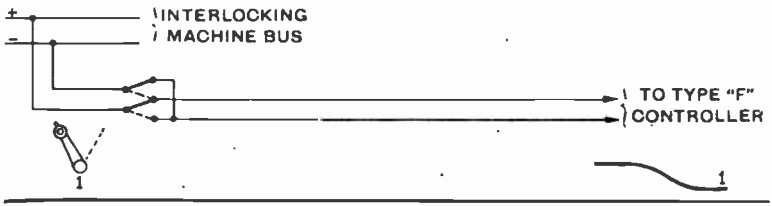


FIG. 6,632.—Switch control circuit. The contacts of lever 1, through which this circuit is broken, function as a pole changer as indicated in the diagram. It will be noted that the switch control circuit consists of two wires only, these running without interruption from the interlocking machine contacts to the terminal board on the controller at the switch. These wires are used for no purpose other than for the control of the switch movement.

The energization of magnet N, causes its armature to be attracted, closing contact between wires 1RW, and W6; W7, and BH; and opening the connection between wires 1W8, and BH. Current will then flow from wire 1RW, through front contact operated by magnet N, wire W6, polarized magnet coils P1, and P2, wire 1NW, lever contact L, to negative machine bus. It will thus be seen that the operating circuit for the type F, controller does not include a common return but is a separate metallic circuit going out over lever contacts to one wire and returning over the lever contacts via another wire.

A local circuit through the other front contact operated by magnet N, is also closed for the purpose of energizing magnet P3, the function of which is similar to that of the permanent magnet used in a polarized relay.

By electrically energizing this magnet during operation, a much higher energization can be obtained than would be possible with a plain permanent magnet. There is, however, a permanent magnet core in this coil which acts to hold the polarized armature in its extreme operated position to allow it to be reliably locked when the armature of magnet N, drops.

Current flowing in the direction stated will cause the polarized magnet to be energized and shift polarized armature P, which causes contact X, to change over the connection for neutral magnet N, from wire 1RW, to wire 1NW. Magnet N, will then be connected to negative machine bus through

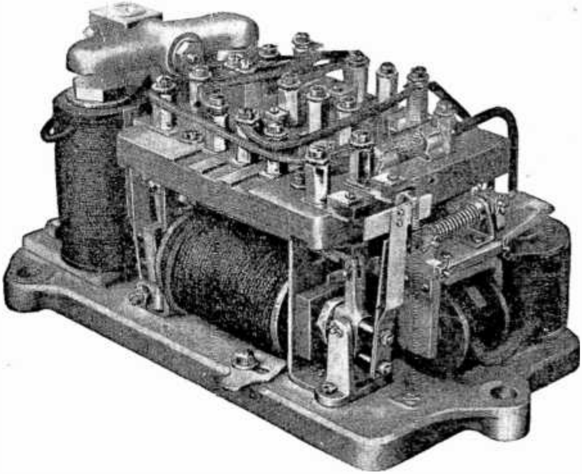


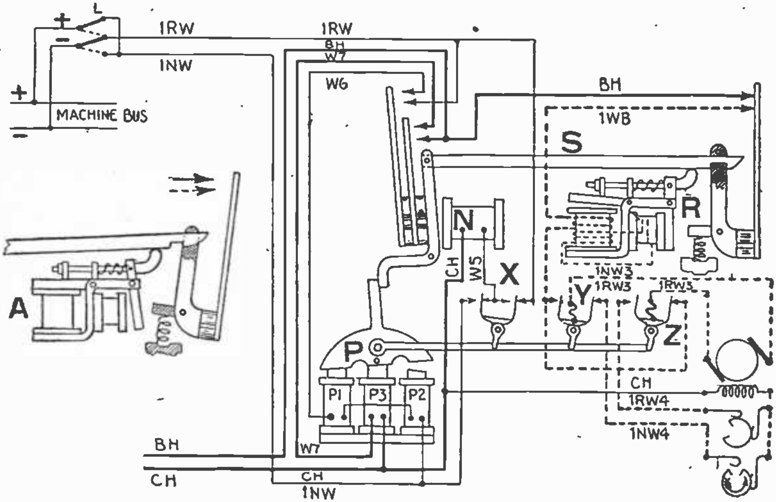
FIG. 6,633.—Union S. and S. Co. switch circuit controller. The coils, which are supplied with current through the circuit shown in fig. 6,632, are of high resistance, and therefore require but very little current for their energization. The controller makes it unnecessary to transmit current over individual *operating* wires from the tower. It also relieves all combination contacts of the interlocking machine, as well as relay contacts, from carrying currents of such magnitude as might be injurious.

lever contact L, and to negative bus CH, at the magnet. This will obviously result in its de-energization and when the armature drops, polarized armature P, will be locked mechanically in its reverse position with its magnet de-energized.

The other two sets of contacts actuated by polarized armature P, will be so connected to the switch motor armature and field, that current will flow through the following path: positive bus BH, back contact of neutral magnet N, wire 1W8, primary coil of motor circuit breaker R, wire 1W9, circuit controller finger Y, wire 1NW3, motor armature. wire 1RW3, circuit controller finger Z, wire 1RW4, motor cut out circuit controller contact, motor field, to negative bus CH.

The switch motor, in revolving, will cause the switch points to be unlocked, thrown and locked in the reverse position, the final movement also resulting in the motor circuit being opened at the motor cut out circuit controller.

It will be noted that before current can pass through the switch motor and cause reversal of the switch movement, the neutral magnet N, must be de-energized, this in turn causing polarized magnet P, to be de-energized. Thus the energization of these magnets is momentary and the amount of power consumed is negligible.



FIGS. 6,634 and 6,635.—Union S. and S. complete control and operating circuit for single switch.

The movement of the switch from reverse to normal is accomplished by the leverman moving the lever to a corresponding position, thus completing the circuit shown in full lines at L. The current will pass through contact L, wire 1NW, circuit controller X, wire W5, neutral magnet N, and to negative bus CH.

While magnet N, is energized the circuit for polar magnet P, will again be completed, but in such a way that current will pass through coils P1 and

P2, in a reverse direction to that previously described. This will cause the polarized armature to be reversed in position which in turn will actuate circuit controller springs X, causing neutral magnet N, to be de-energized, since it will again have both sides connected to negative bus, because wire 1RW, is connected to negative at the interlocking machine.

Contacts Y and Z, actuated by polarized armature P, will cause current to flow through the motor armature in a direction opposite to that when the switch movement traveled from normal to reverse. Contact will again be broken at the motor cut out circuit controller when the switch points have been moved over and locked. The controller springs will then be in the same position as shown in fig. 6,635.

As soon as the motor starts to unlock the switch, the motor cut out circuit controller contacts are shifted to the middle position and remain there until the final locking of the switch reversed, when they are shifted to the extreme reversed position.

The reason for the motor cut out circuit controller maintaining both circuits closed in the middle position during the entire transit of the switch is to allow for reversal of the switch by the lever at any time during transit if desirable, so as to repeatedly attempt to crush snow or ice which might prevent the switch point being forced against the stock rail and locked in that position.

The automatic overload circuit breaker R, is worked on very much the same principle as the overload circuit breakers on power switchboards, except that it is made slow releasing to prevent the possibility of the heavy starting current causing the circuit to be opened at each operation.

If an ordinary circuit breaker were employed, adjusted to open for a heavy current, the momentary current above mentioned would trip the breaker every time the motor started.

If this breaker open up due to high current for an excessive length of time, it can be restored by throwing the interlocking machine lever to its opposite indication position. In doing this, the neutral armature is again attracted, the hook engages the back contact member and upon subsequent de-energization of the neutral magnet the circuit breaker will be reset for another movement of the switch.

By the use of this circuit breaker, it is often possible to crush such objects as snow or a piece of coal lodged between the stock rail and the switch points, even though this may require a dozen operations of the switch. Each time the switch fails to complete its stroke the breaker will go out and will then be reset by moving the lever to the other indication position, avoiding the necessity of going to the back of the machine to renew fuses.

Switch Indication.—The operation of the switch indication circuit is shown in fig. 6,636. Contacts of the switch circuit controller operate only after the switch operating mechanism has completed the stroke of the points and locked them in place.

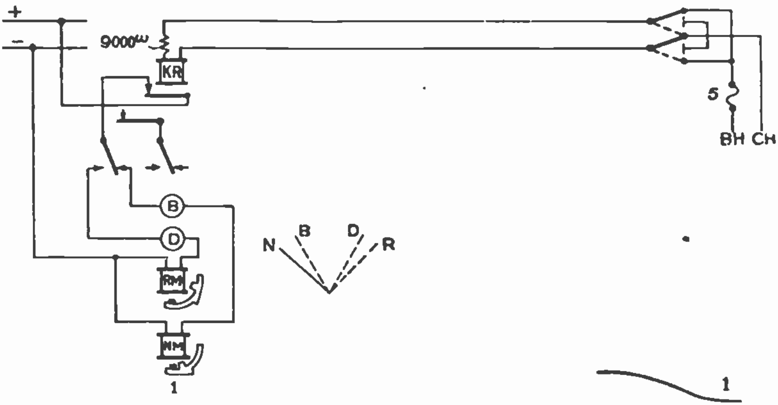


FIG. 6,636.—Switch indication circuit. Two magnets are ordinarily applied to the interlocking machine for the joint indication and detector control of lever movements. These magnets are marked NM, for the normal position and RM, for the reverse position of the lever and switch. The B, and D, lever contacts are mounted on the quick switch previously mentioned, which is so actuated by means of a toggle joint that it snaps over to the position indicated at the last part of the lever movement to the preceding normal or reverse position. This provides a check of the coincidence in position of the lever and the switch movement. Should the switch lever be reversed and the switch and lock mechanism function properly throwing over the points and locking the switch, the pole changer at the right will assume its alternate position, causing the polarized relay KR, to pick up in the reverse direction. Since the lever has been thrown over to the position marked D, indication magnet RM, will be energized, this picking up the dog from engagement with its segment and allowing the lever movement to be continued to the reverse position, which will release the mechanical locking so that a signal may be cleared. Provision is made in the circuit controller actuated by the switch and lock movement for the contacts here shown closed, to be opened at the first movement of the locking bar tending to unlock the switch points. A shunt between the two wires leading to the KR, relay is established at this time and maintained throughout the unlocking, throwing and locking of the switch points and until the last part of the locking stroke, when the pole changer will complete its movement and pick up the KR, relay in the reverse direction, as previously described. The movement from reverse to normal can now be easily traced.

NOTE.—In fig. 6,636 it should be noted that the KR, relay is at all times under the control of the switch, and that the unlocking of the switch by any means whatsoever will cause the KR, relay neutral contacts to open and remain open until the switch points are again fully closed and locked.

These contacts are connected so as to act as a pole changer. Two wires lead from this pole changer to a polarized relay, KR, in the station. A 9,000 ohm resistor is connected in series with this relay when the voltage is 110.

It is obvious that a low voltage polarized *d.c.* relay or a 110 volt three position *a.c.* relay may be substituted for the relay shown in fig. 6,636. The KR, relay functions not only in connection with the switch indication, but also in the SS, selection of signal control circuits. Any number of switches operated by a single lever can be made to indicate their position by means of a single KR, relay as shown for a crossover in fig. 6,637.

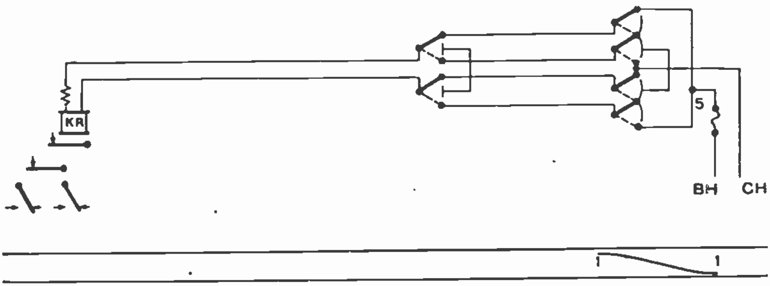


FIG. 6,637.—Indication circuit for cross over.

Section Locking.—Section or detector locking *has practically superseded the older form of switch protection, mechanical detector bars,* used before track circuits were available for preventing the unlocking and moving of switch points when a car was at the switch.

The increased protection gained by the use of section locking, both in the greater extent of track covered and the preliminary locking of the lever against movement, combine with the desirability of eliminating needless load and questionable operation under certain conditions, to remove the detector bar from further consideration. The combination of switch indication and section locking is shown in fig. 6,638.

The NX, and RY, contacts functioning in conjunction with the B and D contacts, provide for the alternate energization of the normal and reverse lever lock or indication magnets in such a way as to secure section or detector locking when moving the lever from either of its extreme positions and indication locking when it is approaching the opposite extreme position, *i.e.*, at the indication point B or D.

A latch contact is provided in the section locking circuit for the sake of battery economy. This circuit breaks through either ordinary track relays TR, or their repeaters TP, or such relays as may be installed for sectional route locking. Approach and route locking may be added with equal facility.

Signal Control.—The control circuit for a single arm signal R2

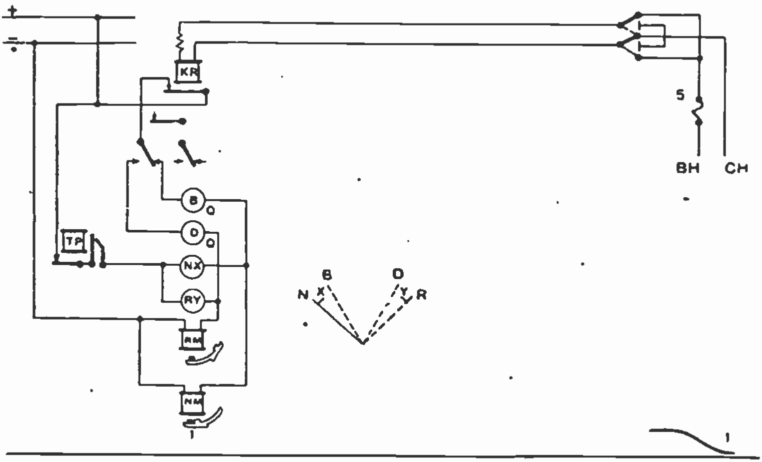


FIG. 6,638.—Combination of switch indcation and section locking.

is shown in fig. 6,639. In fig. 6,640 will be seen an enlargement of the circuit shown in fig. 6,639 to take care of signal RB2. Since only one of the two signals shown can be cleared at a time there is no necessity in this system for a separate lever to be used for each blade.

It will be noted that both sides of the circuit for both blades are broken through the signal lever contacts and selected through No. 1, switch lever contacts. A further enlargement of the signal control scheme is shown in fig. 6,641. It is practicable to control all four blades by one lever No. 2. A slight variation is made in the circuits from those previously described to indicate that by the inter-control of two blades through circuit breaker contacts closed only when the signals indicate stop, one wire between the signal and the tower can be eliminated.

Signal Indication.—The indication circuits for signals in the electric interlocking system embody the same simplicity

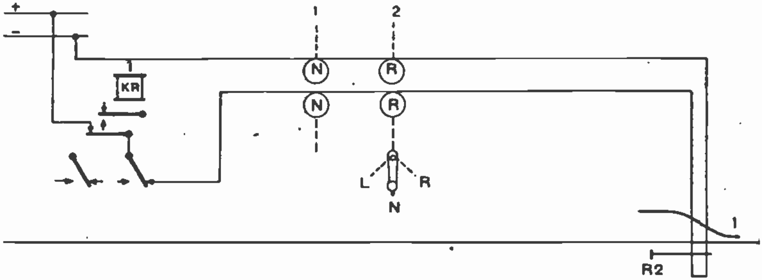


FIG. 6,639.—Signal control circuit. This consists of simply two wires extending from the signal to the interlocking machine, where both are broken through R, contacts on the signal lever and the proper contacts on the switch lever or levers concerned. This circuit is also carried through both neutral and polar contacts of KR, switch indication relays for all switches, movement over which is governed by the signal in question. Current for the signal motor is supplied from the bus mains through contacts of a control relay or signal hold clear device.

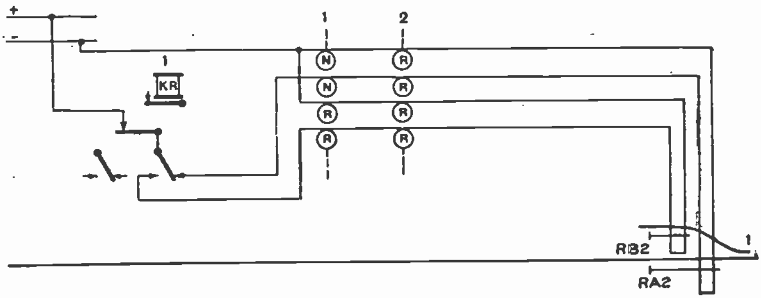


FIG. 6,640.—Signal control circuit for converging routes.

which is characteristic of the signal control circuits, as will be noted by reference to figs. 6,642 and 6,643.

Since the indication magnet should be energized only when all blades controlled by a signal lever indicate stop, the circuit controller contacts

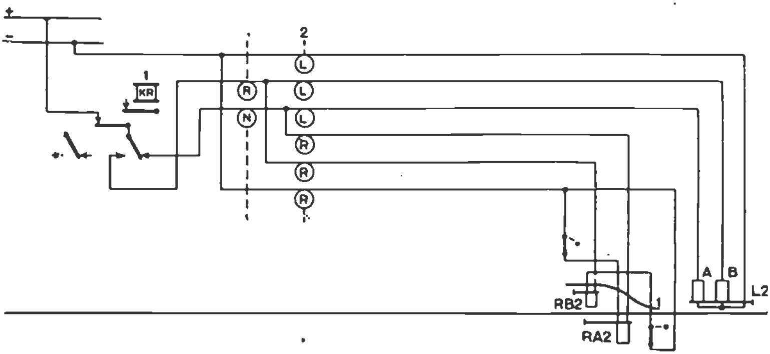


FIG. 6,641.—Signal control circuit for converging and diverging routes.

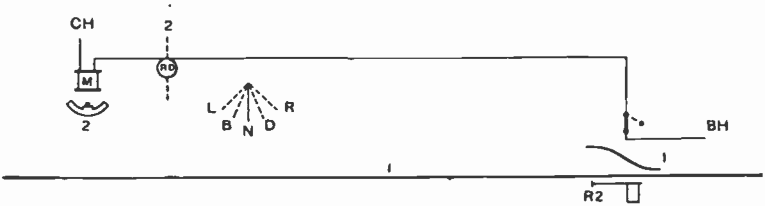


FIG. 6,642.—Signal indication circuit.

actuated by these blades are connected in series. The circuit is also broken through LB, and RD, contacts on the signal lever, connected in multiple.

Alternating Current Electric Interlocking.—Wherever a reliable source of *a.c.* power is available, an *a.c.* interlocking system has the following advantages over one using *d.c.*:

1. The power equipment is simplified.

2. Power losses between source of supply and interlocking units operated are reduced to a minimum.

3. *A.c.* track circuits insure maximum safety and economy.

Fig. 6,644 shows the scheme of *a.c.* power supply. Track circuits in *a.c.* interlocking may be supplied from the same mains that supply the units just mentioned. Signal lights may in either case be controlled over a separate wire in order that this circuit can be opened during the daytime if desired.

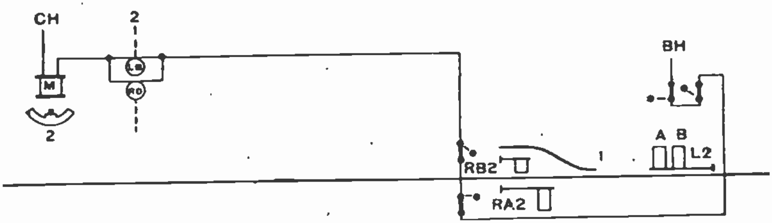


FIG. 6,643.—Signal indication circuit for opposing signals.

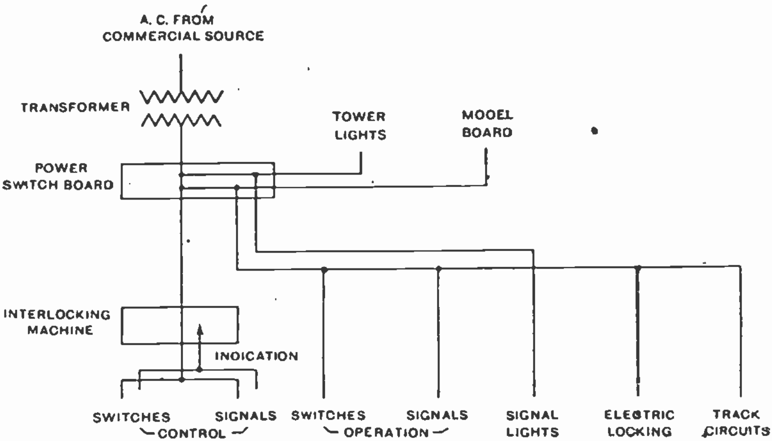
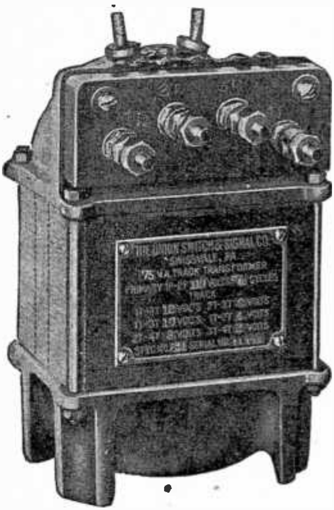


FIG. 6,644.—Diagram of power supply; *a.c.* interlocking.

Track Circuits.—The *a.c.* track circuit consists of a small air cooled track transformer of capacity ranging from 25 to 500 volt amperes, depending upon the circuit, a reactor or resistor and an *a.c.* relay, with the rails and wires connecting the two.



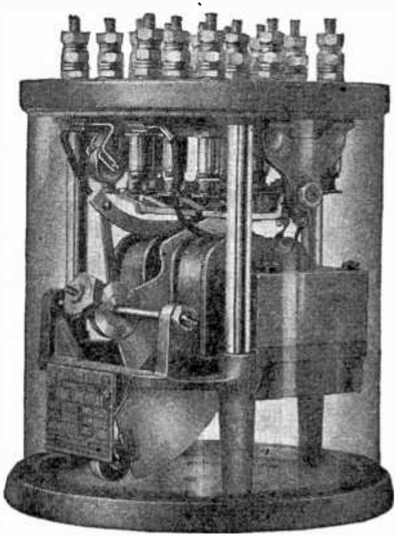


FIG. 6,645.—Track transformer.

FIG. 6,646.—Vane type relay.

Interlocking Machine.—Energy is taken through the switch board and interlocking machine to supply control circuits for switches and signals. *A.c.* is also received at the machine to indicate the position of the units outside.

The interlocking machine shown in figs. 6,619 and 6,620, and described in the section on *d.c.* interlocking, beginning on page 3,957, functions in

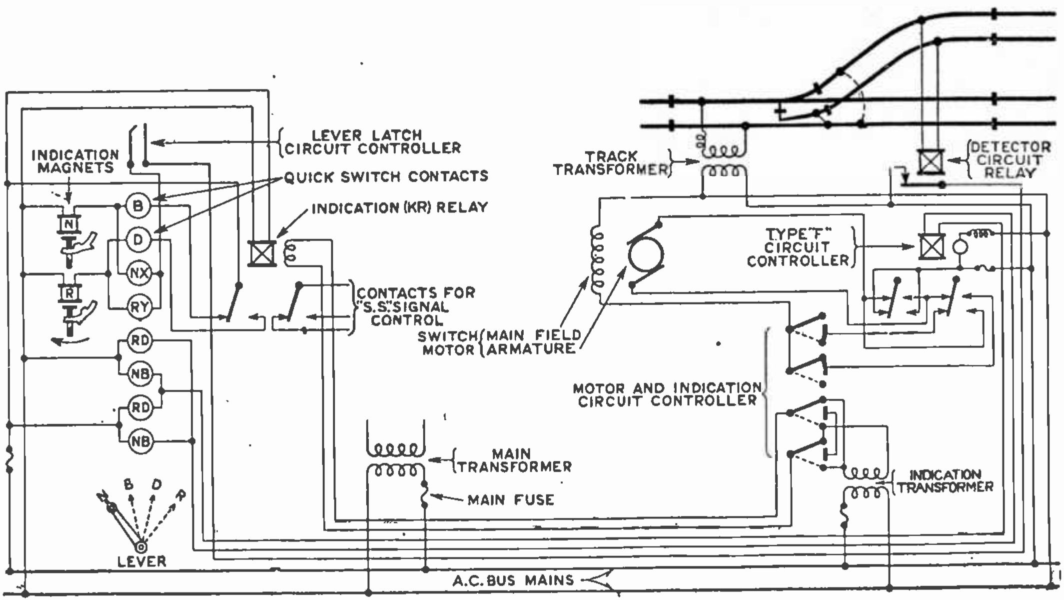
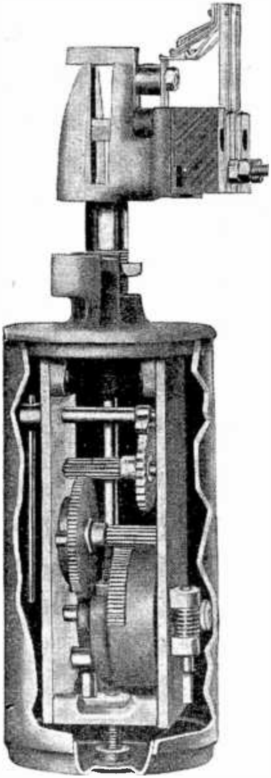


FIG. 6,647.—Complete control, operating and indication circuits for single switch; *a.c.* interlocking.

the same way and possesses the same safeguards for traffic on alternating as on direct current. The only difference in this machine is in the detail construction of the indication and lock magnets.

Controller.—The switch controller used in *a.c.* interlocking is similar to the corresponding device used in *d.c.* interlocking, except that it is not arranged for normal de-energization, nor does it incorporate an automatic circuit breaker for opening up the motor circuit should the switch be blocked. Any dangerous load upon the *a.c.* switch motor, will be taken care of by the blowing of a fuse in the motor circuit.

Signals.—While necessarily differing electrically, these signals all agree in mechanical construction in general with their *d.c.* prototypes, and any one or all of them can be applied to *a.c.* interlocking. Light signals of the position or color type can also be applied.



FIGS. 6,649 and 6,650.—*A.c.* tower indicators. They are similar to standard relays, but with indicator blades or discs actuated by the armature. The position of the blade or disc indicates whether the track is occupied. The tower indicators may be equipped with contacts forming a part of the approach and route locking circuits. In some instances light type indicators have been substituted for those of the relay type.

FIG. 6,648.—Union style TP. clockwork time release. This release enforces a time interval between the preliminary operation of a lever on a power interlocking machine and the completion of its stroke

Tower Indicators.—It is desirable from a standpoint of efficient operation that *the leverman be informed concerning the location of trains both approaching the interlocking and within home signal limits.*

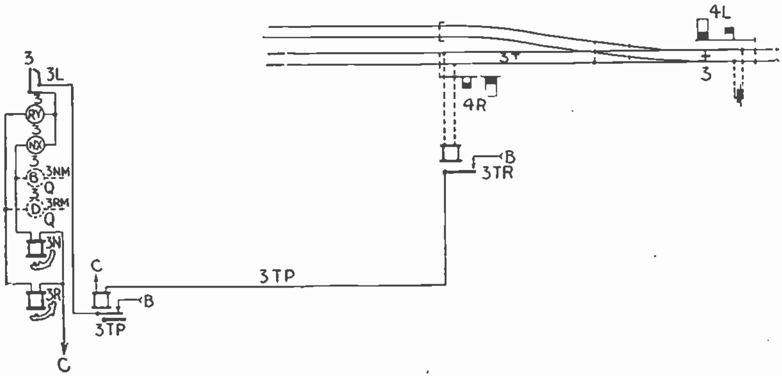


FIG. 6,651.—Section locking circuit.

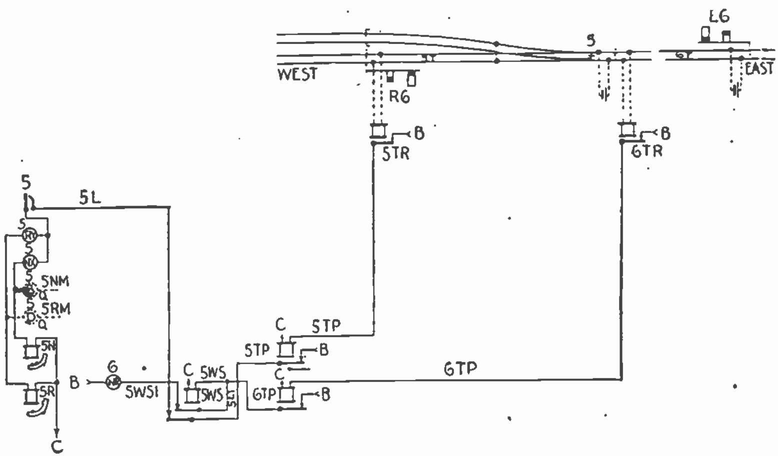


FIG. 6,652.—Sectional route locking circuit.

One means used to show track occupancy is the lever light described as a part of the interlocking machine. Another means is the tower indicator. Figs. 6,649 and 6,650 show *a.c.* type tower indicators.

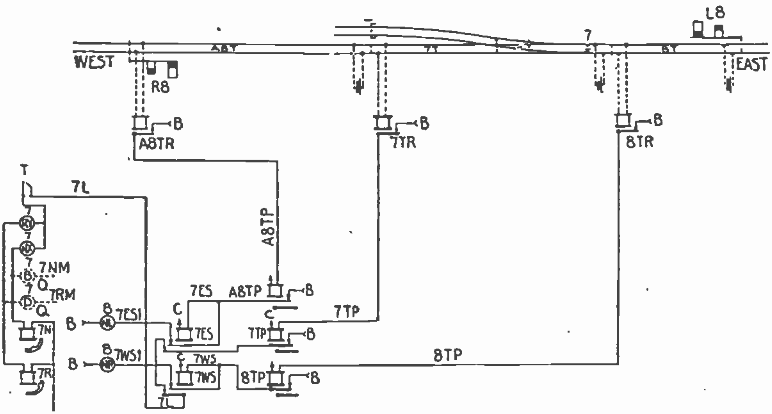


FIG. 6,653.—Sectional route locking circuit.

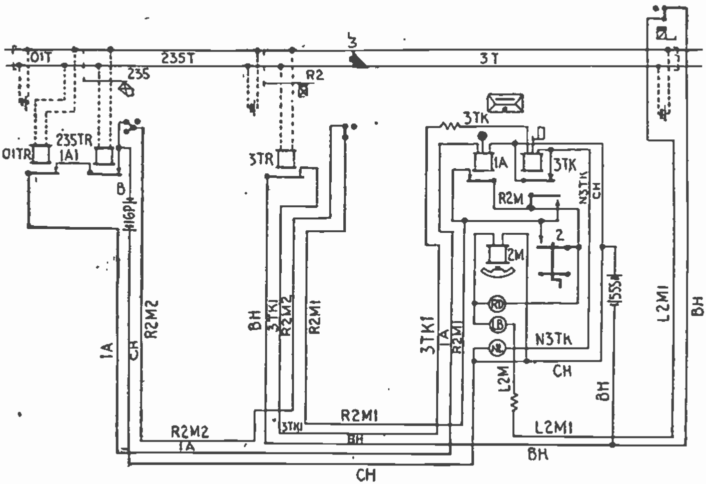
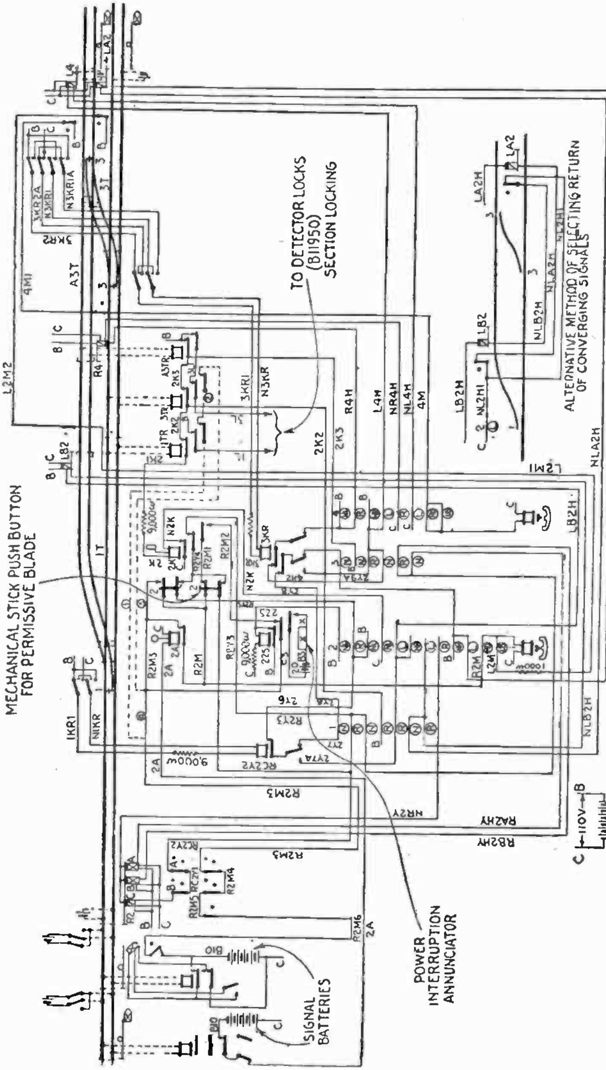


FIG. 6,654.—Approach locking circuit.



FIGS. 6,655 and 6,656.—Circuits for Union S. & S. Co. type F. *d.c.* electric interlocking, with approach, route and section locking.

Time Releases.—If all trains passing through an interlocking plant were to continue on the route first lined up for them by the leverman, and if there were no failures of track or other circuits affecting the automatic locking of the plant, there would be no necessity for time releases, but since it is at times necessary to change a lineup, due either to a misunderstanding on the part of the leverman, or to a change in other conditions, which has made such action desirable, a device which will allow this to be done safely is necessary. A time release is a *mechanical device for securing this result:*

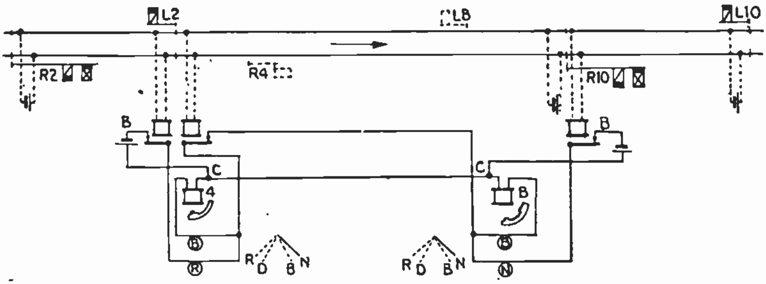


FIG. 6,657.—Check locking circuit.

Two types of time releases are in ordinary use. The mercury time release is intended for direct connection to the lever in the interlocking machine and functions coincidently with lever movement. It is carried on the plate which supports the usual indication or lock magnets, and is operated from the lever shaft.

The clock work time release is usually operated by hand. It has a graduated dial and clock hand which indicates at all times the amount of time elapsed after it has been released. This release may be set so as to provide any time interval up to four minutes.

Automatic Electric Control.—It is not sufficient that the leverman be kept informed concerning the location of trains approaching a plant and within home signal limits, but his hands must be tied so that he cannot take any action which might create a hazard in connection with train movement. This is what automatic electric control does.

TEST QUESTIONS

1. *What is understood by the term "electric interlocking"?*
2. *Name the elements comprising an electric interlocking system.*
3. *Give the methods of power supply.*
4. *How is the power distributed?*
5. *What constitutes the heaviest momentary load on the battery?*
6. *How is power obtained for signal lighting?*
7. *Describe electric locking.*

NOTE.—*"SS" Scheme of Control.* The continuous check of the position of each and every switch over which a signal governs train movement, by carrying the control circuit of that signal through contacts on the KR relays for the switches concerned, is known as the "SS" system or scheme of signal control. This control is characteristically a part of Union type "F" electric as well as of electro-pneumatic interlocking.

NOTE.—The "SS" scheme assures: 1, that should a switch not respond to a lever movement and through some fault or series of faults the lever movement be completed, subsequent operation of any signal lever cannot cause a signal to clear; 2, that should a switch be accidentally or maliciously changed in position, any signal cleared for train movement over the switch will immediately assume its stop position, nor can any signal be cleared until the switch is locked in a position coinciding with that of its controlling lever.

NOTE.—*The "SS" control of signals provides:* that *every* signal, high and dwarf, be directly controlled by *every* switch and derail, both facing and trailing point, over which it governs train movement, and for every minute of the time. In other words, this scheme of control is *complete*. That the signals governing the main track movements be controlled not only by the switch of a turnout, but by the derail which protects against side-wiping. Similar protection is provided at crossovers.

8. *How is concentration of control obtained in electric locking?*
9. *Describe the lever manipulation of the interlocking machine.*
10. *What are the checks on lever movement?*
11. *How are the contact rollers mounted?*
12. *How are the lever lights mounted?*
13. *What is the sequence of operation in moving a switch?*
14. *Draw a diagram showing a switch control circuit.*
15. *How does a controller work?*
16. *Draw a diagram of the switch indication circuit.*
17. *When do the contacts of the switch circuit controller operate?*
18. *What are the names given to section locking?*
19. *Draw diagrams showing control circuit for a single arm signal.*
20. *Draw a diagram showing a signal indication circuit.*
21. *What advantages has* a.c. *over* d.c. *for electric interlocking?*
22. *Draw diagrams showing the scheme of* a.c. *power supply.*
23. *Of what does the track circuit consist?*
24. *What duty is performed by tower indicators?*
25. *What is a time release?*
26. *Describe automatic electric control.*

CHAPTER 149

Electro-Pneumatic Interlocking

The electro-pneumatic system derives its name from the fact that *compressed air is employed to perform the work;* that is, the shifting of the switches and signals, and electricity is used to *control* or *direct* the performance of the work; that is, the admission and discharge of pressure to and from the cylinders by which the work is performed.

The use in the electro-pneumatic system of simple cylinders for switch and signal operation compared with the use of electric motors for like duty in purely electric systems gives to the electro-pneumatic system the advantages of simplicity, accessibility and durability.

There is also the advantage arising from the ready control, in a simple and effective way, of the energy (the compressed air) which is employed without destructive effect either upon the devices controlling it or upon the appliances utilizing it.

The system consists of the following elements:

1. A source of compressed air supply of approximately 75 lbs. per sq. in.

2. A source of current supply of approximately 12 volts.

3. An interlocking machine for controlling the operation of switches and signals.

4. Switch operating mechanisms with their controlling and indicating circuits.

5. Signal operating mechanisms with their controlling and indicating circuits. Auxiliary devices, of optional character, for performing special functions, such time locks, electric clockwork or manual emergency releases, indicators, annunciators, etc., can be installed as desired.

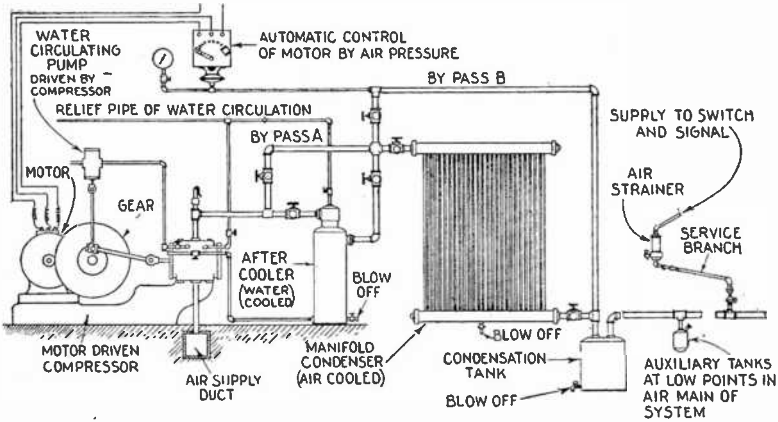


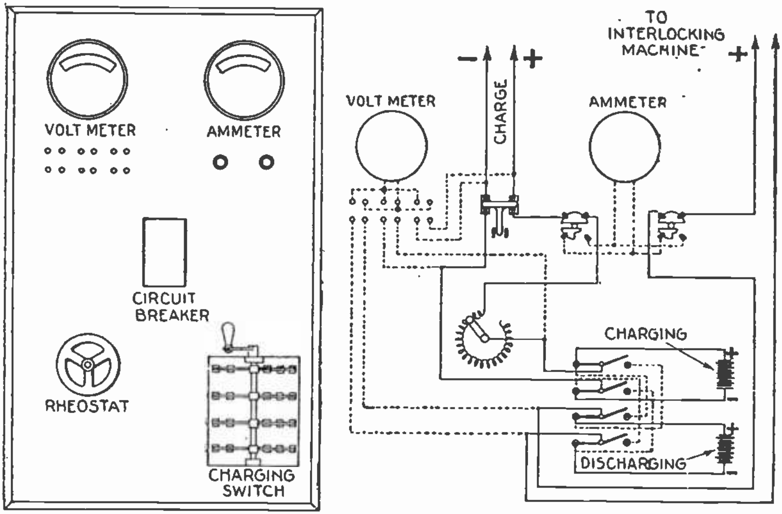
FIG. 6,658.—Diagram of typical air compressing, cooling and distributing system for electro-pneumatic interlocking.

Compressed Air.—This embraces, preferably, two compressors, one as a relay to the other, which may be driven by electric, steam or other available power, as local conditions may justify.

Frequently, especially at terminals, a source of compressed air supply exists, or is required, for other purposes, such as cleaning of cars, operation of tools, etc. This same supply may be used for the interlocking system, with no appreciable reduction in the volume of air available for the purpose it was originally provided for, since the interlocking system requires but a comparatively small amount.

At interlocking sites where no supply of compressed air exists for other than interlocking purposes, there is usually available a source of *d.c.* or *a.c.* which may be utilized for the operation of air compressors.

Fig. 6,658 shows diagrammatically the appliances used for the compression, cooling and distribution of air in large electro-pneumatic interlockings. A two-inch air main extending throughout the interlocked territory is ample for distribution of the pressure to the various cylinders of the system with no appreciable loss due to drop therein. Branch pipes from the main air pipe are usually of ¾ in. diameter, reducing at the switches and signals to a diameter of ½ in.



Figs. 6,659 and 6,660.—Typical switch board equipment and circuits for electro-pneumatic interlocking charging plant.

Electricity.—For the control of the various appliances the *electric current may be taken from any reliable source.*

Such a source is generally already available. Usually *d.c.* is employed for all purposes through the medium of a 12 volt storage battery.

Electro-Pneumatic Interlocking Machine.—This machine is electro-pneumatic in name only, since *there is no compressed air used for any purpose within it.*

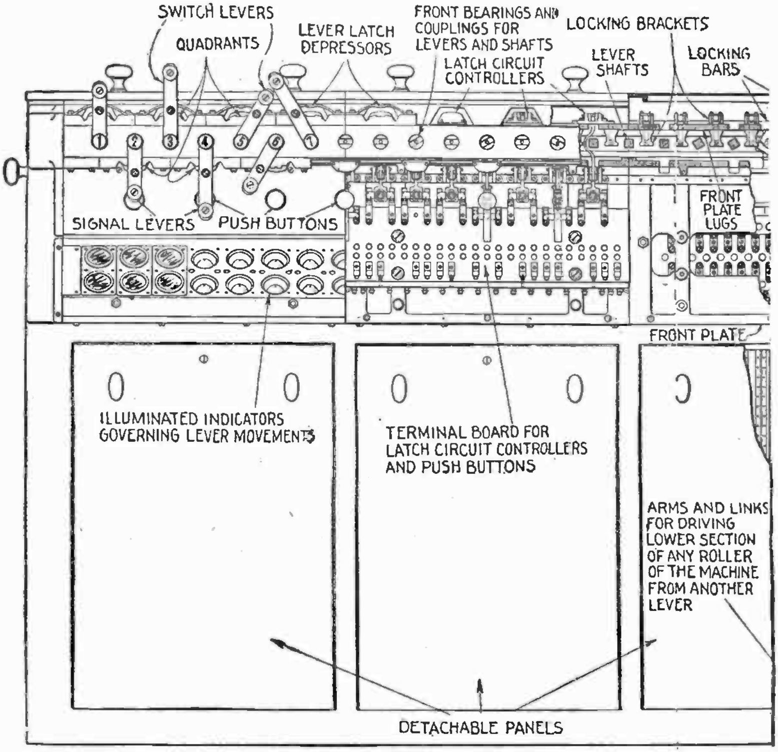


FIG. 6,661.—Union S. and S. Co. electro-pneumatic interlocking machine complete. Side view showing signal levers, terminal board, locking bars, quick switch, indication magnets, etc. This illustration is continued on page 3,995.

The machine consists of *miniature levers conveniently arranged in a common frame and adapted to the operation of a bank of mechanical locking similar in character to that employed in mechanical interlocking machines, but of diminutive design.*

Each lever in the machine also operates a plurality of electric contacts, and attached to each lever is one or more electric locks. The *mechanical locking* is provided to prevent the operation of levers which, if moved, would conflict in function with one or more other levers.

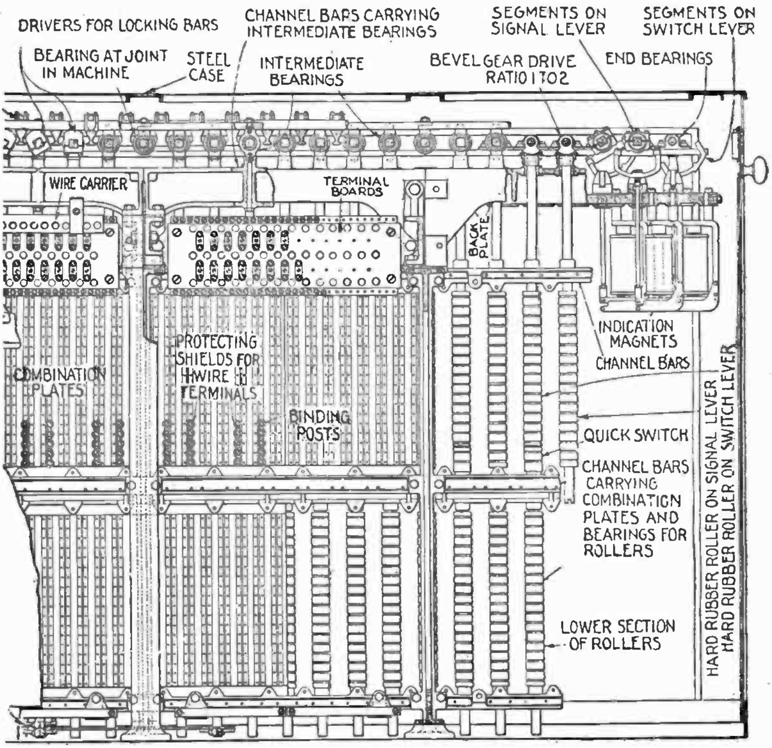
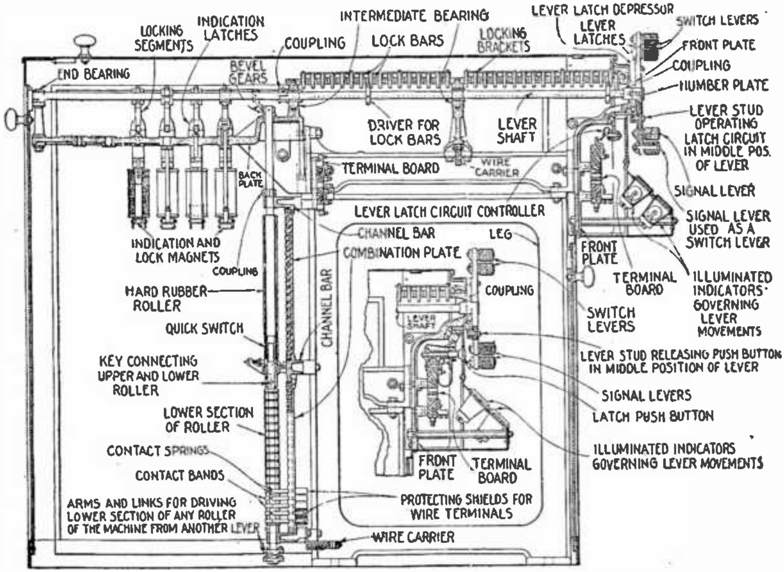


Fig. 6,661.—*Continued*. The above illustration is a continuation of fig. 6,661 on page 3,994.

The *contacts* control electric currents by which switches and signals are operated by the levers and are also used for opening and closing different circuits as required by the many combinations of lever positions.

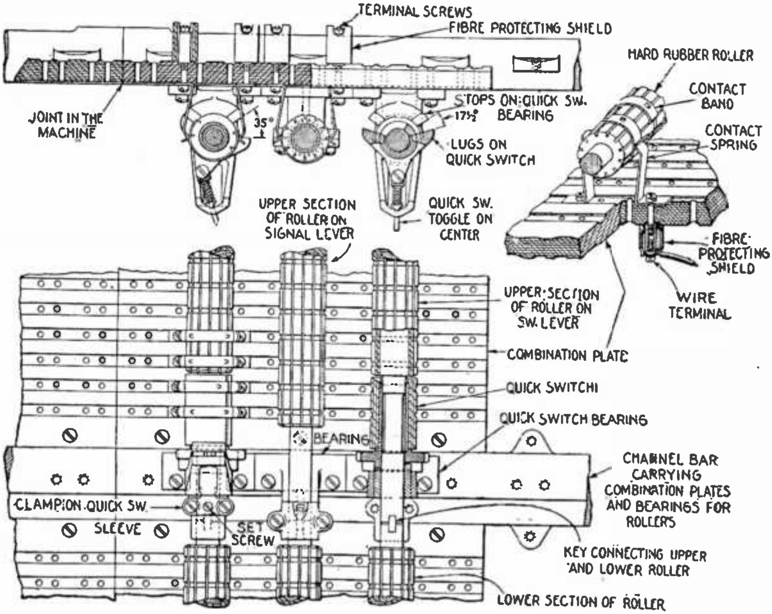
The *electric locks* are provided for restraining lever operation according to conditions remote from the machine when these are adverse to their safe operation, such as preventing final movement of levers until the operated unit has responded to the initial lever movement and preventing effective movement of switch levers by train action where detector track circuits are used in lieu of mechanical detector bars. Figs. 6,662 and 6,663 show end view and detail of the machine.

In the sections following, switch and signal operation from the machine and the inter-control between machine, switches, signals, and track detector circuits are dealt with in such a way



FIGS. 6,662 and 6,663.—End view and detail of Union S. and S. Co. electro-pneumatic interlocking machine. *In operation,* the complete operation and locking of a switch, from either of its two positions, are effected by a partial, preliminary, movement of its lever, the complete, final, movement of the lever being impossible until the proper response of the switch to the preliminary lever movement occurs. Two systems of circuits are employed for these purposes; one for effecting switch operation, and one for releasing the lever thereafter for its final movement; the latter being known as the indication system. The complete operation of a signal from stop to proceed is effected by a continuous, complete lever movement, but its operation from proceed to stop necessitates two movements of the lever; a preliminary movement for interrupting the power supply to the signal, and a final movement that can be made only when the signal so deprived of power, returns fully to the stop position. The operation of switches and signals thus involves the opening and closing of electric contacts during lever movement and at definite points in the lever's throw. The control of lever movement by switch and signal position, which also embraces this contact control, necessitates the use of electric locks upon the machine which permit or prevent lever operations according to the energized or de-energized state of their magnets. Control of these locks is not restricted solely to switch and signal operation, train action being also at times a factor in it.

that the requirements of the interlocking machine for meeting the needs of the many functions involved are clearly understood.



FIGS. 6,664 to 6,666.—Details showing part of combination plate and contact rollers of Union S. and S. Co. electro-pneumatic interlocking machine. The panels or plates which support the contacting system are of moulded insulating material. To these plates the contacting springs are secured by brass screws which pass through them and into square brass nuts by which the screw and spring are secured. These nuts, being square, and set into vertical grooves, cut in the rear of the plate, are non-turning, while the contact springs lying in similar grooves cut in the front of the plate are likewise held against turning by a single screw through each. The nut by which the screw is secured is of special length where wire connection to a contact spring is to be made, and that portion of the nut which extends beyond the screw is equipped with a second screw and washer for securing the external wire connection. Over the terminal posts thus formed, a tube of insulating material is placed; the external wire connection being in a notch cut in the outer end of this tube, and the wire is secured to the post by the screw.

NOTE.—*The front plate* of the electro-pneumatic machine is constructed to recede from the plate in which the levers operate and thus to form a compartment under the levers for the housing of the various lamps and contacting devices that are frequently made a feature of lever manipulation in this system. The lamps serve as indicators and inform the

Switch Operation and Control.—Each set of switch and frog points embraced in the track system is operated by a switch and lock movement, a purely mechanical device designed first to unlock the switch, then shift it and relock it in its new position.

The switch and lock movement is operated by direct action of the piston of a double acting cylinder, of which the admission and exhaust are controlled by a slide valve mounted upon the cylinder.

NOTE.—Union S. and S. Co. signal and switch levers same for electric, and electro-pneumatic interlocking; see figs. 6,625 and 6,629. Assuming that a signal lever has been operated to permit a train to move over the switch, the switch lever shown is mechanically locked in the position it assumes, and this fact secures the lever, the switch valve, the switch, the indicating circuits and the polarized indicating relay in the following respective conditions: 1, lever normal; 2, normal switch valve magnet energized; 3, slide valve held and locked positively in normal position by air pressure; 4, the switch resting without pressure in its cylinder in its normal position and mechanically locked there; 5, the two indicating wires maintained at different voltages of a given polarity; 6, polarized indicating relay energized to close its neutral contacts and its normal polar contacts; 7, source of electric current including the neutral contact and one of the closed polar contacts that constitutes parts of a circuit which includes also the open contacts of the quick switch and the helix of the normal indication magnet; 8, second circuit employing the neutral contact of the polarized indicating relay and the other one of the closed polar contacts as the source of current supply to those contacts actuated by signal levers that primarily operate the one or more signals that govern train movements over the switch. Obviously under this assumption, the switch lever cannot be moved until the signal lever is placed normal and the signal is in the stop position.*

*NOTE.—*The operation* of the switch by other means than its lever as by the malicious or accidental manipulation of its operating mechanism, will be first accompanied by an interruption of the electric energy in the indicating wires and then a shunting of these wires against influence from foreign sources. This produces a de-energization of the indicating relay, the effect of which is to cause it immediately to cut off the electrical energy, through its contacts by which each signal, governing movements over the switch, is controlled, and thereby to place at stop any such signal as may at the time be in the proceed position, or should all of them be in the stop position at the time, prevent the operation to proceed of any such signal.

NOTE—*Continued.*

operator when a lever may or may not be moved. The usual contacting mechanism that is contained in this compartment has several functions; first, the control of switch lever locks by the catch rods of the levers so as normally to retain the locks upon open circuit, as a matter of current economy solely; and, second, the retention of these locks positively separated, during lever movements between indicating positions from any possible supply of current energy to them save through the proper channels of the indicating system. Behind each signal lever is a "latching push" button, the action of which when depressed is to operate a calling on arm when the usual signal does not respond to the lever's movement by reason of the semi-automatic control of the signal and the presence of a train upon the track it governs. The depression of the button, in such cases, mechanically latches it, depressed, and in consequence, the circuit of the calling on arm is closed until the latch is released. This release occurs by the partial restoration of the signal lever to normal.

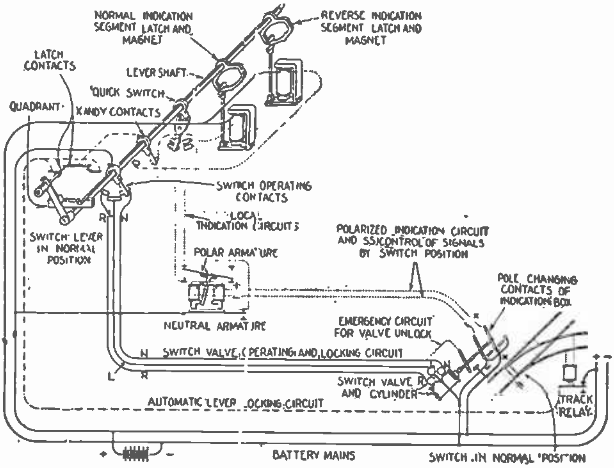


FIG. 6,667.—Diagram of complete *switch control*, indication and locking circuits; *switch and lever in the normal position*. The indicating system is in corresponding condition and the switch is unoccupied by trains and its lever free to be operated.

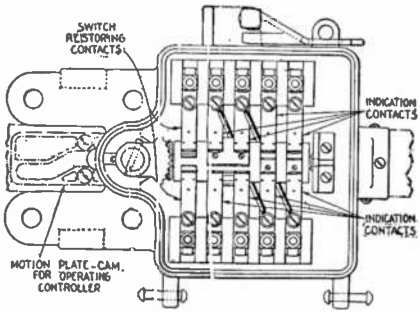


FIG. 6,668.—Union S. and S. Co. pole changing indication circuit controller.

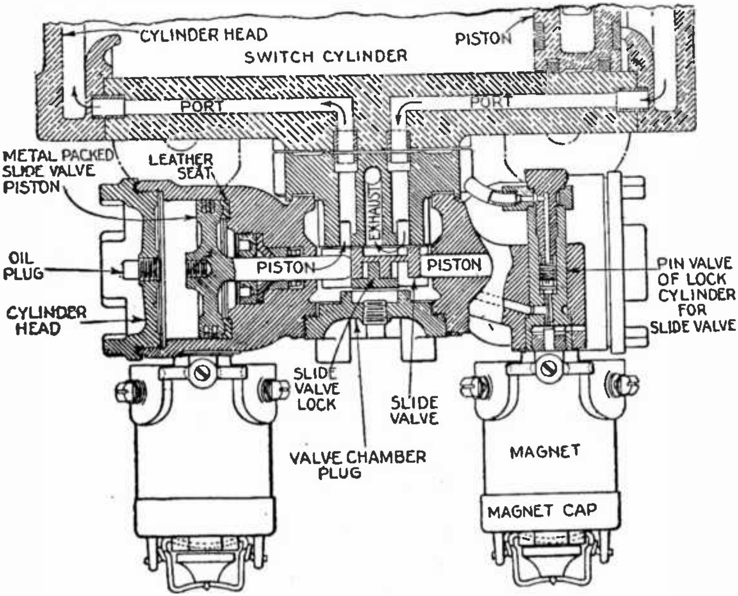


FIG. 6,669.—Union S. and S. Co. switch valve, magnets and switch cylinder. *It comprises* a slide valve that is shifted by two opposed, miniature pistons actuated by air pressure which are controlled from the switch lever through the medium of two electro-magnets, one upon each cylinder. Through the operation of the slide valve, air is admitted directly from the air main to one end of the switch cylinder, while the pressure within the other end of the cylinder is simultaneously liberated to atmosphere. Means are also provided for mechanically locking the slide valve after each operation of the switch and upon completion of the final movement of the switch lever thereafter. Not only does this final movement of the switch lever apply a positive lock to the slide valve, but after so locking the valve, it cuts off the air supply to the slide valve chamber, and hence to the switch cylinder. There are three electro-magnetically operated pin valves embraced in the shifting and locking of the slide valve by which the movements of pneumatic switch cylinder pistons are effected. One of the magnets of these valves is energized normally to retain air pressure constantly against one of the two miniature slide valve pistons, and hence, positively holds this valve in one of its two positions. One of the other magnets becomes energized as the first mentioned one becomes deenergized when the lever is shifted to cause switch reversal. The application of air pressure thus to the other miniature piston, simultaneously with the discharge of air from behind the first one, causes the slide valve to shift and thereby to reverse the piston of the switch cylinder. Such action of the slide valve, however, can occur only after the third magnet and pin valve have been actuated to unlock the valve and simultaneously to admit the pressure from the air main into the slide valve chamber. The energization of this third (lock) magnet occurs the instant the switch lever is shifted from either of its extreme positions, and hence the slide valve remains unlocked and the pressure remains within the slide valve chamber at all times save when the lever is in its completely normal or in its completely

The operation of the slide valve is effected by three electro-magnets, mounted on the valve, which are connected to the lever contacts of the machine by three individual wires. These are the *control wires.*

Safety Devices.—Failures of switches to respond to their levers *are indicated by the switch indication system.* Mounted on the switch and lock movement operating the switch points is a contacting device known as the *indication circuit controller.* Two wires between this controller and the polarized indicating relay for the corresponding switch serve for indicating purposes.

FIG. 6,669.—*Text continued.*

reversed position. Movements of switch levers into these extreme positions can occur only when switches and their levers coincide in position and when the switch is thus securely locked mechanically, and hence the locking of the slide valve and the release of air from the valve chamber can take place only after complete switch and lever operation have occurred and complete coincidence of position of both has been assured.

NOTE.—***Detector bars.*** When detector bars are made a feature of electro-pneumatic interlockings they operate continuously with the piston of the cylinder from the slide bar of the switch and lock movement. The first part of the piston's movement, employed primarily for unlocking the switch, is also employed for the elevation of the bar above rail level. A train standing upon or moving over a switch obviously prevents the elevation of the bar, and hence the unlocking and movement of the switch under trains. During that part of the piston's stroke that effects switch operation, the bar travels idly in its elevated position without material resistance; and during the final movement to lock the shifted switch the bar is depressed to its former position below rail level.

NOTE.—***Indication circuit controller.*** This device is mounted directly over the slide bar of the movement and is actuated positively thereby. The device comprises an oscillating drum of insulating material carrying contacting plates, which make and break electrical contacts with a system of flexible contacting fingers included in the circuits of the indicating system at predetermined points in the operation of the switch and lock movement as shown in fig. 6,668. Normally, a current flow is maintained through two contacts of this device in one direction, and through two of its other contacts in an opposite direction. This current, through two isolated conductors which extend to a polarized relay at the interlocking machine, maintains a normally active state of that relay to retain closed certain contacts and to retain open certain other contacts. Upon full reversal of the switch and lock movement a reversal of the flow of current is produced by reason of the changed relations then occurring between the contacting members of the indication circuit controller. The polarized relay is thus caused to reverse its influence upon its contacts and hence closes those contacts that formerly were open and opens those that were formerly closed. The contacts of the relay thus repeat the two positions of the switch and lock movement, and are therefore employed for controlling not only the normal and reverse indication magnet of switch levers during switch operation by simple local circuits, but are used also as a means wholly within the interlocking tower to obtain control of the current supply to every signal of the system by actual positions of each and every switch over which it governs.

These wires are separate and distinct from the control wires, thus completely isolating the indication system from the control system. These two wires energize a polarized relay at the machine in the tower and constitute the complete indication circuit without connection with the common return wire, so that crosses or grounds have no serious effect. This arrangement eliminates the necessity of providing complicated apparatus for preserving the integrity of the control and indication circuits.

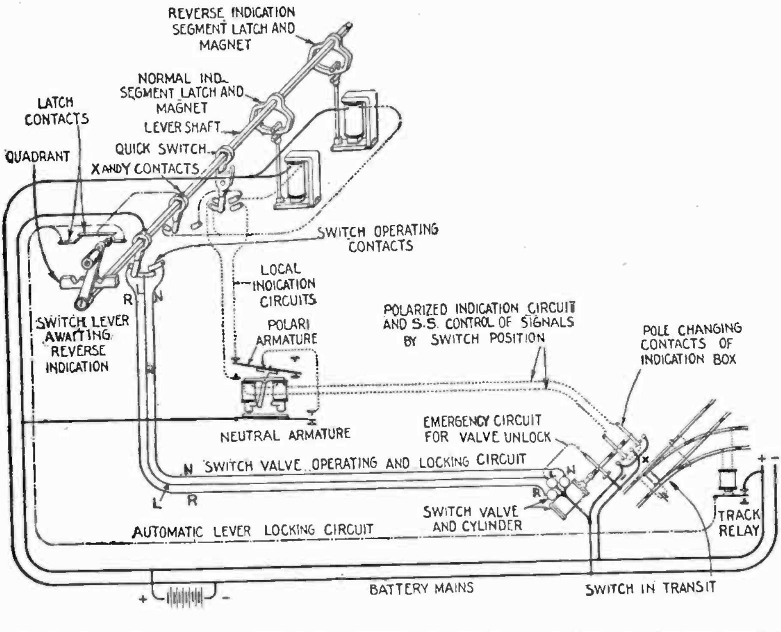


FIG. 6,670.—Diagram of complete ***switch control,*** indication and locking circuits; ***lever partly reversed, switch in transit.*** The lever is moved as far as the indicating segments and latches permit, the switch valve as having responded and the switch as responding, at mid-stroke. It shows the effect, the shunting of indicating wires, produced in the indicating system by the mechanical unlocking of the switch prior to and during its change of position.

Protection against crosses is obtained by the two indication wires and the polarized indication relay (without a common return wire) forming a complete circuit from positive battery through a contact of the indication pole changing circuit controller on the switch and lock movement, through one indication wire to, and thence through the coils of the indication relay back over the second indication wire to another contact of the indication circuit controller and thence to the negative side of the battery.

Thus each switch lever embraces the use of a polarized relay that can respond to a current of one polarity only for one indication, and which

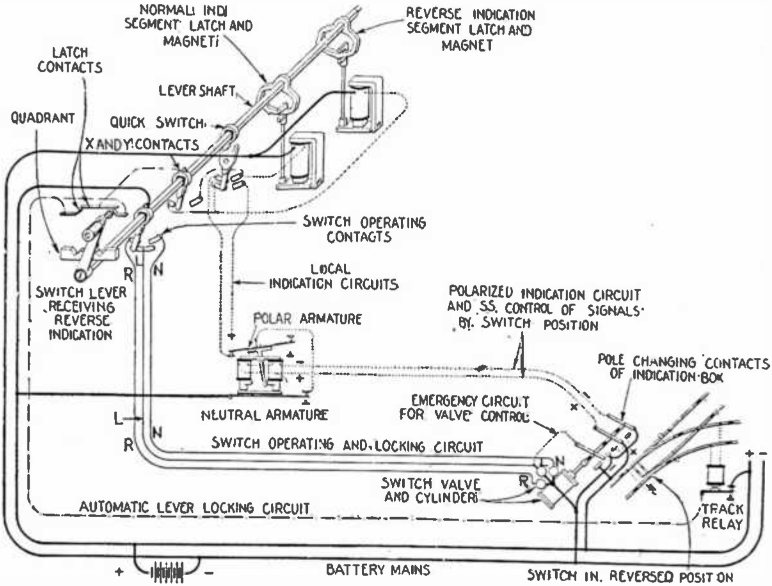


FIG. 6,671.—Diagram of complete *switch control*, indication and locking circuits; switch reversed, *lever about to receive the indication*. The switch having responded, the lever is released for final movement. The conditions of fig. 6,671 are here represented. When in ordinary operation the switch assumes a reversed position by virtue of a partial reversal of its lever, the indicating relay becomes again energized, but by current of a reversed polarity from that existing when the switch and lever were normal. The effect of this is to shift the polar contacts of the relay to establish current through the reverse indication magnet and the closed contacts of the quick switch, and thus to release the lever for final movement to its full reversed position. This final movement causes action of the quick switch again to open the circuit of the reverse indication magnet, and so to connect the normal indication magnet with the open polar contacts of the indicating relay as to prepare that magnet for its next indicating function, as shown in fig. 6,672.

requires a reversal of that current for another indication; the use of two conductors electrically separated from other wires of the system, which include in circuit the polarized relay; and a pole changing circuit controller contact

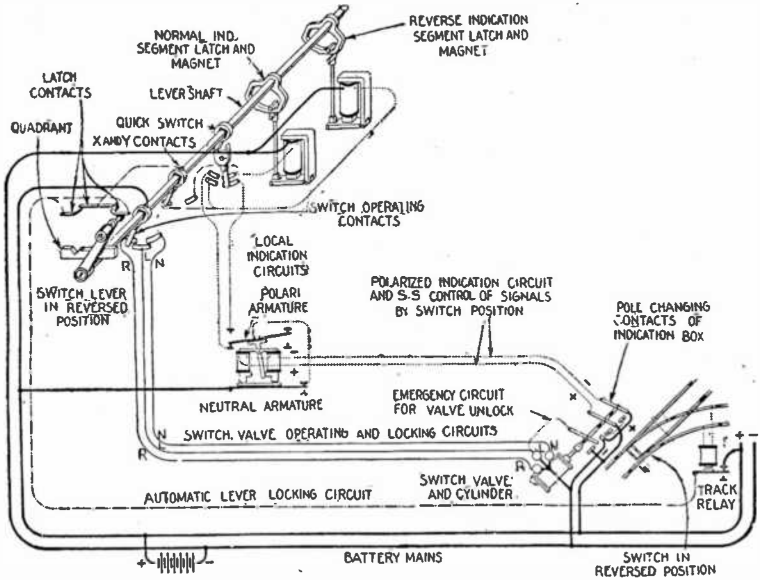
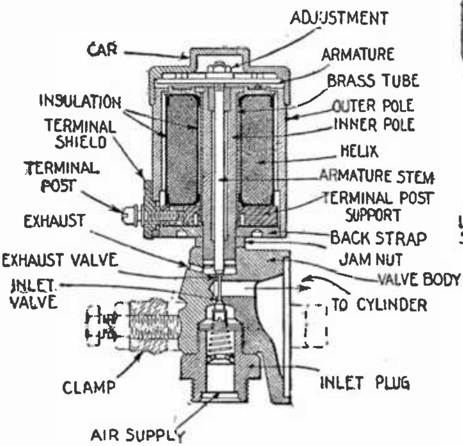


FIG. 6,672.—Diagram of complete *switch control*, indication and locking circuits; *switch and lever reversed:* this is the final position. During the movement of the lever to shift the switch from normal, the lower magnet, latches and segments alone are called into service; during a corresponding reverse operation of the lever and switch, the upper set of magnets, latches and segments alone are called into service. Preliminary to each lever movement, however, that magnet which lies idle during final lever movement, is in actual practice, actively controlled, by train action upon the switch, as an electric lock to the lever. While one magnet thus permits the use of a lever for effecting switch operation, the other one insures, during lever operation, a correct response of the switch before the final lever movement can be made, this final movement transferring that magnet which permitted it, to the duty of locking the lever automatically by train action, and simultaneously withdrawing the other magnet from that service and into the indicating service required for the next operation of the switch. This transfer of the magnet from one field of usefulness to another occurs at the completion of each full lever operation and is performed jointly by what is termed the *quick switch*, and by what are designated as X, and Y, springs of the contacting system.

NOTE.—***The control of the indication magnets*** by the quick switch, as shown in fig. 6,672, involves the use of but one magnet at a time for indicating purposes, and hence, leaves at all times one of the magnets free for other duties if desired. It is this fact that promoted the alternative use of each indication magnet for detector circuit switch lever locking by trains in the electro-pneumatic system. To render this effective, two contacts operated by the switch lever are employed, that are designated as X, and Y, contacts, for the purpose of throwing, alternatively, the indicating magnets into circuit with the contacts of a track relay that embraces the switch rails in its control. In this way, trains entering upon the switch cause that



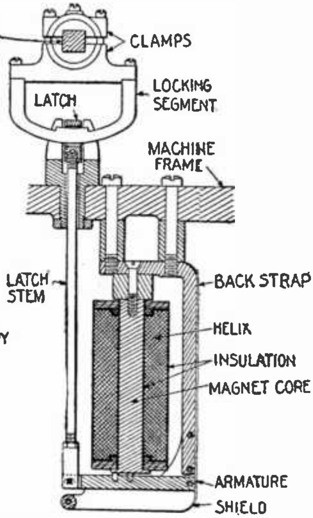


FIG. 6,673.—Union S. and S. pin valve and magnet which controls the pressure to and from the air cylinders. In signal operation it controls directly the pressure to and from the operating cylinder; in switch operation it is not so well adapted to this direct control because of the great volume of air required by switch cylinders and because, also, of the quicker action demanded of switches. For this service it is made to control a D, slide valve, through the medium of two miniature cylinders, the D, valve directly controlling the pressure to and from the switch cylinder.

FIG. 6,674.—Union S. and S. Co. indication or lock magnet on the interlocking machine for duty which does not include the control of air pressure.

NOTE—*Continued*.

one of the indicating magnets that was last used for switch indicating purposes to remain upon open circuit and therefore to prevent initial movements of the lever, until the train has passed clear of the switch. The locking circuit thus formed also passes through a contact that is acted upon jointly by both the catch rod and the lever, a contact closed as the catch rod is elevated to energize the lock, if the track be unoccupied, and which is opened again by the levers during its movements between its positions of engagement by the locks. This is done by the latch to economize in current energy when the lever is at rest in either the normal or the reversed position, and by the lever absolutely to disconnect both magnets from any possible current influence save that peculiar to the indicating system, as soon as the lever moves beyond the influence of the automatic track circuit control of levers and into that entirely separate field of control that embraces only the switch indicating system.

for each indication wire. This arrangement not only separates both conductors of the indicating system from the source of electrical energy during transit of the switch but, at the same time, establishes a shunt or short circuit between the indicating conductors.

Signal Operation and Control.—*Each signal of the system is operated by a single acting cylinder*, the admission of air to which is under the control of a pin valve and electro-magnet of similar construction to those employed on the valves used for switch operation.

Since gravity is employed to return signals to their stop position, double acting cylinders are not required in signal service.

The pin valve magnet (see fig. 6,673) is connected by wire with its operating lever in the interlocking machine and is energized only when the lever assumes one of its extreme reverse positions. When so energized, air is admitted to the cylinder and the signal moved to the proceed position. This movement of the signal opens a contact in a second circuit including an electric lock engaging the signal lever, thereby applying the lock to prevent complete return of the lever to its normal position. Its partial return, however, is permitted, a movement which causes the interruption of the signal circuit, and hence a return of the signal to the stop position.

Upon reaching the stop position the circuit including the lever lock is again established and the lock re-energized. This results in the release of the lever so that it may again be placed in its normal position.

Electro-pneumatic signals may be operated in either two or three positions, upper or lower quadrant, and giving right or left hand indications as desired. They may also be operated without change by lever only, by track circuit only, or by combination of the two.

Auxiliary Features.—The elements already described are what may be termed *essentials* of the system. Additional special features are frequently desired or required by the peculiarities of the local conditions under which the system is to operate. These features are:

1. Semi-automatic control of signals;

2. Calling on arms;
3. Section locking;
4. Approach locking;
5. Time release;
6. Check locking;
7. Automatic train stops.

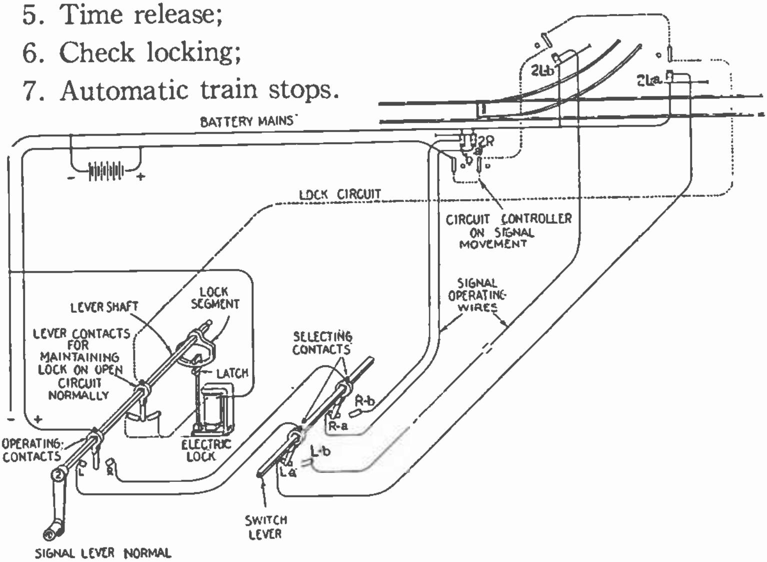


Fig. 6,675.—Diagram of complete *signal control* and indication circuits; *lever and signals normal.*

Numerous accompanying diagrams are given to illustrate the auxiliary features.

Signal Lever Operation and Control.—The signal levers of the electro-pneumatic machines occupy five distinct positions as shown in fig. 6,626, when used to *full capacity.**

*NOTE.—*Full capacity* means the use of the lever to the right for the operation of one signal or set of signals and to the left for another signal or set of signals, the two sets necessarily conflicting, always, with each other in respect to the route or routes governed by them. This feature gives to each signal lever the capacity of two levers.

Evidently from figs. 6,675 to 6,680 the signal levers normally occupy a vertical central position; when moved to the extreme right, a signal is operated that governs traffic over a given track in one direction; when thrown to the left, a signal is operated which governs traffic over the same track in an opposite direction, or in any direction over any conflicting track, as convenience of manipulation may determine in arranging lever functions. Any signal thus operated to proceed, applies an electric lock to the signal lever and prevents the full return of the lever to the normal until

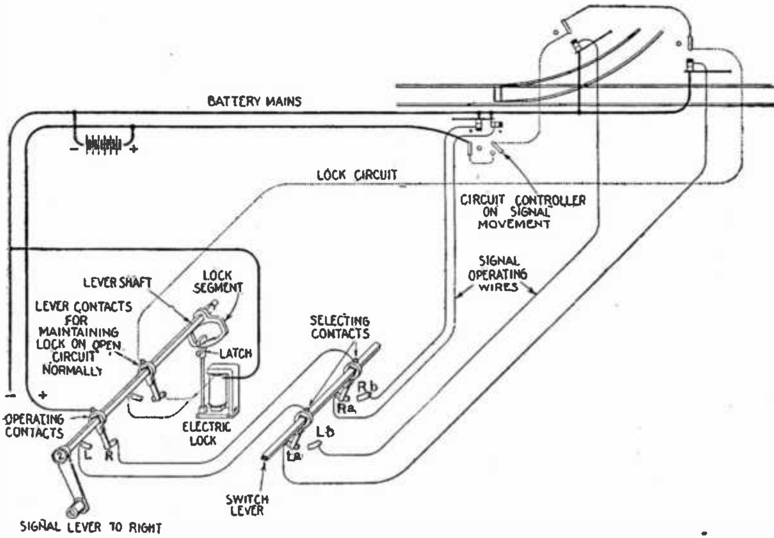
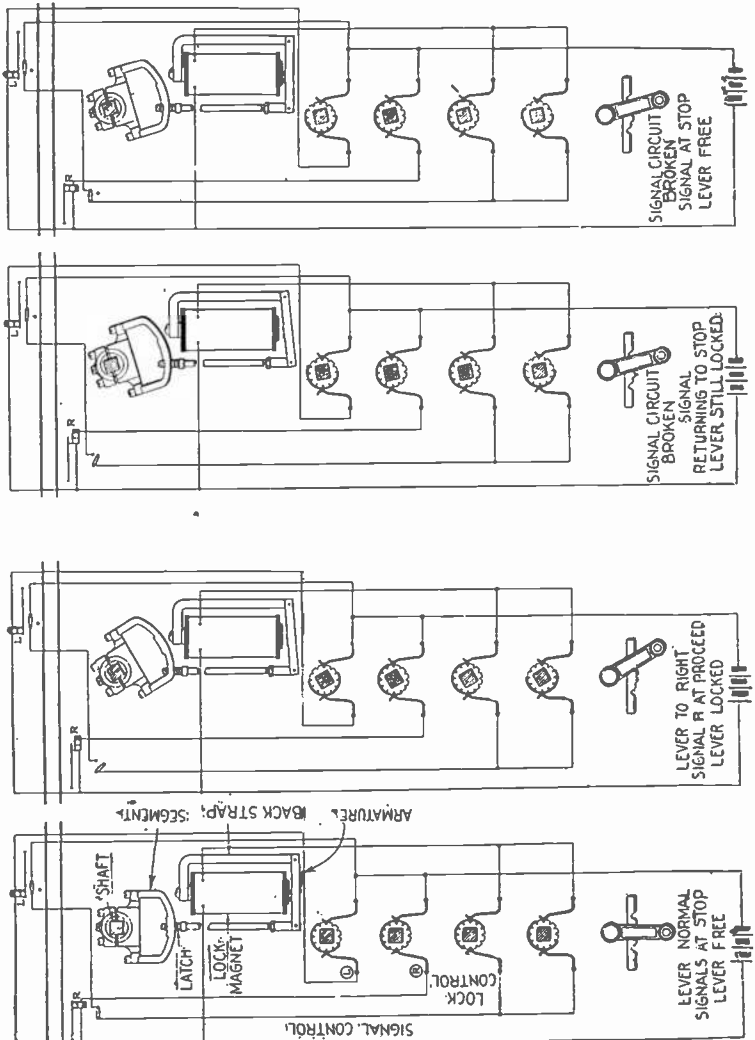


FIG. 6,676.—Diagram of complete *signal control* and indication circuits; *lever and one signal reversed.*

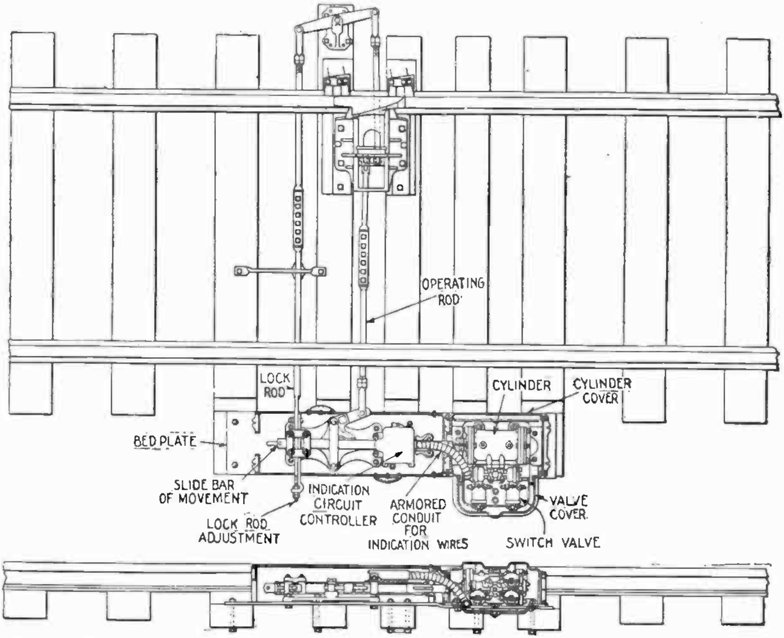
the signal, in response to a partial return of the lever toward normal, re-energizes the lock and releases the lever for this final movement.

Positions D, and B, of the diagram, fig. 6,626, represent those assumed by signal levers when moved from their extreme positions, represented by lines L, and R, to restore signals to the stop position and beyond which they cannot be moved, toward their central normal position, until the signal assumes the stop position.



FIGS. 6,677 to 6,680.—Diagram of signal lever and circuits for selecting opposing signals.

Switch Operation and Control.—Switches are unlocked, operated and again locked by one continuous operation of the prime mover, the cylinder. Its characteristics are shown in figs. 6,681 to 6,686. As before stated, switch and lock movements are applied to the operation of switches of every character and rail section.



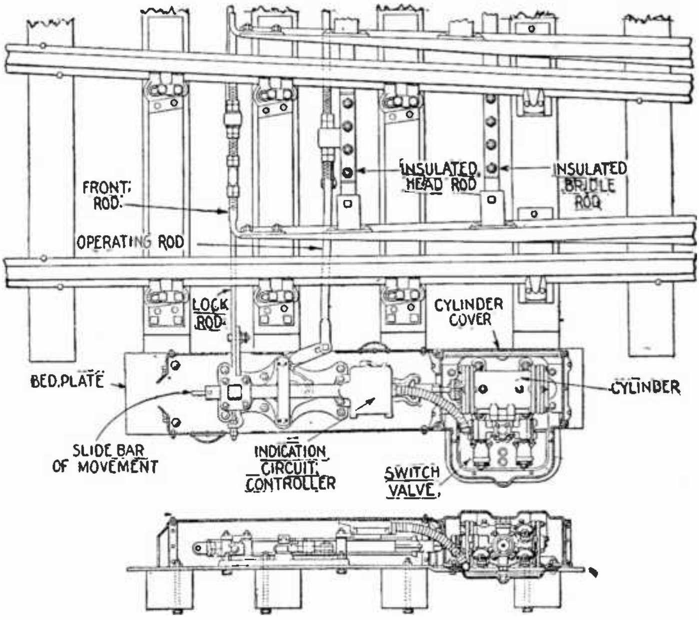
FIGS. 6,681 and 6,682.—Union S. and S. Co. electro-pneumatic switch and lock movement applied to a Hayes derail. The switch and lock movements comprise a slide bar moved in a longitudinal direction by the cylinder to unlock, operate and again to lock the switch through the medium of an alligator jaw crank engaging it.

The equipment as shown in figs. 6,681 to 6,684 consists of four separate elements:

1. Switch valve;

2. Switch cylinder;
3. Switch and lock movement;
4. Indication circuit controller.

These details are shown in the accompanying illustrations.

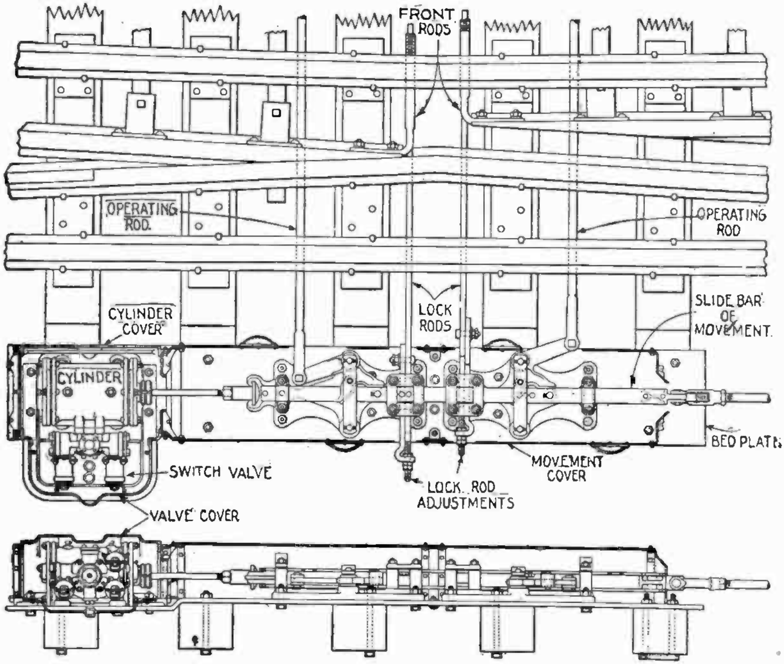


FIGS. 6,683 and 6,684.—Union S. and S. Co. electro-pneumatic switch and lock movement applied to one end of a double slip switch.

Signal Operation and Control.—Figs. 6,687 and 6,688 show the *signal motor* of the system comprising the magnet and pin valve already described, the cylinder and the piston by which the signal is operated from one of its positions to another.

Where a signal embraces three positions of indication, two such devices are employed to act jointly upon it, one for each proceed indication displayed.

Attached to the signal motor is a circuit controller that actuates certain electric contacts at predetermined positions of the signal. These contacts control the electric locks of signal levers whereby the latter may not be restored to normal until the signals which they operate have first assumed the stop position; they also control the circuits of other signals and govern



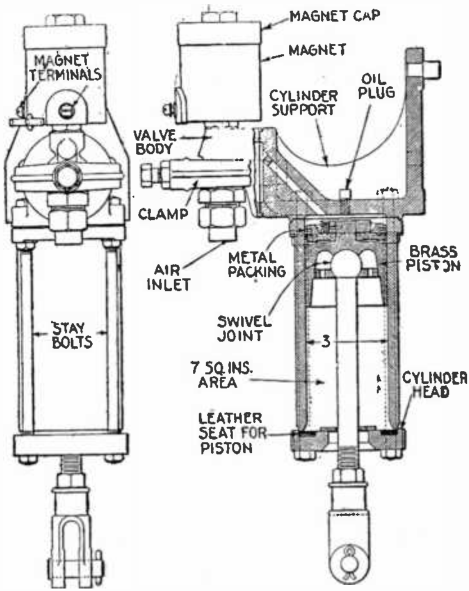
FIGS. 6,685 and 6,686.—Union S. and S. Co. electro-pneumatic switch and lock movement applied to a movable point frog.

the display, by the other signals, of those indications which relate to conditions more or less common to both.

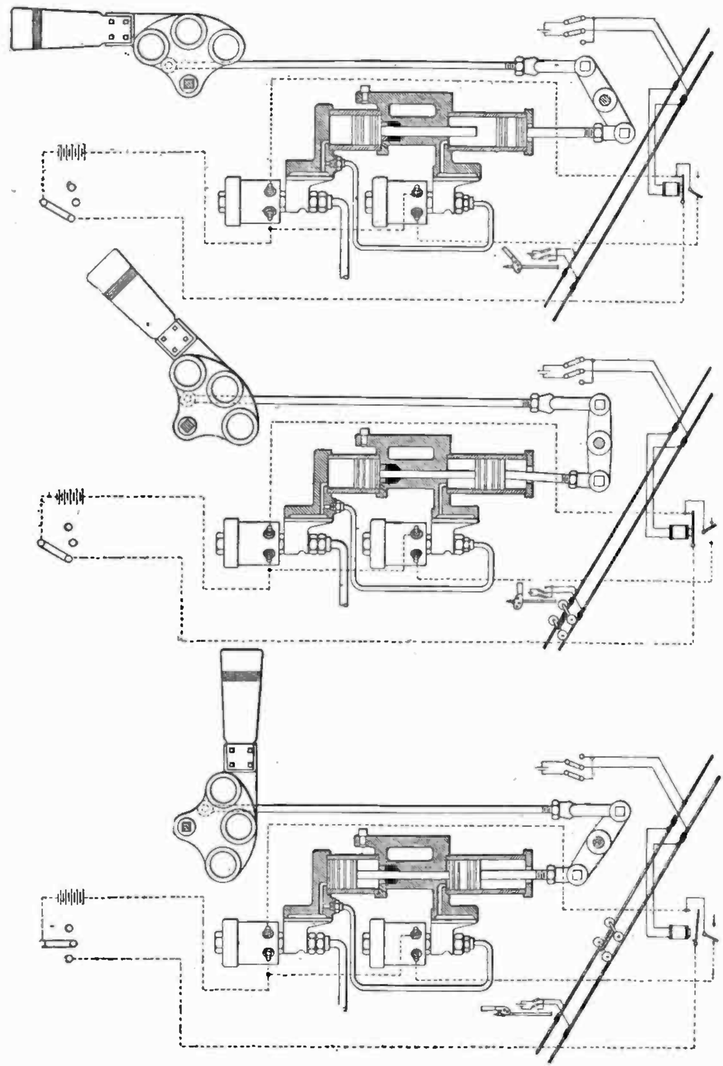
Approach, Detector and Sectional Route Locking.—That feature of automatic lever locking by trains, which is peculiar to the action of trains prior to their entrance upon the switches of the interlocking, is generally referred to as *approach locking*, and embraces also *the automatic announcement of trains*.

That feature which involves the action of lever locks by train movement over the switches of the interlocking, is generally termed detector locking and sectional route locking. The latter feature embraces, besides the automatic locking and releasing of switch levers, the semi-automatic control of signals by trains through the medium of track circuits common to both.

Calling on Arms.—In the diagram, fig. 6,692, for simplicity, only the circuits peculiar to the operation and control of the



Figs. 6,687 and 6,688.—Union S. and S. Co. signal motor. In three position signals, while a single cylinder, valve and magnet are employed for each of the two proceed indications displayed by such signals, the air supply is direct from the main to that valve and cylinder only by which the caution or 45° position is displayed; the air supply to the other valve and cylinder being drawn from the 45° position cylinder. This is done to insure that the 90° position of the signal is always dependent upon the complete prior activity of the 45° mechanism, and that the interruption of either the air pressure or the electrical current by which the signal is held in the vertical position will insure its return therefrom whichever magnet or valve may be deprived of power.



FIGS. 6,689 to 6,691.—Diagrams of three position, upper quadrant, semi-automatic, electro-pneumatic signals, showing joint operation from the interlocking machine and by automatic train action upon the track it governs.

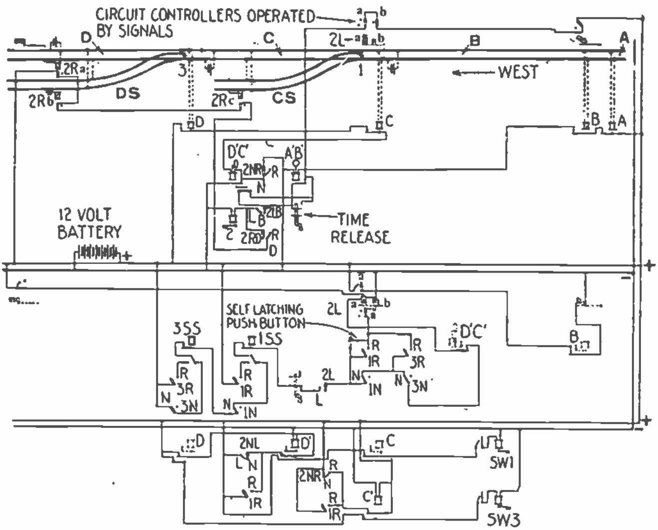


FIG. 6,692.—Diagram of sectional route locking circuits. It will be noted that the rails of each switch are included within separate track circuits, and that these circuits embrace both leads as far as their fouling points, and extend in each direction to the signals governing movements over these two switches. A track circuit also extends from the signal which primarily governs the first switch to the preceding signal, usually called the distant signal. A fourth section also extends from this distant signal to a point preceding it 3,000 ft. or more. These sections are designated D, C, B, and A, the switches, 1 and 3, corresponding with the numbers of the two levers assigned to their operation. The signals are all operated by lever No. 2; the three east bound signals being operated by the lever thrown to the right and the two arms of the west bound signal by the lever thrown to the left, this being possible because each of these signals conflicts with each other signal under all circumstances. The operation of signal 2L-a, for a west bound train requires that switches 1 and 3, be set and locked as shown, before lever 2, may be moved to operate the signal. The operation of lever 2, to the left through the mechanical locking of the machine locks levers 1 and 3, normal, and hence the switches 1 and 3, for the route governed by the signal so long as lever 2, remains moved from its normal position. ***Approach locking.*** Even though signal 2L-a, be restored to the stop position by the partial return of the signal lever toward normal, the switches of the route still remain mechanically locked. It is evident too, that whether lever 2, is retained out of its normal (central) position by choice or by compulsion, the switches remain locked with equal security. The return of signal 2L-a, to normal, ordinarily, releases the lever for its restoration to normal; where route locking is in vogue, this release of the lever by the signal's return is made dependent upon an added condition.*

*NOTE.—*This condition* is that a train has not, previous to the signal's return, entered upon the track circuits A or B. If the train has so entered, its approach is automatically announced to the operator by annunciator A'B', and the electric lock of lever 2. is retained upon open circuit during the train's presence, upon either of the sections. Before the annunciator A'B', can be re-energized to release the lock 2, the train must have left sections A and B completely. If its leaving was by permission of signal 2L, the train naturally entered

NOTE.—*Continued.*
upon section C, before it left section B. This act causes, through relay C, the indicator D'C' to become de-energized before the annunciator A'B' becomes re-energized and releases the lock of lever 2, whereby that lever becomes free to be put normal and the mechanical release of switches 1, and 3, becomes possible. The release of lever 2, by indicator D'C' when this indicator is de-energized has another important function.

NOTE.—*If a second train* (in fig. 6,692) enter section A B, before lever 2, is restored, this lever having been thrown to clear signal 2L, for a previous train, indicator D'C', will not pick up, being a stick indicator. The release circuit, through a back contact of indicator D'C', will remain closed and allow the leverman to restore lever 2, although the lock circuit of lever 2, is open through indicator A'B'. The signal lever may also be restored while a train is in section A B, by the use of a time release, the operation of which is described in a subsequent paragraph. Should lever 2, be restored to normal after a train has accepted signal 2L, the release, mechanically, of levers 1, and 3, that follows is without danger, because the entrance of the train upon section C, that necessarily preceded this event, caused, through relay C, the interruption of the electric lock circuit of lever 1, and through stick relay C', the interruption of the electric lock circuit of lever 3; thus effectually retaining these levers still locked against operation, but by direct electric means peculiar to each.

NOTE.—*Switch locking.* While switch levers are locked automatically in groups by train action upon the first switch of the group, their release must occur not in like manner by the exit of the train from the last switch of the group, but each lever must be released individually as the train passes over its switch and clear of the fouling limits of the switch leads. The movement of the train westward off of section C, and into section D, causes relay C, and stick relay C' to become re-energized and the electric lock of lever 1, released. Before this occurs, however, relay D, has been de-energized, by the entrance of the train upon section D, in its movement from section C, and hence the circuit of lock 3, is continued open at relay D, notwithstanding its closure at relay C', and lever 3, still remains locked until the train passes entirely clear of section D, and until relay D, becomes thereby re-energized. It will be observed that stick relay D', is not operated with relay D, for were this done, the lock circuit of lever 1, would be opened thereby and the release of switch 1, which is desirable, would not follow the train's exit from section C. The action of the train on section D, and the consequent de-energization of relay D, would not open the circuit of relay D', because of a by pass formed by lever 2, when that lever is not in a position for governing east bound traffic. This by pass bridges the open contact of relay D, and prevents the action of relay D, for west bound traffic; when lever 2, is thrown to the right, however, for signaling east bound traffic, the train's action upon section D, operates not only relay D, but also the relay D', thereby opening the lock circuits of both levers 1 and 3. Upon passing on to section C, relay C, only is de-energized and not relay C', as when the west bound train entered section C, from section B. Relay C' is thus retained in an energized state by virtue of a by pass formed by lever 2, when that lever is in any position other than that employed for east bound traffic, and hence when the train moves from section D, into section C, the re-energization of relay D, closes the lock circuit of lever 3, and releases switch 3, for possible operation. This would not occur did not the relay C', remain energized, through the by pass referred to. The lock circuit of lever 1, is necessarily opened by relay C, before the exit of the train from section D, into section C, fully occurs, so that after the occurrence, when both relay D, and relay D', are energized, the circuit of lock 1, remains open at relay C, and until the train passes clear of section C, whereupon switch 1, may be moved if desired. It will also be observed that when switch 1, is reversed, a by pass is established on stick relay D', which causes this relay to remain energized regardless of the condition of track relay D. The purpose of this by pass is as follows: With switch 1, reversed and a west bound train having not yet cleared section D, if signal 2R-c, were cleared for a second train to move from siding CS, to the main line, stick relay D', would open if it were not for this by pass and switch 1, would be locked and remain locked as long as the first train stood on section D, thus preventing all movements of traffic over switch 1, in its normal position. A similar by pass acts on stick relay C', and prevents switch 3, from being locked while a train is passing into siding CS, after having accepted signal 2L-b.

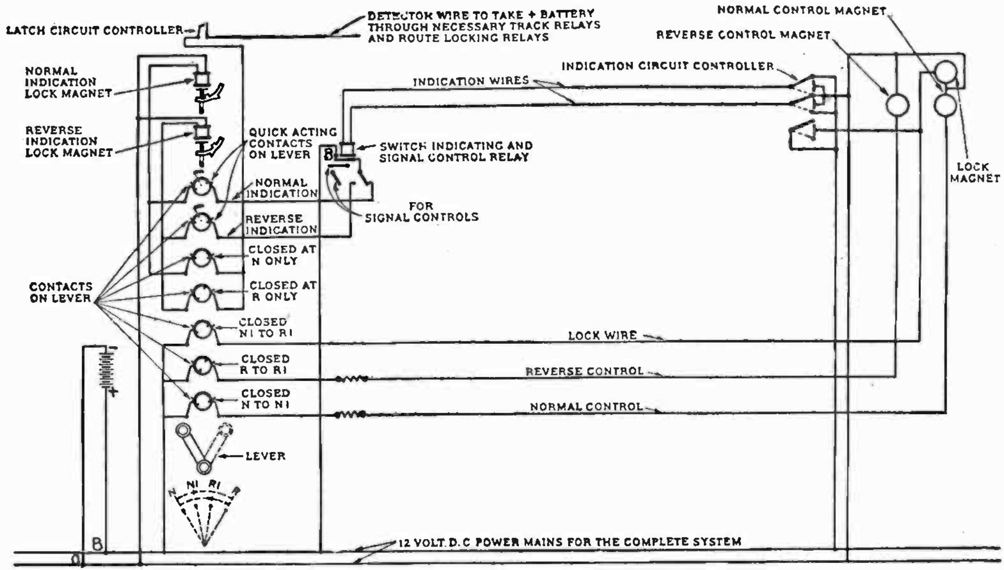


FIG. 6,693.—Diagram of complete control, indication and locking circuits for single switch with *d.c.* indication.

two westbound signal arms are shown. The top arm only is under automatic control by trains, through the indicator D′, C′, the lower or "calling on" arm being assigned to movements into either one of the two sidings whether these be occupied or not, and also to the main track D, only in case that track is already occupied, and the top arm is hence restrained against operation by indicator D′, C′, for such train movements.

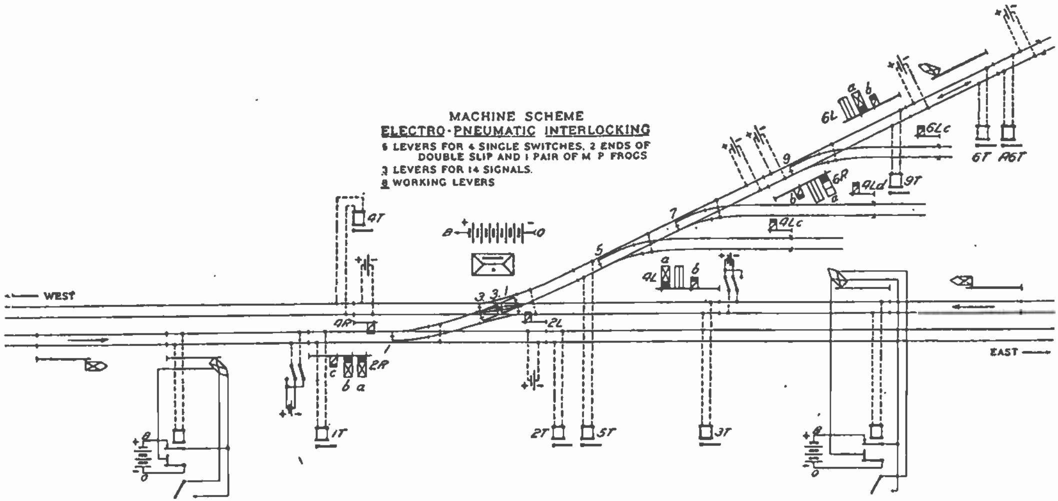


FIG. 6,694.—Complete layout of small electro-pneumatic interlocking plant.

NOTE.—*Clockwork time release.* The operation of the time release is to unlock electrically during emergencies a lever properly held locked by train action, and requires first, a distinct action by the leverman, and second, that a sufficient period of time must elapse, following this action, to insure that the train, which is locking this lever, has either stopped or is traveling at a reduced speed, before the lever is restored to its normal position. It is also to compel the restoration of the time release to its normal position after each operation, before signals can be again operated for traffic movement under them, that signal circuits are thus controlled by contacts on the time release.*

*NOTE.—*The current supply* to both signals is further drawn through contacts of other devices than the indicator D'C' (fig. 6,692) and the time release. In order to insure that a misplaced switch, wrongfully set from any cause out of coincidence with the new position of its operating lever, and to insure also that a lever which from any cause assumes a position at variance with that of the switch it operated, may effectually prevent the display at such times of any signal giving proceed rights over the switch, this current supply is also drawn through the contacts of the switch indicating relay and through corresponding contacts operated by the switch levers.

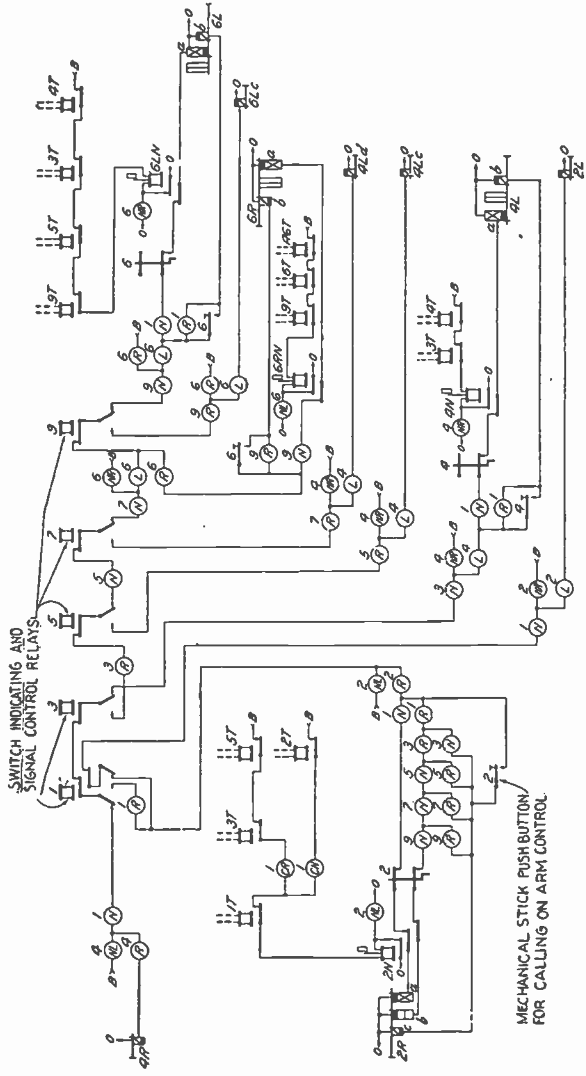


FIG. 6,695.—Signal control circuits for plant shown in fig. 6,694.

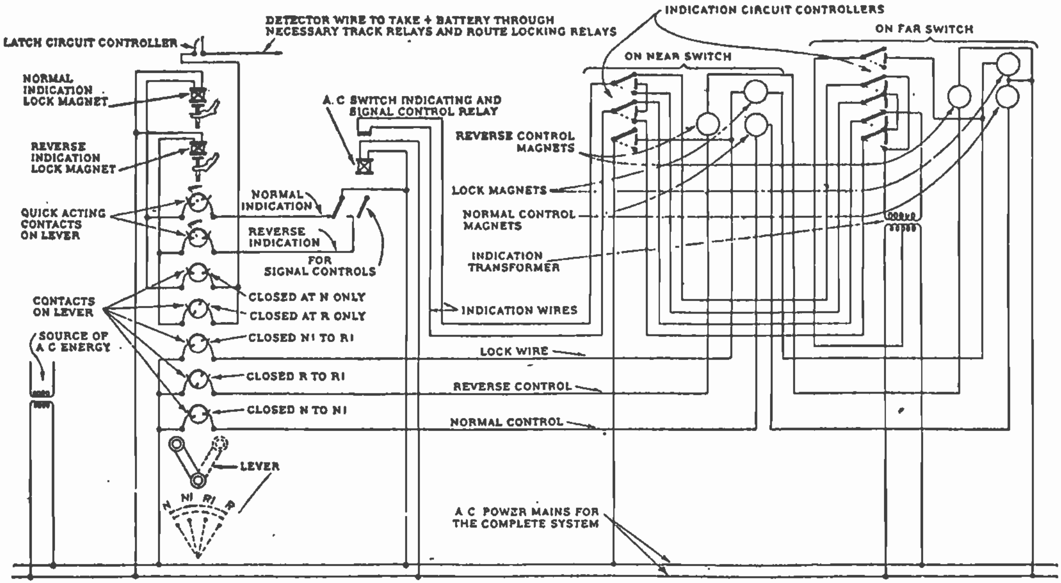


FIG. 6,696.—Diagram of complete control, indication and locking circuits for crossover with *a.c.* indication.

The use of the lower arm in this capacity is, as shown, not possible by lever action alone, but demands in addition the operation of a push button which is mounted behind the signal levers so that its operation is convenient only when the lever is moved from normal, a movement that must necessarily precede the effective use of the button for clearing the calling on arm. This button, when depressed, closes a pair of contacts in the signal circuits that are effective to clear the calling on arm providing the high speed signal above it is in the stop position, and providing also that the signal lever 2, is moved to the left.

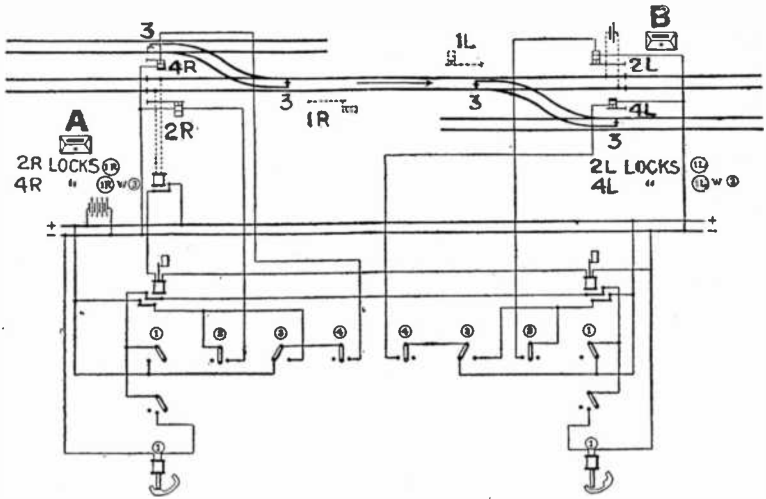


FIG. 6,697.—Check locking or locking between towers. *In the diagram* lever 1L, of tower B, and lever 1R, of tower A, are the master levers while 2L, and 4L, are the actual signal levers of tower B; and 2R, and 4R, are those of tower A. Assuming a gauntlet track being unoccupied, and each towerman being made aware of this by his indicator, A, may desire to move a train under signal 2R, to B. This he can do under the conditions prevailing, because signal lever 2R, is free to be moved when master lever 1R, is thrown to the right as shown. This action of lever 2R, however, operates the signal only upon condition that the current supply to the signal is not interrupted by either or both of the tower indicators. A train acting upon the authority of signal 2R, operates that signal automatically to stop through the medium of the track circuit and the tower indicators controlled therefrom, and simultaneously retains the locks of levers 1R, and 1L, upon open circuit until it passes completely from the track circuit. While levers 1R, and 1L, may at any time be placed in their central position, that one at A, lever 1R, may be moved only to the extreme left at all times while that one at B, lever 1L, may be moved only to the extreme right at all times. The application of the electric locks to these levers by train action restrains but one of the master levers against full reversal. For the direction of traffic shown in the diagram, lever 1L, tower B, is so restrained, while for traffic in the opposite direction lever 1R, tower A, is likewise restrained. When the train has passed clear of the gauntlet track section both indicators give evidence of the fact and the master levers may then be operated to change the direction of traffic. Reversal of 1R, locks mechanically signals 2R, and 4R, against operation while reversal of 1L, releases signals 2L, and 4L, for operation. A west bound train now acting upon authority of signal 2L, or 4L, de-energizes both indicators and retains both electric locks upon open circuit as before. Now, however, it is lever 1R, that is restricted against full operation in reverse by the train until the latter has passed clear of the gauntlet section, thus automatically holding traffic over the gauntlet to conform with its own direction.

The current supply to both arms is also drawn through contacts of a device known as a time release, as shown in fig. 6,692, and already referred to in a general way. This is done in order to insure that the first act of its operation will be to open the signal circuit and thus prevent any possible operation of the signals until the device has been again returned to its original position.

Check Locking or Locking Between Towers.—The first requisite of a safe method to prevent the simultaneous entrance of trains from opposite directions onto a piece of common track is *the interlocking of the two signal levers by which movements to such a track are governed.* This is also known as "*traffic locking.*"

When both levers are comprised in a single machine, both signals embraced in the same interlocking, this interlocking is done mechanically and in a very simple way well understood. When, however, the levers constitute elements of two separate machines, the signals embraced in two different interlockings, the locking is not practicable by purely mechanical means and is accomplished electrically. Usually, more than one signal governs train movements for each interlocking over a gauntlet track. To obtain the simplest circuits and the least number of instruments, contacts, etc., for the protection sought in such cases, an independent lever in each interlocking is employed as a *master* lever and it is to these levers that the electric locking is applied; these levers, through the mechanical locking of the machine, being locked by each signal lever of the machine giving train rights over the gauntlet track.

TEST QUESTIONS

1. *What is an electro-pneumatic system?*
2. *What is the advantage of the electro-pneumatic system?*
3. *Of what does the system consist?*
4. *How is the compressed air obtained?*
5. *Is the source of electricity for the control of the various appliances usually already available?*
6. *Describe at great length the electro-pneumatic interlocking machine.*
7. *Explain switch operation and control.*
8. *How is the operation of the slide valve effected?*
9. *Name the different safety devices employed.*
10. *What are detector bars?*
11. *Describe the indication circuit control.*
12. *Draw a diagram of complete switch control.*
13. *How are the indication magnets controlled by the quick switch?*
14. *How is each signal of the system operated?*
15. *Name the special auxiliary features.*
16. *Describe the signal lever operation and control.*
17. *Describe the switch operation and control.*
18. *Explain approach, detector and sectional route locking.*
19. *Define the term "calling on arms."*

20. *How is the top arm controlled?*
21. *What is the other name given to check locking?*
22. *Explain check locking.*
23. *What is a gauntlet track?*

CHAPTER 150

Automatic Train Control

The object of this system is to enforce the observance of the speed restricting indications of wayside signals by compelling the engineman to perform some manual act called ***acknowledging*** *when passing such signals.* By speed restricting indications is meant both the caution and stop indications of wayside signals.

Penalty for Failure to Acknowledge Restrictive Signals.—The penalty for failure to acknowledge either a caution or stop signal is an automatic brake application from which the brakes cannot be released until the train has been brought to a stop.

Transmission of Control Wayside to Locomotive.—The control device between the wayside and the locomotive is composed of two parts:

1. Receiver;
2. Inductor.

The receiver is securely fastened to the trucks of the locomotive; the inductor to special ties with its pole face 2½ ins. above the top of the running rail and its center line parallel with and usually 19½ ins. outside the gauge line.

The receiver is adjusted so that as the locomotive moves along the track the pole faces of the receiver pass about 2 ins. above and directly over the inductor pole faces. Fig. 6,698 shows the essentials of receiver and inductor.

In action when the receiver carried by a locomotive approaches an unwound inductor or a wound inductor on open circuit, *a surge of magnetic flux builds up in the secondary coil and produces a negative current in the relay* as shown by curve ABC, fig. 6,699.

This negative current is sufficient to allow the relay to open, and once open stays open until restored due to its being a stick relay.

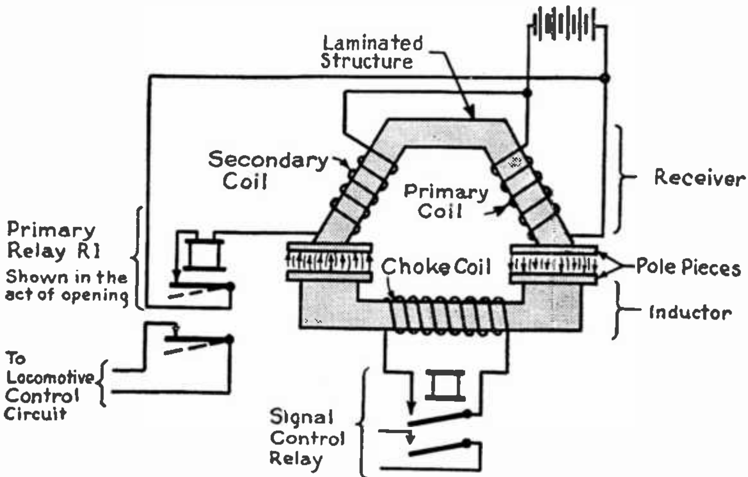


FIG. 6,698.—Diagram of ***receiver*** and ***inductor*** illustrating construction and principles of control wayside to locomotive. The receiver consists of an inverted U shaped magnet with laminated cores, large pole pieces and two coils. The inductor consists of a U shaped magnet with laminated cores and large pole pieces the same shape, size and spacing as the pole pieces of the receiver. One of the two coils of the receiver is called the primary coil, and being constantly energized from a source of electrical energy, it produces a strong magnetic field. The other coil, called the secondary coil, is connected to the same source of energy and in series with the coil and front contact of relay R1, through which a current of about 14 milli-amperes flows normally. Certain of the inductors which are used in this combination are called wound inductors. These are provided with a choke coil which is automatically controlled in such a way that when a speed restricting impulse is to be given the coil is an open circuit and when no impulse is to be given the coil is closed on itself. Other inductors have no choke coils and they will therefore always act to give a speed restricting impulse. They are called unwound inductors.

Current curve ABCDE, shows approximately how the normal battery current through the relay R1, would be varied as the result of a receiver passing an inductor on open circuit if said relay were non-stick, the amplitude of the cycle varying with the speed at which the receiver passes the inductor.

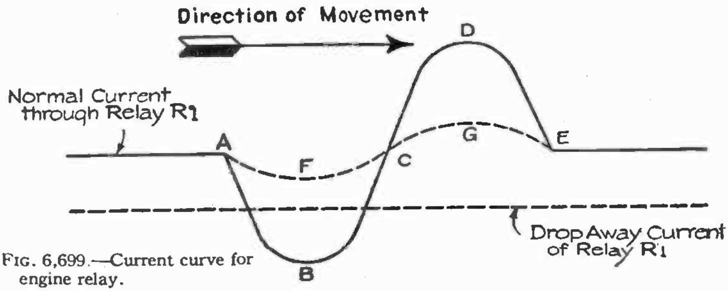


FIG. 6,699.—Current curve for engine relay.

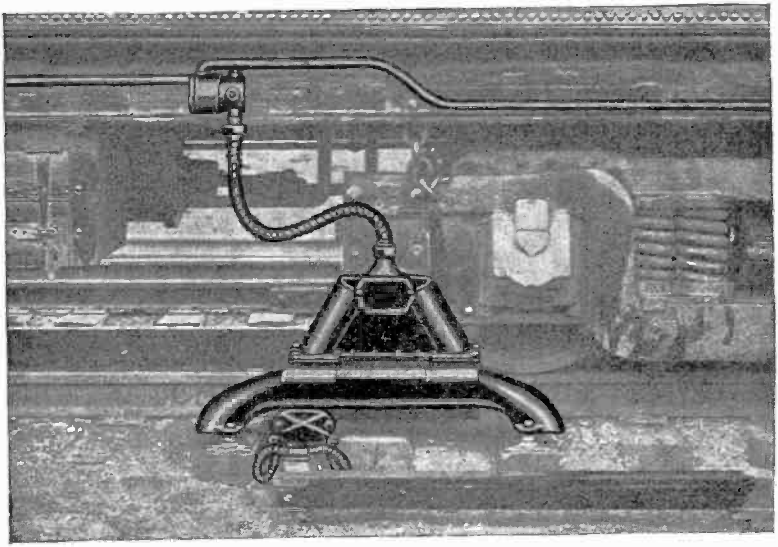


FIG. 6,700.—General Railway Signal Co. receiver and inductor mountings, receiver mounted to truck side frame. The receiver proper is protected by a non-magnetic casing which is adjustably mounted to one of the tender trucks in such a way that no car springs intervene between the receiver and the car axle. The terminals for the receiver windings are made accessible for testing and inspecting by removing a small cover plate on the side of the receiver housing. The wires leading from the receiver are connected to the locomotive wiring through a plug coupling which facilitates the making of repairs to locomotives as well as the manner of replacing the receiver.

Incidentally, it is to be noted that this is a valuable characteristic of a purely inductive device such as this, namely, that the power of the transmitted electrical impulse increases with speed.

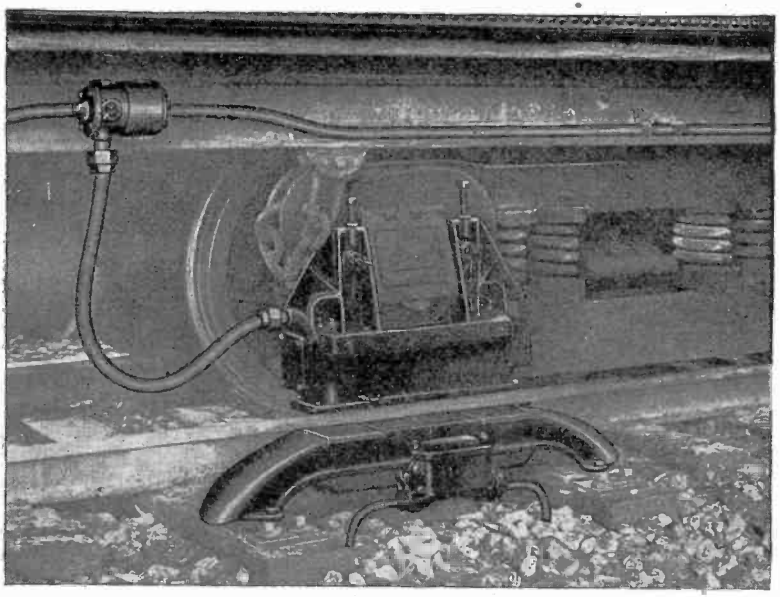


FIG. 6,701.—General Railway Signal Co. receiver and inductor mountings, receiver mounted on journal box. The inductor is protected by a strong, ramp shaped, non-magnetic housing securely fastened, through special ties, to the rails in such a manner as to maintain correct operative relation between the rail and the inductor. The two terminals for the inductor winding are located in an outlet box attached to the under part of the inductor housing, and the connecting wires lead into trunking through flexible conduit or into parkway cable.

Current curve AFCGE, shows approximately how the normal battery current through relay R1, would vary as the result of a receiver passing an inductor on closed circuit, which would be the case under clear conditions. The amplitude of the cycle AFCGE, as a result of the effect of the choke coil, is never enough to cause relay R1, to open.

Figs. 6,700 and 6,701 show the manner in which inductors and receivers are protected and the most approved means of mounting.

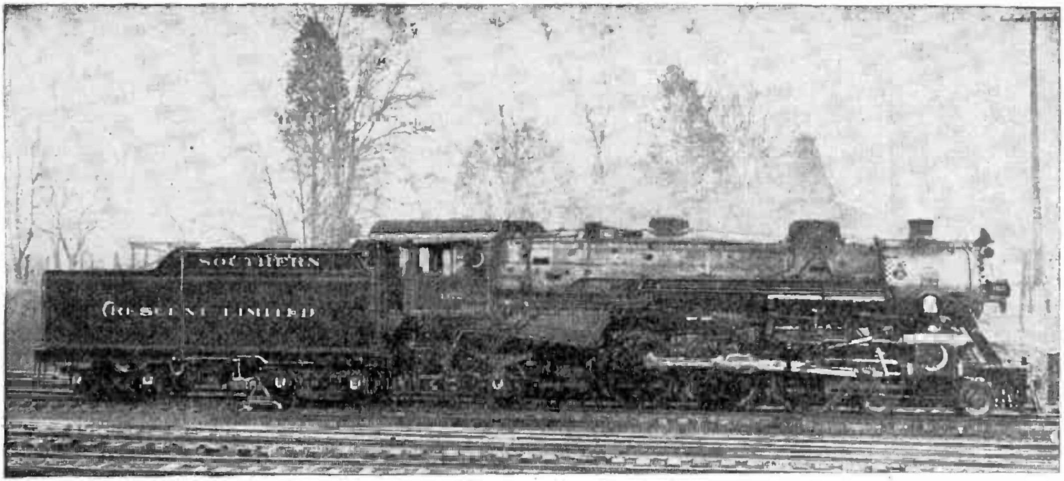


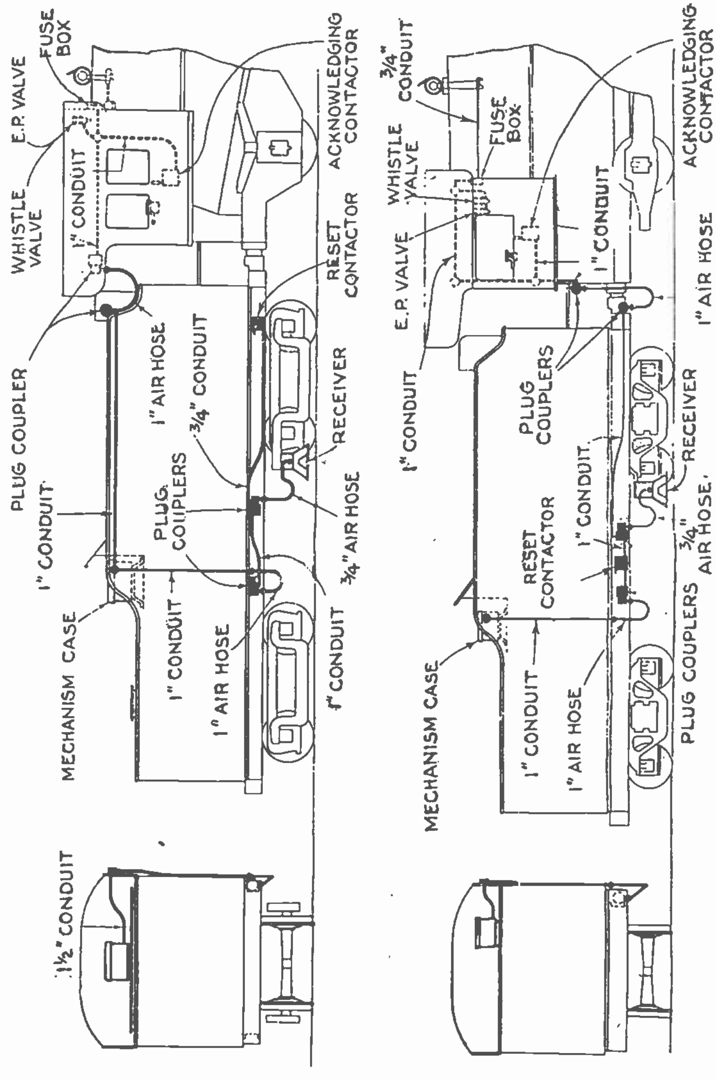
FIG. 6,702.—Southern Railway locomotive showing location of automatic train control apparatus.

Brake Applying Apparatus.—The devices employed in applying the brake consist of:

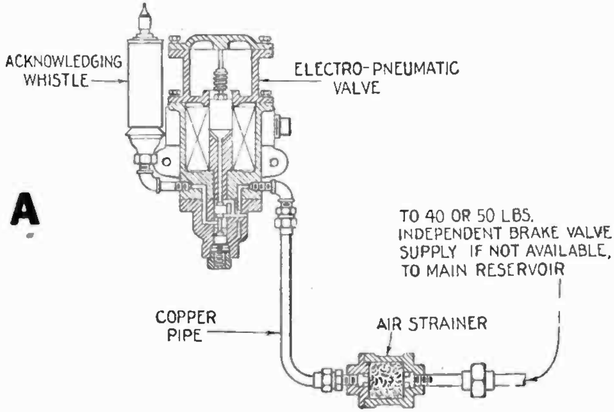
1. Electro-pneumatic valve;
2. Brake valve actuator.

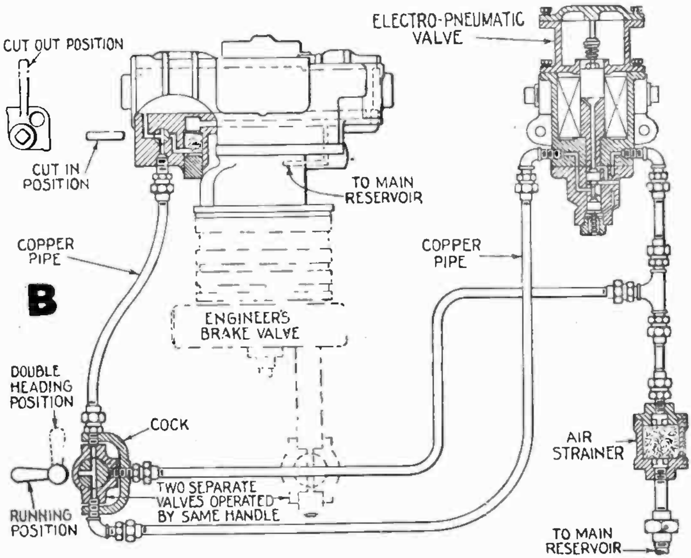
Ques. What is the actuator?

Ans. An air operated differential piston and mechanism mounted on the automatic brake valve.

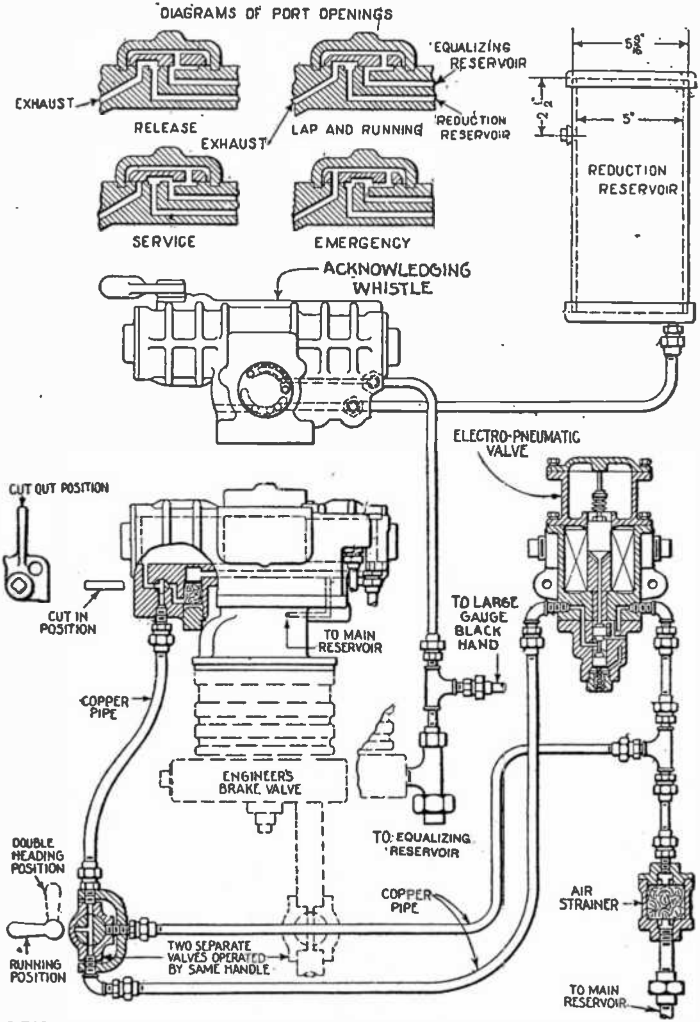


Figs. 6,703 to 6,706.—General Railway Signal Co. automatic train control apparatus. Diagram showing location of parts and connections.





FIGS. 6,707 to 6,711.—General Railway Signal Co. air pipe layout for actuator giving unlimited brake pipe reduction. A, air pipe layout for acknowledging whistle; B, air pipe layout for actuator.



Figs. 6,712 to 6,719.—General Railway Signal Co. air pipe layout for actuator giving limited brake pipe reduction.

Ques. What is the purpose of the actuator?

Ans. To move the rotary valve to the service position automatically when air is exhausted from behind the large piston.

The actuator is designed to be used with or without a means for limiting the service application to a pre-determined brake pipe pressure reduction,

Ques. What is the acknowledger?

Ans. An electrical contactor operated by a lever.

Ques. What is the purpose of the acknowledger?

Ans. It is used to prevent an automatic application of the brakes when passing a caution or a stop signal.

If the lever of an acknowledger be held down for a longer period than 15 seconds, an automatic brake application will result.

Ques. What is the purpose of the reset contactor?

Ans. It is used after an automatic application of the brakes to restore the electrical apparatus.

The push button is pressed for two seconds and then released after which the brake applying apparatus may be restored to normal.

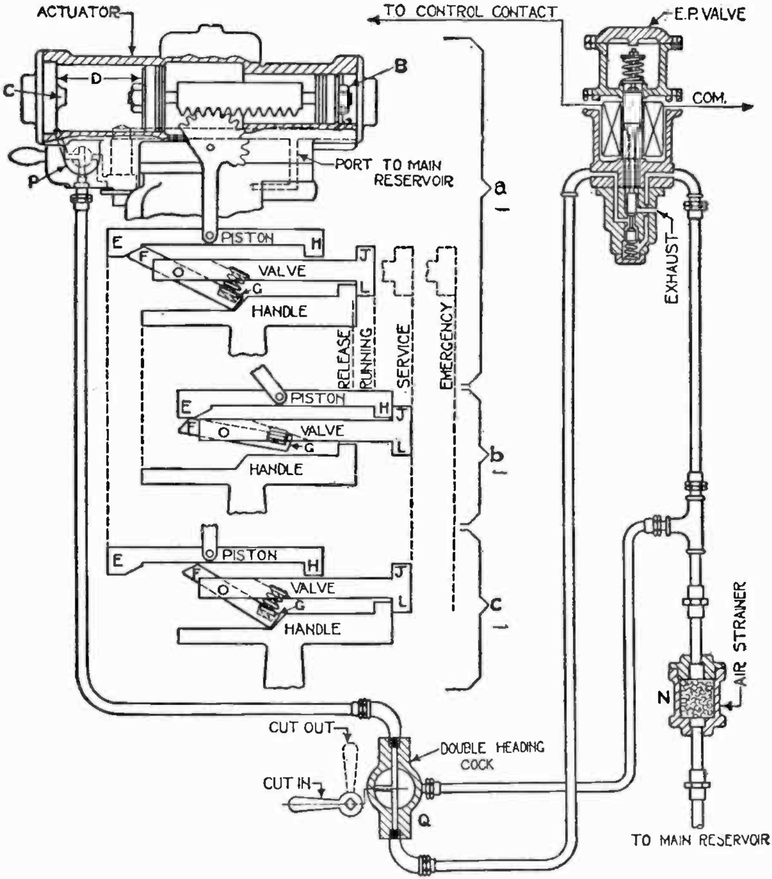
Ques. What is the electro-pneumatic valve?

Ans. An electrically operated air valve used to control the operation of the actuator.

In operation, when energized it connects main reservoir to the large cylinder, left hand side, of actuator, and when de-energized, it blanks main reservoir and vents the large cylinder of actuator to atmosphere.

Ques. What is the whistle valve?

Ans. An electrically operated air valve used to sound an acknowledging whistle.



FIGS. 6,720 and 6,721.—Diagram showing principles of brake applying apparatus. ***In operation:*** Under all conditions, air direct from the main reservoir is supplied to the cylinder B, which is the smaller of the two cylinders of the actuator. When the E.P. valve is energized, air is supplied from the same source through the air strainer N, the E.P. valve, the double heading cock Q, and the cut out cock P, to cylinder D, the larger of the two cylinders of the actuator. The part marked *piston* is, therefore, shifted to the extreme left hand position as indicated in that part of the diagram shown within the bracket, a. Under these conditions the actuator is entirely disconnected from the brake valve handle so that the engineer has the same control of the brake valve that he would have if the actuator did not exist. When the E.P. valve is

It is energized momentarily when a caution or stop signal is acknowledged and during this short interval connects the independent brake valve air supply or main reservoir to the acknowledging whistle.

The diagram fig. 6,720, shows the operation of the actuator. In the diagram, the part marked *piston* is attached to and operated by the piston of the actuating cylinder. The part marked *valve* is connected to the *rotary* of the brake valve. The part marked *handle* is connected to and moves with the brake valve handle.

In the explanation of fig. 6,720 it is assumed that the reader is familiar with the regular air braking equipment used on locomotives.

Where it is desired to limit the service application to a predetermined reduction in brake pipe pressure, the equalizing reservoir is connected to a reduction reservoir of the proper capacity, through an additional rotary valve which is connected to the regular valve, the part marked *valve* in diagram, fig. 6,720.

When the regular valve is in any position between release and lap, this additional rotary valve opens the reduction reservoir to atmosphere and closes the connection from the equalizing reservoir to the reduction reservoir.

FIGS. 6,720 and 6,721.—*Text continued.*

de-energized, air is exhausted from the cylinder D, which allows air in the cylinder B, to move the actuator piston to the left until it comes against stop C. During the first part of this movement, the cam surface E, on the part marked *piston*, being moved to the right, comes in contact with the latch FG, which is attached to the valve, lifting the portion G, out of engagement with the handle. During the rest of the movement, the lug H, on the piston is in contact with the projection J, on the valve so that the valve is moved to the right to the service position as indicated in that part of the diagram included within the bracket, b. In this position, it will be noted that the *handle* is disconnected from the valve in such manner that the valve cannot be moved by the handle toward the left or release position. The valve can, however, be moved to the right or emergency position. The engineer can, therefore, at any time make an emergency application, but he cannot again move the brake valve until the E.P. valve is re-energized by a reset which cannot be done until the train has been brought to a stop, as will be explained later. In order to regain control of the brake valve after it has been moved to the service position by the actuator as explained above, the E.P. valve must first be re-energized by the operation of a reset contactor. This allows air to again flow into cylinder D, of the actuator which moves the part marked *piston* back to its original position, as shown in that part of the diagram included within the bracket, c. The engineer then places the brake valve handle in the service position which permits latch FG, of the valve to engage the handle, after which he has regained control of the valve and may release. It is therefore noted that the service application put on by the actuator is entirely automatic, whereas, the release from this application is a manual operation.

When the regular valve is moved to the service position, either manually or by the actuator, the additional valve closes the reduction reservoir to atmosphere and opens the connection to the equalizing reservoir, allowing air to discharge through a limited orifice of the proper size from the equalizing reservoir into the reduction reservoir. Therefore, after the pressure in the two reservoirs equalizes, the reduction in brake pipe pressure will stop when it reaches a pressure equal to that in the reservoirs. This limits the reduction to an amount determined by the capacity of the reduction reservoir used.

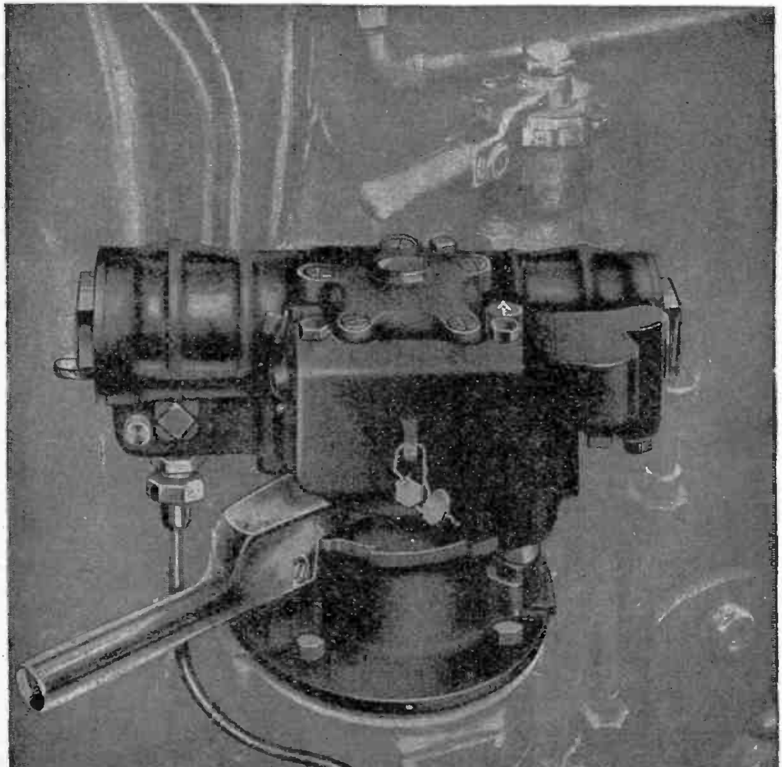


FIG. 6,722.—Actuator applied to engineer's brake valve.

Circuits.—Having described the principles upon which the operation of the circuits are based, the purpose of the following paragraphs is to describe actual application of typical circuits in the operation of the system. These circuits are:

1. Wayside circuits; 2. Locomotive circuits.

Wayside Circuits.—In this system an inductor is placed at every signal and the circuits controlling it are simple. It is only necessary to have the circuits so arranged that when the signal gives a restricting indication the coils of the inductor are open and when the signal is in the clear position the coils of the inductor are closed.

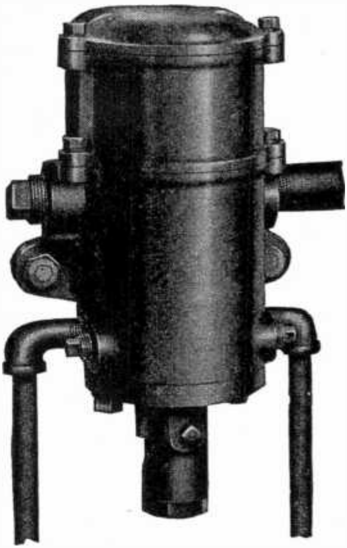


Fig. 6,723.—Electro-pneumatic valve.

Fig. 6,724 shows typical wayside circuits for a three position normal clear signal system. The signal circuits shown in this figure are the well known polarized track circuits, but it does not matter what kind of signal circuits are used.

The circuits controlling the inductors will always accomplish the same thing; that is, open the inductor coils when a restrictive signal is displayed and close the inductor coils when a clear signal is displayed.

It will be noted at signal 3, which is in the clear position, that the coils of inductor R3, are closed by a circuit controller operated by the signal itself and by the relay which controls the signal.

It is not necessary that the inductor be controlled by contacts on both the signal and the relay which controls it, but this gives a check on the integrity of the signal indication and is generally considered good practice.

Either the contacts on the signal or the relay contacts may be used if desired.

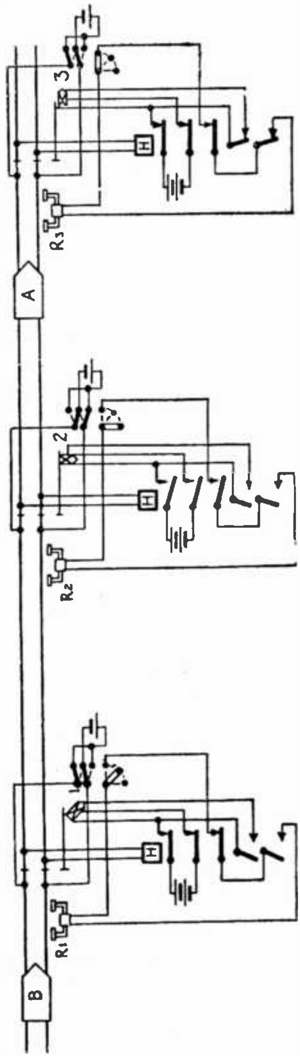


Fig. 6,724.—Diagram of wayside circuits.

At signal 2, which is at stop due to the presence of the train A, in the block, the coils of inductor R2, are open and consequently the receiver of a train passing inductor R2, would receive an impulse as previously described under heading "Transmission of Control Wayside to Locomotive."

At signal 1, which is at caution, the coils of inductor R1, are also open and the receiver of a train passing this signal would receive an impulse.

At signal 3, which is in the clear position, the coils of the inductor R3, are closed as mentioned before, therefore, the receiver of a train passing this signal would not receive an impulse.

If it be desired to check against the removal of an inductor, the track circuit may be bonded through the inductor housing as follows: One of the wires leading from the rail to the track relay at the signal location is carried to the tie supporting one end of the inductor and is anchored to the tie by means of a flexible connection, thence is bonded into the end of the inductor housing. A similar connection is made to the other end of the inductor housing and the wire carried back to the track relay.

The current operating the track relay must then pass through the inductor housing and if the inductor be dislodged from its support the wires being attached to the ties will be broken and the track relay de-energized which will cause the signal ahead of the inductor to indicate stop and the signal in the rear to indicate caution.

If desired, the track battery, feeding the relay at the signal in the rear can be bonded through the inductor instead of the relay wire referred to, in which case the dislodgment of the inductor would place at stop the first signal in the rear and the second signal in the rear would show caution.

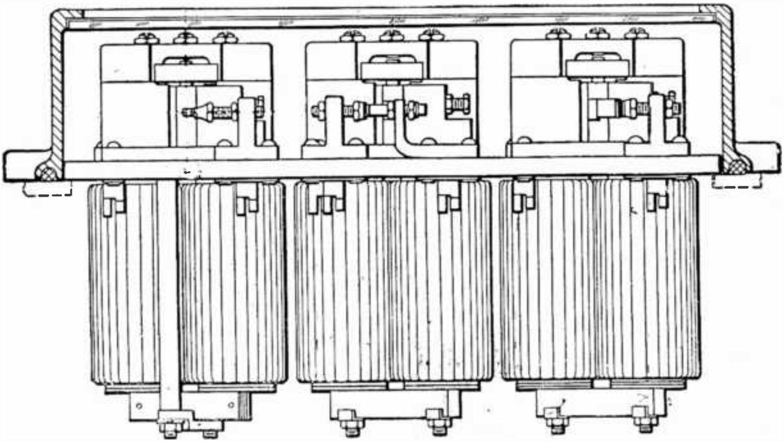


FIG. 6,725.—Construction and grouping of relays R1, R2 and R3. Relay R3 controls the electro-pneumatic valve.

Locomotive Circuits.—Typical circuits used on the locomotive are shown in fig. 6.730 and the following is an explanation of the symbols and a brief description of the contacts and magnets employed:

S.—Secondary coils of the receiver, see fig. 6,698.

P.—Primary coils of the receiver, see fig. 6,698.

G.—Turbo-generator. usually the one used on the locomotive for lighting purposes.

EPV.—Electro-pneumatic valve controlling air to the brake applying actuator, see fig. 6,719.

R1.—Primary relay operated by the locomotive receiver, see fig. 6,698.

R2.—Secondary relay controlled by relay R1.

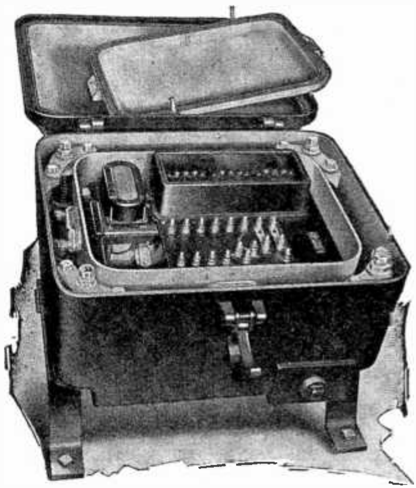


FIG. 6,726.—Locomotive relays and housing. It will be noted that the relays and lamps together with their terminals, are mounted in an inner case which is floated on heavy springs and equipment with snubbers. The three relays are mounted on one base and the contacts are protected by a cover which has a glass top. The ballast lamps are protected by a wire mesh cover shown to tne left of relays.

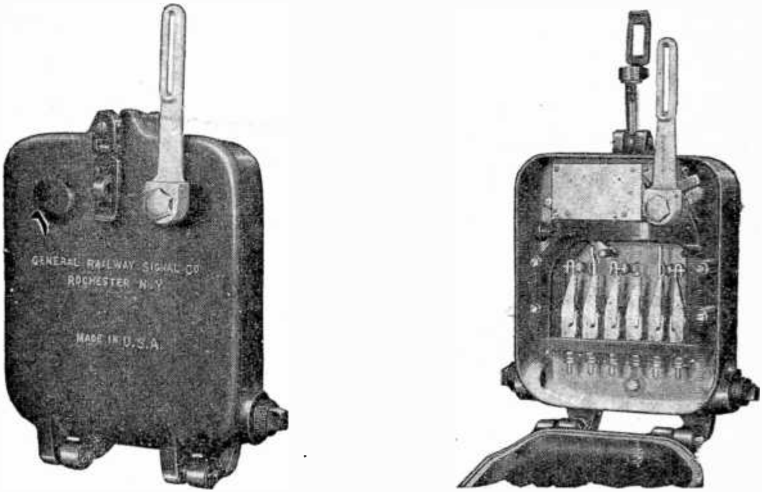
R3.—Relay controlling the electro-pneumatic valve. Fig. 6,725 shows the grouping and construction of relays R1, R2, and R3, and fig. 6,726 shows the relay housing.

WV.—Electro-pneumatic valve controlling air to an audible signal, see fig. 6,723.

LL.—Ballast lamp used for correcting the fluctuation of the voltage of the turbo-generator. Any increase in current through the ballast lamp heats the filament which reduces the current, or a decrease in current through the lamp cools the filament and increases the current, therefore, the ballast lamp serves to limit the current through the relays R1, R2, and R3, to the proper amount during a fluctuation in voltage of the turbo-generator.

Ack.—Acknowledging contactor, see figs. 6,727 and 6,728.

Cont.—When the operating handle is moved from its normal position, contacts X, and Y, are closed and a clockwork mechanism is started so that if the handle be held down for a longer period than 15 seconds contact Z, will open.



Figs. 6,727 and 6,728.—Acknowledging contactor with cover, and open showing contact construction.

Reset.—Reset contactor, see fig. 6,729.

Cont.—Contacts 8, 9, 10 are operated by the reset contactor which is so located on the locomotive that it can be operated only when the engine is at rest.

In the diagrams the positions of parts are shown as they would be when the train is running subject to automatic control between impulse receiving points. Under these conditions the active circuits are as in fig. 6,730.

In fig. 6,730 the operation of the circuits is as follows:

When the receiver passes an inductor whose coils are closed as explained under the heading "Transmission of Control, Wayside to Locomotive," the current through the relay R1, is not materially changed, but when the receiver passes over an inductor whose coils are open, the current through relay R1, is decreased, so that its contacts are opened.

The opening of contact 2, of relay R1, deprives relay R2, of current and the opening of contact 3, of relay R2, deprives relay R3, of current.

The opening of contacts 6, and 7, of relay R3, deprives the electro-pneumatic valve of current and, as described under the heading "Brake Applying

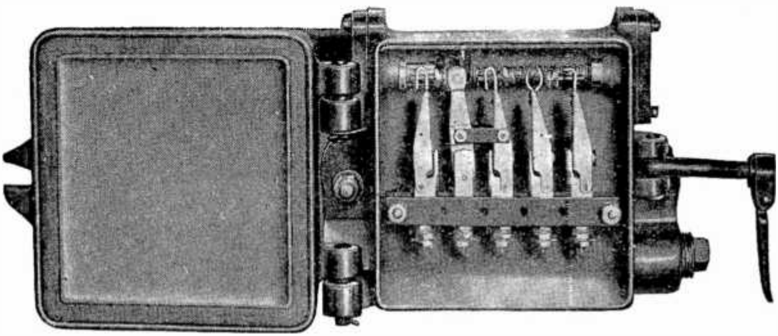


FIG. 6,729.—Reset contactor showing contacts.

Apparatus," a full service brake application results. The E.P. valve cannot then be supplied with current until relay R3, is again energized.

Relays R3, R1, and R2, are re-energized by the operation of the reset contactor as follows:

When contact 9, of the reset contactor is closed, relay R3, will receive current through the following circuits: From the positive side of the dynamo, wire B32, contact 9, of the reset contactor, wire P2, coils of relay R3, wire P1, ballast lamp L,L, wire P, primary coil of receiver, wire C, back to the negative side of the generator. This produces a drop in voltage across the coils of the relay R3, so that the relay R1, will be energized by the following circuit: Starting from the left hand side of the coils of relay R3, wire P2, contact 10, of reset contactor, wire S, coils of relay R1, wire P1, back to the right hand side of coils of relay R3. Having thus closed contact 2, of relay

R1, relay R2, will be energized so that contact 3, will be closed and the reset contactor can be returned to its normal position, thereby closing contact 8, which re-energizes the electro-pneumatic valve.

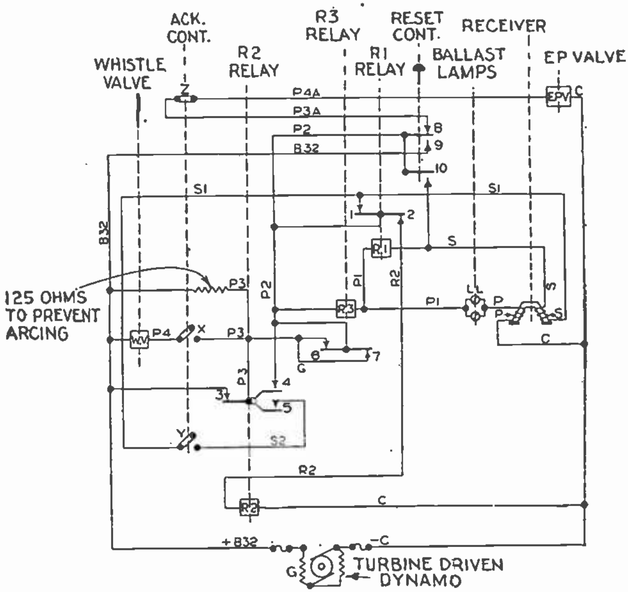


FIG. 6,730.—Locomotive circuit protection forward running only. Under the conditions shown, *the active circuits are:* P, primary coil of the receiver is energized by current flowing from the positive side of the dynamo through wire B32, contact 3, of relay R2, wire P3, contact 6 or 7 of relay R3, wire P2, the coils of relay R3, wire P1, the ballast lamp LL, wire P, through the primary coil of the receiver and wire C, to the negative side of the dynamo; R3, this relay is energized by the circuit last described; R1, this relay is energized by the drop in voltage across the coils of the relay R3, due to current flowing in the circuit last described. The circuit is as follows: Starting from the left hand side of the coils of relay R3, wire P2, contact 1, of relay R1, wire S1, secondary coil of the receiver, wire S, coils of the relay R1, wire P1, back to the right hand side of the coils of relay R3; S, the secondary coil of the receiver is energized by the circuit described above for relay R1; R2, the circuit which supplies current to the coils of relay R2, is traced as follows: Starting from the positive side of the turbine driven dynamo through wire B32, contact 3, of relay R2, wire P3, contact 6 or 7 of relay R3, wire P2, contact 2 of relay R1, wire R2, the coils of relay R2, and wire C, to the negative side of the dynamo; EPV, the electro-pneumatic valve is receiving current through the following circuit: starting from the positive side of the turbine driven dynamo, wire B32, contact 3, of relay R2, wire P3, contact 6 or 7, of relay R3, wire P2, contact 8, of reset contactor, wire P3A, contact Z, of the acknowledging contactor, wire P4A, the coils of the electro-pneumatic valve and wire C, to the negative side of the dynamo.

If, at the time the receiver passes over an inductor whose coils are open, contact X, on the acknowledging contactor is closed, relay R3, will not be opened, consequently the electro-pneumatic valve will not be deprived of current.

The circuit which holds relay R3, energized at this time, is as follows: From the positive side of the dynamo, wire B32, the coils of the whistle valve WV, wire P4, contact X, of the acknowledging contactor, wire P3, contact 6 or 7, of relay R3, wire P2, the coils of relay R3, wire P1, the ballast lamp LL, wire P, the primary coil of the receiver and wire C, back

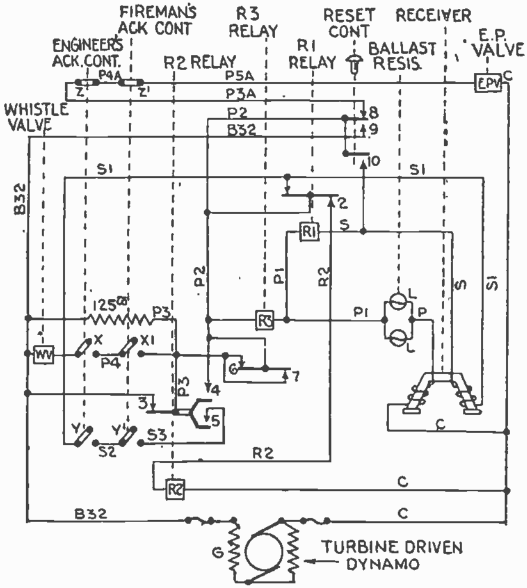


FIG. 6,731.—Typical locomotive circuit, forward running only, requiring acknowledgment by engineer and fireman.

to the negative side of the dynamo. With contact X, of the acknowledging contactor closed and contact 3, of relay R2, open, energy passes through the audible signal WV, causing a blast of the whistle. The blast, however, is of short duration because contact 3, of relay R2, is opened only momentarily and when closed short circuits the coils of the whistle valve WV.

When the receiver passes over an inductor under these conditions, that is, with contact X, of the acknowledging contactor closed, the impulse received will cause relay R1, to open, but since relay R3, is energized, as explained, relay R1, will immediately pick up. The momentary opening of relay R1, opens relay R2, which immediately picks up again.

Immediately after the relay R2, is opened, with the acknowledging contactor operated so that contact Y, is closed, relay R1, will be energized by the drop in voltage across the coils of relay R3, the circuit being as follows: Starting from the left hand side of relay R3, through wire P2, to contact 4, of relay R2, contact 5, of relay R2, wire S2, contact Y, of the acknowledging contactor, wire S1, secondary coil of receiver, wire S, the coils of relay R1, wire P1, back to the right hand side of the coils of relay R3.

Energizing relay R1, closes contact 2, of this relay which again energizes relay R2, so that all of the circuits are restored to normal. It will be noted that if the contacts X and Y, of the acknowledging contactor are closed for more than 15 seconds, contact Z, will open. This will deprive the E.P. valve of current and cause an automatic brake application. It will also be noted that if the acknowledging contactor be not operated at the time an inductor is passed whose coils are open, circuits cannot be restored to normal until contacts 9 and 10, of the reset contactor are operated.

The resistance of 125 ohms is placed between wires R32 and P3, for the purpose of preventing excess arcing of the relay contacts.

Where a locomotive is to operate with automatic train control protection for both forward and backward running, it is equipped with a receiver on each side and a reversing switch is operated from an axle drive.

The reversing switch closes contacts to include the coils of the right hand receiver when the locomotive is running forward, or it operates to disconnect the right hand receiver and include the coils of the left hand receiver in the locomotive circuits when the locomotive is running backward. In this case two ballast lamps are used, one in series with the primary coil of each receiver; otherwise the circuits are the same as formerly described.

Instructions to Enginemen.—To acquaint the engineman with the essential characteristics of the train control apparatus with which he comes in contact, it is necessary to outline what will take place under certain conditions. Apparently, the most suitable means of instruction is by the use of questions and answers.

In addition to the explanations already given the following questions and answers will be found helpful on operation:

Ques. What happens when the following occurs: 1. When the turbo is shut down? 2. When the turbo delivers a pulsating current due to a swinging short circuit in wiring? 3. When a train control fuse blows?

Ans. An automatic brake application results.

Ques. Can the equipment be reset under the above conditions?

Ans. No.

Ques. What must be done to reset under the conditions mentioned above?

Ans. 1, The turbo must be kept running; 2, train control should be cut out; 3, blown fuses must be replaced.

Ques. How is train control cut out?

Ans. By manipulation of cock handle on left end of actuator as follows: 1, break seal on locking pin; 2, withdraw locking pin to disengage handle; 3, raise handle to vertical position.

Ques. Where is the air supply to RH, or small cylinder of actuator obtained?

Ans. It is obtained from main reservoir above the rotary in the brake valve.

Ques. Where is the air supply to LH, or larger cylinder of actuator obtained with the equipment cut in?

Ans. It is obtained from main reservoir tap through the air strainer, the E.P. valve energized and the double heading cock normal.

Ques. Where is the air supply to LH, or large cylinder of actuator obtained with equipment cut out?

Ans. It is obtained from main reservoir above the rotary in the brake valve through the control cut out cock in the vertical position.

Ques. Where is the air supply to LH, or larger cylinder of actuator obtained when double heading?

Ans. It is obtained from same main reservoir tap which feeds E.P. valve. It is necessary that double heading cock be closed.

Ques. Is the second engine of double header subject to automatic train control?

Ans. No.

Ques. What must the engineman of a second engine do when lead engine cuts off?

Ans. He must have his turbo running and must reset before opening his double-heading cock.

Ques. How does the engineman know when he can relatch handle with rotary?

Ans. When indicator on top of actuator points to R.

Ques. To what position must the brake valve handle be placed in order to relatch?

Ans. The full service position.

Ques. A manual emergency application has been made following an automatic service application, what is the relatching position?

Ans. Slightly beyond the service position toward emergency.

Ques. What is the correct manner of operating reset contactor?

Ans. The button must be pressed for at least 2 seconds.

Ques. Can brake valve handle be relatched while reset contactor is being operated?

Ans. Not until reset is released to normal position.

Ques. In what position can the actuator cut out cock handle be sealed?

Ans. Only in the horizontal or cut in position.

Ques. If the acknowledger be operated continuously for more than 15 seconds what takes place?

Ans. At approximately 15 seconds an automatic brake application will result.

Ques. Will the whistle blow when passing an inductor under the above conditions?

Ans. Yes, provided the acknowledger is still pulled down and the indication of the roadway is still caution or stop.

Ques. Is it necessary to reset under the conditions described in the two preceding questions?

Ans. No.

Ques. An automatic brake application is received passing a proceed wayside signal. What should be done?

Ans. Reset. Acknowledge the next signal and if the whistle blow and signal be clear, it indicates that engine apparatus is at fault. Full report should be made to cover. If, however, the whistle do not blow when acknowledging the next proceed signal, it indicates that the inductor previously passed and at which the automatic application was received is at fault. Report should so state.

Ques. Is it possible that loose rails lying along the track in the approximate position of the inductor could cause an automatic brake application?

Ans. Yes—loose rails should, therefore, not be higher than the main track.

Ques. Is it necessary to acknowledge at inductor locations when backing against the current of traffic?

Ans. Yes.

Ques. If an automatic application of the brakes result from a broken air pipe, in the train control system, what should be done?

Ans. Plug the pipe, and if unable to relatch actuator, cut out train control.

Ques. Should the train control be cut out because of a leak in the copper piping?

Ans. It requires quite a leak to offset the differential in the actuator pistons. Train control should not be cut out unless the leak is sufficient to overcome the differential in the actuator or unless the engineman cannot repair or close the leak.

NOTE.—The three questions following apply to equipments having actuators with the R, L, R, valve used in connection with a reduction reservoir for limiting the brake pipe reduction.

Ques. If the blow down be not limited, where would the trouble be?

Ans. The back pipe on right hand cylinder of actuator is broken. This is the pipe which leads to the reduction reservoir.

Ques. If the back pipe on the right hand cylinder of actuator be broken should it be plugged?

Ans. No.

Ques. If the front pipe on the right hand cylinder of actuator be broken what must be done? This is the pipe which connects to the equalizing reservoir.

Ans. The pipe must be plugged and a brake pipe reduction must be obtained by moving the brake handle toward the emergency position as far as may be required.

Typical Form of Instructions

(to enginemen)

Wayside Equipment

1. Inductor Location.

Inductors are located outside the right hand rail and approximately 70 ft. from each home signal, not including dwarf signals, governing entrance to a block in the direction from which trains normally approach such signals.

Engine Equipment

2. Receiver.

Receiver is mounted on the right side of the forward tender truck.

3. Actuator.

Actuator is mounted on automatic brake valve. When an automatic brake pipe reduction occurs, the actuator disconnects the brake valve handle on rotary valve and moves rotary valve to service position. When arrow on actuator points to R, running position, the brake valve handle can be relatched by moving to or slightly beyond service position. The handle of automatic brake valve is operative to manually apply brakes at all times.

4. Cut out Cock.

Cut out cock is provided on left hand actuator cylinder. When cut out cock handle is horizontal, automatic train stop is operative; it must be sealed in this position. When handle is vertical, automatic train stop is cut out.

5. Double Heading Cock.

Double heading cock when closed cuts out automatic train stop; this cock must be closed on all engines except the engine operating the train brakes.

6. Dynamo.

The headlight dynamo provides current for the operation of the automatic train stop and engine lights. Bright cab lights indicate there is sufficient voltage for the operation of the automatic train stop.

7. Main Reservoir Pressure.

For proper operation of automatic train stop, main reservoir must be maintained at designated normal pressure.

8. Forestalling Lever.

Forestalling lever is provided in engine cab which, when held in forestalling position, will prevent automatic brake pipe reduction when passing over inductor at signal which gives indication other than indication as determined by operating rules.

9. Reset Button.

Reset button, for re-establishing control of rotary valve so engineman can release after an automatic brake pipe reduction, is located on the right and near rear of tender frame.

10. Forestalling Whistle.

This is located in the engine cab. The stopping of the sounding of whistle is an indication that automatic train stop impulse has been received and forestalled by operation of the forestalling lever.

At Engine Terminal

11. Before Taking Engine out for Road Service.

1. See that cut out cock is sealed.
2. Start head light dynamo. Dynamo must be kept running continuously with throttle wide open when automatic train stop is cut in.
3. Press reset button for two seconds to set up automatic train stop apparatus.
4. Start air compressor. When pressure is 25 lbs. or over and indicator is at R, running position, move automatic brake handle to service position, or slightly beyond, then to running position.
5. Apply and release brakes to determine if working properly.
6. Move engine over test inductor at not less than 2 miles per hr. without forestalling, to determine if brake application be made. Operate reset button after engine has been brought to a stop.
7. Move forestalling lever to forestalling position while again passing over a test inductor to determine that whistle will sound and no brake pipe reduction is made.
8. If equipment fail to operate as intended, engineman must report to proper authority before departing.

Road Operation

12. Automatic Brake Application.

Automatic brake pipe reduction will occur when passing over inductor at signal which gives indication other than indication as determined by operating rules unless engineman holds lever in forestalling position until receiver is passing over the inductor and whistle has stopped sounding. Brake pipe reduction will occur if lever be held in forestalling position more than fifteen seconds continuously.

13. Forestalling.

1. When passing over inductor at signal displaying the indication as determined by operating rules.

2. Engineman must forestall at each inductor: *a*, When passing over inductor in making back up movement against the current of traffic; *b*, when running forward and pushing cars; *c*, in an emergency when double heading and automatic brakes are being operated by the second engine.

3. Engineman must not forestall until after signal indication has been observed and obeyed when passing over inductor at signal displaying other than the indication as determined by operating rules.

14. Automatic Brake Application and Release.

When automatic brake pipe reduction occurs, it will continue until the train is brought to a stop, after which the reset button must be pushed for two seconds and the button then released; the automatic brake valve handle must then be moved to, or slightly beyond, the full service position so as to relatch the handle with the rotary valve after which the brakes may be released by operating the brake valve handle in the usual manner.

15. To Cut Out Automatic Train Stop.

To cut out automatic train stop, due to failure of apparatus to operate properly, break seal on cut out cock handle, pull pin out and turn handle to the vertical position.

16. Broken Pipes.

If pipes to actuator cylinder, double heading cock or E.P. valve should break, the end toward source of air supply must be plugged, automatic train stop cut out and automatic brake valve latched up before proceeding. If branch of main reservoir pipe leading to side outlet of double heading cock should break, the end toward the source of supply must be plugged; automatic train stop must be left cut in unless necessary to close double heading cock in which case automatic train stop must be cut out.

17. Reports.

If necessary to break seal on cut out cock, or, in the event of improper automatic train stop operation, report must be made. Defects in apparatus must be reported, and seals, if broken, turned in with reports which are made on special forms.

18. Operating Rules.

The use of the automatic train stop system does not supersede nor dispense with the use or observance of signals as prescribed by the rules in the book of "Rules for the Government of the Operating Department" by special instructions in the current time table, or bulletin order; nor does it modify the permissible maximum speed specified by bulletin order, or by special instructions in the current time table.

TEST QUESTIONS

1. *What is the object of automatic train control?*
2. *What is the penalty for failing to acknowledge restrictive signals?*
3. *What are the two parts comprising the device between the wayside and the locomotive?*
4. *How is a receiver mounted?*
5. *How does the receiver work?*
6. *Of what does the brake applying apparatus consist?*
7. *What is the actuator?*
8. *What is the purpose of the actuator?*
9. *What is the acknowledger?*
10. *What is the purpose of the acknowledger?*
11. *What is the purpose of the reset contactor?*
12. *What is the electro-pneumatic valve?*
13. *What is the whistle valve?*
14. *Draw diagrams showing operations of the actuator.*
15. *Describe the wayside circuits.*
16. *Draw diagram of the locomotive circuits.*
17. *Explain at great length the operation of the system.*
18. *What happens when the following occurs:* 1, *when the turbo is shut down;* 2, *when the turbo delivers a pulsating current due to a swinging short circuit in wiring;* 3, *when a train control fuse blows?*
19. *How is train control cut out?*

20. *What must the engineman of a second engine do when lead engine cuts off?*
21. *How does the engineman know when he can relatch handle with rotary?*
22. *To what position must the brake valve handle be placed in order to relatch?*
23. *If the acknowledger be operated continuously for more than 15 seconds what takes place?*
24. *Should the train control be cut out because of a leak in the copper piping?*
25. *If the front pipe on the right hand cylinder of actuator be broken what must be done?*

CHAPTER 151

Maintenance of Signal Systems

It may be said of any system of signaling and interlocking that *the system is as safe as its maintenance*. Efficient maintenance therefore, must consist in the rigid adherence to a carefully planned program of systematic inspection and testing for the detection of any tendencies to failure on the part of apparatus.

It must further consist in the necessary adjustment, replacement or repair which will preclude the possibility of any failure or derangement. Such a program can be discussed only in a general way since the frequency of inspection and the nature of the testing must depend upon the type of equipment, of the particular system, and the character and density of the operated traffic.

Points on Maintenance

Safety Measures.—1. The properly maintained signal system will provide for all devices being under lock and key to prevent tampering by unauthorized persons, and so that leverman or others without authority will not be permitted access to devices which might be manipulated to circumvent the restrictions imposed by interlocking equipment.

2. Those appliances to which the leverman is given access in an emergency are sealed, the breaking of a seal being a check on emergency procedure.

Sealing irons, keys, etc., are in the possession of the maintainer in charge of the plant and it is his duty to see that all equipment is properly locked and that all seals are intact.

Inspection and Tests.—1. It is good practice for each section of block signals and interlocking to be inspected at least every two weeks.

2. Every part of the equipment should come under the observation of the inspector or maintainer who should take careful note of all parts which show evidence of wear or are in immediate need of replacement.

3. The equipment should be subjected to tests herein described, or other necessary physical or electrical tests which will assist in the determination of its condition whenever this is doubtful.

4. A large percentage of signal failures is due to defective track circuits.

Particular attention should therefore be given to track circuit equipment such as signal rail bonds, jumper connections, track relay and battery leads to track, as well as transformer leads and impedance bond connections where *a.c.* track circuits are employed. Resistance tests will verify the effectiveness of rail connections.

5. Insulated rail joints should be inspected to see that they are properly insulating the rails of adjacent track sections.

6. Where necessary, the megger test for insulation resistance should be applied.

The megger is connected from rail to rail across the joint when readings should be of satisfactory value for the insulating material of the joint and the thickness thereof.

7. Tests to ascertain that automatic block signals are operating properly are carried out by setting up conditions along the

track which would be similar to the occupancy of signal block sections by a train.

This is accomplished by shunting out the respective track relays and observing that automatic signals immediately in the rear of shunted section are giving the proper indication, and where automatic train stops are a part of the equipment as in rapid transit railways, that the stop arms are assuming the stop and clear positions in accordance with train stop control circuit plans.

8. The stop arms should be checked for alignment with relation to track to see that when in the stop position they will engage positively with the tripping device on a train or car, and operate to trip the train.

9. Inspection should be made of all moving mechanical parts to see that they are properly lubricated and that all screws, bolts, nuts, cotter pins, etc., are securely fastened.

10. The foregoing should be carried out through all interlocking territory as well as block signal territory.

11. At interlockings, all track switches should be carefully examined to see that all switch throw rods and front rods are properly adjusted so that switch point rails are correctly lined up with stock rails when the switch is in either the normal or reverse position, and that lock rods are carefully adjusted to properly engage with locking plungers of switch mechanisms.

12. At interlocking plants careful inspection and frequent service tests of electric locking are imperative to the safe operation of the plants.

Lever locks of the plunger type should be inspected, cleaned and tested every day to insure that dirt or other foreign substance will not prevent the lock dropping by gravity.

13. Test each lock by putting on and taking off current several times to see that the lock works properly.

If proper its operation will be quick and sharp.

14. All releases, the design of which might allow them to stick in one position and destroy their effectiveness, should also be inspected every day.

15. The maintenance of an interlocking machine consists principally in keeping the machine clean, all connections tight, and of wiping with an oiled rag at frequent intervals all parts that are liable to rust.

16. A high grade oil should be used when cleaning the mechanical locking of an interlocking machine.

17. Lever operation of the various functions controlled, may generally be said to be a good check on the condition of the interlocking machine, since completed operation of the interlocked functions gives assurance of the machine's integrity as the central controlling element.

18. It is good practice to anticipate the possibility of loose connections, etc., and at frequent intervals to inspect the different connections, contact springs, and various mechanical parts of the interlocking machine to insure that all parts are in the best condition.

19. Attention should be given to all other apparatus forming part of the interlocking system such as relays, annunciators, indicators, time locks, screw releases, bells, etc.

20. Careful attention should always be given to primary batteries to insure that they at no time approach a state of exhaustion, and to storage batteries as a check that they are in good condition and sufficiently charged to render the service which is required of them.

TEST QUESTIONS

1. *Upon what does the safety of an interlocking system depend?*
2. *How is efficient maintenance carried out?*
3. *What should be provided to prevent tampering by unauthorized persons?*
4. *What devices should be sealed?*
5. *What does the breaking of a seal indicate?*
6. *Who has charge of sealing irons, keys, etc.?*
7. *How often should each section of block signals and interlocking be inspected?*
8. *When inspecting, what memorandum should be made by the inspector?*
9. *What is the cause of a large percentage of signal failures?*
10. *How are the track circuits maintained in perfect condition?*
11. *How is the effectiveness of rail connections verified?*
12. *For what should rail joints be tested?*
13. *How is the megger test made?*
14. *How are tests made to ascertain that automatic block signals are operating properly?*
15. *For what should stop arms be checked?*
16. *In testing moving mechanical parts, what should be noted?*
17. *What tests should be made at an interlocking plant?*
18. *How often should lever locks of the plunger type be inspected?*
19. *What is the indication that a lock is working properly?*

20. *How often should releases which are liable to stick in one position, be inspected?*
21. *Of what-does the maintenance of an interlocking machine consist?*
22. *What is a good check on the condition of the interlocking machine?*
23. *Name one piece of apparatus that should always receive special attention.*

CHAPTER 152

Electric Elevators

(Classification)

The ever increasing height to which buildings are being erected has resulted in the development of elevators and the introduction of numerous types to meet the requirements of a great variety of service conditions.

These numerous types may be classified:

1. With respect to service, as:

   a. Passenger;

   b. Freight { for hotels; apartments; stores, etc.

   c. Special { "sidewalk"; garage. "energy"

   d. Combination (mixed passenger and freight).

2. With respect to capacity, as:

   a. Light duty;

   b. Medium duty;

   c. Heavy duty;

   d. Extra heavy duty.

3. With respect to speed, as:

   a. Low speed;
   b. Medium speed;
   c. High speed.

4. With respect to the power unit (elevator machine), as:

   a. Drum;
   b. Traction.

5. With respect to the location of the power unit, as:

   a. Over mounted;
   b. Under mounted.

6. With respect to the electric current, as:

   a. Direct;
   b. Alternating.

7. With respect to the motor drive, as.

   a. Gearless;
   b. Geared.

8. With respect to the rope drive, as:

   a. Drum;
   b. Traction.

9. With respect to the cable transmission (method of roping) on traction elevators, as:

   a. Half wrap;
   b. Full wrap.

10. With respect to the control, as:

    a. Semi-magnetic;
    b. Full magnetic;
    c. Rheostatic;
    d. Variable voltage;
    e. Inductor;
    f. Two speed;
    g. Push button;
    etc.

11. With respect to the method of operating the control, as:

    a. Semi-magnetic;
    b. Full magnetic.

12. With respect to the basic principle of the control, as:

    a. Rheostatic;
    b. Variable voltage.

13. With respect to the method of operating the elevator, as:

    a. Manual;
    b. Push button;
    c. Signal;
    d. Dual.

NOTE.—***A large elevator installation.*** The cost of installing elevators in the higher skyscrapers is indicated by the report that $2,900,000 will be spent for sixty-six elevators in the eighty-five-story Empire State Building which will rise on the site of the old Waldorf-Astoria Hotel at Fifth Avenue and Thirty-fourth St., New York City. This shows an average cost of $43,500 for one elevator. Contract for the equipment is the largest single award of its kind ever made. The old hotel has now been completely demolished, and work is progressing rapidly on the foundations of the new tower, which will be the tallest structure in the world when completed.

14. With respect to the velocity ratio between motor and car, as:

a. Direct drive (1:1);

b. 2:1 reduction;

c. Multi-reduction.

15. With respect to balancing the load, as:

a. Counter-balanced;

b. Compensated.

CHAPTER 153

Selection and Installation of Electric Elevators

The initial elevator problem is one of service; so many factors enter into this problem that each individual case must be considered as a separate problem in itself. However, some accepted general rules may be stated for the guidance of elevator selection.

Size and Shape of Car.—In planning an elevator installation, consideration should first be given to the size and shape of the elevator car. The conditions surrounding the design of the building usually determine the space available for the elevators, which, when the proper clearance allowances between the car and the walls are made, fix the size and shape of the car or cars, as the case may be.

There are, however, certain shapes of cars that are desirable and, where conditions permit, these should be adopted in order to obtain the highest operating efficiency in the moving of traffic.

Experience has shown that the best shape for an elevator car is one having a wide front in conjunction with a shallow depth. The wide front permits of ample door openings, thus providing for a quick transfer of passengers at floor levels, while the shallow depth reduces to a minimum the delays at landings incident to crowded cars whereby the passengers at the rear are hindered from free egress by the number of people standing in front of them.

The size of the car is determined either from the number of passengers to be carried or by limitations in the building design, as mentioned previously.

In figuring the car area required for a given number of passengers, the usual practice is to allow a space of 2 sq. ft. per person. The maximum load capacity of the elevator is figured on a basis of 75 lbs. per sq. ft. which assumes the average weight of a passenger to be 150 lbs.

Elevator Speeds.—The measure for the speed of a car is *the number of feet the car will travel during the period of one minute.*

The speed at which an elevator *should* travel is determined by consideration of the size and height of the building in addition to the character of the service to be performed; that is, whether for passengers, freight or a combination of both. The usual American practice for the speed of elevators is as follows:—

Passenger Elevators

	ft. per minute
Private residences	100 to 150
Hotels and apartment houses:	
Up to 5 floors (inclusive)	100 to 200
6 to 10 floors	200 to 350

Passenger Elevators

(Continued)

Department stores:	ft. per minute
Up to 5 floors (inclusive)	100 to 200
6 to 10 floors	200 to 300
Office buildings:	
Up to 10 floors	250 to 450
10th floor and above	400 to 800

For extra heavy duty, it is customary to select a speed as low as is permissible considering the rise of the elevator in order that the horse power requirements of the motor will not be excessive. When such loads exceed 10,000 lbs. it is the usual practice to install sheaves on car and counterweight and pass the hoisting cables under these sheaves and then to their fastenings at the top of the hoistway. The elevator is then classed as a rope geared installation. This construction transfers one half of the moving loads from the machine directly to the framework of the building and permits the use of standard machines.

Notes on Elevator Speed

NOTE.—*For automatic push button service.* 300 ft. per minute is usually considered the limit of speed, as the automatic elevator is inherently a time waster inasmuch as the person within the car has complete control and runs the car without regard to the floor demands.

NOTE.—*It should be understood* that many state and city codes limit the speed of elevators to 600 ft. per min.

NOTE.—*In department store service* where stopping at every floor is required for sales reasons, 350 ft. per min. is the maximum desirable speed because above this the car would not attain full speed between floors and therefore would give very inefficient operation; 250 ft. per min. is about the accepted correct average speed for this service.

NOTE.—*Freight elevators* are generally installed in warehouses and large manufacturing plants and for any load. The speeds vary from 35 to 150 ft. per minute, the higher speeds being used in buildings where the distance from floor to floor is the greatest.

NOTE.—*Combination elevators* are usually installed in buildings used for manufacturing purposes, and comply with all the regulations for passenger elevators. They generally run at a slower speed than elevators installed for passenger service and carry larger loads. The American practice for combination elevators is as follows:

	ft. per minute
Building up to 5 floors	50 to 100
Building 5 to 10 floors	100 to 200

Capacity of Elevators.—The capacity of passenger elevators varies from about 1,000 lbs. in residences to 5,000 lbs. in department stores, and from 2,000 to 3,000 lbs. in office buildings. The capacity determines the car size which should be of sufficient floor area to provide not over 75 lbs. per sq. ft. as before stated. This is standard practice in the U. S.

Number of Elevators Required.—The number of elevators required to supply a given service is difficult to determine accurately because each building is an individual problem in itself, due to the large variation in the demands such as internal traffic, insurance office traffic, consulting office traffic, etc. Accordingly, the results obtained in similar buildings are used as a basis of calculation.

The following method may be used as a guide for determining the number of elevators required in a building of known dimensions. The population can be estimated from the rentable area as follows:—

New York City	75 to 100 sq. ft. per person
Other large cities	100 to 130 sq. ft. per person
Small cities	125 to 150 sq. ft. per person

Total travel in feet if not known, can be estimated by assuming 17½ ft. for the first floor and 12½ ft. between other floors.

Floor area of car platform:

27 sq. ft. for 2,000 lbs. for medium height buildings.

33 sq. ft. for 2,500 lbs. for standard office building capacity.

40 sq. ft. for 3,000 lbs. for special service where a lift for safes is required or the time schedule of leaving the first floor is not a feature.

The normal capacity of a car in passengers without crowding is determined by allowing 2 *sq. ft. per person including the operator.*

The estimated time for synchronizing the cars, loss in time due to accelerating and retarding, loading and unloading at the first floor is 27½ seconds. The estimated time for accelerating and retarding, loading and unloading for each floor above the first is 7 to 8 seconds, or, if positive door locks be used, 8 to 10 seconds.

The estimated time required to empty the building above the first floor usually ranges from 40 to 60 minutes.

Example.—The following is an example of an office building calculation for New York City:—

Rentable area above first floor . . . . 190,000 sq. ft.

Travel first to 16th floors—all local . . . . 192 ft.

Car capacity, 2,500 lb. 33 sq. ft. . . . . 15 persons

Speed of car . . . . 550 ft. per min.
Positive door locks used.

Time required to empty building . . . . 45 min.

Estimated stops per mile of travel . . . . 150 stops

Estimated sq. ft. per person in building . . . . 80 sq. ft.

Population of building $= 190{,}000 \div 80$ . . . . 2,375 persons

Number of trips to empty building $= 2{,}375 \div 15$ . . . . 159 trips

Time lost. Stops at first floor $= 27.5 + 2$ . . . . 29.5 sec.

Actual running time per round trip $= \dfrac{2 \times 192 \times 60}{550}$ . . . . 42 sec.

Total round trip travel $= 2 \times 192$ . . . . 384 ft.

The average number of feet between stops $= 5{,}280 \div 150$ . . 35 ft.

Number of stops above first floor $= 384 \div 35 - 1$ . . . . 10 stops

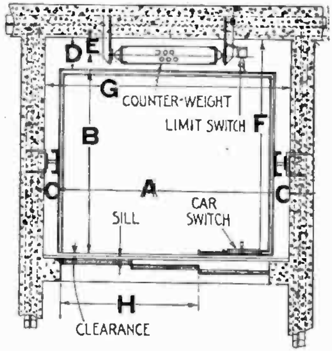
Stopping time above the first floor $= (7\frac{1}{2} + 2) \times 10$ . . . . . . 95 sec.

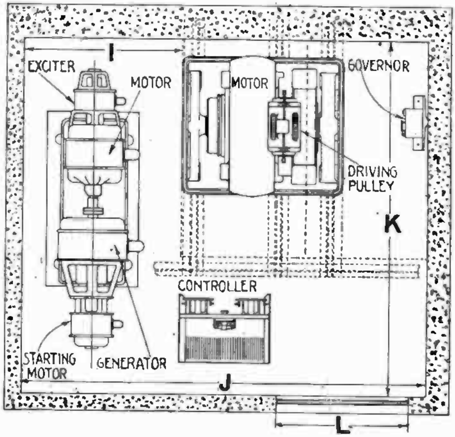
Total time of round trip $= 29.5 + 42 + 95$ . . . . 166.5 sec.

Total time of round trip . . . . 2¾ min.

Time required for one elevator to empty the building $=$
$159 \times 2\frac{3}{4}$ . . . . 437 min.

Number of elevators required to empty building in 45
min. $= 437 \div 45$ . . . . 10 elevators





SUGGESTED DIMENSIONS FOR 1:1 GEARLESS TRACTION ELEVATORS

LOAD	SPEED F.P.M.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2250	600	6'-6"	5'-5"	6"	12½"	6"	6'-4½"	7'-6"	3'-10"	5'-0"	12'-6"	10'-2"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	9'-0"
2700	600	7'-4"	5'-6"	6"	12½"	6"	6'-7½"	8'-4"	4'-2"	5'-0"	13'-4"	10'-10"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	9'-0"
3150	600	7'-9"	6'-0"	6"	12½"	6"	7'-1½"	8'-9"	4'-6"	5'-0"	13'-9"	11'-5"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	9'-0"

FIGS. 6,732 to 6,734.—A. B. See layout and recommended dimensions for 1:1 gearless traction elevators.

From the above it will be seen that during the rush hours ten elevators with a capacity of 2,500 lb. at 550 ft. per min. will give approximately 17 second service leaving the first floor. For the other hours of the day eight elevators will handle the traffic and give 20 second service from the first floor. If 15 second interval service be required eleven elevators will be necessary. This question of time interval must always be checked before definitely determining the number of elevators.

The foregoing calculations can only represent average conditions as the human element enters into the problem to a considerable degree.

For example, the time the car will be stopped at a floor varies from 4 to 12 seconds depending mainly on the characteristics of the people served.

Points on Elevator Selection.—To aid in selecting the proper elevator, the table on page 4,074 is given. This table shows the correct size of car for a given number of passengers and the plumb size of hatchway for the same car. Due to conditions imposed by the plans of a building, other shapes and sizes of cars than those shown in the table may of course be adopted.

The table also gives horse power output of motor. These figures are based upon the usual practice in elevator counterweighting and average efficiency of the completed installation. They are subject to variation in individual cases.

It is well to remember, however, that while the horse power figures are approximately correct for *d.c.* motors, these may be materially increased when *a.c.* motors are used; as the starting torque and horse power of *a.c.* motors vary with different manufacturers and largely determine the size selected for the duty to be performed.

NOTE.—*Service or capacity* of elevators is affected by safety appliances such as door and gate interlocks inasmuch as the introduction of these devices increases the time for loading and unloading. Thus the extension of safety appliances tends to increase the number of elevators installed. This is unfortunate, but the safety consideration is so vastly important that the reduction of service efficiency is not to be deplored.

Table Giving Number of Passengers, Car and Hatchway Size, Load, Speed and Horsepower Output of Motor

No. Passengers	Size of Car		Size of Hatchway		Load	CAR SPEED IN FEET PER MINUTE							
	Width	Depth	Width	Depth		100	150	200	250	300	350	400	450
4	3′-2″	3′-2″	4′-0″	4′-0″	600	2.43	3.33	3.73	4.66	5.59	6.06	6.68	7.27
5	3′-7″	3′-5″	4′-5″	4′-3″	750	3.03	4.13	4.66	5.82	6.99	7.58	8.35	9.10
6	3′-11″	3′-8″	4′-9″	4′-6″	900	3.64	4.95	5.60	6.98	8.39	9.09	10.02	10.91
7	4′-3″	3′-11″	5′-1″	4′-9″	1050	4.25	5.78	6.54	8.16	9.79	10.61	11.70	12.72
8	4′-7″	4′-1″	5′-5″	4′-11″	1200	4.85	6.62	7.46	9.32	11.19	12.17	13.36	14.55
10	5′-2″	4′-6″	6′-2″	5′-9″	1500	6.07	8.26	9.34	11.62	13.99	15.15	16.70	18.20
12	5′-8″	4′-10″	6′-8″	5′-11″	1800	7.28	9.92	11.20	13.98	16.79	18.18	20.04	21.82
15	6′-6″	5′-3″	7′-6″	6′-4½″	2250	9.10	12.40	14.00	17.48	20.99	22.74	25.05	27.30
18	7′-4″	5′-6″	8′-4″	6′-7½″	2700	10.90	14.78	16.80	20.94	25.19	27.27	30.06	32.73
21	7′-9″	6′-0″	8′-9″	7′-1½″	3150	12.70	17.30	19.60	24.48	29.39	31.80	35.07	38.20
24	8′-4″	6′-4″	9′-4″	7′-5½″	3600	14.56	19.80	22.40	27.96	33.56	36.36	40.16	43.62

Installation Information.—Figs. 6,732 to 6,737 show typical layouts of elevator installations giving the clearance dimensions around the car; also the space requirements for shaft doors, etc., the over travel distances above and below the normal limits of car travel, and the desirable size of the machine room.

To illustrate, assume a load of ten passengers totaling 1,500 lbs. The table on this page specifies a car 5 ft. 2 in. × 4 ft. 6 in., and the finished dimensions of hoistway work out to the sizes shown. In this connection, it should be noted that an extra one inch is shown as an additional allowance for finished plaster on three sides of the hoistway.

In the case where two or more elevators run in the same hoistway, it is customary to divide the hoistway by an eight inch I beam placed at the floor levels to act as a support for the car guides; an allowance of 4 ins. should be made where such beams are used.

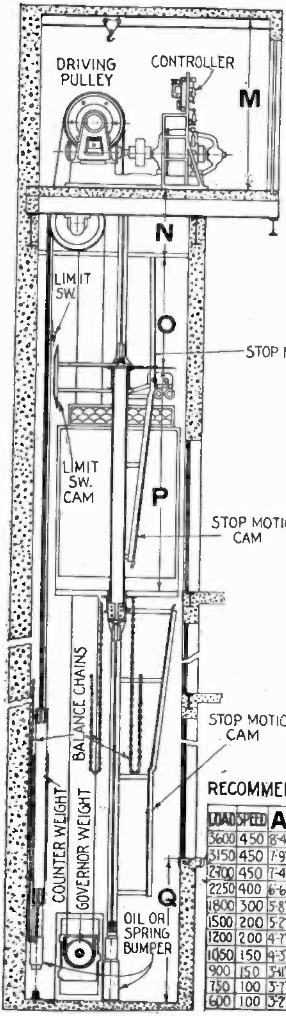
Assuming a car speed of 150 ft. per min. as suitable for this elevator, the size of the motor can now be determined. The table for 1,500 lbs. at 150 ft. per min. gives 8.26 horse power, which in standard sizes would fix the selection on a 10 horse power motor as ample to do the work specified. The elevator machine, of size suitable for the duty, can now be selected and its location determined.

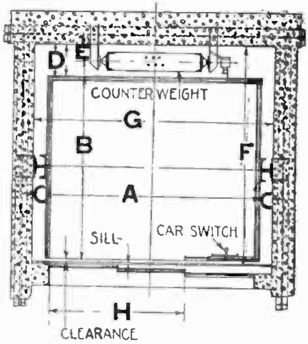
There are several types of machines manufactured, each of which has its advantages and uses depending upon the service requirements and the conditions of installation.

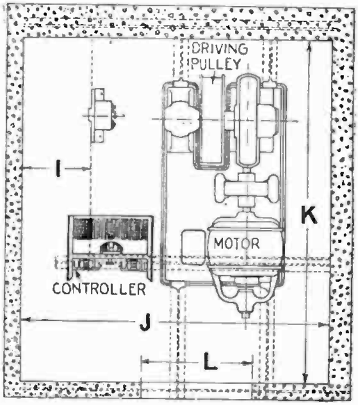
Location of Elevator Machine.—Sometimes the elevator machine is located in the basement. Probably 98% of all new installations in the United States use an overhead machine installed in a room called the pent house at the top of the building. Basement installations are objectionable because they require much longer hoisting cables and more idler sheaves than for overhead machines; they occupy valuable space in the basement and in many cases the actual load on the building is greater. Placing the machine directly over the hoistway imposes a load on the building equal to the weight of the hoisting machine, plus the loads on the car and counter-weight ropes, whereas placing the machine below, imposes a load on the building equivalent to twice the loads on the car hoisting and counterweight ropes. Therefore, if the hoisting engine weigh less than the combined loads on the car and counter-weight ropes, placing the machine overhead reduces the load on the building. This relation of weights often occurs.

The drum type machine is suitable for overhead location, and the traction type, single and double wrap are best adapted to basement location.

The single wrap traction in modified design may also be used in basement locations. The overhead location is desirable principally for the reason that the machine occupies a less valuable space in the building







RECOMMENDED DIMENSIONS FOR GEARED TRACTION ELEVATORS

LOAD	SPEED	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	BUMPER
3600	450	8'-4"	6'-4"	6"	12½"	6½"	7'-5½"	9'-4"	5'-0"	2'-7"	11'-11"	12'-9"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	7'-6"	OIL
3150	450	7'-9"	6'-0"	6"	12½"	6½"	7'-1½"	8'-9"	5'-0"	2'-11"	11'-8"	11'-9"	4'-0"	12'-0"	6'-0"	9'-0"	10'-6"	7'-6"	OIL
2700	450	7'-4"	5'-6"	6"	12½"	6½"	6'-7½"	8'-4"	4'-6"	3'-3"	11'-7"	11'-2"	3'-6"	11'-6"	5'-10"	9'-0"	10'-6"	7'-6"	OIL
2250	400	6'-6"	5'-3"	6"	12½"	6½"	6'-4"	7'-6"	4'-2"	3'-6"	11'-0"	10'-9"	3'-6"	11'-6"	5'-10"	9'-0"	10'-6"	7'-6"	OIL
1800	300	5'-8"	4'-10"	6"	12"	6"	5'-11"	6'-8"	3'-10"	3'-11"	10'-7"	8'-9"	3'-6"	11'-0"	5'-7"	6'-0"	10'-6"	5'-0"	SPRING
1500	200	5'-2"	4'-6"	6"	12"	6"	5'-9"	6'-2"	3'-4"	4'-2"	10'-4"	8'-6"	3'-6"	11'-0"	5'-7"	6'-0"	10'-6"	4'-0"	SPRING
1200	200	4'-7"	4'-1"	5"	9"	4"	4'-11"	5'-5"	2'-10"	4'-6"	9'-11"	8'-6"	3'-6"	11'-0"	5'-7"	6'-0"	10'-6"	4'-0"	SPRING
1050	150	4'-3"	3'-11"	5"	9"	4"	4'-9"	5'-1"	2'-7"	4'-8"	9'-9"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING
900	150	3'-11"	3'-8"	5"	9"	4"	4'-6"	4'-9"	2'-6"	4'-10"	9'-7"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING
750	100	3'-7"	3'-5"	5"	9"	4"	4'-5"	4'-5"	2'-6"	5'-0"	9'-5"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING
600	100	3'-2"	3'-2"	5"	9"	4"	4'-0"	4'-0"	2'-6"	5'-3"	9'-5"	8'-6"	3'-6"	10'-0"	5'-7"	4'-0"	10'-6"	4'-0"	SPRING

FIGS. 6,735 to 6,737.—A. B. See layout and recommended dimensions for geared traction elevators.

and also because the hoisting ropes, subject to wear and replacement, are only one third the length as compared with those required by a basement machine.

In figs. 6,732 to 6,734 an outline of the elevator machinery is shown together with dimensions of the machine room.

In figs. 6,732 and 6,734 is shown a concrete slab under the machine base.

This construction is desirable as it forms a solid floor for the machine room, in place of the usual open iron grating and furthermore, acts as a barrier to the transmission of unavoidable sounds to other portions of the building.

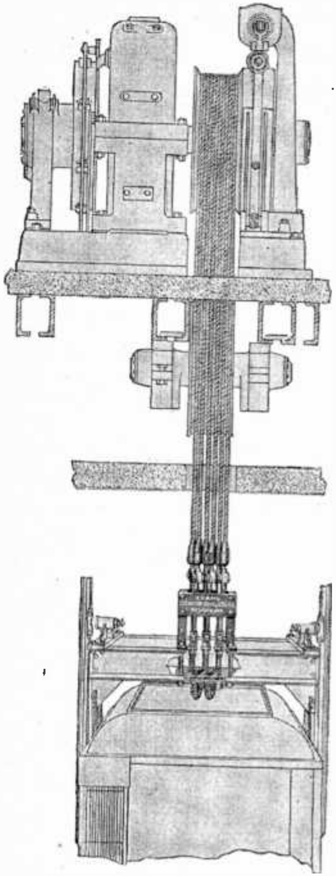
In apartment houses, hotels and hospitals where extreme quiet is required, the machine is often located in the basement on a solid concrete foundation. The elevator specifications require that the owner should provide supports for the overhead machine beams supplied by the elevator contractor.

Fig. 6,732 shows the height and location of these beams above the top floor landing. This height dimension is not fixed; it varies with different installations and is determined from the drawing which shows the height of car when at the top landing, the over travel clearance allowance between top of car and idler sheave, and the distance this sheave projects below the machine beams.

A considerable saving of space, and incidentally, wear of hoisting ropes, can be obtained by the elimination of the idler sheave.

This sheave with certain types of machines is required only when the distance between the centers of the car and counterweight is greater than the span of the driving sheave on the machine overhead. Limitations in design, however, fix the maximum diameter of the driving sheave or drum permissible on the different sizes of elevator machines.

The factors that have a bearing on the selection of the type of machine to use are as follows:



The utilization of the traction or friction drive principle for transmitting motion to an elevator car solved the problem of the high rise elevator so that now the height of a building is no longer a difficulty. The single wrap traction is particularly adaptable to cars where there is little deflection of the hoisting ropes. This drive has the advantage of giving longer life to the ropes as compared with the double wrap traction, but, on the other hand, the double wrap usually shows less wear on the grooves of the driving sheave.

NOTE.—*Properly installed traction elevators* have the length of the lifting ropes so proportioned that when the car is resting on the bumpers at the bottom of the hatchway, the counter-weight is some distance below the overhead work and vice versa. As the driving power for the elevator car is obtained by friction between the ropes and the driving sheave, it is evident that when either the car or counterweight is resting on the bumpers the tractive effort is reduced to a minimum.

FIG. 6,738.—Evans equalizer attached to elevator. The object of this device is to equalize the tension in all the ropes. The equalizer also takes care of any differential travel caused by variable diameter of the grooves, or by oversize or undersize cables. 1/8 in. variation in the diameter of the sheave grooves or in cable diameter will, with 20 turns of the sheave, as the car travels from top to bottom, create a variable travel of the cables at 2 ins. or more. Even if sheaves be perfect when installed, it is only a question of time until the groove diameters are worn to such an extent that the differential travel becomes irregular. This means that a few of the ropes carrying the load going in one direction transfer it to the other ropes going in the opposite direction.

TEST QUESTIONS

1. *What is the most important item in planning an elevator installation?*
2. *Name the various items which determine the size and shape of car.*
3. *What is the advantage of a car with a wide front?*
4. *What is the space allowance in the car per person?*
5. *How is elevator speed measured?*
6. *How is the desirable speed determined for a given installation?*
7. *What should the speed be for extra heavy duty?*
8. *What is the best speed for department store service?*
9. *What is the range of elevator capacity?*
10. *Can the number of elevators required for a given building be easily determined?*
11. *Give an example for determining the number of elevators.*
12. *Make a layout with recommended dimensions for* 1:1 *gearless traction elevators.*
13. *Mention a few points on elevator selection.*
14. *How is service or capacity of elevators affected by safety appliances?*
15. *Sketch a typical layout giving necessary installation information.*
16. *What is the customary arrangement where two or more elevators run in the same hoistway?*
17. *How is the size of motor determined?*
18. *Name two locations of the elevator machine.*
19. *What type of machine is suitable for overhead location?*

20. *Make a layout with recommended dimensions for geared traction elevators.*
21. *Where is the elevator machine located in apartment houses, and why?*
22. *What is the advantage of eliminating the idler sheave?*
23. *What are the factors that have a bearing on the selection of the type of machine to use?*

CHAPTER 154

Types of Elevator Machine

There is a great variety of types of *power unit* or *elevator machines* employed to drive electric elevators. With respect to the method of transmitting the power to the car ropes, elevator machines are divided into two general classes:

1. Drum;

2. Traction;

there being numerous types of each class.

An elevator machine consists essentially of *a motor, drum or traction pulley, brake and motor-drum drive.*

The drive may consist of a direct shaft connection between the motor and drum, or one of the numerous types of gearing. A comparison of these two types is shown in figs. 6,739 and 6,740, in which the important distinguishing features are emphasized.

Drum Elevator Machines—The word drum, as correctly used to distinguish one of the two general classes of elevator machines, means a *winding drum* as distinguished from what looks like a short drum; that is, a traction drum, the latter being simply a type of pulley or sheave. A drum then, is *a form of spool on which the ends of ropes are attached and around which they are wound and unwound in the operation of the car*, as shown in fig. 6,741. Note the difference between this drum and the traction pulley shown in fig. 6,742.

The principle of drum drive is shown in fig. 6,743.

In the operation of a drum elevator machine, power when applied to the driving gear, turning it in one direction, winds the ropes upon the

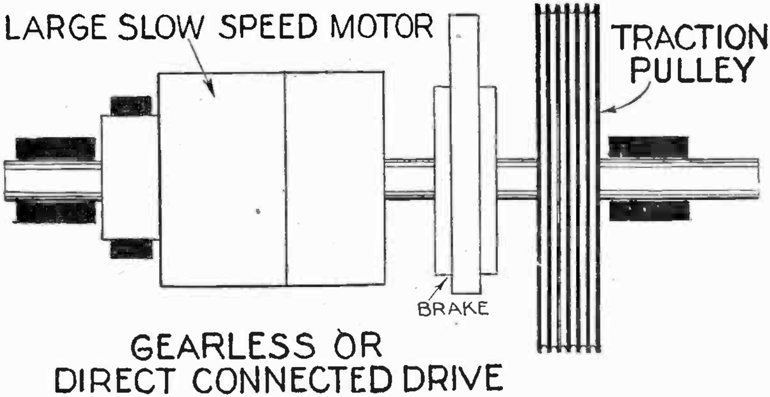


FIG. 6,739.—Elementary elevator machine with gearless or direct connected drive. A large slow speed motor is required.

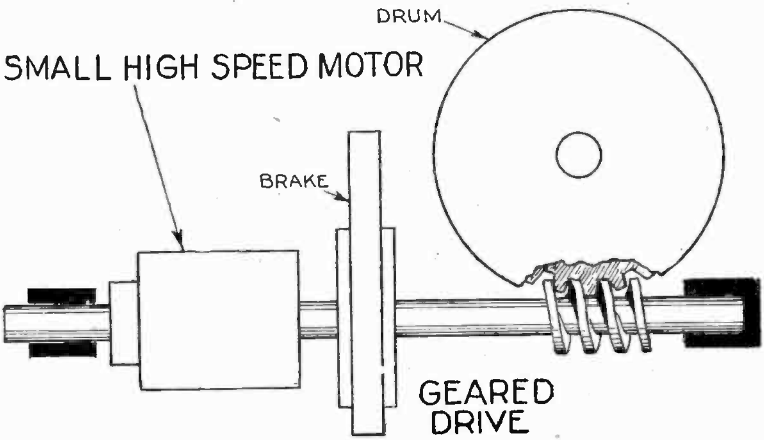
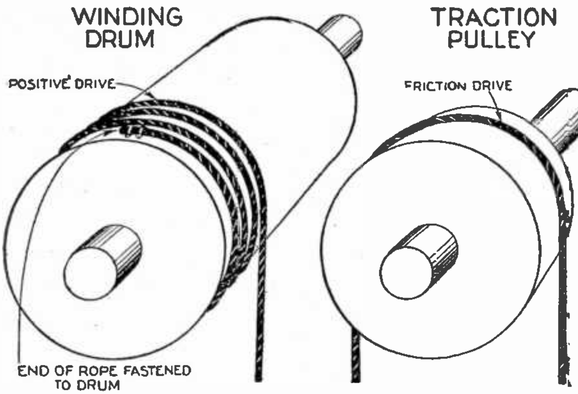


FIG. 6,740.—Elementary elevator machine with geared drive. Note the small high speed motor. With this type of elevator machine any one of several forms of gear may be used.



FIGS. 6,741 and 6,742.—The two types of drum used on elevator machines. *In construction*, grooves (not shown) are provided on both types of drum, *the grooves being spiral for drum elevators* and *straight* for *traction elevators*.

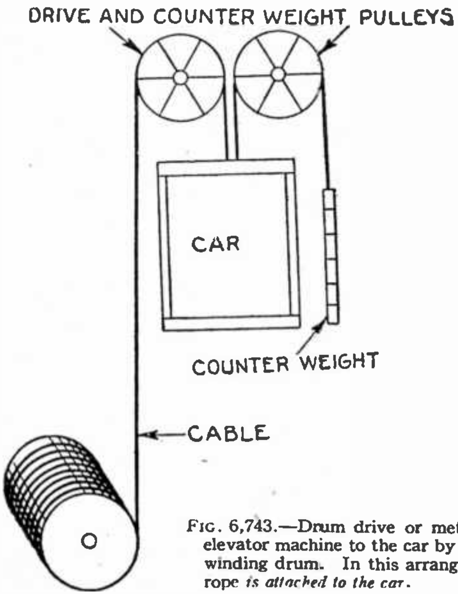


FIG. 6,743.—Drum drive or method of transmitting power from the elevator machine to the car by means of winding the hoist rope on a winding drum. In this arrangement the end of the counter weight rope *is attached to the car*.

drum and causes the car to ascend, and when the power is reversed, the drum turns in the opposite direction, paying out the ropes, and causing the car to descend.

The weight of the car is balanced by a counter-weight, thus reducing the energy to be expended in operating the car. Automatic devices, to be described later, are used to insure the proper and safe control of the movements of the car.

Sometimes the ends of the counter-weight ropes are attached to the drum as in fig. 6,744 instead of to the car, as in fig. 6,743. In the arrangement shown in fig. 6,744, when the hoisting ropes wind up, the counter-weight ropes unwind and vice versa.

The drum is machined with spiral grooves to guide the ropes.

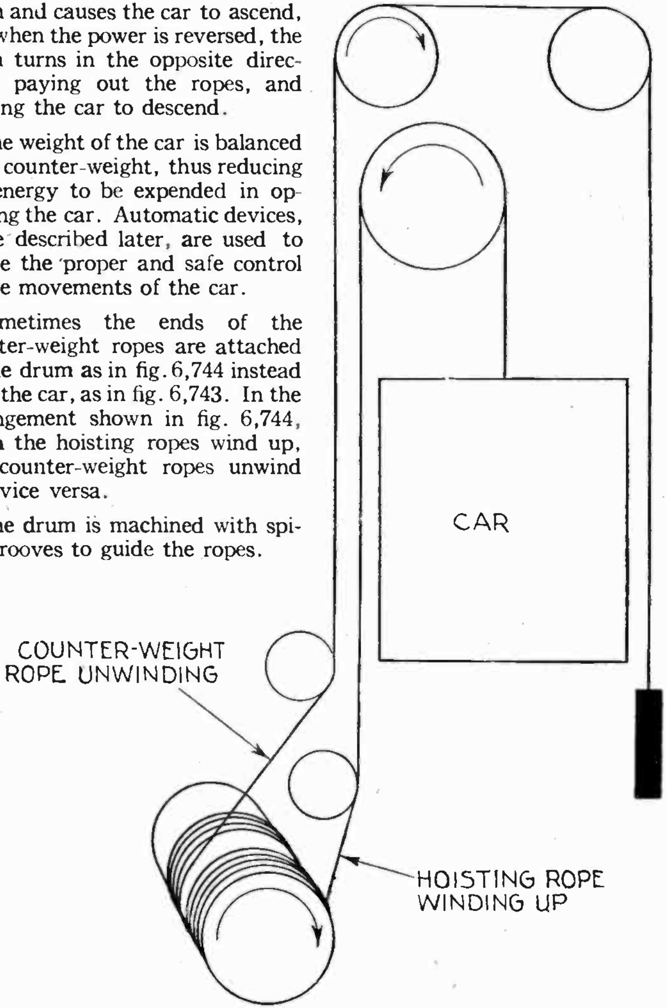
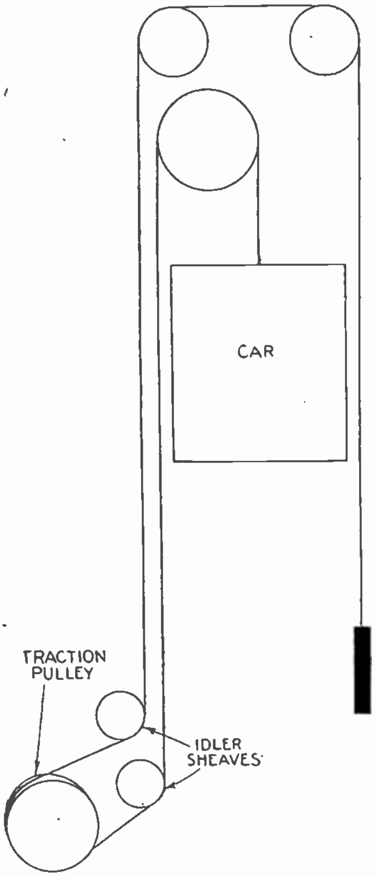


FIG. 6,744.—Drum drive arrangement in which the end of the counter-weight rope *is attached to the drum.*



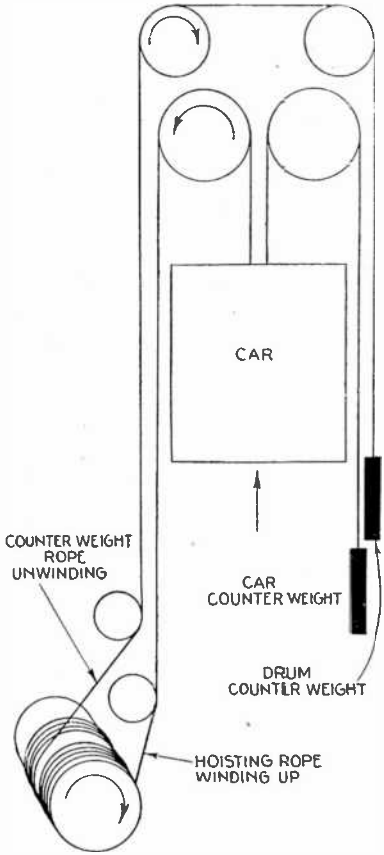


FIG. 6,745.—Rope drive arrangement for basement type V groove single traction elevator.

FIG. 6,746.—Drum drive arrangement having two counter-weights, one roped to the drum and the other to the car. This arrangement reduces the load on the drum and bearings and is used on large cars.

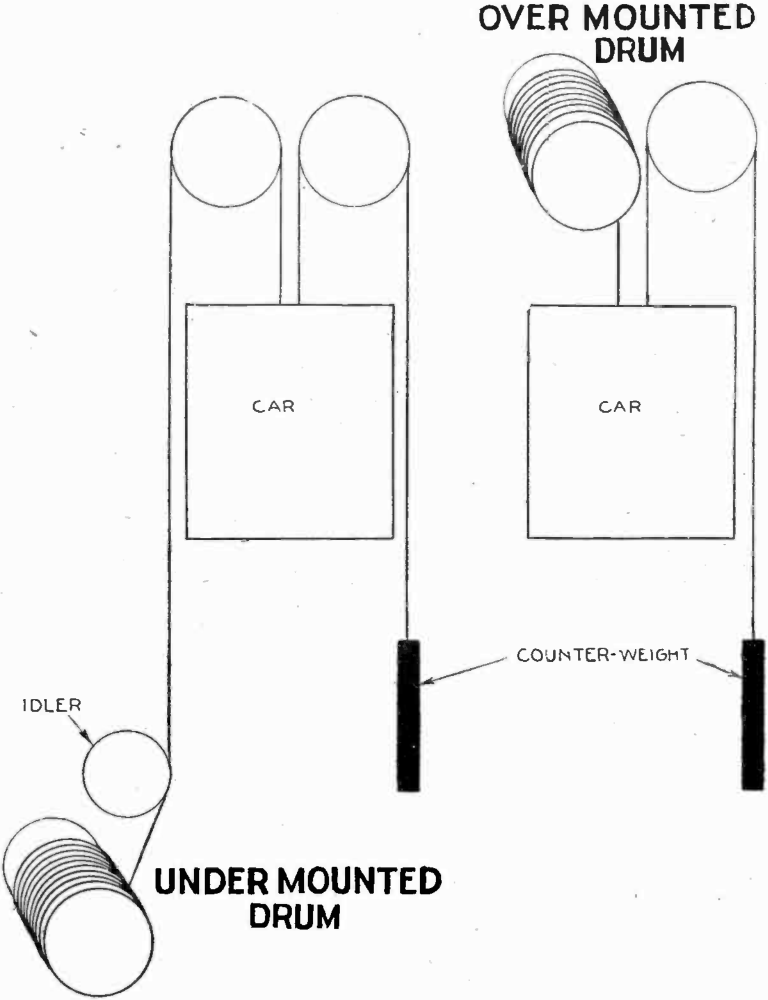


FIG. 6,747.—Under mounted drum elevator.

FIG. 6.748.—Over mounted drum elevator.

With respect to location, there are two types of machine, known as:

1. Over mounted;
2. Under mounted;

according to whether the machine is placed above the hoistway or in the basement.

The over mounted machine gives direct transmission; that is, no pulleys are required between drum and car, also the drum may be so located that one face of the drum is over the center of the car, and the other face over the counter-balance, thus allowing the car ropes to be fastened at one end of the drum and the counter-balance ropes at the other end of the drum grooves, the car ropes occupying the entire surface of the drum when the car is up, and the counter-balance ropes following alongside of them, occupying the entire drum surface when the car is down.

This arrangement transmits power with the minimum length of ropes.

If the drum type machine be installed overhead it will give remarkably long rope life because there is no possible rope creepage and the bending is always in one direction. However, if the machine be installed in the basement, reverse bends are necessary in the ropes and this materially reduces the rope life.

One reason for the decreased use of the drum machine is because it requires a modification of the machine for each installation, as the length of travel determines the length of the winding drum. Another bad feature is that should the terminal stops and overtravel limit switches fail to stop the car at the terminals, the machine may continue to travel and finally pull the ropes from their sockets.

Fig. 6,747 shows an elevator installation with under mounted type of drum machine. An over mounted drum machine with worm drive is shown in fig. 6,748.

Traction Elevators.—This type of elevator derives its name from the fact that motion is obtained *by means of the* ***traction,*** that is to say, *the friction existing between the driving pulley* and the hoisting ropes.

The ropes are not wound on a drum, but a continuous rope from the car to the counter-weight passes over a driving pulley.

The traction machine carries the hoist ropes over the hoisting sheave and down to the counter-weight and relies on the grip of the ropes on the sheaves to give enough traction to lift the load.

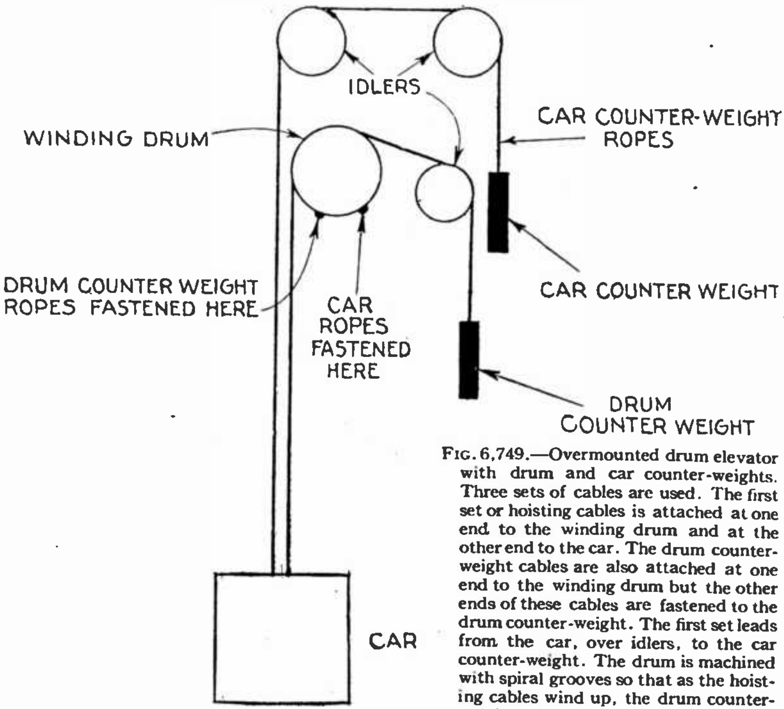


FIG. 6,749.—Overmounted drum elevator with drum and car counter-weights. Three sets of cables are used. The first set or hoisting cables is attached at one end to the winding drum and at the other end to the car. The drum counter-weight cables are also attached at one end to the winding drum but the other ends of these cables are fastened to the drum counter-weight. The first set leads from the car, over idlers, to the car counter-weight. The drum is machined with spiral grooves so that as the hoisting cables wind up, the drum counter-weight cables unwind.

Practically all elevators except a few low speed low lift machines to-day are the traction type. It is common to hear a gearless machine spoken of as a "traction machine," as though geared machines were not traction machines, but this is wrong, as a geared machine may be just as much a traction machine as a gearless machine.

There are two methods of roping known as

1. Half wrap (V groove);
   Figs. 6,759 and 6,760.
2. Full wrap (U groove).
   Figs. 6,755 to 6.758.

The term single wrap and double wrap are sometimes used respectively for half wrap and full wrap.

When hoist ropes lead over the driving, or traction sheave and down to the counter-weight, either straight or over an idler sheave, as in figs. 6,759 and 6,760, the grooves on the traction sheave are V shaped, to grip the sides of the rope, so a half wrap traction machine is frequently called a V groove traction. The V grooves cause the ropes to be pinched tightly,

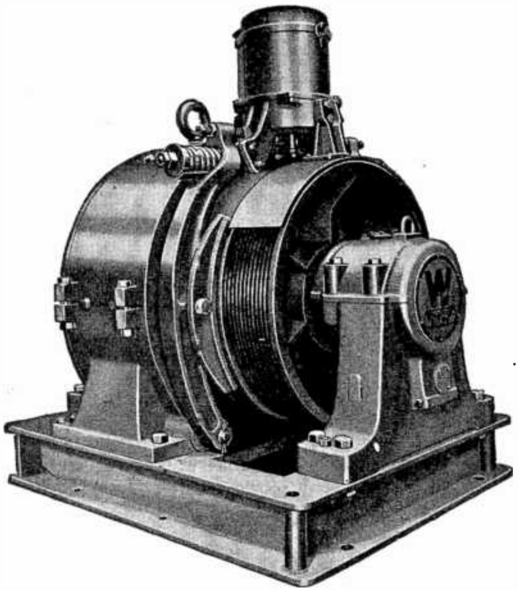


FIG. 6,750.—Westinghouse gearless traction elevator machine for high speed passenger service. A slow speed motor is used, having a grooved sheave wheel assembled on the armature shaft. The ropes which support the car and the counter balancing weights pass over the sheave wheel, giving the traction that moves the car. This type of elevator is accepted as the best for car speeds of approximately 400 *f.p.m.* and higher because it is more economical in operation and all wear and vibration of gearing are eliminated.

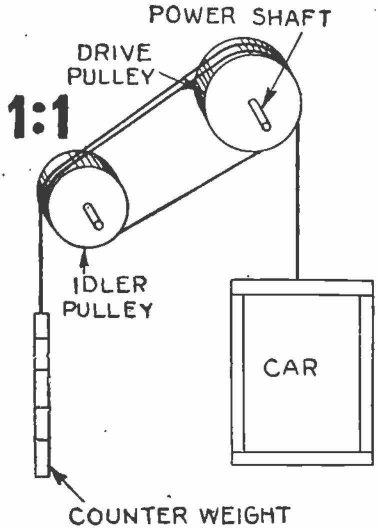


FIG. 6,752.—Direct (1:1) traction drive or method of transmitting power from the power unit to the car by means of frictional contact of the rope in passing one or more times around the drive pulley. This arrangement, since it does not employ a drum where size has to be considered, can be used for lifts of any height, and is the prevailing type today.

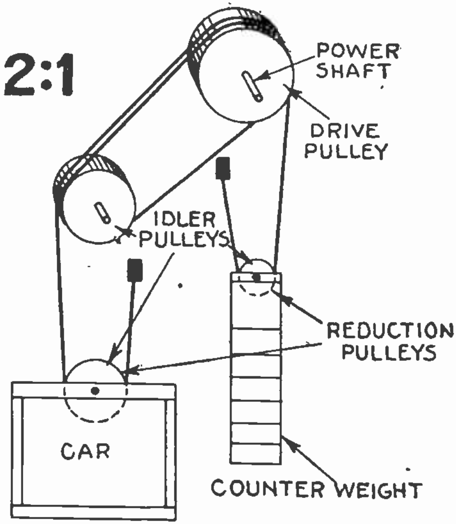
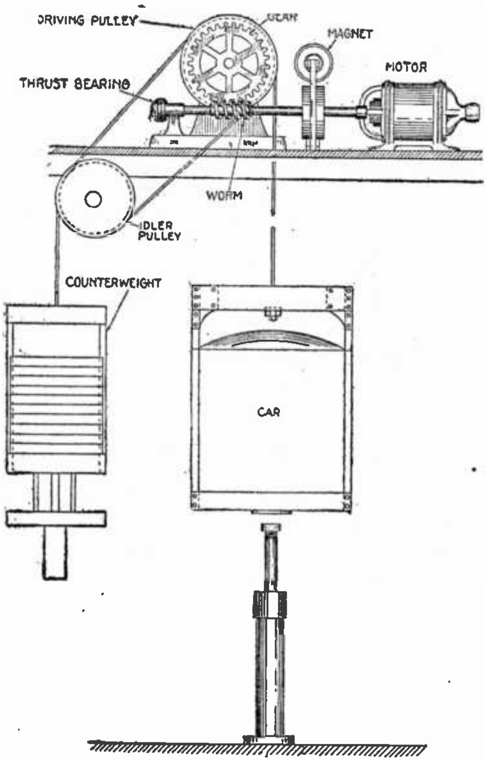


FIG. 6,753.—Geared, or 2:1 friction drive, or frictional contact transmission with reduction gear pulleys—a type used for moderate speed elevators.

due to the weight of the car and counter-weight. The advantage of this system is its simplicity, and long rope life is claimed for it, due to the reduced number of bends and the absence of slippage between the ropes and the sheave. The disadvantage lies in the tendency of the sides of the grooves to wear down and reduce the grip on the ropes.



For higher speeds, over 500 *f.p.m.* and sometimes for speeds 500 *f.p.m.* and below, the hoist ropes lead around the traction sheave for another half wrap and so down to the counter weight, as in figs. 6,752 and 6,756.

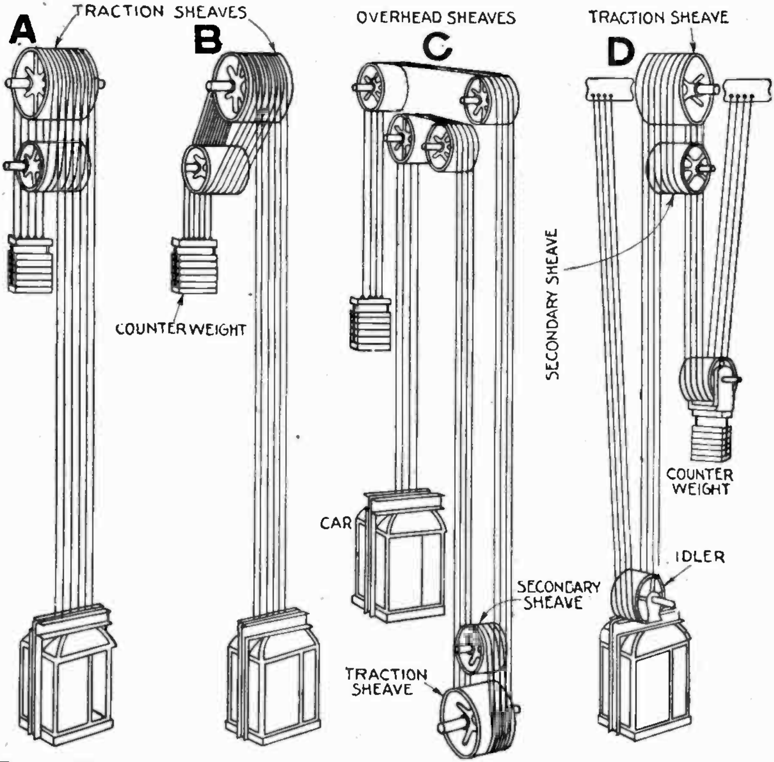
This is called full wrap or double traction. The grooves of the traction sheave of full wrap machines are U shaped, and such machines are sometimes called U groove machines.

There are two forms of the so called gearless traction elevators: the

Fig. 6,754.—Diagram of an overmounted traction elevator with multi-reduction or worm drive. The traction feature is identical with fig. 6,752. Attached to the driving pulley is a gear which meshes with the worm underneath, the latter being direct connected to the motor. Clearly, the worm gives a large velocity reduction permitting the use of a high speed motor. The magnetic brake being located to act on a brake pulley attached to the fast revolving motor shaft gives considerable braking power light grip on the brake pulley. The action of the single worm gear is such as to require a thrust bearing, as later explained in detail.

1 to 1 or direct drive type shown in fig. 6,752 and the 2:1 reduction type shown in fig. 6,753.

A third form of traction elevator known as a multi-reduction or worm drive is shown in fig. 6,754, the essential features of each being mentioned under the illustrations.



FIGS. 6,755 to 6,758.—Roping for full wrap traction elevators. This machine, cabled directly one to one, or two to one, has the advantage of being a standard stock machine for all lengths of travel. One possible objection to this type of machine is that the driving sheave bearing is required to take double load due to the double wrap necessary in this form of drive. This produces a somewhat lower efficiency than could otherwise be realized. Because of the round grooves the traction is limited but it does not change much with wear as it does in the case of the half wrap traction machine.

By comparing the three figures it is obvious that the direct drive machine (fig. 6,752) is suitable for high speed service; that the 2:1 reduction machine (fig. 6,753) is an adaptation of the direct drive type permitting of slower car speeds; the multi-reduction type (fig. 6,754) permitting the use of small high speed motor.

The traction type machine has the advantage of being more compact than the drum type, since a traction pulley is substituted for the larger drum and a single design may be used for buildings of greatly varying heights. It is inherently safer than the drum type machine, due to the fact that it will not over wind. Should the motor fail to stop, either the car or counter-weights will land at the bottom of the pit and the machine will lose its traction.

Roping.—The simplest roping or hitch is 1:1. See fig. 6,752. Here the peripheral velocity of the rope sheave is equal to the elevator speed. With 2:1 roping the peripheral velocity of the rope sheave is twice the elevator speed.

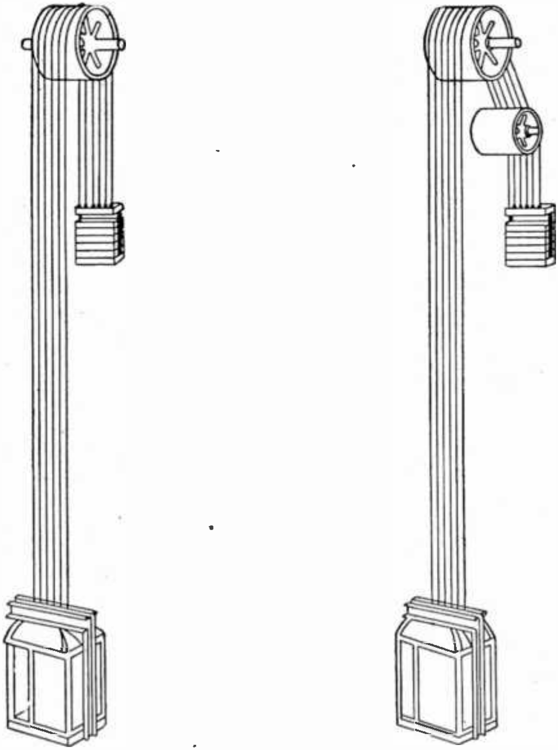
2:1 roping gives, usually, twice the capacity at half the speed. Thus an elevator rated 2,500 lbs. at 300 *f.p.m.* 1:1 roping could be roped 2:1 to carry 5,000 lbs. at 150 *f.p.m.* See fig. 6,753.

Gearless machines are 1:1 roped for 600 *f.p.m.* and above. For 500 or 450 *f.p.m.* they may be either 2:1 or 1:1. For 400 *f.p.m.* they are almost always 2:1 roped. The selection of one or the other depends on the speed and duty. 1:1 roping is sometimes called "direct hitch" or "straight hitch."

The object of using 2:1 roping instead of 1:1 roping in certain cases is to get the advantage of the lower first cost of the higher speed driving unit.

Thus, for example, an elevator rated 10,000 lbs. at 100 *f.p.m.* would have a lower first cost if it used a hoisting machine with a combination of gear ratio and sheave diameter suitable for 5,000 lbs. at 200 *f.p.m.* and roped 2:1 than if the hoisting machine were built with a gear ratio suitable for 100 *f.p.m.* and a load of 10,000 lbs. Such a machine could not be built economically with a single worm and gear.

A compound geared machine, that is a worm geared machine with an additional spur gear reduction, roped 1:1, could be used instead of the single geared machine roped 2:1, and there are certain cases, especially where the elevator speed does not exceed 100 *f. p.m.* where a compound geared arrangement is preferred.



FIGS. 6,759 and 6,760.—Roping for half wrap traction elevators. It will be noted how simple the roping is, there being only two cable bends (one as the cable leads onto the driving sheave and the other as it leaves) where the driving sheave diameter is one half the car width, although this is doubled when a deflecting sheave is necessary. However, for loads above approximately 15,000 lbs. a two to one roping is generally used. As the car width increases to a point where it is impracticable to further increase the diameter of the driving sheave, the amount of wrap possible on the driving sheave decreases. Therefore in the case of wide freight cars it is sometimes necessary to use the full wrap traction machine in order to get sufficient driving friction. The driving sheave bearing load is only one half that of the full wrap traction machine. One criticism of this type of elevator is the wearing of grooves in the sides of the V, thereby reducing the pinching action, although sheaves properly machined are still in good operating condition after eight or ten years of constant regular service. Moreover the rim in which the grooves are cut can readily be made removable for replacement.

As another example, take the case of 2,500 lbs. at 500 *f.p.m.* gearless.

In the motor speed table, page 4,121, if the traction sheave be 28 ins. the speed of the gearless motor is 136 *r.p.m.* 2:1 roping. If this machine were 1:1 roped, the speed of the gearless motor would have to be 68 *r.p.m.*

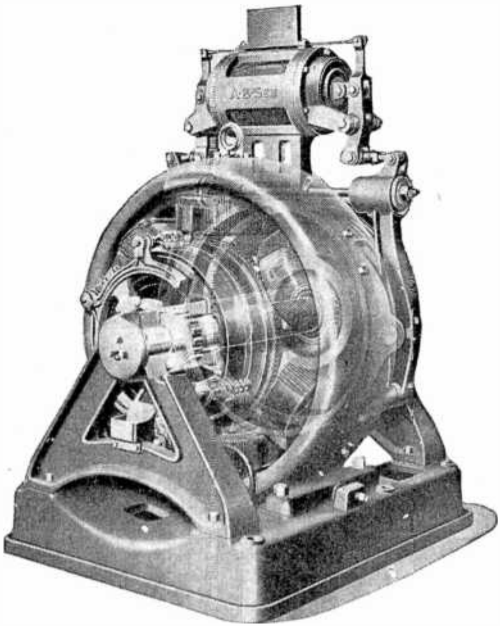


Fig. 6,761.—A. B. See gearless half wrap (V groove) traction elevator machine. It is built in sizes suitable for loads of 1,500 to 3,500 lbs. with one to one roping and speeds varying from 450 ft. per min. to the highest allowed under state and municipal regulations. The shaft does not revolve, being fastened to the pedestals. The duty of this shaft is solely to carry the load imposed upon it by the revolving parts of the machine and the weight of the moving parts in the hoistway. The brake consists of two independently operated shoes, provided with fabric linings. The pressure of the shoes on the brake drum is obtained by adjustable compression springs, and is released electro-magnetically on the application of current to the motor, in such a manner that should this current be interrupted from any cause the brake will be immediately applied and bring the car to rest. Means are provided to regulate the application of the brake so that it brings the car to a smooth stop. The various parts comprising the brake are all mounted directly on the field frame of the motor.

and such a motor would be much larger, heavier, and more costly than the 136 *r.p.m.* motor. However, the gain in cost of the higher speed motor is not all a net gain, as it is offset to a considerable extent by the added cost for sheaves, rope, etc., in 2:1 roping. Furthermore, owing to extra bends in the reverse direction, hoist ropes do not last as long in 2:1 roping as in 1:1 roping, and when they do wear out, cost more to replace.

Figs. 6,755 to 6,760 are roping diagrams showing all of the ropes. Figs. 6,759 and 6,760 show half wrap and figs. 6,755 to 6,758, full wrap roping for traction elevators.

Extension of Elevator Ropes

(According to American Steel & Wire Co.)

Length of rope in feet	Extension for cast steel rope in feet	Extension for plow steel in feet
500	0.833	1.000
1000	1.667	2.000
1500	2.500	3.000
2000	3.333	4.000
2500	4.167	5.000
3000	5.000	6.000
3500	5.833	7.000
4000	6.667	8.000
4500	7.500	9.000
5000	8.333	10.000

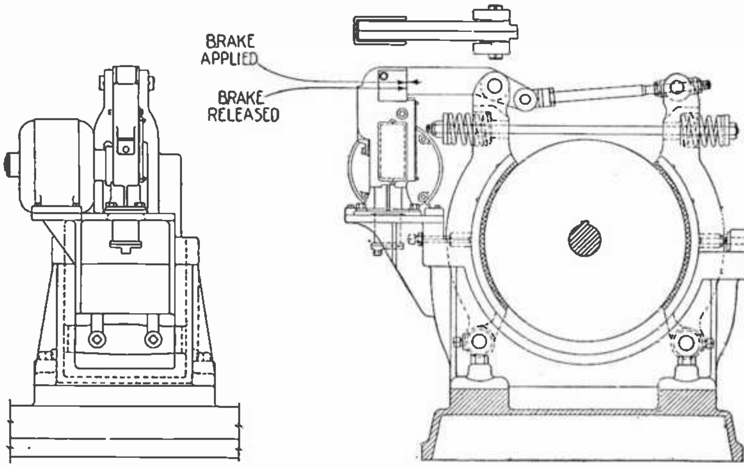
NOTE.—The foregoing extension acts in the case of sudden stopping or starting of a load attached to a wire rope to ease the stress a little. In the case of a short rope the elastic extension is small, but it increases proportionally to the increase in length of rope. This needs to be given due weight in any problem involving fast acceleration, jerks or shocks on a wire cable and the final safety factor should take into consideration these points.

NOTE.—*With all traction elevators* there is the danger of slippage of the ropes on the driving drum, especially if the ropes become greasy. This slippage is most noticeable when the operator endeavors to stop in descending with a heavy load, with the result that on high speed cars when attempting to make a quick stop, the car sometimes slides past the landing even to the extent of one or more stories.

NOTE.—*The traction drive is not a positive drive.* This is a safeguard for the reason that rope strains can never increase beyond a certain limit, well within the factor of safety of the ropes and fastenings. This means that the danger of the car or weight dropping, as a result of being pulled into the overhead work, and thus breaking ropes or fastenings, is eliminated.

Every elevator machine requires a mechanical or friction brake to make the final stop and hold the load.

In some of the early forms of elevator machines, the brakes were mechanically released by hand ropes passing down beside the car, which also operated the control. The modern elevator brake is set by means of a spring and is released by a magnet. The brake wheel is mounted on the motor and worm shafts and usually serves also as a coupling between the two. The friction brake plays an important part in the successful operation of the elevator, since it must stop the car quickly and without producing an uncomfortable jar in the car



FIGS. 6,762 to 6,764.—American torque type brake.

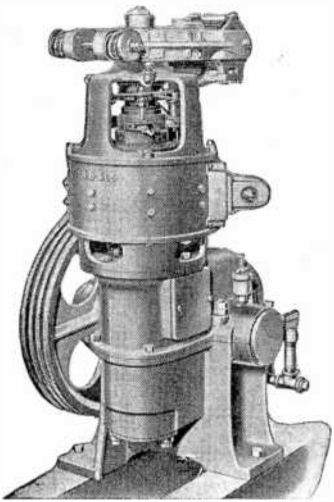
NOTE.—*In general* gearless traction machines do not require commutating poles, as excellent commutation can be obtained without them. The most important requirements of such a machine are good speed regulation both as a motor and as a dynamo, also compactness in design so that adjacent machines can be set above their hatchways.

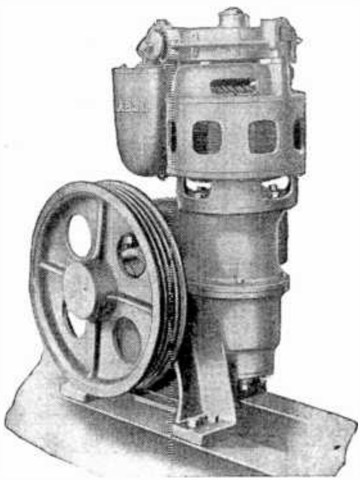
NOTE.—*The gearless traction motor* is smooth in operation and gives long life. It is free from the lost motion or back lash which is inherent in the geared machine, and may be used in severe service where frequent starting and stopping and high rates of acceleration are essential. As the speed of elevators is extended upward to meet the needs of higher buildings and more intensive elevator service, the gearless machine has the further advantage over other types in that the increased speeds can be obtained by using higher speed motors, so that the cost of the machine does not increase as rapidly as its output.

The accompanying illustrations show the brake as placed on the machine and figs. 6,768 to 6,770 construction details.

Gearing between Motor and Drum.—There are several forms of gear used to secure the velocity reduction between the motor and drum, necessary in most types of elevator. These may be classified as

1. Spur gear;
2. Herringbone gear;
3. Worm gear.





Figs. 6,765 and 6,766.—A. B. See single wrap traction elevator machine. Fig. 6,765 for *d.c.* fig. 6,766 for *a.c.* It is designed especially for installation in locations where the space is limited. In order to obtain these small overall dimensions the driving motor has been placed in a vertical position and the brake placed above the outboard bearing of the motor instead of between the motor and the worm gear housing as in general practice.

Spur Gear Drive.—This well known method of transmitting power is extensively used in elevator practice. It is a "positive" drive, as distinguished from belt drive which is subject to slippage. For moderate speed motors or machines in which the speed reduction between the motor and drum is not too great, spur gearing is well suited.

Obviously, where great speed reduction is required, as in an installation comprising a high speed motor and slow speed elevator it is not so well suited because of the large diameter of the drum gear required or the extra gears for double reduction necessary to obtain the necessary speed reduction. Clearly, such installations are best fitted with worm gear drive, as any speed reduction is easily obtained without the necessity of double reduction drive.

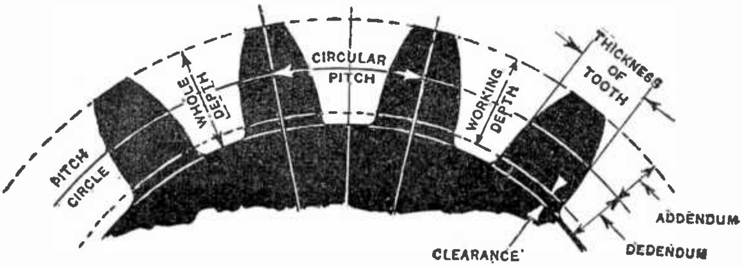
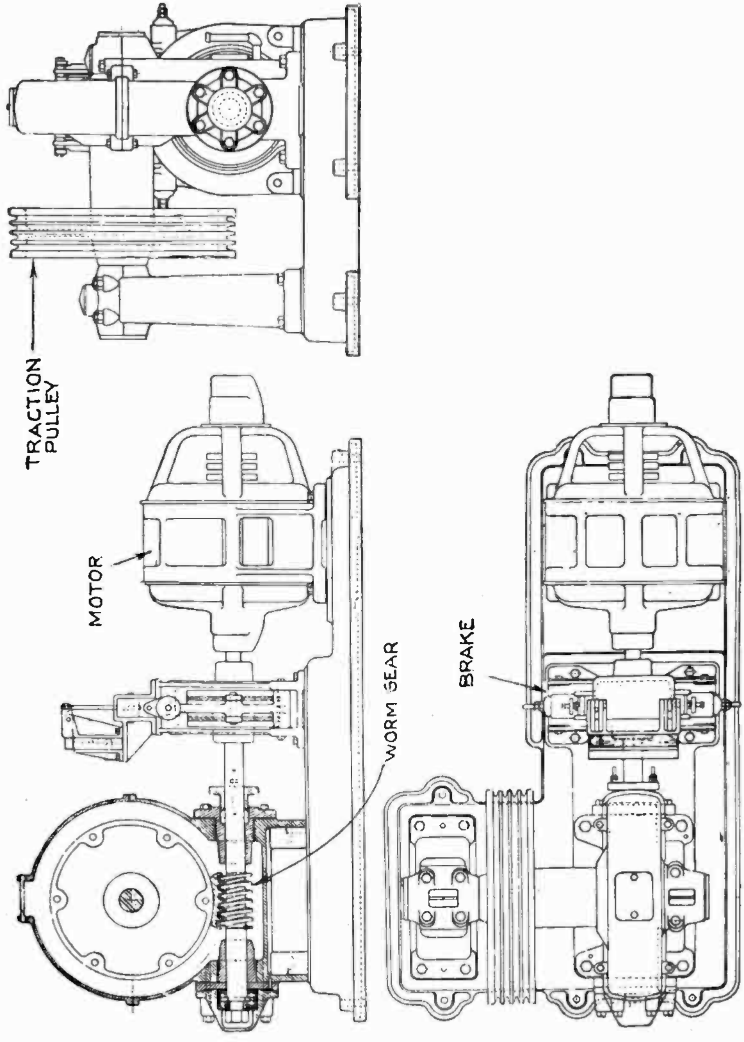


FIG. 6,767.—Gear tooth parts. ***Systems of spur gearing.*** Two systems of gear tooth are used for spur gears: the ***cycloidal*** and the ***involute.*** Of these, the involute system is the one more commonly used, especially for cut gearing. The standard involute gear tooth has a 14½ degree pressure angle, hence the rack meshing with gears cut according to this standard has straight sides inclined 14½ degrees from the vertical. ***Definition: Circular pitch*** is *the distance from center to center of two adjacent teeth along the pitch circle.* ***Diametrical pitch*** is *a number found by dividing the number of teeth by the pitch diameter;* that is, it gives *the number of teeth for each inch of pitch diameter.* ***Internal spur gears.*** The dimension of internal spur gears may be found by the same formulae as those for external spur gears, except for the modification made necessary by the fact that the center distance in internal gearing is equal to the *difference* between the two pitch radii, instead of the *sum.* In addition, the term inside diameter takes the place of the outside diameter of external spur gearing. This diameter, of course, is the diameter of the hole in the blank before the teeth are cut. ***In laying out*** the shape of teeth for internal gearing, interferences are almost sure to be met with. The points of internal gear teeth must, therefore, be relieved to avoid interference with the flanks of the meshing teeth. ***Interference occurs*** also when the pinion has too nearly the same number of teeth as the gear. In this case there is a tendency for the points of the pinion and the gear teeth to strike as they roll into and out of engagement. To avoid this interference, the teeth must be cut by specially made cutters or shaped on a gear shaping machine.

Herringbone Gear Drive.—This form of gear, sometimes called double helical tooth gear is a type in which right and left hand spiral teeth are both used.



FIGS. 6,768 to 6,770.—Watson worm drive half wrap (V groove) traction elevator machine showing construction.

This gear has been tried extensively, giving very efficient operation, but it is understood that it is expensive to cut gears that insure quiet and smooth operation. This fact has limited its use.

Ques. Describe the Wuest system of herringbone gears.

Ans. The right and left hand sides of the gears are stepped half a space apart and do not meet at a common apex at the center of the face, as in the usual type of herringbone gear.

This stepped form wears more evenly under extreme loads than the ordinary type.

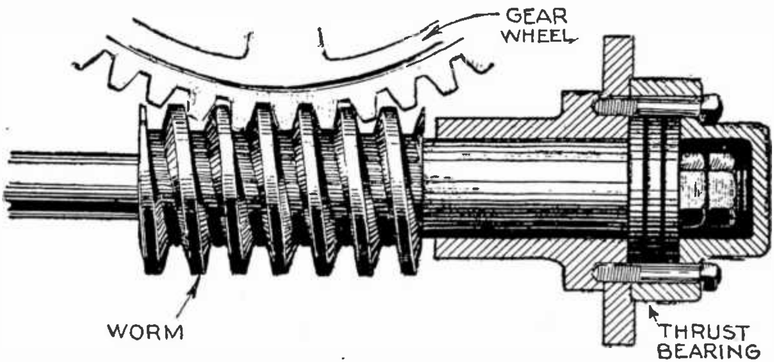


FIG. 6,771.—Single worm drive with ball bearing end thrust. The shaft on which the worm is cut is direct connected to the motor through a coupling with pulley shaped flange which is used as a braking surface. The single worm drive is suitable for relatively slow car speed and light loads. *In construction* worm drives are arranged to run in oil, accordingly the worm is placed below the gear wheel.

Worm Gear Drive.—This form of gear is very extensively used and is especially suited to slow speed elevators driven by high speed motors. A feature of worm gear drive is that it is self-locking because of the high velocity ratio, that is to say, no change in the loading of the car will produce movement.

In construction the gearing is enclosed in a cast iron box or casing which serves to protect the gears from dust and also to form a reservoir for oil used for lubrication. The worm is generally placed below the gear,

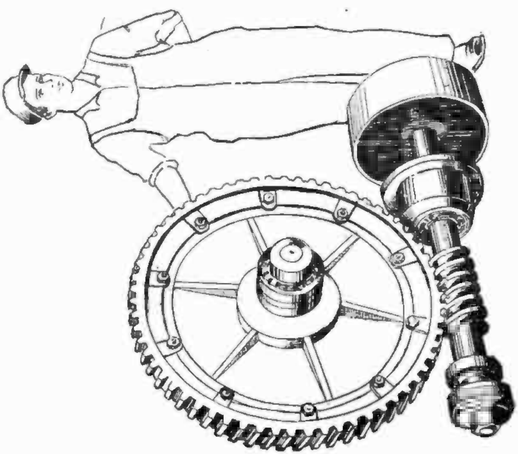


FIG. 6,772.—Haughton single worm gear.

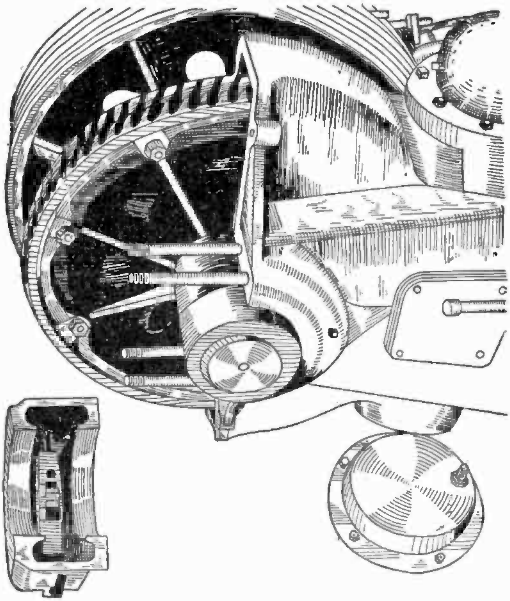


FIG. 6,773.—Haughton adjustable bearings on one gear machine. This construction allows the gear to be adjusted under operating conditions to the correct position giving the proper contact and oil clearance.

in order that the worm may run in an oil bath. There are two kinds of gear:

1. Single gear;
2. Double or tandem gear.

An undesirable feature of the single worm drive is *end thrust*.

Clearly with a heavy load there is considerable pressure endwise on the threads of the worm which is accompanied by friction (loss of power) and wear, moreover a special form of bearing called a thrust bearing is required to take this end thrust.

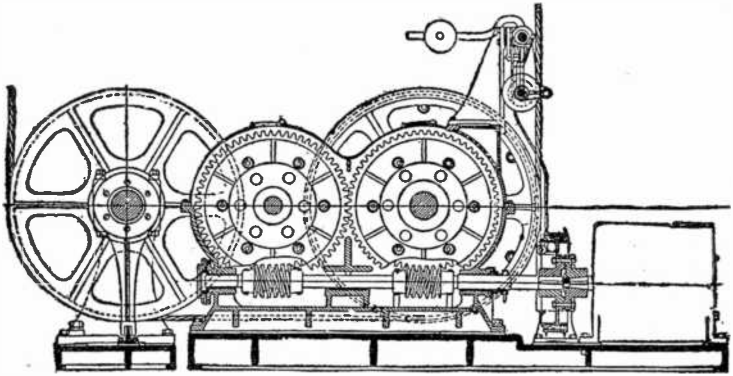


FIG. 6,774.—Tandem worm drive machine with independent concave face gears meshing with the worm as shown by the portions of the larger gears cut away above the worms. As shown, there are four gear wheels bolted together in pairs, the two larger ones meshing with each other, and the two smaller ones with the worms.

Ques. Describe some forms of end thrust bearing.

Ans. For light service, discs of bronze and steel suffice to take the thrust; for medium duty ball bearings should be used; and for heavy duty, roller bearings.

The details of construction are shown in the accompanying cuts.

Ques. What is the object of a double or tandem worm gear?

Ans. To eliminate the end thrust.

Ques. Describe a double worm gear.

Ans. Two worms, usually forged solid to one shaft, are employed; one, a right hand worm, and the other left hand. These worms mesh with two gears of equal size as in fig. 6,774.

Double Reduction Worm and Internal Gear Drive.—For very slow heavy duty freight elevators, operated by high speed motors, the excessive speed reduction necessary is best obtained by double reduction drive employing a combination of worm and internal spur gear.

TEST QUESTIONS

1. *Name two general classes of elevator machines.*
2. *What are the essential parts of an elevator machine?*
3. *What is the difference between a drum and a traction pulley?*
4. *Describe the operation of a drum machine.*
5. *How is the weight of the car balanced?*
6. *Describe different methods of roping the counter-weight.*
7. *What names are given to the two types of machine with respect to location?*
8. *Which type of machine gives direct transmission?*
9. *What is the advantage of installing the drum machine overhead?*

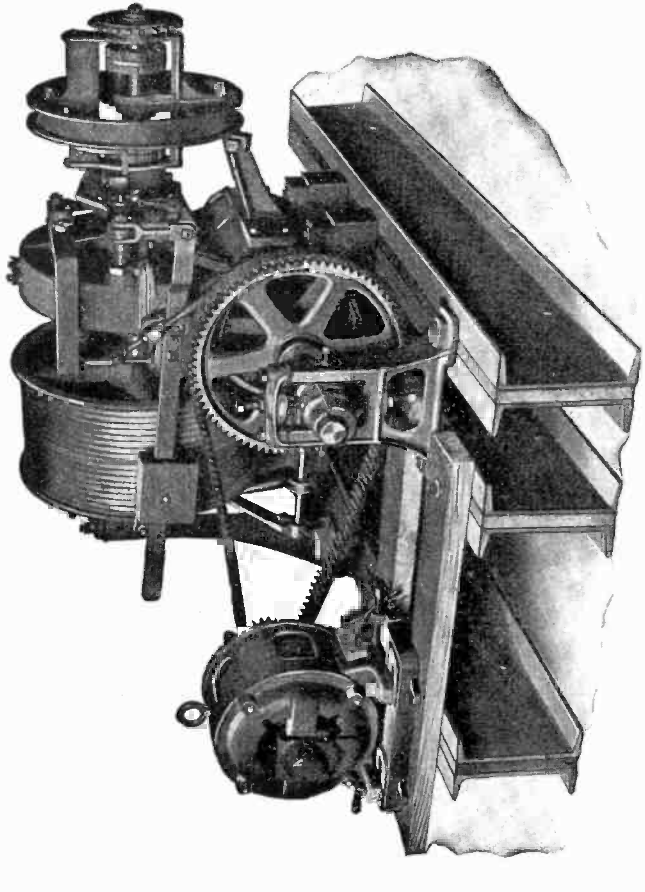


FIG. 6,775.—Energy chain drive electric elevator or *winder type* elevator machine. ***It is driven*** by a silent steel chain belt from a reversible motor. The transmission between motor and drum is double reduction: and the second reduction is obtained through a worm gear; the latter runs submerged in heavy oil for lubrication and protection against dust or grit. The lateral friction of the worm is reduced to its lowest point by means of ball thrust bearings at each end. If the car should meet with any obstruction in its descent, a slack cable stop shuts off the machine and prevents disarrangement of the cable on the drum.

10. *Why is the drum machine not the prevailing type?*
11. *Describe at length a traction elevator installation.*
12. *What is the difference between half wrap and full wrap roping?*
13. *What other names are sometimes given to half wrap and full wrap?*
14. *What determines whether a V groove or a U groove be used?*
15. *Describe one to one or direct drive and two to one reduction roping.*
16. *What type drive is used for multi-reduction transmission?*
17. *For what speeds are the various types of roping used?*
18. *What is the principal object of using a two to one roping instead of one to one?*
19. *Mention an inherent fault of traction elevators.*
20. *Describe the various forms of gearing between motor and drum.*
21. *Name an objection to herringbone gear.*
22. *Describe the construction of worm gearing.*
23. *Name some forms of end thrust bearing.*

CHAPTER 155

Elevator Motors

No matter how good an elevator controller may be, it is obvious that without the right type of motor the elevator service is bound to be unsatisfactory.

A few suggestions regarding the selection of motors for elevator work may be helpful.

In order to insure rapid acceleration and retardation, the inertia of moving parts must be kept as low as possible. For this reason motors for elevator service are designed with armatures of comparatively small diameter. Slow speed motors are preferable.

Generally speaking, the motor speed should not exceed 900 revolutions per minute.

Motor speed, of course, is not so important on slow speed as on high speed elevators.

Power Calculations.—In order to determine the size of motor required for a given installation three factors must be considered:

1. Load or net weight to be hoisted;
2. Speed of the car;
3. Efficiency.

NOTE.—***For full information*** on principles, construction, operation and maintenance or *a.c.* and *d.c.* motors, see Volumes 2 and 5 of this Series.

With regard to the load or weight to be hoisted, since it is customary to counterbalance the weight of the car and part of the load this must be taken into account, that is, only the unbalanced load is considered.

The efficiency is the "overall" efficiency; it includes the various frictional and electrical losses. Accordingly when this is known and inserted in the formula the horse power obtained is the horse power input to the motor.

The horse power required may be obtained by inserting the given values in the following formula:

$$\text{horse power} = \frac{L \times S}{E \times 33{,}000}$$

in which

L = unbalanced load in pounds;

S = speed of elevator in feet per minute;

E = efficiency of the system generally taken at 50%.

Example—What size motor will be required for an elevator having an unbalanced load of 2,000 lbs. 400 ft. per minute speed and overall efficiency of 50%?

$$\text{horse power} = \frac{2{,}000 \times 400}{.5 \times 33{,}000} = 48$$

The horse power required for a given installation may be easily and quickly obtained from the chart shown in fig. 6,776. In the chart the efficiency of the elevator is assumed to be 50%. For any other efficiency divide the horse power obtained from the chart by two and then divide this result by the known efficiency.

Example—A certain elevator has a capacity of 3,000 lbs.; car speed 200 ft. per minute and with 1,000 lbs. over counter-weight; 65% overall efficiency. Determine from chart the size of motor required.

The net load to be lifted will be 2,000 lbs. The diagonal line for 2,000 lbs. cuts the 200 ft. per minute vertical line at the horizontal line which corresponds to about 25 *h.p.* This will be the size of the motor required if the overall efficiency of the elevator be 50%. If 65% be the known efficiency, the required horse power will be less.

$$\text{horse power} = \frac{25}{2} \times \frac{1}{.65} = 19.2, \text{ say } 20.$$

Starting Torque Requirements—While the formula and chart just given provide a reasonably accurate method of obtaining the horse power rating of the motor for a particular installation, it is desirable, especially with *a.c.* motors, to consider each motor from the standpoint of its starting torque as well as its horse

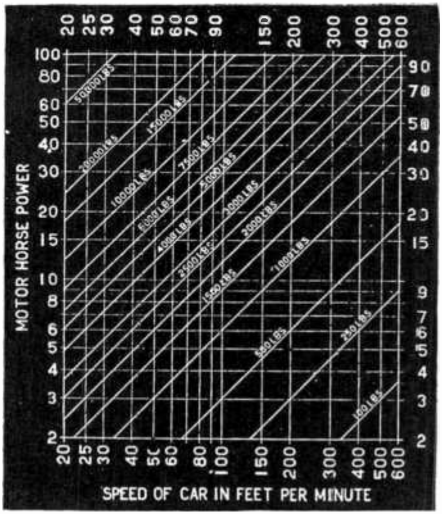


FIG. 6,776.—Elevator motor horse power diagram. Three factors determine the horse power of the motor that should be used, namely, the weight to be hoisted, the speed of travel and the efficiency of the elevator. *In the diagram*, the efficiency of the elevator is assumed to be 50 per cent. To determine the proper size motor to use in any case follow the diagonal line corresponding to the unbalanced load up to the point where it crosses the vertical line corresponding to the speed desired. The horizontal line at this point will indicate the horse power of motor required.

power rating. The chart cannot always be depended upon to insure sufficient starting torque.

It is a well known fact that an elevator requires greater starting torque than is necessary to keep the same elevator running at its rated speed and load.

With full rated load on an elevator the effort or torque required to start this load will be, as a rule, from two to two and one half times as great as the torque required at full load. This is due mainly to static friction, and the exact amount varies with the overall efficiency of the installation. A motor, therefore, to be suitable for elevator work, should be capable of developing from two and one-quarter to three times as much starting torque as is represented by its horse power rating.

Motor builders do not as yet design all their motors with the same ratio of starting torque to full load torque.

This is particularly true in the case of high torque squirrel cage motors, and also to some extent in the case of wound rotor slip ring motors.

The "inrush" current limitations which are placed on elevator motors by many central stations also cut down the amount of starting torque which could otherwise be obtained.

After any gear driven machine starts there is usually a decided increase in efficiency of the gearing owing to the oil film which rotation effects between the gears. Also on all types of elevator machines the efficiency increases after starting due to the oil film which rotation automatically places between the bearings. Therefore, immediately after starting there is an excess of torque which becomes available for acceleration. The amount of this torque depends first, upon the excess motor torque that is provided over and above that actually required to start the machine in motion, and second, upon the excess in elevator starting efficiency over and above an assumed 20 per cent.

In the following formula for the determination of torque required to start an elevator, the starting efficiency has been assumed at 20 per cent as outlined below.

NOTE.—The difference in treating the matter of torque and horse power by different manufacturers of motors has proved confusing. It is therefore of interest to know that the Electric Power Club has taken the subject in hand and is now working out standard ratings which it is hoped all motor manufacturers will adopt. If a specific installation have an overall running efficiency of 50 per cent and it requires two and a half times full load running torque of the motor in order to start the maximum rated load in the hoisting direction, the starting efficiency will be only 20 per cent.

If this efficiency in any case be lower, the elevator will not start with the torque as derived by the formula.

If the efficiency be greater and allowance be not made in the formula, the derived torque may be so great that the start will be abrupt unless some control arrangement, external to the motor, be included to reduce the initial torque.

$$T = \frac{5,252 \times L \times S \times 2\frac{1}{2}}{33,000 \times .5 \times r.p.m.}$$

$$T = \frac{.8 \times L \times S}{r.p.m.}$$

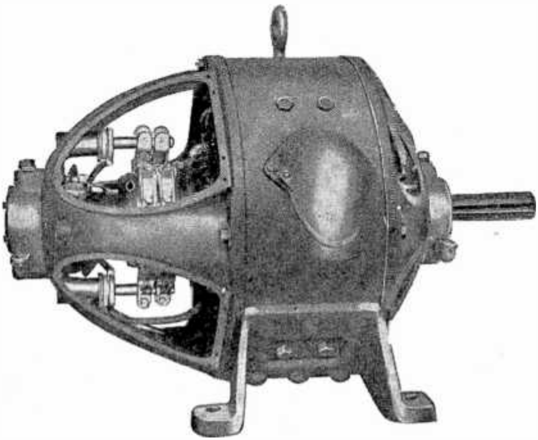


FIG. 6.777.—Exterior view of Westinghouse *d.c.* elevator motor. To secure good commutation and quiet running interpoles are used and the armature provided with a large number of slots; also the main poles are beveled.

in which

T = Torque in pounds at one ft. radius on the motor shaft.

L = Net load in lbs.

S = Full speed of elevator in ft. per min.

r.p.m. = Full load speed of motor selected.

Direct Current Motors—The type of direct current motor which is best suited to elevator service depends to a considerable extent on the type of service, that is, the speed and frequency of stops.

The elevator motor must not only raise and lower the load, but one of its principal duties is to accelerate and decelerate the car rapidly. This must be accomplished smoothly without jars or jerks which might cause discomfort to the passengers.

For freight service compound wound motors are recommended.

The series winding provides a high starting torque, an essential factor for heavy duty work. With full load current the compound winding should

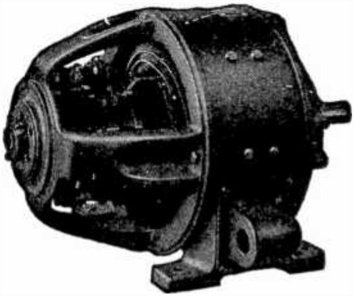
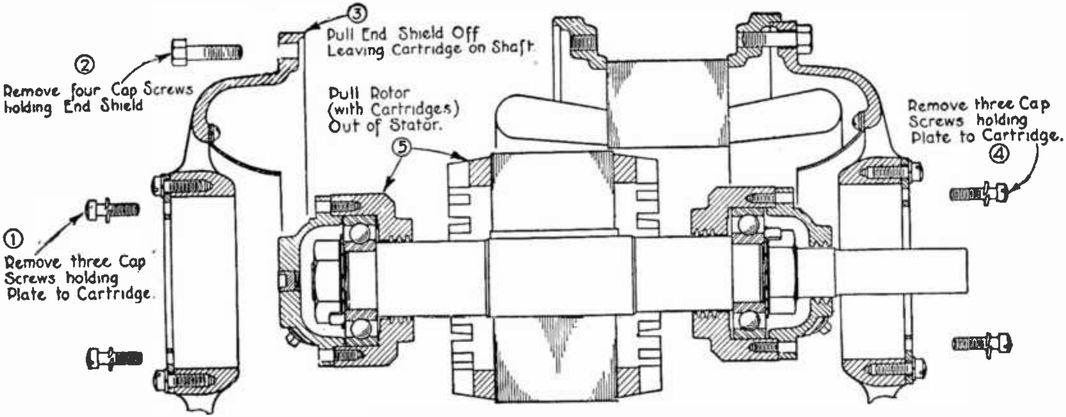


FIG. 6,778.—General Electric *d.c.* ball bearing elevator motor with cartridge type housing. The construction of the housing for oil lubrication differs somewhat from that employed for grease lubrication. The latter type is here shown.

have from 10 to 15 per cent of the ampere turns of the shunt field. By cutting out the series winding after starting, the motor becomes a constant speed machine, the most desirable type for the varying loads encountered in elevator service.

For passenger service, either compound wound or shunt wound motors give satisfactory results.

For speeds above 200 ft. per minute, motors of the variable speed type should be used. Between 200 and 350 feet per minute, a speed range by shunt field control of two to one is common. Above 350 feet per minute greater speed ranges are necessary to secure satisfactory operation. Many



FIGS. 6,779 to 6,785.—Details of construction of General Electric cartridge type unit elevator motors for *a.c.* or *d.c.*

installations are now being made with three to one motors for car speeds of between 500 and 600 feet per minute.

When a dynamic braking controller is used the motor should be capable of commutating, without difficulty, dynamic braking currents whose values approximate 175 percent of the full load current of the motor.

Controllers which provide the dynamic braking feature also require a motor whose shunt field winding is capable of standing one-half the line voltage continuously without overheating with the motor armature at rest.

Most direct current motors, whether shunt or compound wound have suitable commutating pole windings so as to insure sparkless commutation in both directions of rotation.

The commutation should be such that with heavy momentary overloads at starting and during dynamic braking, the commutator will remain in satisfactory operating condition without need for frequent attention.

The adjustable-speed, shunt-wound motor, usually having a speed range of two to one or more by shunt field control, provides ample starting torque without a compound winding. For high speed installations, if this type of

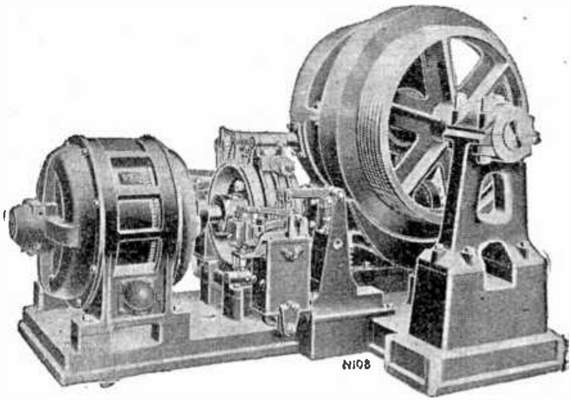


FIG. 6,786.—General Electric multi-speed induction motor on a V-grooved geared traction elevator machine. This type of motor can be used for elevators running as fast as 350 *f.p.m.* provided the car is traveling slow enough when operating on slow speed connections (about one half full load speed) to give the required accuracy of landing, which depends on the character of service. For department store service, demanding stops at each floor, the highest elevator speed for which this type of motor is recommended is 275 *f.p.m.* These motors are wound for three phase circuits only. When two phase power is available use Scott connected or auto transformers depending on the power supply. The field has but one winding. The two synchronous speeds are obtained by polar regrouping. This regrouping of poles is accomplished by contactors on the control board. The armature is of the high resistance, indestructible squirrel cage type, and gives high starting torque. The low speed connection is used in starting and stopping. The high speed connection is used for high speed running. The motor is furnished for direct connection without base or pulley. These motors operate very quietly and can be used in such places as clubs, hotels, private residences, hospitals, etc.

motor be used, the elevator can be run at full field speed practically as efficiently as at high speed. In transferring from high to full field speed the motor acts as a dynamo and returns current to the line. The amount of this returned current has been found from actual test of a three to one motor to equal 10 per cent of the total power consumption on an elevator making 150 stops per car mile. For slowing down from full field to "drag" speed, *series parallel* resistor connections are used, but the horse power is only a fraction of that at high speed, so that a saving of power at drag speed is realized over power used in slowing down a single speed motor. Should anything happen to the armature shunt contactor or to the armature shunt resistor circuit the operator can always slow down to full field speed and make a safe stop without dynamic braking.

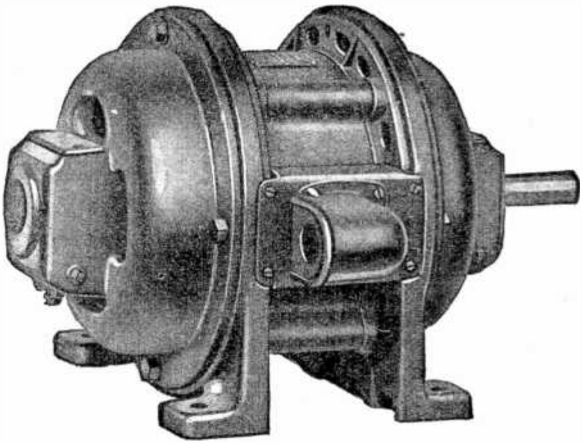


FIG. 6,787.—General electric constant speed induction motor. Designed for continuous duty cycle at rated horse power 15 seconds on, 45 seconds off, without exceeding 50 deg. Cen. rise. They will operate at rated horse power 30 minutes without exceeding 50 deg. Cen. rise, if started cold. The temperature on the armature may exceed 55 deg. Cen. rise. Motor heating on ordinary counter-weighted elevators is not as important as the starting torque because full rated horse power is required only when the elevator is hoisting full load or lowering light load, whereas a much smaller horse power is required when the elevator is hoisting a light load or lowering a heavy load; but the motor is liable to damage if an attempt be made to lift a greater load than it can start. This type motor attains full speed in less than one half of a second under usual conditions of full load; and during this time, the average starting current is less than twice full load current.

Alternating Current Motors.—Because of improvements in motor design and through the use of properly designed controllers, many of the limitations which were formerly attributed to the use of alternating current motors in elevator service have been successfully overcome. With the usual single speed motor, it is still impossible to employ dynamic braking or anything equivalent to it. The elevator must be slowed down and stopped by the mechanical brake alone.

This is a difficult problem because the mechanical brake is capable of absorbing this energy only in direct proportion to the velocity, while a dynamic brake will dissipate this energy in proportion to the square of the velocity. The dynamic brake, unavailable with alternating current, is an important adjunct in assisting the mechanical brake for quick, smooth stopping of the elevator.

There are two general types of *a.c.* motors suitable for elevator service:

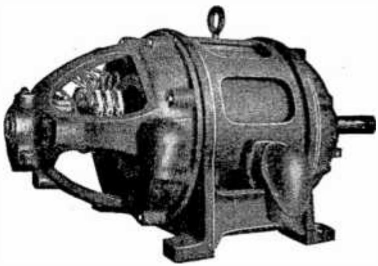


Fig. 6,788.—Westinghouse single speed, slip ring elevator motor. Designed for freight and passenger service where the elevator speeds are not too high to permit making satisfactory stops with a mechanical brake. Largely used for operating heavy elevators requiring motors larger than 25 horse power.

1. Squirrel cage motor;

2. Slip ring motor.

The squirrel cage motor is used extensively up to about 20 *h.p.* because of its simplicity and because it requires only a relatively simple form of controller as it is generally thrown across the line with no starting resistor.

When the installation is such as to require a smooth start, a resistor or reactance is placed in the motor primary circuit and gradually cut out after starting. The last method of starting has been applied to motors as large as 50 *h.p.* with success. However, it has one disadvantage in that its speed regulation is poorer than that of a slip ring motor. While this is of little moment for the lower speed elevators, it may not be satisfactory on the higher speed cars. It is of interest to note that this regulation is not as bad as that of a hydraulic elevator.

In actual service the power consumption of the squirrel cage motor is slightly higher than that of the slip ring machine, but due to the lack of slip rings and fewer controller parts it is somewhat more reliable.

The slip ring motor for the same rating is more expensive and has a somewhat lower power factor than the squirrel cage motor.

The slip ring motor is a standard product and has been used practically as long as electric elevators have had *a.c.* drive.

It has a higher full speed running efficiency because the resistor in the rotor circuit is cut out by the controller after the motor starts. Its disadvantages have already been outlined.

A.c. motors of the two speed type are now available and are being used successfully on elevators whose car speeds are as high as 400 feet per minute.

The customary speed range is three to one, the motor being designed with two separate primary windings. Under normal conditions the motor is accelerated on the high speed winding. The slow speed winding is used for inching and in slowing down to make a landing. For this latter use, the slow speed winding acts as a sort of dynamic brake and insures smoother retardation and a more accurate stop than would be possible with the customary *a.c.* motor.

By using a suitable controller and an automatic governor it is possible to secure automatic dynamic braking on this type of motor when the car switch is thrown from the high speed to the off position without stopping at the slow down position. The governor automatically provides dynamic braking in the off position of the car switch in case the motor is running above synchronous speed of the slow speed winding. The use of this governor eliminates the possibility of an extreme slide of the car.

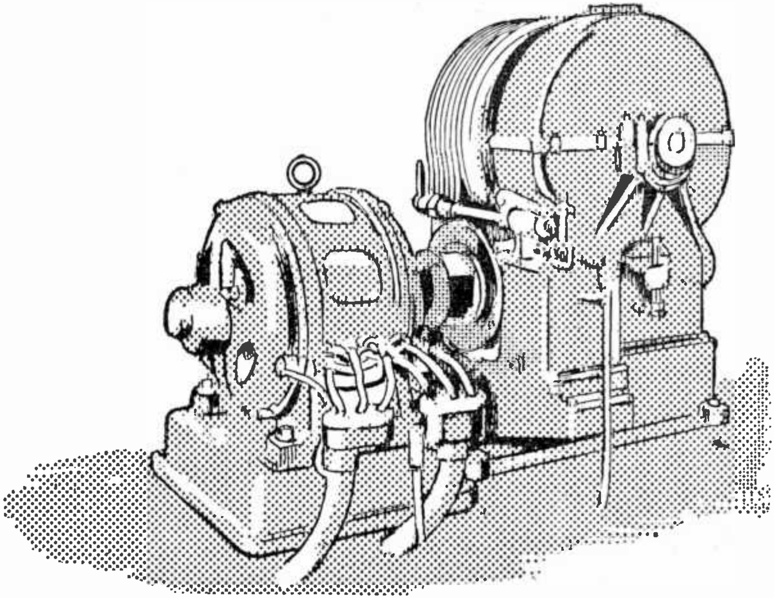


FIG. 6,789.—Westinghouse two speed induction motor driving elevator machine. *In operation* the controller is so arranged that the motor starts on the slow speed winding with resistors in series with this winding. The resistance is automatically cut out of the circuit as the motor accelerates. After the motor is operating on full voltage low speed, it is switched over to the high speed winding with resistors again in series with the motor. The resistors are in turn switched out of the circuit, leaving the motor running at its high speed, on full voltage. This sequence of operation takes place automatically when the operator moves the car switch handle from the off position to the full speed position. For moving the car short distances, the car switch handle is moved to the intermediate position and the motor operates at its low speed. When the car is stopped, the equipment follows a similar cycle, although reversed. The operator moves the car switch handle from the full speed position, directly to the off position. The motor is switched automatically to the low speed winding and it operates at this speed for a short period of time before being stopped. This always gives the desired braking action on stopping independently of any action of the operator. Resistance steps are also used on stopping, to give smooth stops. In addition, with equipments for car speeds above 250 feet per minute reactor coils are used in the line circuit to smooth out sudden changes of current values, giving extremely smooth changes in car speeds.

As in *d.c.* service all *a.c.* elevator motors should be designed especially for elevator work.

The starting torque should be at least 225% of the rated full load torque. Motors having more than approximately 15% variation in speed from no load to full load are not recommended for elevator service.

Polyphase motors of both the slip ring and squirrel cage types give satisfactory results.

A secondary resistor is used with slip ring induction motors. Primary resistors are used with squirrel cage motors to secure smooth acceleration. For slow speed service the squirrel cage motor is often thrown directly across the line. Motors of this type when connected directly to the line should not take more than two and one half to three times normal full load current.

Single phase motors of the self starting *repulsion induction* type may also be used for elevator service.

Single phase motors of the standard split phase or standard repulsion induction type are not suitable for elevator service because of the uncertainty as to whether the motor will reverse when the connections are reversed quickly.

Starting Current Inrush.—The National Electric Light Association has adopted certain rules which limit the starting current inrush. The two tables which follow show the maximum current inrush for the various sizes of motors.

NOTE.—*Some manufacturers* in order to get positive speed control with *a.c.* are using two motors of different rated speeds both of which are direct connected to the elevator machine. This scheme permits the use of a squirrel cage motor for the low speed member and a slip ring motor for the high speed member. With this arrangement it is possible to obtain the advantages of lower slip and higher operating efficiency which are characteristic of the slip ring motor. Another point in favor of the two motor arrangement is that the windings are in the usual form with which all repairmen are familiar and therefore the chances are that quicker repairs can be made. Also equipments have been built consisting of two distinct motors, both in one motor frame. The two speed *a.c.* motor is being successfully used with car speeds as high as 350 ft. per min. Further development will undoubtedly increase this maximum.

These tables show the maximum permissible starting current values for a single motor installed and connected to its load. Many power companies have already adopted these rules as being reasonable and well within the possibilities of good elevator practice. All power companies should be urged to adopt them, in order to have a universal standard.

Some power companies place practically no limitations on starting currents, while others are more rigid in their requirements than the rules of the N.E.L.A.

Alternating Current Motors

Polyphase—Sixty Cycles

h.p. of motor.	Line voltage.	*Line amperes per phase per *h.p.*	
		Two phase.	Three phase.
1 1–2	220 220	17.3 15.2	20 17.5
3–5	220 440 550	11.2 5.6 4.5	13 6.5 5.2
6–30	220 440 550 2,200	8 4 3.2 1	9 4.5 3.6 1
Above 30	220 440 550 2,200	5.2 2.6 2.1 0.5	6 3 2.4 0.6

*Current values are those indicated by a suitable well damped ammeter in the motor circuit on the line side of the starting device, and are 75% of the permissible locked rotor values.

Direct Current Motors

Shunt and Compound Wound

Size of motor	Volts	*Amperes per *h.p.*
3 *h.p.* and below	230 550	12 5
Above 3 *h.p.*	230 550	9 4

*Current values are those indicated by a suitable well damped ammeter on the line side of the starting resistor.

Motor Speeds

	Load	Speed *f.p.m.*	Sheave diam. ins.	Sheave speed *r.p.m.*	Motor speed *r.p.m.*	Ratio of worm and gear
Single worm geared V groove single wrap traction elevator 1:1 roped	2,000	300	30	38	1,030	27:1
Gearless U groove full wrap traction elevator 2:1 roped	2,500	500	28	136	136	None
Gearless U groove full wrap traction elevator 1:1 roped	3,000	700	36	75	75	None

In such cases an unnecessary hardship is placed on the elevator manufacturer and on the owner of the building in which the elevator is installed. As a rule, such stringent regulations can only be met by using an oversized motor.

If the motor be of the squirrel cage, high torque type, the addition of a primary resistor on starting will be helpful. This resistor can be short circuited while running.

Motor Speeds.—The table on page 4,121 shows values typical of those in common use of a few types of elevators.

This table shows very clearly the distinction between geared and gearless machines. In the geared machine the required slow speed for the traction sheave is obtained by a gear reduction. In the gearless machine the required slow speed is obtained by using a large frame direct current motor with a winding which produces full power at a very low *r.p.m.*

TEST QUESTIONS

1. *What is the maximum motor speed which should be used?*
2. *Name three factors which must be considered in determining the size of motor required for a given installation.*
3. *Define overall efficiency.*
4. *Give formula for horse power of motor.*

NOTE.—For additional practical information on motors of all types see other volumes of this series.

5. *How may the horse power required be easily determined?*
6. *What are the starting torque requirements?*
7. *Is greater torque required while starting or while running?*
8. *Name the important requirement for a motor to be suitable for elevator service.*
9. *Give formula for the determination of starting torque.*
10. *Upon what does the type of* d.c. *motor best suited to elevator service depend?*
11. *For what service are compound wound motors desirable?*
12. *What two types of* d.c. *motor are satisfactory for passenger service?*
13. *Are* a.c. *motors desirable for elevator service?*
14. *Name two types of* a.c. *motor in general use.*
15. *What is the advantage of the squirrel cage motor?*
16. *Describe the conditions for which the various types of* a.c. *motor are suitable.*
17. *Are polyphase motors used?*
18. *What type of single phase motor is used?*
19. *Are split phase motors suitable for elevator service?*
20. *Why should the starting current inrush be considered?*
21. *Do all power companies place limitations on starting current?*

22. *How can stringent regulations in regard to starting current be met?*

23. *What are the motor speeds used for various types of motor?*

CHAPTER 156

Elevator Control Systems

The author is indebted to Mr. C. F. Scott, E.E. of the Gurney Elevator Co. for able assistance in the preparation of this chapter.

In any elevator installation, the type of control system used governs the selection of the motor. Accordingly, further explanation relating to motors will be given in this chapter.

The great variety of control systems may be broadly divided into two general groups, classified according to the basic principle of operation employed, and known as

1. Rheostatic control.
2. Variable voltage control.

Rheostatic control.—This method includes *practically everything not included in variable voltage control.* It includes control of single speed motors and motors with two or more speeds.

With rheostatic control the motor which is connected to the worm shaft of the elevator is direct current if the supply circuit be direct, and alternating current if the supply circuit be alternating. In variable voltage control, the motor on the elevator machine is always direct current.

The various types of rheostatic control, according to speed and motors used, are:

1. Single speed, direct current.
2. Single speed, alternating current.

   a. High resistance rotor squirrel cage induction motor.

   b. Slip ring or wound rotor induction motor.

   c. Single phase motor.

Single speed motors are seldom used for elevators with a speed higher than 200 *f.p.m.* and frequently not above 100 *f.p.m.*

High resistance squirrel cage induction motors are used much more than slip ring motors.

Single phase motors are used in elevators only where two or three phase is not available, and usually only where the power requirement is very small, 5 *h.p.* or less.

3. Multi-speed, direct current.

a. With small range field control on the motor and with armature by pass resistance.

b. With wide range field control on the motor and with or without armature by pass resistance.

4. Two speed, alternating current.

a. Single rotor squirrel cage induction motor with two superimposed stator windings.

b. Single rotor squirrel cage induction motor with single stator winding arranged for grouping in two different polar combinations, one giving twice the speed of the motor.

c. Double rotor induction motor, with one squirrel cage and one slip ring rotor, and two separate stator windings.

The typical *d.c.* elevator motor for speeds 200 to 400 *f.p.m.* is compound wound, the series field being frequently shorted out at full speed; starts with a resistance by-passed around the armature, this resistance being increased in value, then shorted out as the elevator comes up to speed and finally inserts resistance into the field to reach top speed.

The motor in this case has a range of speed by field of about 700 to 850 *r.p.m.* Dynamic braking is applied to retard the elevator before the mechanical brake is applied.

The *d.c.* elevator motor with wide range field control involves the use of a large and more costly motor for the same duty, as compared with the motor described in the preceding paragraphs but the control is simpler, the energy consumption less and the regulation is better, making stops easier.

An example of this type is the Gurney motor and control for a duty such as 2,500 lbs. 450 *f.p.m*. The motor is shunt wound, with a speed range by field of 300 to 900 *r.p.m*. No armature by-pass is used in starting, but dynamic braking is used in stopping. This system shown in fig. 6,791, has the lowest *kw. hr*. consumption per car mile that it is possible to attain.

The single rotor squirrel cage induction motor with two super-imposed windings is the standard type for 2 speed *a.c.* rheostatic control.

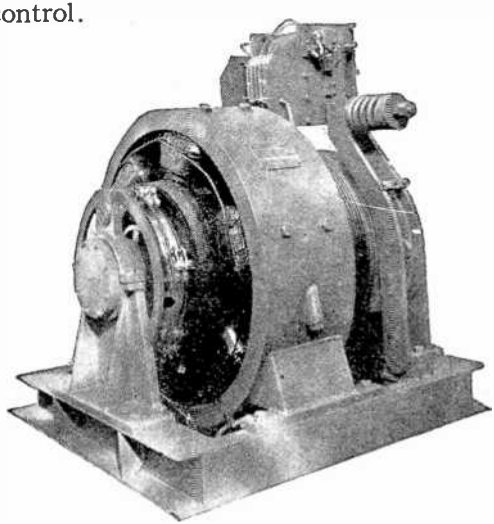


FIG. 6,790.—General Electric all steel roller bearing gearless elevator motor. In a gearless machine the traction sheave is mounted on the armature shaft or spider and turns at the same speed as the armature, which must develop full power at a low speed of revolution. For example, if the sheave be 36″ diameter and the elevator speed 700 *f.p.m*. the motor armature must run at approximately 75 *r.p.m*.

It is used for speeds of from 200 to 400 *f.p.m*. for passenger service and for speeds of 100 to 250 *f.p.m*. for freight service. The ratio of the high speed to the low speed may be 3:1, 4:1, or 6:1. Occasionally odd ratios are used, as, 16:6. On 60 cycles these ratios give speeds such as 1,200/400, 900/300, 1,200/300, 900/225, 900/150, 1,200/450.

The motor is started usually on the high speed winding, with resistance in series which is cut out in one or more steps in the first second or so of acceleration. Smooth performance is the result of the inherent characteristics of the motor and depends also on proper adjustment of the resistance in the controller.

In retarding the car, the high speed winding is disconnected and the low speed winding connected in circuit. During the few seconds required for the car to slow down from high speed to low speed, the elevator, owing to its momentum, actually drives the motor, which then for the time being becomes a dynamo, and exerts a powerful counter-torque or braking action.

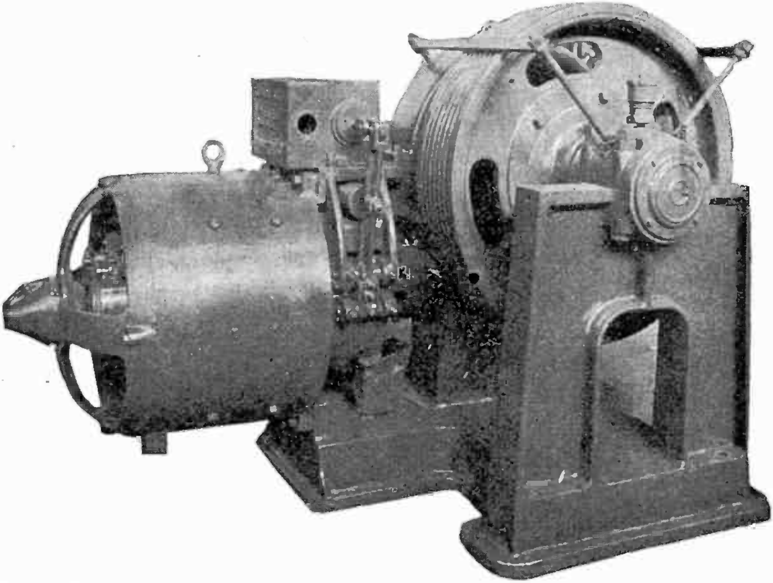


FIG. 6,791.—Gurney worm geared elevator machine with Gurney *d.c.* adjustable speed wide range field control motor. This type of motor is used for elevator speeds of from 200 to 450 *r.p.m.* with rheostatic control, where the source of current supply is *d.c.*

As the dynamo or braking action of an induction motor can only occur at speeds above synchronous speeds, the regenerative braking in an elevator with a two speed motor can be maintained only down to the point where the elevator speed corresponds to the rated speed of the low speed winding. From this point down to final stop the retarding force is derived from the mechanical brake.

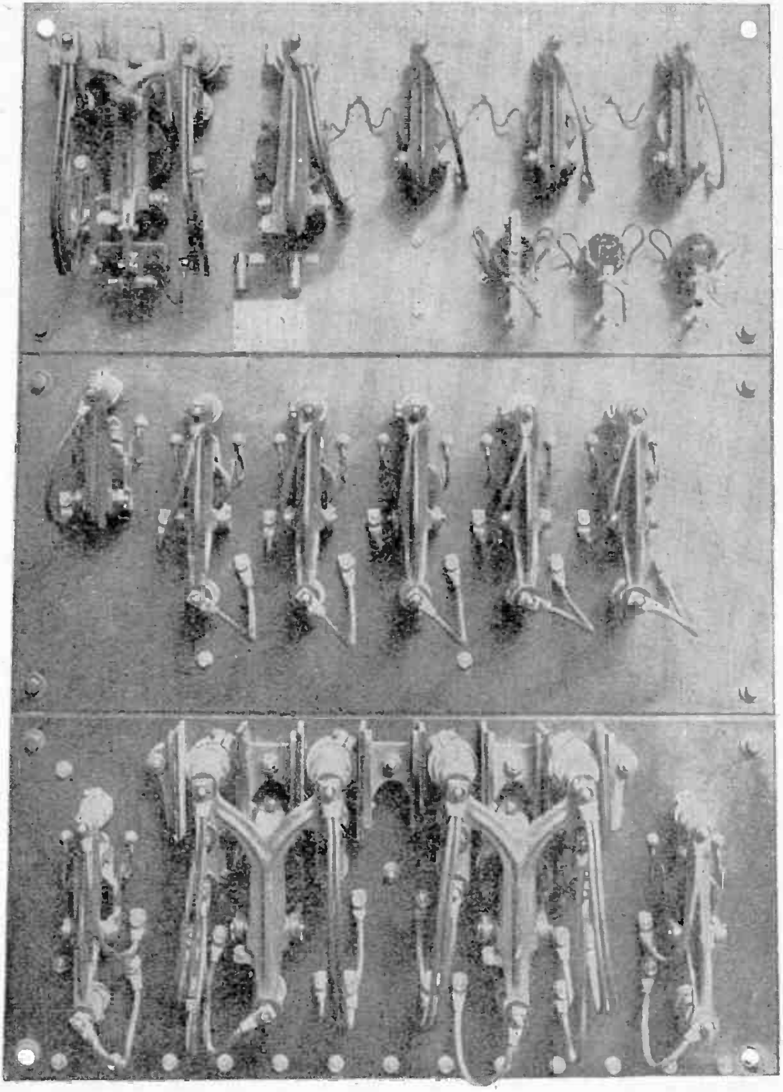


FIG. 6,792.—Gurney *d.c.* rheostatic controller for the *d.c.* motor illustrated in fig. 6,791.

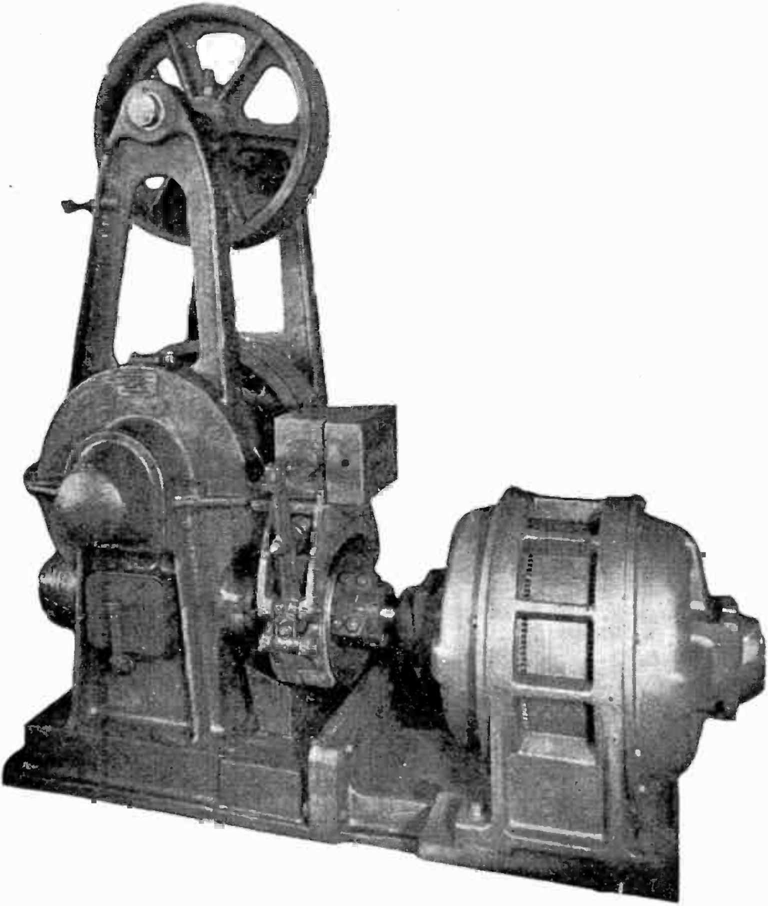


FIG. 6,793.—Gurney worm geared elevator machine with General Electric *a.c.* 2 speed motor for rheostatic control. This machine has a *d.c.* solenoid brake and the control magnets are also operated on *d.c.* this current being obtained from a small motor dynamo set. This machine is for basement mounting.

The control is provided with a timing device, so that even if the switch be centered or returned to neutral position from full speed, the low speed winding will be held in long enough to bring the elevator down to the proper speed for the mechanical brake to be applied.

On retarding, resistances are inserted in the low speed winding. These resistances are shorted out automatically in a number of steps during the first few moments of retardation. The smoothness of retardation is dependent to a considerable extent on the proper adjustment of these resistances.

Because of the greater simplicity, more compact construction, quieter operation and greater adaptability to gradual application and release, a direct current brake solenoid is to be preferred to an alternating current brake.

For this reason it is becoming common practice to equip the better grade *a.c.* rheostatic elevators with a direct current circuit for the brake and the control magnets. This *d.c.* is usually obtained from a small motor generator set that is automatically controlled.

The second type of 2 speed motor has a single stator winding, usually with 6 or 8 poles in 60 cycles, with leads brought out so the winding can be regrouped to give 12 or 16 poles.

This gives speeds of 1,200/600 or 900/450. This type of induction motor has a relatively wide application in industrial fields, and formerly was extensively used in elevator service, but now is largely superseded by the first type just described.

The third type of 2 speed motor usually has a squirrel cage rotor and a slip ring rotor on the same shaft.

The slip ring element is usually the high speed part, 1,200 or 900 *r.p.m.* and the squirrel cage element the low speed part, 400 or 300 *r.p.m.* This type of motor has higher running efficiency and closer speed regulation in the high speed winding when running at full speed, but its starting efficiency is low, and its great size and weight, combined with high power consumption when there are many stops, have caused it to be largely superseded by the first type.

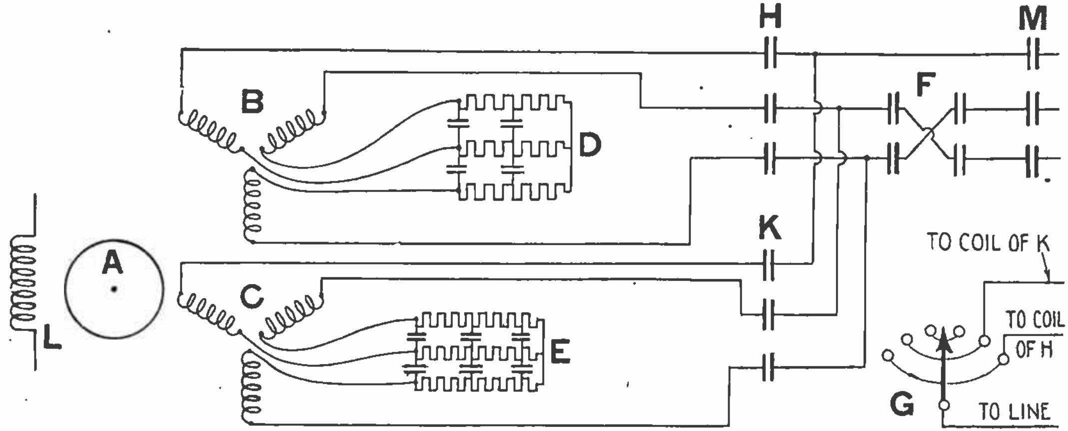


Fig. 6,794.—Elementary diagram of basic circuits for *a.c.* rheostatic two speed control.

Principles of Rheostatic Control.—To illustrate this method of control, a schematic diagram of the basic circuits for an *a.c.* low speed installation is shown in fig. 6,794.

In the figure, A, is the squirrel cage armature of the motor; B, upper or high speed field winding, grouped say for 6 poles; C, lower or low speed field winding, grouped say for 18 poles; D, starting resistance for winding B; E, buffer or retarding resistance for winding C. Sometimes D, and E, are combined by putting B and C, in series instead of in parallel as shown.

F, is a reversing device, usually two double pole magnetic switches, called direction switches, whose coils are energized by contacts (not shown) on car switch G; G, car switch with contacts for energizing the coils of the low speed switch, K, and the high speed switch H.

In operation, the car is usually started by bringing the switch directly to the high speed point, the motor starting and accelerating on the high speed winding without going through the low speed winding, which is used for retarding, though it is possible to run steadily, if need be, on low speed.

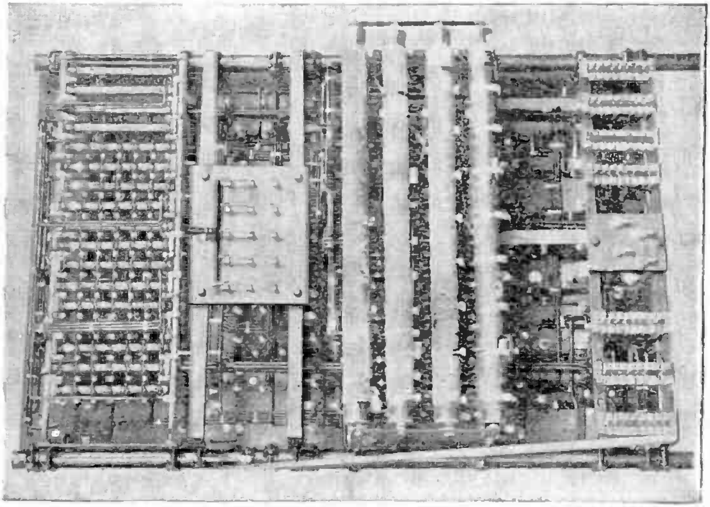
On retarding, the switch is moved to the low speed point, opening winding B, and inserting winding C, with buffer resistance E, in circuit, which is cut out automatically in several steps. Even if the car switch be brought at once to neutral on stopping, automatic devices (not shown) cause winding C, to be inserted for a short but definite time, to insure dynamic retardation to low speed before the mechanical brake L, is applied.

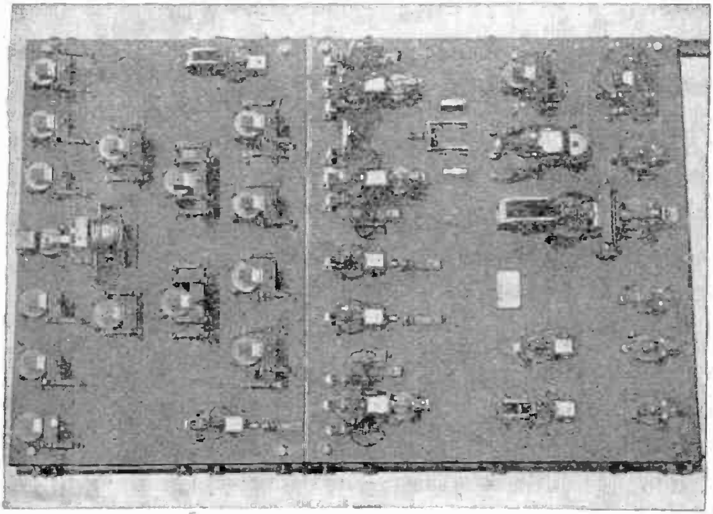
L, is the coil of the mechanical brake. If this be *a.c.* it is connected inside switches F; if *d.c.* it is connected to a magneto dynamo set through a contactor which is in turn connected inside switches F. M, is a main line or voltage switch.

Variable Voltage Control.—This control is also called *unit multi-voltage control* and was formerly called Ward-Leonard control.

In the variable voltage system *the elevator motor is always a d.c. machine.*

Each elevator has a motor generator set, thus having in effect its own private source of current, the voltage of which is varied at will to change the speed of the elevator.





FIGS. 6,795 and 6,796.—***Westinghouse variable voltage control system 1.*** *Contactor panel, front and rear views.* ***In operation,*** the car starts in the usual way by throwing the car switch to the running position. When it is desired to stop at any floor, the operator releases or returns the car switch handle to the center or off position.

The motor which drives the dynamo of the motor generator set is a constant speed, continuous running machine, and may be either a *d.c.* motor or an *a.c.* motor.

Hence the variable voltage system is independent of the source of current, and the performance of the elevator is the same whether the building has *d.c.* or *a.c*

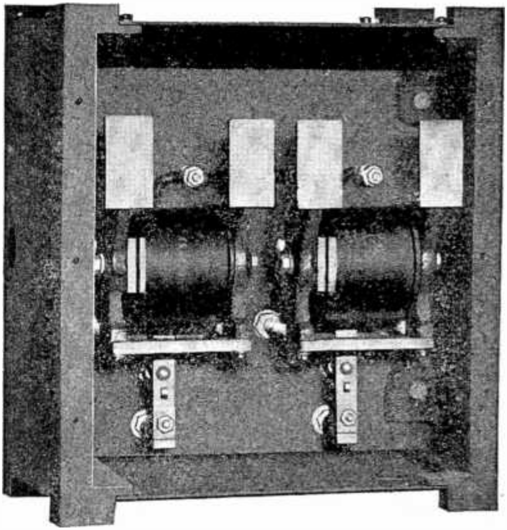


FIG. 6,797.—*Westinghouse variable voltage control system 2. Inductor switch, cover removed. In construction,* there are two contacts, each operated by a coil and magnet. Iron plates, called inductors, mounted in the hatchway, close this magnetic circuit, when the car brings the switch opposite these inductors. Then the switch magnets move forward and open a control circuit causing the car to slow down. As stationary and moving parts never come into physical contact, noise and operating troubles are avoided, even at the highest car speed. The operating parts are enclosed in a cast iron box with cover of non-magnetic materi al (brass) giving protection against dust and dirt.

The dynamo of the motor generator set is a special constant speed variable voltage machine.

The car switch by which the elevator is operated, is in effect a combined reversing switch and field rheostat, as the car switch points cut resistance in and out of the dynamo field to lower or raise the dynamo voltage and so slow down or speed up the elevator.

When the elevator is at rest there is no current flowing in the dynamo field; at full speed the dynamo field is at full strength. Weakening the dynamo field lowers the elevator speed.

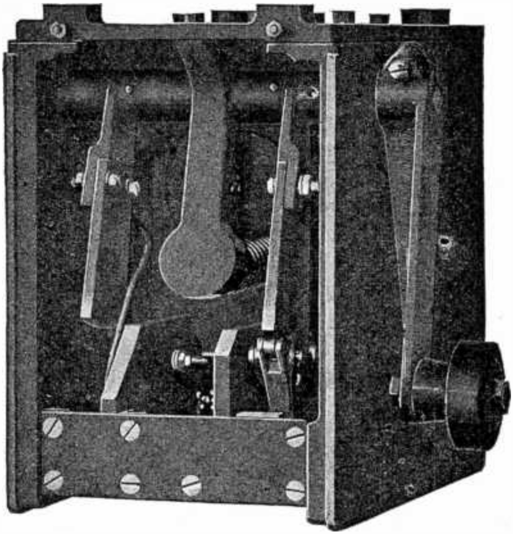
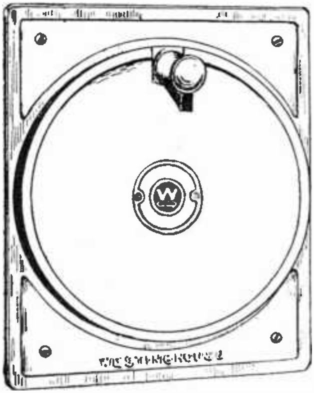


FIG. 6,798.—***Westinghouse variable voltage control system 3. Landing switch. It has*** three contacts enclosed in an iron box. These contacts are closed by an operating arm with rubber tired roller that engages cams in the hatchway. A magnet with an exciting coil holds the operating arm away from the hatchway cams at all normal operating speeds of the car.

Practically all gearless elevators to-day use variable voltage control. Formerly a great many gearless machines used rheostatic control, but very few are to-day being installed.

The majority of geared machines use rheostatic control (chiefly *a.c.* single or two speed because of the wide spread prevalence of *a.c.* distribution)



but a considerable and increasing number of geared machines use variable voltage control, especially at speeds 300 to 500 *f.p.m.* for passenger service, and 150 *f.p.m.* and higher for heavy duty freight elevators.

Variable voltage control has no losses in resistances during acceleration and retardation, hence the energy consumption is lower than with rheostatic control if the duty be severe; that is, many stops per mile.

FIG. 6,799.—***Westinghouse variable voltage control system 4. Car switch.*** This acts as master switch, controlling the direction and speed of movement of the car. An operating handle is rigidly connected to an arm which moves in a circular path, making necessary contacts. An emergency safety switch is supplied, which can be operated to make emergency stops, independent of the automatic floor landing control.

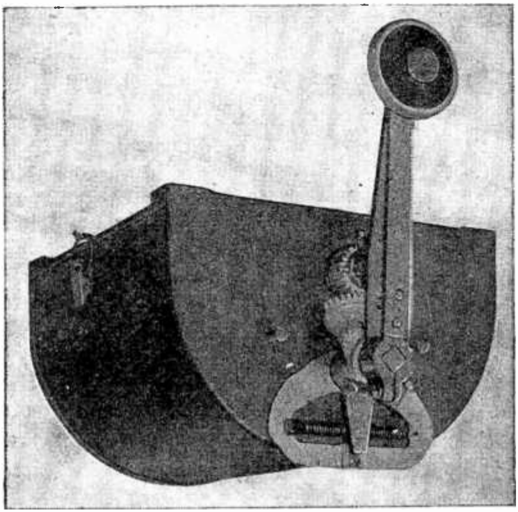
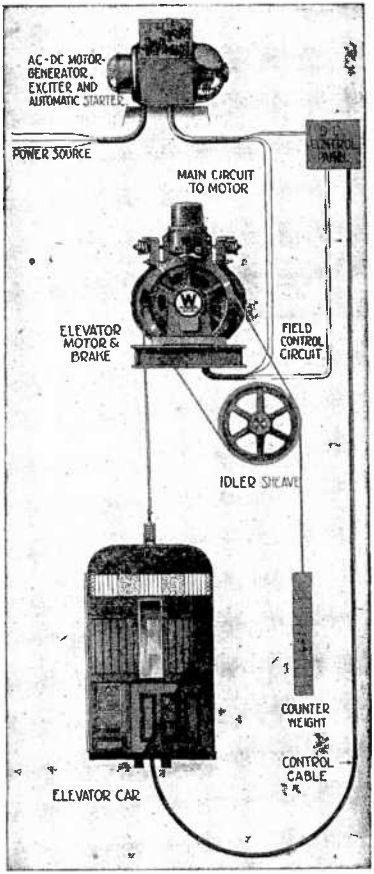


FIG. 6,800.—***Westinghouse variable voltage control system 5. Car slow down switch.*** This limit switch similar in construction to the landing switch is mounted on top of the car. An operating arm actuated by properly located cams, opens and closes the control circuits, causing the car to automatically slow down and stop at the extreme limits of travel.

Where the power supply is alternating, the motor generator set of the variable voltage system has a direct connected exciter, to supply a source of constant voltage direct current for the traction motor, the brake solenoid and the control magnet coils.



The controller for a medium or slow speed variable voltage system, with car switch operation is a very simple one.

It includes, first, an automatic starter with overload relay for the motor of the motor generator set. Then there are the two direction switches, or reversing contactors, for determining the direction of motion.

An emergency stop switch, or dynamic brake contactor is furnished, to open the loop circuit between motor and generator and apply a dynamic brake on an emergency stop; this switch is not actuated on regular operation. A brake relay, accelerating relay, and overload relay usually complete the list.

The field resistances are connected to the car switch contacts, also to the slow down limit switches, as shown in fig. 6,793.

FIG. 6,801.—Westinghouse complete variable voltage control equipment applied to traction elevator.

As in all other forms of multi-speed or two speed elevator control, the major part of the retardation of the elevator is dynamic, or what may more properly be called in this case, regenerative braking. The mechanical brake is applied only at the very last, when there is an inch or so to go before the car stops.

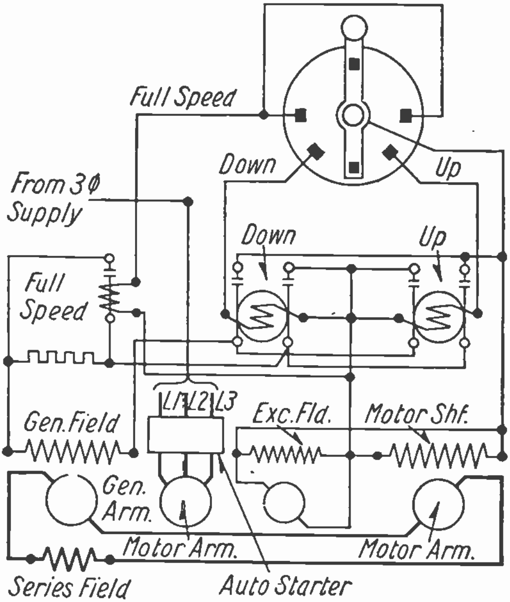
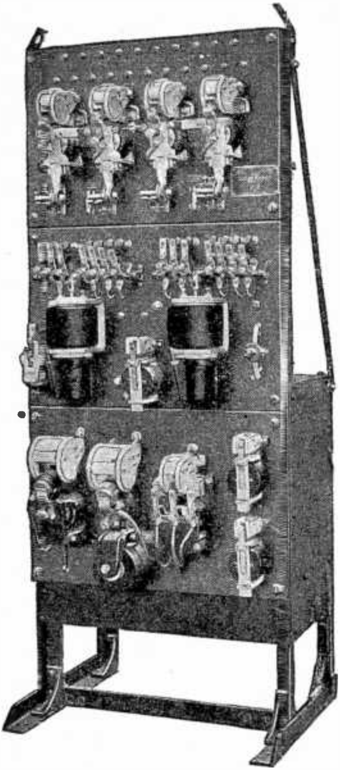


FIG. 6,802.—Elementary wiring diagram of Westinghouse variable voltage control. ***In operation*** the car is started in the usual way by moving the car switch handle to the running position. Control circuits are thereby established that close the directional switch and the dynamo field contactors on the panel. The dynamo field contactors establish a dynamo field current, which causes the car to move at a speed proportional to the voltage. The dynamo voltage builds up gradually but quickly and the car accelerates automatically smoothly and rapidly. The contactor panel has one single pole contactor in the armature circuit, between the dynamo and elevator motor, which closes before operation begins and opens after the elevator motor stops. This contactor is an essential safety feature because it prevents any possibility of the dynamo building up on residual magnetism after a stop is made. Two double pole contactors with mechanical interlock reverse the dynamo field circuit and thereby control the direction of the car. One contactor with a back contact controls the brake circuit. This brake circuit is so arranged that both sides are disconnected when the reversing contactors are open. In case of failure of current through the elevator motor field, or of power to the motor generator the elevator motor is completely disconnected and the brake is set automatically.



Principles of Variable Voltage Control.—This method of control is shown in fig. 6,804, which is a schematic diagram showing only the basic circuits.

In the figure A, is the elevator motor; with a shunt field E, separately excited, B, variable voltage dynamo with a shunt field F (also separately excited), and a series field S. C, motor which drives the dynamo; D, exciter (and C

FIG. 6,803.—Cutler Hammer variable voltage controller panel. *In operation* it changes the voltage of the dynamo of a motor generator set by field control, thus altering the speed of the elevator motor by varying the supply voltage. When the car switch is moved to the first speed position, the field and brake relay and either the up or down direction contactors close, providing full field for the elevator motor, releasing the brake, and energizing the dynamo field with all of its field resistor in circuit. The field resistor is so designed that the voltage generated, when it is all in series with the field, will be such that with full load on the elevator car the elevator motor will turn over very slowly. In the second speed position of the car switch, the first field relay is energized and operates gradually to short out five steps of field resistor. The time required depends upon the oil dash pot, which is used to retard the closure of this field relay. The voltage then generated is sufficient to operate the elevator at one half its full speed. With the car switch in the third speed position, a second field relay similar to the first is energized and this operates to gradually short out the remainder of the field resistor so that the elevator car accelerates smoothly to full speed. While running at full speed the operator may move the car switch back to any position, and the elevator car will automatically decelerate to the speed corresponding to the position of the car switch. In case the operator move the car switch from the full speed to the off position, or full speed in the other direction, the relays and contactors on the controller will automatically operate in the proper sequence due to interlocks, and the elevator car will decelerate, stop or accelerate without a jerk. Over speed of the elevator motor on an overhauling load is prevented by a compound wound relay, which operates to insert resistance in series with the dynamo field, thus reducing the voltage and causing the motor to slow down.

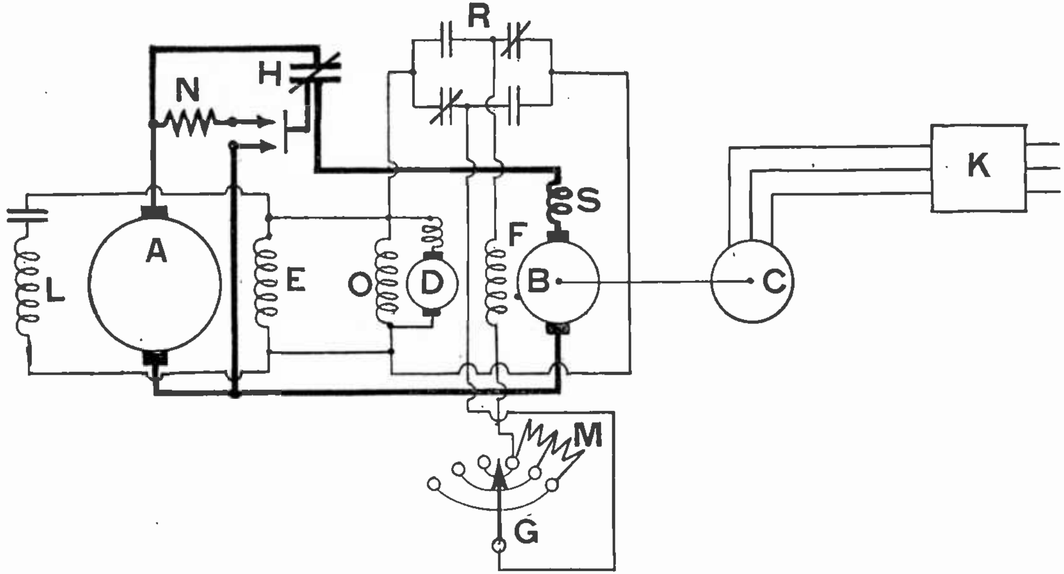


FIG. 6,804.—Elementary diagram of basic circuits for a variable voltage system.

its self-excited field) for supplying current for the dynamo field, elevator motor field, brake L, and control magnet coils; R, reversing switch by which the field F, is reversed—this reverses the voltage of the dynamo B, and so reverses the rotation of elevator motor A, to reverse the travel of the car.

R, is usually a pair of double pole magnetic switches whose coils are energized through contacts (not shown) on car switch G. This switch has contacts for inserting resistance M, in the field circuit F.

In operation, when resistance is inserted in F, it weakens the dynamo field, which lowers the dynamo voltage, and so lowers the speed of elevator motor A.

The circuit between the armature of dynamo B, and elevator motor A, is normally kept closed, the elevator being started,

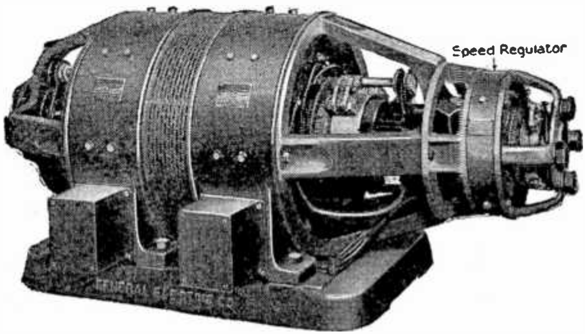


FIG. 6,805.—General Electric motor dynamo set of variable voltage control system with *d.c* source of supply showing speed regulator.

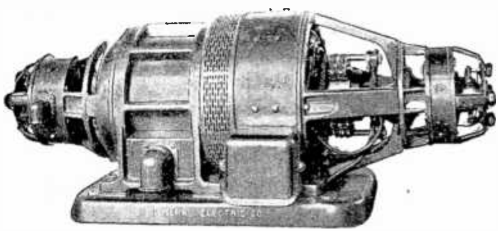


FIG. 6,806.—General Electric motor alternator set for *a.c.* source of supply.

stopped and reversed by switches R. However, in emergencies, the double throw switch H, is opened, opening the circuit between B, and A, and applying dynamic brake N. K, is the starter for motor C; L, solenoid coil of the mechanical brake on A. The brake is applied by spring pressure and released by the magnet. Hence L, is energized when the motor A, is moving.

Automatic Leveling.—To properly understand automatic leveling, it is necessary to consider regulation.

Regulation, as applied to elevator control means the *tendency of the elevator motor to maintain its speed with changes of load, after the speed has been adjusted or set at any point.*

Thus full speed regulation of an elevator with a rated speed of 600 *f.p.m.* means the extent to which the actual speed departs from 600 *f.p.m.* hoisting and overhauling, at different loads.

If the speed never fall below 570 *f.p.m.* or rise above 630 *f.p.m.* under any conditions of load, the regulation is said to be 5% (30 *f.p.m.* is 5% of 600 *f.p.m.*)

Automatic leveling is primarily a problem of regulation on low speed, or first point of control.

Consider a gearless rheostatic control on the first point of the car switch. There is a good deal of resistance in the circuit. The load on the elevator affects the current and the current affects the voltage drop in the resistance and this in turn determines the voltage in the armature which in turn determines the speed. Hence the speed varies widely with the load.

Now assume a switch contact to be established in the hoistway at a certain fixed distance from the floor, just about far enough away so that under average conditions the elevator could come to a final stop under the brake if the power be cut off and the brake applied by this switch contact. Then run the elevator on the first point of the car switch, that is, at lowest speed. Because of the poor regulation in low speed, the speed of the elevator will vary widely with different loads, and so when this fixed cut off switch acts, the slide or drift of the elevator under the brake will also vary widely. Sometimes the platform will be level with the landing, sometimes above it, sometimes below it.

Now assume that the elevator control to be such that on the first point or lowest speed the speed is always just the same, regardless of load. Then the drift or slide after cut off by the fixed switch contact in the hoistway

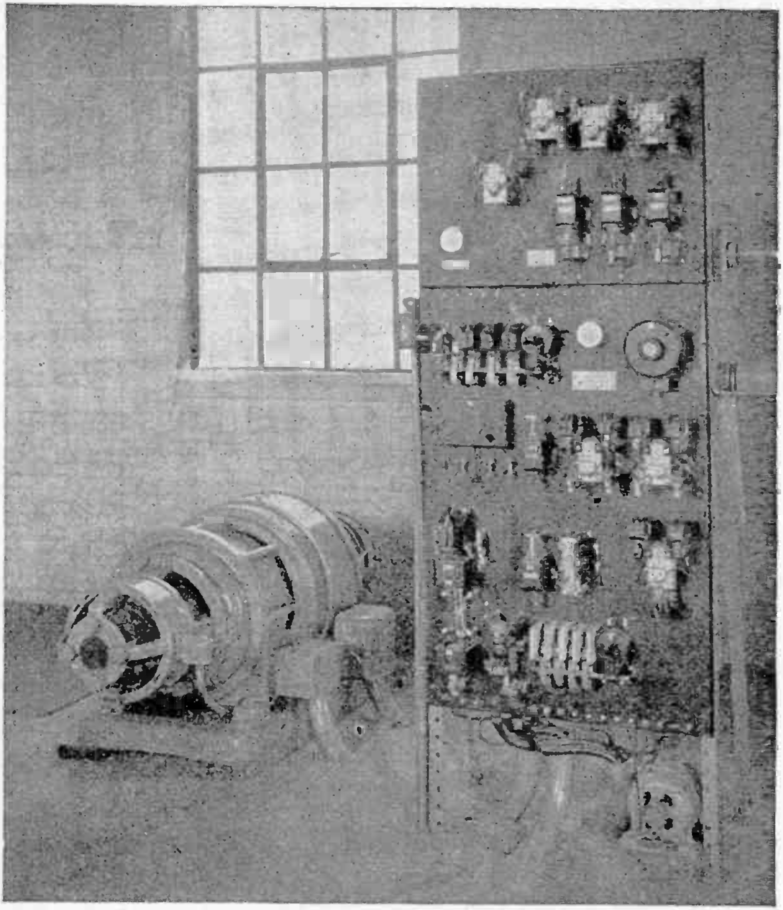


FIG. 6,807.—General Electric variable voltage control system consisting of a motor dynamo set and controller for elevator having automatic leveling devices.

would be more nearly uniform. It would not always be just the same, because this drift itself is influenced by the load. However, it would be close enough for accurate leveling.

The problem of leveling is 1, to get good regulation on the lowest speed and 2, to get a suitable device for influencing the control at fixed points in the hoistway.

Auxiliary Motor Micro-drive.—One method of getting good regulation on the first point is used in the *auxiliary motor micro-drive*. In this system *a small constant speed motor is geared down so as to drive the elevator at an exceedingly low speed* (*low enough so as to make a final stop from this speed in a very short distance*) *just before stopping*.

This motor, because it runs without resistance at its most favorable point, has very close regulation, and the low speed or leveling speed is substantially independent of load.

The auxiliary motor is not geared permanently to the main motor, but is connected only when leveling, by means of an electric clutch, which also acts as a brake on the main motor.

Automatic Leveling with the Main Motor.—With variable voltage control the regulation on the low speed or first point is so close that a low speed for leveling can be obtained without an auxiliary motor, merely running the main motor on very low voltage. This regulation under these conditions is suitable for leveling provided the apparatus be not worked too close to capacity; hence variable voltage equipment for automatic leveling is sometimes built larger than for non-leveling duty of the same rated load.

Automatic Leveling with Two Speed Motor.—Under certain conditions automatic leveling can be obtained with a two speed *a.c.* motor. A low speed winding can be selected which gives low enough speed for leveling (provided the rated speed of the elevator is moderate) and this speed will be reasonably constant with changes of load. The inherent regulation, however, is not as close as with variable voltage control.

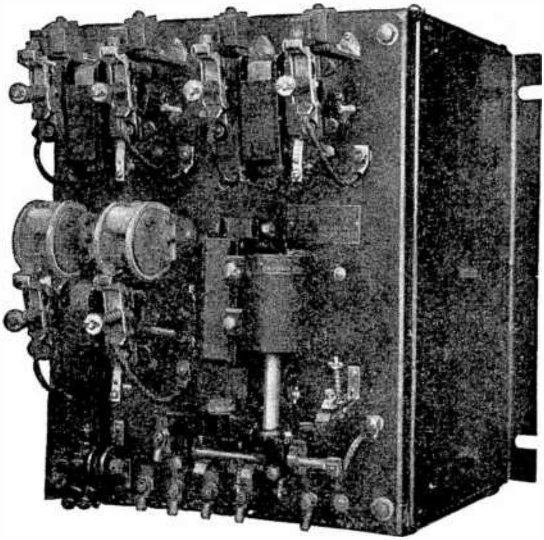


FIG. 6,808.—Cutler Hammer semi-magnetic control panel for slow speed elevators driven by slip ring induction motors. *It consists of* an automatic starter and a separately mounted reversing switch. Motor acceleration is controlled by an adjustable time limit relay. When the dashpot on this relay is once set, the starter will always cut out the resistor in the same length of time. The accelerating relay on the automatic starter operates the pilot circuit contacts of the accelerating contactors. If this controller be used on a winding drum type elevator, the traveling nut on the elevator machine should be arranged to throw the drum reversing switch to the off position at the normal limits of travel. For traction type elevator machines, two hoistway limit switches may be used for obtaining the terminal stops. All controllers of this type are arranged for the operation of either a single phase or a polyphase magnetic brake. When such a brake is installed, hoistway limit switches are recommended in place of the more expensive traveling nut device. In any case, all installations should include two hoistway limit switches to prevent overtravel of the elevator. In order to prevent the automatic starting of the elevator upon resumption of voltage after failure, when the shipper mechanism is left in the running position, a low voltage protective relay should be added to the standard equipment, two relays on two phase, four wire installations. This relay will also prevent the starting of the elevator car upon the closure of a gate or door, where door switches are used, without first moving the drum reversing switch to the neutral and then to the running position.

Automatic Leveling Devices.—Reference has been made to a switch in the hoistway at a fixed distance from the landing to cut off power at the proper place. Substantially this principle is widely used on low speed elevators. The device usually takes the form of suitably placed cams for each floor, and a switch carried on the car, with an arm and roller to engage the cam. When a stop is to be made the switch contact is in circuit. When no stop is to be made the switch contact is ineffective

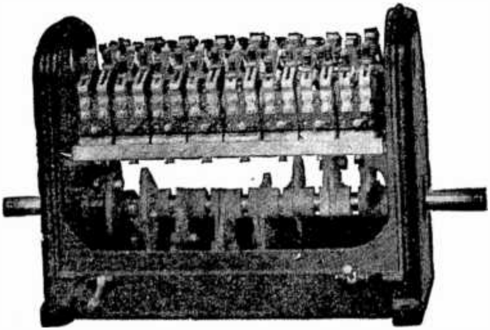
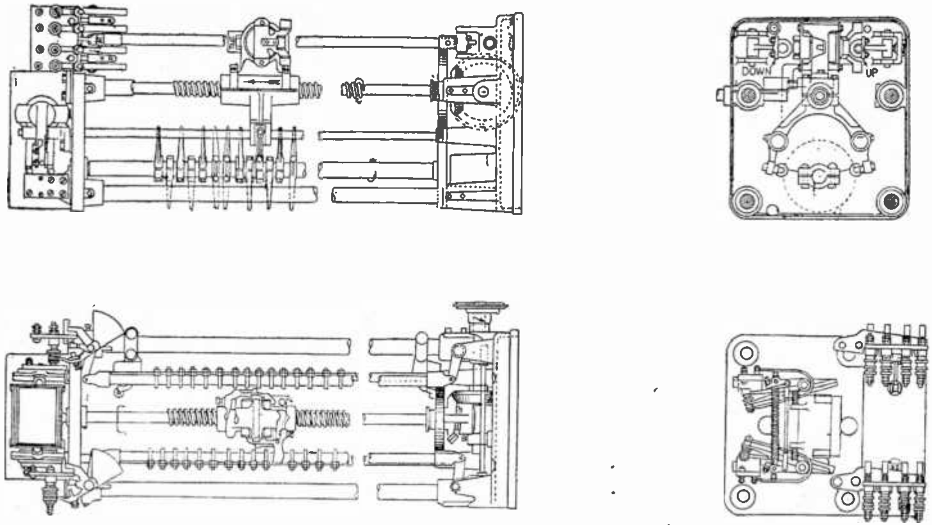


Fig. 6,809.—Cutler Hammer *a.c.* or *d.c.* floor selector for push button controlled elevators or dumb waiters with or without slow down. They can be used with either winding drum or traction type elevators. ***For traction type elevators*** a separate small winding drum must be geared to the selector. This drum should be operated directly from the elevator car by means of a cable so that the accuracy of stops will not be disturbed by the shifting of the traction cables on the driving sheave. This applies to the V groove as well as the wrap traction elevators. ***For winding drum type elevators,*** the selector may be geared directly to the elevator winding drum shaft. It is recommended, however, that the separate small winding drum be used for this type as well as for the traction type. This arrangement has a distinct advantage in that it automatically compensates for stretch of the hoisting cables, thereby eliminating the necessity of adjusting the selector to compensate for the stretch of the cable. A sprocket wheel and a long chain may be used instead of the winding drum and steel cables, if desired.

even though the cam caused the usual movement of the switch arm.

This device is widely used on push button elevators as a stopping switch. The difference between a straight push button elevator and an automatic leveling push button elevator lies chiefly in the provision for a very low stopping speed in the latter, with close regulation on this speed.



FIGS. 6,810 to 6,812.—General arrangement of Otis micro-selector.

With the cam roller switch type of leveling and stopping device, the switch arm is sometimes arranged to be retracted by mechanical means (by a magnet or motor) when no stop is to be made, to prevent wear and tear on the parts, but this device is seldom used because the cam roller switch type is generally employed only on low speeds.

At high speeds, where the engagement of the roller with the cam would be objectionable due to noise and wear, other types of leveling device are usually employed

Floor Selector Type.—The floor selector type of leveling device in effect *reproduces on a small scale, in the machine room the motion of the elevator in the hoistway.*

It is equipped with contacts located to correspond to the various floors, and arranged to actuate magnets on the controller at the proper time and place (that is, corresponding to proper place in the hoistway) to produce low speed and then to stop the elevator.

Floor selectors are of many types, some having sliding contacts in a plane, with a brush carriage or cross head carried on a traveling nut on a screw; some having contacts actuated as a result of rotary motion around a shaft; and others having various combinations and variations of these two fundamental forms.

Floor selectors are sometimes driven direct from the elevator car by tape or cable, and sometimes from the hoisting machine or secondary sheave. In the latter case, a re-set, or corrective device is usually provided to keep the selector in synchronism with the movement of the car, and to correct for rope slippage.

Floor selectors are also sometimes called signal machines, especially where automatic leveling is provided as a part of signal operation.

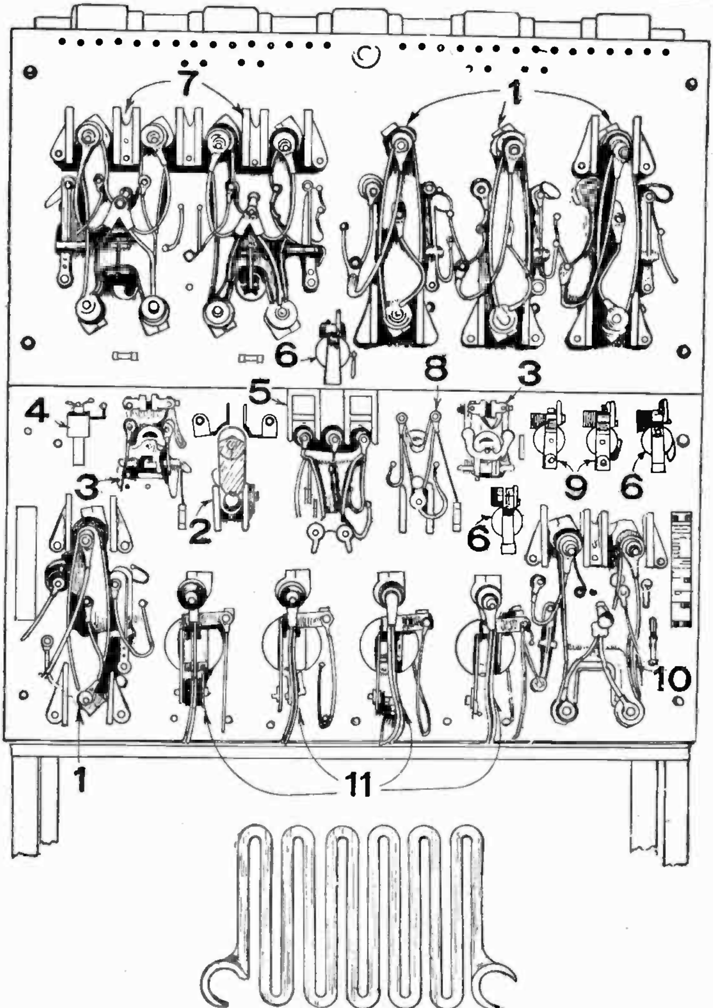
Hoistway switching devices operating without mechanical contact.—There are two forms of such devices used in automatic leveling:

1. Vacuum tube;
2. Inductor.

Both forms work generally in the following manner:

The tube or inductor (or several of them), are mounted on the car, while at suitable points in the hoistway, steel plates are mounted, so that at the proper place with respect to a floor at which a stop is to be made, the device in the car will come opposite (or go by) a plate, whereupon relays are actuated, to produce the required action on the elevator, for slow speed, or stop.

It is merely necessary for the device on the car to be close to the plate (but not touching it) in the case of the inductor, or to span the plate (with



FIGS. 6,813 and 6,814.—Otis type DGS controller and detail of grid resistance. 1, fast speed magnets; 2, breaking sw; 3, relay sws; 4, overload relay; 5, making and breaking sw; 6, WA magnets; 7, reversing sw; 8, main line sw; 9, W magnets; 10, potential sw; 11, accelerating magnets

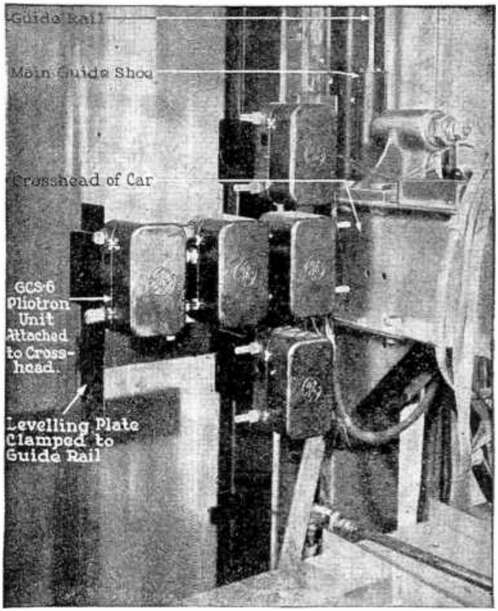
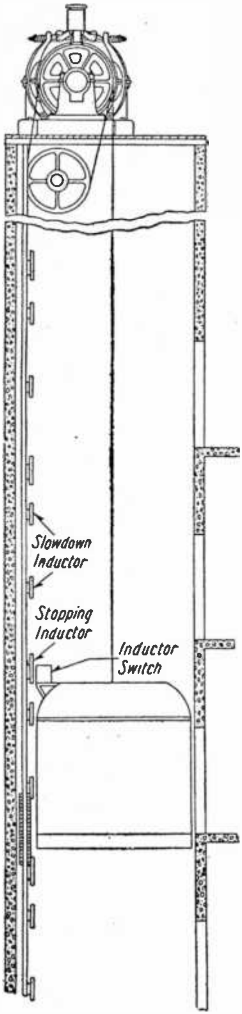


FIG. 6,815.—General Electric vacuum tube or pliotron leveler as used with General Electric automatic control; view of top of car showing pliotron units. Automatic leveling with this system is accomplished with the main traction motor without hatchway cams, or rollers, or cab mounted retiring cams, or any electric contacts made or broken in the hatchway or on the car. The leveler consists of: 1, fixed steel plates suitably mounted in the hatchway, having no electric circuits and no mechanical contact; 2, leveling units, known as pliotron units, mounted on top of the car. No contacts are made or broken in these units; and they have no moving parts; 3, relays on the control panel. For car switch control with automatic leveling, four relays are added as compared with ordinary manual leveling, regardless of the number of floors served. The parts mounted in the hatchway at the various floors consist of plates ⅛ in. thick, and usually less than 2 ft. in length. Because the leveler operates by the damping of an oscillating circuit, causing abrupt rise of current to operate the relays, and involves no make and break contacts and no inductor or reactor control, its response is practically instantaneous. The leveler acts directly on the main traction motor and involves no auxiliary driving mechanisms, gears, clutches, or brakes. Accurate leveling with one motor is possible, largely because of the inherent design of the motor itself and the immediate response of the pliotron control. This leveler is applicable not only to straight car switch control but also to control where the operator may automatically effect a landing at the floors in response to signals pre-registered from the calls made in the hallways, or to the wishes of the passengers in the car.



a substantial air gap on each side) in the case of the vacuum tube, to bring about the required action on the control.

The inductor consists of a sort of relay, normally open, which becomes closed as the result of magnetic action when the plate passes it.

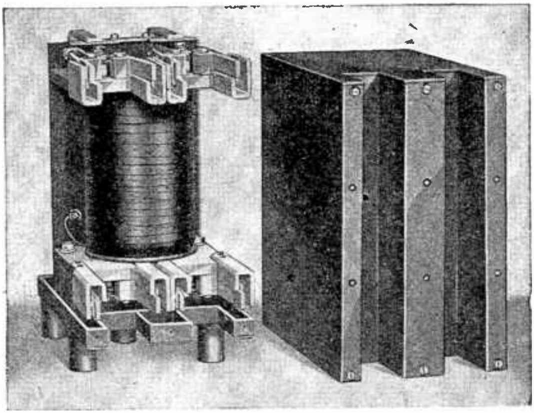
The vacuum tube, or pliotron, is a three element tube, with filament, grid and plate. Projections from the box holding the tube contain flat circular coils which are in the grid and plate circuits respectively. A relay on the controller is in the plate circuit. A current is always flowing in the plate circuit when the elevator is running, but this is an oscillating circuit of very low value, and cannot operate the relay till the oscillations are damped. Passage of the unit containing the tube and coils past the plate in the hoistway damps the oscillations, and instantly actuates the relay on the controller.

Elevator Operation.—The three basic methods of elevator operation are:

1. Manual operation;
2. Push button operation;
3. Signal operation.

Manual Operation.—This is the correct name to describe what is often spoken of as a car switch control, or switch control or hand control. The

FIG. 6,816.—Automatic inductor control system showing Westinghouse traction elevator installation with variable voltage control. *In construction,* inductor switches mounted term control, however, is properly limited to the method of speed variation, as rheostatic control or variable voltage control.



FIGS. 6,817 and 6,818.—Westinghouse inductor switch with cover removed.

FIG. 6,816.—*Text continued.*

upon the top of the car are used to give automatic control without any mechanically operated devices. There is one set of inductor switches for the up direction and another for the down direction. Only part of the magnetic circuit of the inductor switch is on the car. To complete the magnetic circuit the inductor switch must come opposite an iron plate or inductor in the hatchway. The car is started in the usual way by moving the car switch handle to the running position. When it is desired to stop the car at any floor the operator returns the car switch handle to the center or off position. The coil of the inductor switch is thereby energized and as the inductor switch passes the inductor plate in the hatchway the armature of the inductor switch magnet is pulled toward the inductor plate, thereby opening the circuit to the relays on the elevator control panel, slowing down and stopping the car. The inductor switches operate in sequence as the car approaches the floor, slowing it down smoothly and rapidly, the final one stopping the car at the floor level. The iron plates or inductors in the hatchway are fastened by clips to the counterweight or car rails. There is one set of inductors for each direction of travel. They are placed the same distance from each floor, giving the operator a zone equal to the distance between floors in which to center the car switch handle to stop the car at any floor. When the car switch handle is centered, the inductor switch coil is energized but will not operate until the car has reached the point where the inductor switch is opposite the inductor in the hatchway. This point is the minimum distance from the floor in which the car can be slowed down rapidly but smoothly and stopped accurately at the floor level. When making floor to floor runs the operator moves the car switch handle to the running position and immediately returns it to the off position. In this case the high speed relays of the control are not energized and the car speed builds up to an intermediate value which is so proportioned that a run can be made from one floor to the next in the minimum time. In this case the inductor switch is actuated by an inductor midway between the floors, so that the car attains its maximum speed for a one floor run.

Push Button Operation.—This method of control is of three basic types:

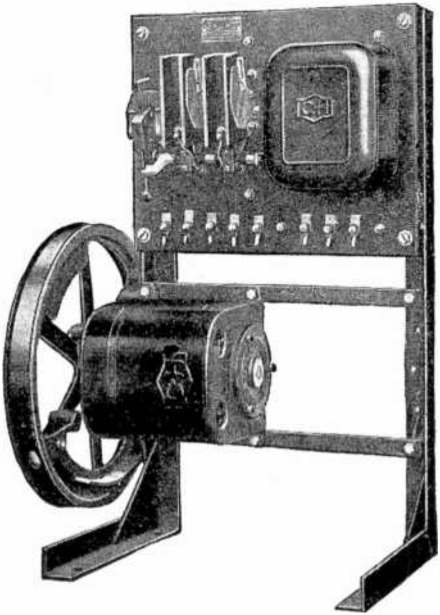


FIG. 6,819.—Cutler Hammer *a.c.* semi-magnetic elevator controller, single speed, across-the-line type, with combined reverse and master drum switch self contained, for slow speed freight service. ***It consists of*** a magnetic contactor panel and a combined reverse and master drum switch, mounted on an angle iron floor type frame. The contactor panel contains the main line magnetic contactor and the phase reversal relay. The combined reverse and master drum switch contains the reversing contacts and auxiliary contacts for handling the main line contactor. The drum switch is mounted below the panel on heavy supporting bars and can be easily turned around so that the sheave wheel is at the right or left of the panel as desired. ***In operation*** moving the combined reverse and master drum switch to either the up or down running position connects the phases in their correct order for up or down operation. Auxiliary contacts in the drum complete the circuit to the coil of the main line contactor, releasing the brake and starting the motor. Returning the switch to the off position breaks the motor circuit and sets the brake. Reversing of the motor is accomplished in the drum switch. The phase reversal relay prevents starting of the motor if the line phases be accidentally reversed. Reversing of the phases would cause the elevator car to start in a direction opposite to that in which the operator expects it to move. Under these conditions, the relay prevents the motor starting until the phases have been reconnected in their normal order.

1. Hold in push button operation;
2. Full automatic push button operation;
3. Dual operation.

Hold in Push Button Operation.—In this system *up and down buttons are mounted in the car and also at each landing.*

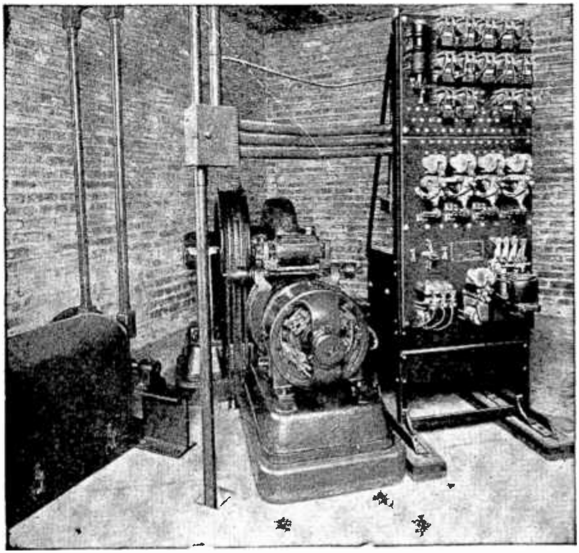


FIG. 6,820.—Cutler Hammer full magnetic, single speed push button *d.c.* controller panel installation showing elevator machine. When push button control is used the car is sometimes "stolen" before the person in it has had a chance to open the car gate or door after arriving at its destination. To overcome this objection a non-interference relay may be used to provide ample time for opening the gate or door.

Pressure on an up button, for example, starts the car up, and it runs only so long as the button is held depressed. When the button is released, the car stops. Hence this system is applicable only to low speed elevators. Provision is made to prevent operation by the landing buttons when the car is in motion as the result of pressure on one of the car buttons. This system is widely used for freight elevators at 100 *f.p.m.* or less. It is sometimes called *double button control.*

Full Automatic Push Button Operation.—In this system *buttons are mounted in the car corresponding to each floor. Buttons are also mounted at each landing.*

Pressure of a button starts the car, which then continues to run after the button has been released, and stops automatically at the floor corresponding to the button pushed.

A specialized form of full automatic push button operation is the *collective or interceptive operation.*

In the straight push button operation when a button has been pushed, the car is entirely under control of that one button, and cannot be stopped or intercepted by another button (except when the emergency stop button in the car has been pushed, which cancels all calls, including the one being answered at the time).

FIG. 6,821.—General Electric car operator's switch and push button panel for pliotron unit automatic control. In operation passengers entering the car make known the floors at which they will leave, and such calls are recorded on an operator's push button panel in the car. Thus, both outside and inside calls are registered in the same way, and the operator automatically receives a signal to stop in precisely the same manner, and at just the proper time, for inside as well as for outside calls. With this system of signals, in conjunction with pliotron unit control the operator need pay no attention to his position in the hoistway, in order to make a landing. Furthermore, the operator always receives the same signal to stop, and always makes the same simple movement of the car switch in response to this signal, so that response becomes automatic.

In the collective interceptive type of push button operation, however, the car can be started by pressing a button in the car, or at a landing, and it can afterwards be stopped or intercepted by another button, if that button be at a floor (or corresponds to such a floor, in the case of buttons in the car) in between the point from which the car started and the floor to which it was called or dispatched by the first button pushed.

Dual Operation.—Where push button operation is combined with manual operation in the same car, the combination is called dual operation.

An elevator with dual operation has a car switch, a push button station and an annunciator in the car, and a throw over switch on the controller so that, when on push button operation, the landing buttons will call the car, while on manual operation, the landing buttons will operate the annunciator.

A simplified and widely used form of dual operation is that called semi-dual.

In this system there is no car switch, but the annunciator and the throw over switch are retained. When an operator is on the car, the landing buttons operate the annunciator, and the operator runs the car by the car push buttons. Semi-dual operation is really necessary, as distinguished from straight dual operation, when the car has automatically operated cab doors.

With collective-interceptive control an operator may be engaged to run the car (so as to be helpful to passengers) without the need for an annunciator and hence without dual or semi-dual operation.

Signal Operation.—The term *signal operation* is the proper one to apply to that type of elevator operation *where the elevator is started by an operator, but where the stopping is brought about as the result of pressing one of the signal buttons.*

In addition to the stopping buttons on the landings, which serve for a bank of several cars, and which when pressed cause the first car of the bank approaching in the proper direction to stop, buttons are mounted in each car also, one for each floor served, which when pressed set up stop calls, or stop impulses for that car alone, the car stopping at those floors in proper order regardless of the order in which the buttons are pressed.

Signal operation, like push button operation, requires a floor selector or signal machine, and a relay panel, in addition to the regular control, for recording the stop calls, releasing the stop impulses at the proper time, cancelling the signals from the other cars, and resetting the relays after stops are made.

There must also be means for automatic leveling, which may be one or the other of the types previously described, either separate from the signal machine, or combined with it.

TEST QUESTIONS

1. *Name the two general types of control systems.*
2. *Is rheostatic control extensively used?*
3. *Name the various types of rheostatic control classified according to speed and type of motor used.*
4. *How are typical* d.c. *motors wound for speeds of* 200 *to* 400 f.p.m.?
5. *What is the feature of the* d.c. *motor with wide range field control?*
6. *What is the standard type motor for two speed* a.c. *rheostatic control?*
7. *Describe the braking action of an induction motor.*
8. *Is a* d.c. *brake solenoid preferable to an* a.c. *brake?*
9. *What are the features of the various types of two speed motors used?*

10. *Describe in detail the principles of rheostatic control.*

11. *Define variable voltage control.*

12. *What type motor is always used for variable voltage control?*

13. *What is the object of the motor generator set used in the variable voltage system?*

14. *Describe at length the variable voltage system.*

15. *How is the motor generator set arranged when the power supply is* a.c.*?*

16. *Draw elementary diagram of Westinghouse variable voltage control.*

17. *Define the word* regulation *as applied to elevator control.*

18. *What is understood by the term* full speed regulation?

19. *Upon what does automatic leveling depend?*

20. *Describe at length the methods of automatic leveling.*

21. *Of what does the auxiliary motor micro-drive consist?*

22. *Describe automatic leveling with the main motor.*

23. *How is automatic leveling obtained with two speed motor?*

24. *What is the difference between semi-magnetic and full magnetic control?*

25. *Describé in detail the various automatic leveling devices used.*

26. *Describe the vacuum tube and inductor systems of leveling.*
27. *Name three basic types of push button control, and describe them.*
28. *Define dual operation.*
29. *What are the requirements for signal operation?*

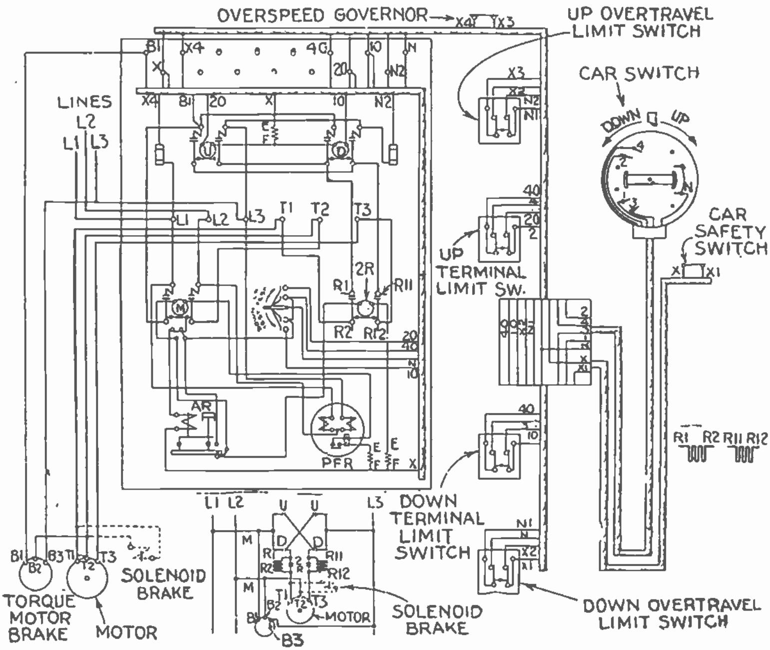
CHAPTER 157

Elevator Control Diagrams

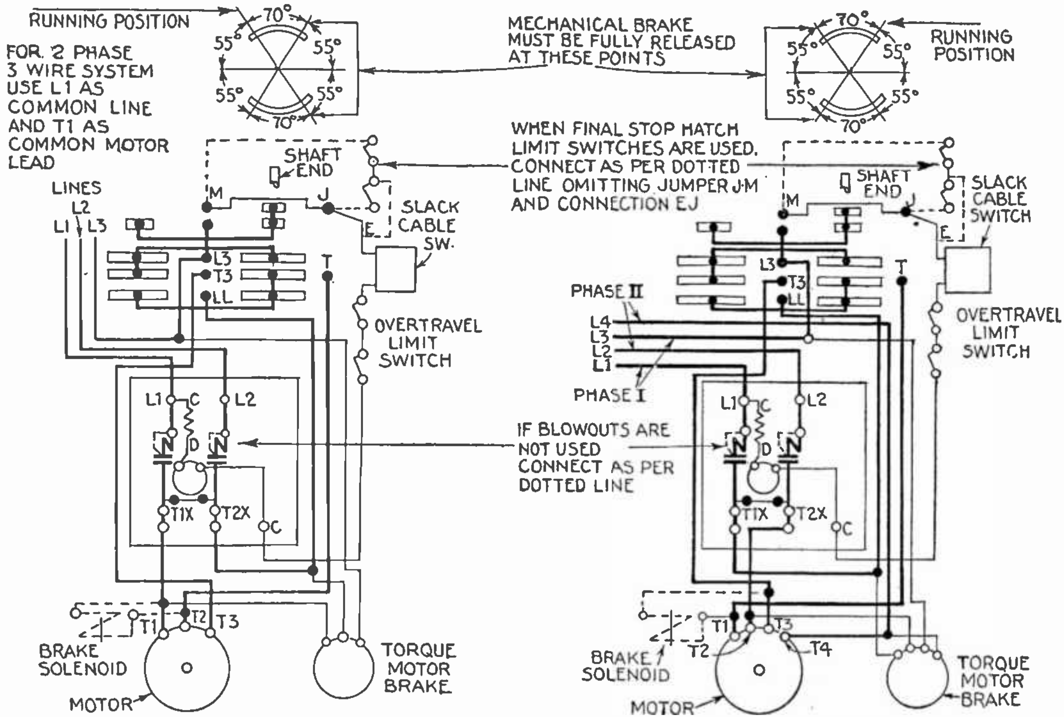
The following notation as given by Cutler-Hammer will be found useful in reading diagrams:

The lines should be placed sufficiently far apart to enable the wiring circuits to be traced without confusion.

(Text continued on page 4,168)



FIGS. 6,822 to 6,824.—A typical Cutler Hammer wiring diagram.



FIGS. 6,825 and 6,826.—Cutler-Hammer connections for *a.c.* semi-magnetic elevator controller. Fig. 6,825 three phase or two phase three wire; fig. 6,826, two phase four wire.

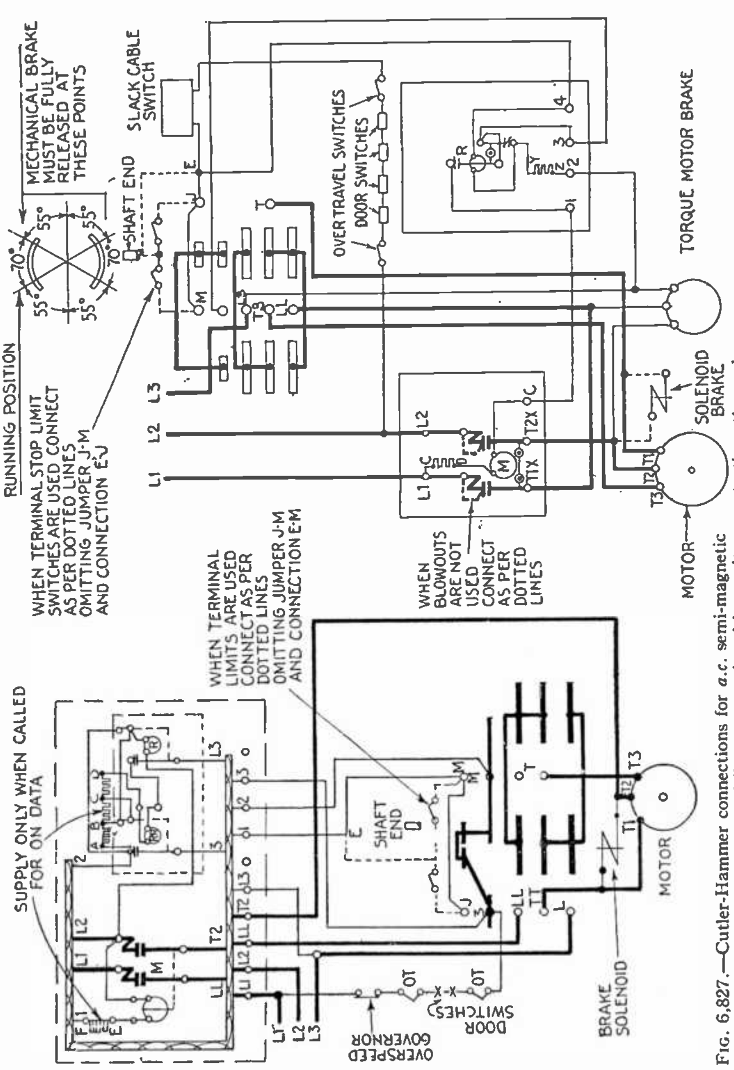


FIG. 6,827.—Cutler-Hammer connections for *a.c.* semi-magnetic elevator controller with phase failure, reversal and low voltage protection; three phase.
FIG. 6,828.—Cutler-Hammer connections for semi-magnetic elevator controller with low voltage and phase failure protection, for three phase or two phase, three wire.

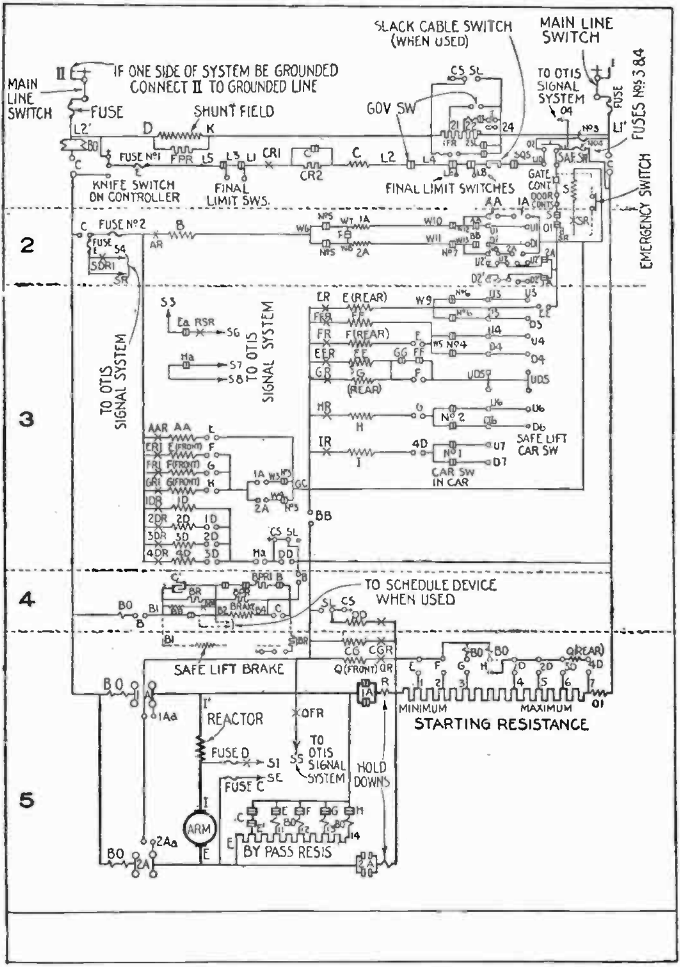
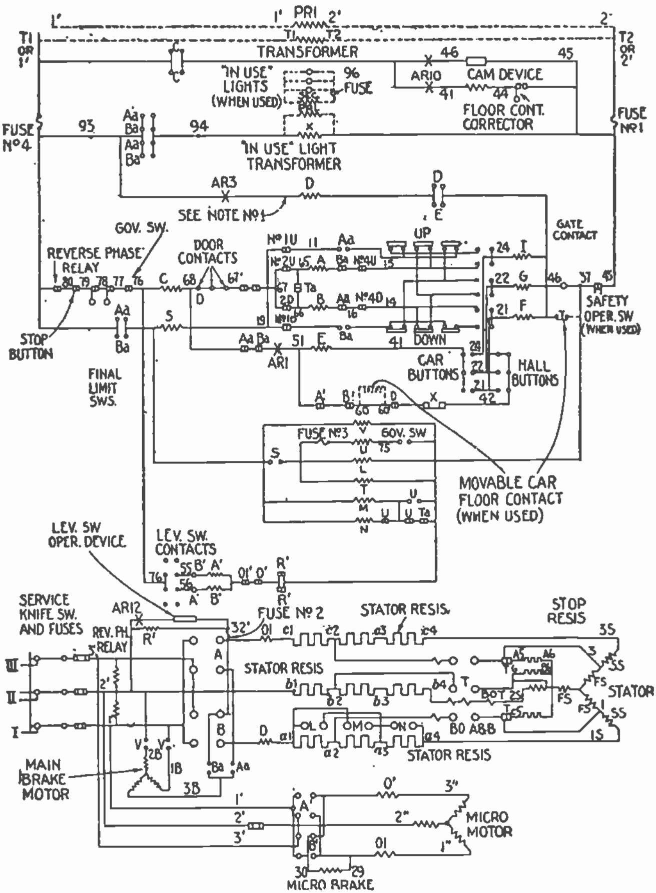


FIG. 6,829—Otis *d.c.* resistance controller for use with gearless traction machine, car switch operated with safe lift 1A, 2A, reversing switch; B, brake switch; C, potential switch; E,F,G,H, speed switches; 1D, 2D, 3D, 4D, accelerating sws; I, field switch; S, door contact relay; Q, load switch; AA, reversing sw. relay; EE, 1st speed sw. relay; GG, 3rd speed sw. relay, 01, overload relay; FF, 2nd speed sw. relay; BB, brake relay; DD, safe lift relay.



FIGS. 6,830 and 6,831—Otis magnet controller for micro drive worm gear traction machine. Three phase, three wire, two speed push button control. ***Names of switches. Main controller:*** A,B, reversing switches; C, aux. cam switch; D, self holding switch; E, non interference sw; F,G,I, floor switches; L,M,N, accelerating sws; S, aux. fast and slow speed sw; T, fast and slow speed sw; U, aux accelerating sw; V, aux. brake switch time limit relay; O,Cl, protective relays. ***Micro controller.*** A'B', reversing switches; O'O', protective relays; R', micro retarding switch. ***Note No. 1.***—If movable car floor contacts be used omit connection between D coil and AR3, resistance.

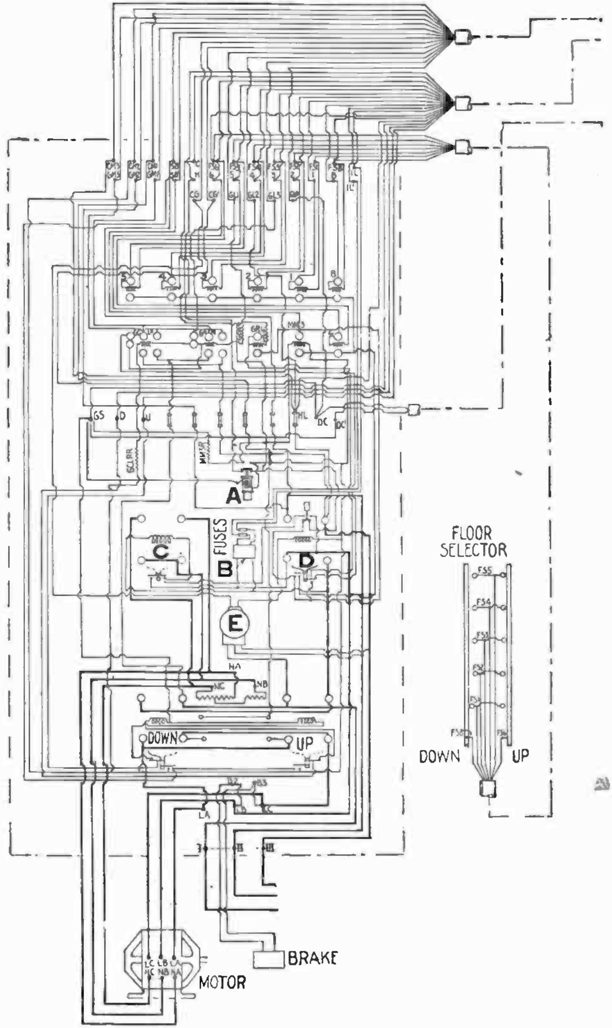
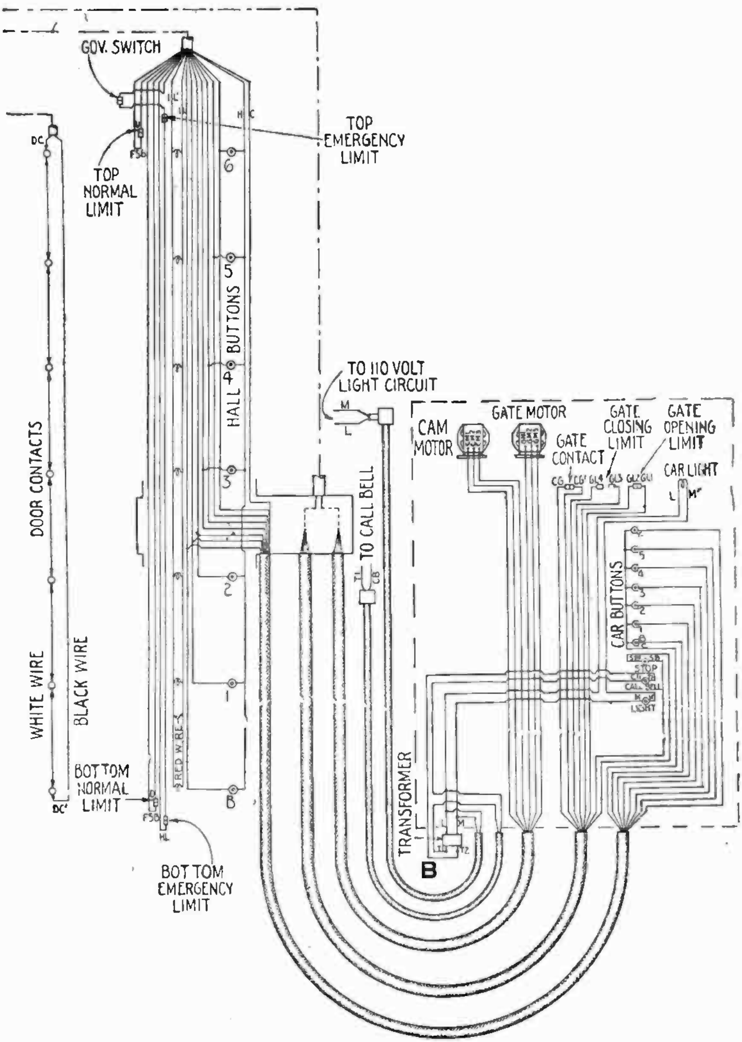


FIG. 6,832—Watson three phase controller for push button operation. A, time relay; B, trans-



former; C, accelerating switch; D, potential switch; E, reverse phase relay.

An elementary diagram should always be included; especially is this necessary on complicated diagrams. Overtravel and hoistway limit switches are shown on all diagrams. On drum machine control diagrams a slack cable switch is shown.

On *a.c.* wiring diagrams the connections for both single phase and polyphase brakes are indicated.

On *d.c.* diagrams connections for a compound wound motor and a compound wound brake magnet with the series windings cut out in one step after starting are shown. Optional connections for a shunt motor and a shunt brake are also placed on the diagram.

D.c. diagrams carry polarity signs, because of the fact that the carbon copper contacts have much longer life when the current flows from the carbon to the copper.

On all diagrams for showing full magnetic controllers control fuses are included. A try out switch is shown, except on two landing push button installations and on three landing dumb waiter installations.

The try out switch is connected outside of the terminal limits, so that it is possible to run into the overtravel switches from the try out switch. This method of connecting the try out switch saves running four wires from the limit switches to the control panel.

A single pole overspeed governor contact is shown on all diagrams. The car safety switch is connected to the line whose polarity is opposite to that which is used for the car switch, and the connection is made by a separate cable.

CHAPTER 158

Safety and Protective Devices

These may be classified as electrical and mechanical. The mechanical are so closely allied to the electrical that they will be briefly described. The principal safety devices are:

1. Guide grips;
2. Overspeed governor with governor switch;
3. Car operating switch;
4. Car safety switch;
5. Terminal limit switches;
6. Over travel limit switches;
7. Slack cable switch;
8. Door switches;
9. Compensating rope sheave switch;
10. Buffers and air cushions.

Guide Grips and Overspeed Governor.—Guide grips have been made in a number of different types such as eccentric, dog, roller, and wedge, *the wedge type now being almost universally adopted*, an example of this type being shown in fig. 6,833.

The mechanism, is mounted below the car with a small winding drum which is connected to the overspeed governor by a steel rope. The holding of this rope at excessive car speeds rotates the drum so that the wedges force the grips against the guide rails and stop the car.

Usually a fly ball type of governor is used in connection with the guide grips so arranged that the rope referred to rotates the governor shaft.

The governor is arranged with a grip so that if the normal speed of the elevator be exceeded by a fixed amount it holds the governor rope and effects the setting of the guide grips.

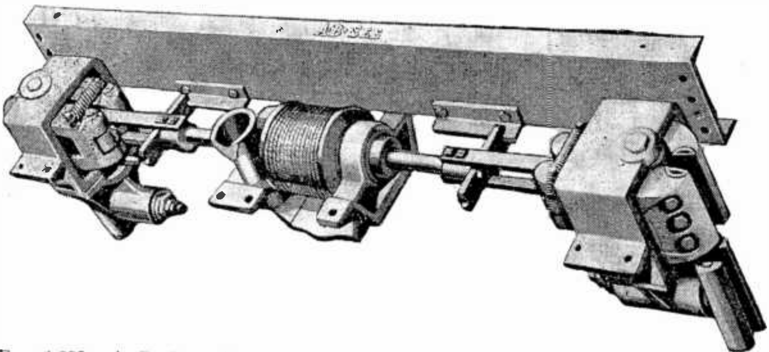
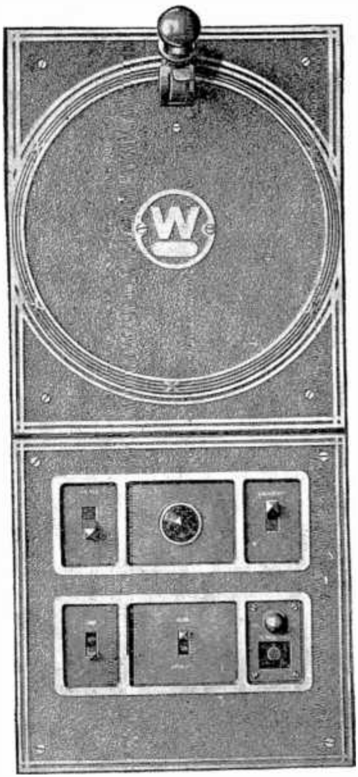


FIG. 6,833.—A. B. See safety guide grip or gradual clamp. *It consists of* a centrifugal governor connected by means of a wire rope to a clamping device which is located under the car platform. The whole apparatus is designed so that if for any reason the car should descend at a greater speed than that predetermined, and for which the governor is set, the elevator car will be brought to a gradual and smooth stop. This governor revolves at a speed corresponding to the movement of the car by means of a wire rope, one end of which is connected to the clamping device, located under the car platform, the rope is then led up the hoistway to the governor, over the governor driving sheave, thence down the hoistway to the tension sheave in the pit, under the tension sheave and back to the car where the other end is fixed. The clamping device is fastened securely to the lower members of the sling supporting the car platform and enclosure. It consists of a system of levers and wedges so arranged that when the governor brings the safety into action the guide rails on each side of the car are gripped between a pair of jaws. To prevent too rapid clamping on high speed elevators the construction is such that the jaws gripping the rails are actuated through a compression spring. This spring is graduated so that the distance the car travels, after the jaws have made contact with the guide rails, must be greater than that the car would fall through with a free drop, to attain the speed of car at the instant the safety is applied. For slower speeds than 500 ft. per min. the inherent elasticity of the various parts comprising the clamping device is sufficient to insure the required stopping distance.

It is accepted practice to install a control switch on the governor, so adjusted that the switch will trip to open the control circuit and disconnect power from the motor at a speed lower than the speed at which the guide grips act.

This switch prevents the guide grips setting in case of a slight overspeeding. The switch is arranged so that it cannot be reset unless the guide grips are in the running position.



Car Operating Switch.—This switch, shown in fig. 6,834, usually has *the automatic return or self centering feature so that if the operator's hands be removed from the lever it will return to the off position.* It is also usually provided with a center latch so arranged that any accidental leaning against the switch will not move the lever to the running position.

Car Safety Switch. — This switch is *for the purpose of stopping the car in emergency in case of the failure of the car operating switch.*

FIG. 6,834.—Westinghouse elevator car operating switch for variable voltage system in flush panel with auxiliary switch. Five operating positions are provided, giving speeds from a creeping speed up to full speed.

It is shown in fig. 6,835. It is wired in a separate cable of opposite polarity to the car switch cable, so that in case of grounds, etc., in the car switch cable, the car safety switch will not be thrown out of commission.

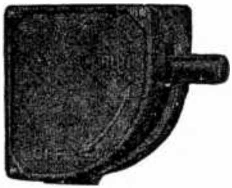


FIG. 6,835.—Cutler Hammer car safety switch for mounting adjacent to the car operating switch. It is a single pole switch and is connected in the control circuit on the side of opposite polarity to the car switch and insures a safe stop regardless of any possible combination of grounds. A separate two wire car control cable connects the switch with the control panel. Any grounds which are of a sufficiently serious nature to interfere with the operation of both the car switch and the safety switch will render the elevator equipment itself inoperative.

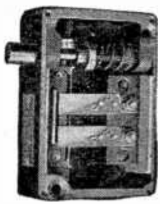


FIG. 6,836—Cutler Hammer door electric contact. Fig. 6,836 type is generally used where space limitations compel the installation of a small switch. It is operated by a push button which engages the end of the sliding door. Fig. 6,841 type is used wherever space limitations will permit. It is operated by a lever and roller which engages with a cam on the sliding door. Either type may be used with wheel, lever or rope operated elevators if a main magnetic contactor be used to control the main line current. The contacts are of single pole double break type.

Terminal Limit Switches.—These switches such as shown in fig. 6,837 *act each time the car approaches the terminal landings, and function to bring the car to rest at these landings in case the operator be careless.*

They may be mounted on the car and operated by cams in the hoistway or vice versa for a traction type elevator. These may also be used on a drum type elevator although frequently limit switches geared to the elevator machine are used instead.

Overtravel Limit Switches.—These switches shown in fig. 6,839 are always mounted in the hoistway and are operated by cams on the elevator car. They are placed beyond the normal

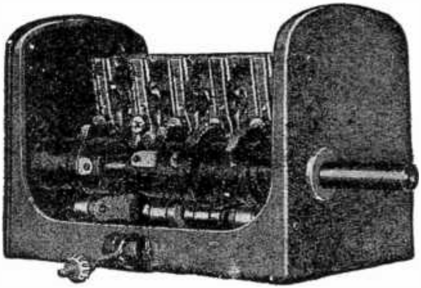


FIG. 6,837.—Cutler Hammer rotating cam machine limit device for drum type machine. This device is connected with the traveling nut mechanism of the winding drum and opens the control circuits of the magnetic contactors on the elevator controller. The device provides automatic slow down and stop at the terminal landings if the controller has the slow down feature. A centering device must be provided which will return the limit device and the yoke of the traveling unit mechanism to the central position whenever the car moves away from either limit of travel.

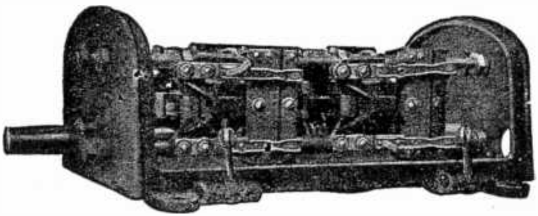


FIG. 6,838.—Cutler Hammer traveling cam machine limit device for full magnetic elevator controllers on winding drum type elevators. The device combines the functions of the ordinary traveling nut device and a machine limit switch. It is geared directly to the shaft of the elevator winding drum. The traveling cam or nut is driven along the length of the threaded shaft as the car moves from one limit of travel to the other. As it reaches either limit the traveling nut trips the double pole snap switches. Two double pole snap switches are provided for each direction of travel. They are the quick break type, adjustable as to position along the threaded shaft and arranged so that they can be locked positively when located. If the elevator controller be provided with the slow down feature, two of the switches may be used for this purpose, one for each direction of travel.

range of car travel, and function *to stop the car in case of the failure of the regular terminal stop limits.*

It is very desirable and the usual practice to arrange the connections to these limits so that the car cannot be backed out of them by manipulating the car switch. This gives an added safety feature as it requires the operator to call the attention of an electrician or someone connected with the maintenance department to the fact that the car ran into the overtravel limits, and have the cause of this overrunning corrected.

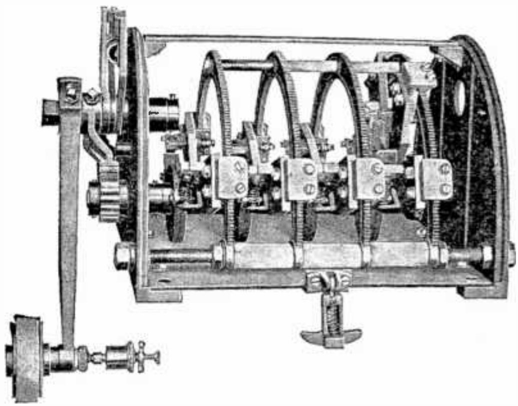


FIG. 6,839.—Westinghouse hoistway or terminal cam type limit switch. ***In construction*** the shaft carries moving cams that operate contacts located on a number of semi-circular supports inside the case. These contacts can be moved to allow adjustment of slow down and stopping position. The main operating shaft is actuated by an arm with a rubber tired roller which engages a cam suitably located in the hatchway. All movements of the switch are extremely quiet.

Slack Cable Switch.—Ordinarily this is used on a drum type elevator *to open the control circuit in case of slack rope caused by the car or counter-weight being caught in the guides.*

It is operated automatically when the ropes slacken. Fig. 6,840 shows the construction. It is sometimes mounted on top of an elevator car of high travel traction elevators where the rope weight is great so that the machine may not entirely lose traction in case of the bottoming of the car.

Door Safety Switches.—These switches (fig. 6,841) in combination with door locks, *prevent the car operating unless all doors are closed and locked.*

The design requirements of these devices are in many cases regulated by safety codes. There are numerous types manufactured and many have little value, so that door locks and switches should be investigated before installing. Some combinations lock the car operating switch in neutral while the door is open. Others interrupt the car control circuit when the door is open.

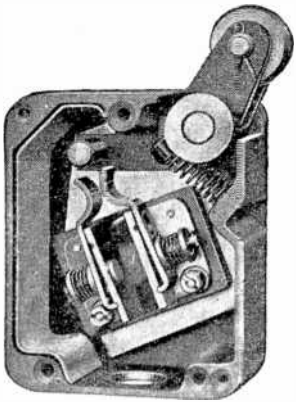


FIG. 6,840.—Cutler Hammer slack rope switch. *It has* a latch which, when tripped, causes the contacts to remain open until reset by hand. The switch is used on drum type elevators and on traction elevators over ten or fifteen stories. It opens the main contactor on either semi-magnetic or full magnetic elevator controllers, should the rope become slack either because the car or the counter-weight is caught in the guides. When no slack rope switch is used, considerable rope may become unwound before the operator has an opportunity to shut off the power. The car might then release itself, drop and break the rope.

FIG. 6,841.—Cutler Hammer *a.c.* or *d.c.* door safety switch. ***Designed primarily*** for use in the control circuit of automatic and semi-automatic elevator controllers to prevent starting of the elevator car until all doors are closed. The switches with normally open contacts are used for this service. They are also used as limit switches in the control circuit of *a.c.* or *d.c.* automatic starters on applications such as machine tools, conveyors, etc. The switches are single pole and provide a double break in one side of the control circuit. ***It is operated*** by means of a lever and roller. A cam on the sliding door engages the roller and closes the contacts when the elevator door is closed.

Because the large majority of elevator accidents are due to not using suitable door interlocks, it is advisable to use them even though it decreases the service of the elevator to some extent.

Compensating Cable Switch.—This switch (shown in fig. 6,842) is connected so that *it is opened by the lowering or raising of the compensating rope sheaves in the pit.*

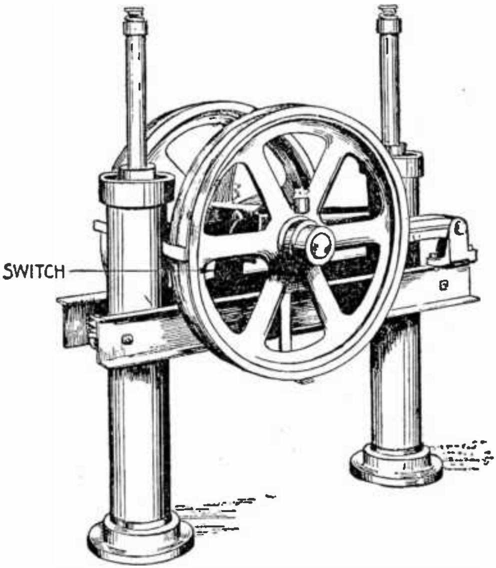


FIG. 6,842.—Elevator compensating rope sheaves with switch.

The switch interrupts the control circuit and stops the car should the sheaves lower to any appreciable extent due to rope stretch. Also, in case of the car or its counter-weight being caught in the guides, the compensating rope sheave will raise and operate the switch to cut off power.

Buffers and Air Cushions.—A buffer is *always required under the car*. For lower speeds a spring alone is used, but for higher speeds a combination of oil dash pot and spring is used (fig. 6,843).

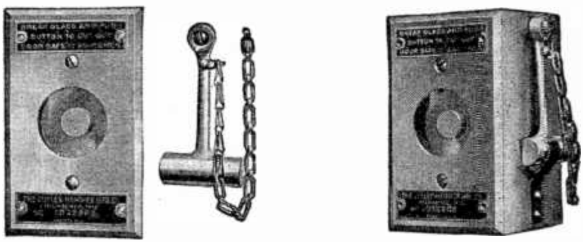
FIG. 6,843.—Oil buffer.

These must provide a retarding effect so that maximum retardation will not exceed 64.4 feet per second per second.

At one time an air cushion was required for certain service in certain localities. This consists of a hoistway practically air tight at the lower end for a certain percentage of the total height. This involved very expensive enclosure construction and while effective in retarding the motion of a falling car it is understood the air cushion has been practically abandoned as unnecessary for safety. Another disadvantage of this scheme is the additional power required to move the car due to air friction.

Protective Devices.—Besides the various safety devices described most elevators are protected against abuse by the following apparatus:

1. Main line service switch and fuses;
2. Circuit breakers and overload relays;



FIGS. 6,844 to 6,846.—Cutler Hammer emergency releases. Fig. 6,844, flush mounted; fig. 6,846, surface mounted. The emergency release is used to short circuit the hoistway door electric contacts in case of emergency such as fire or upon failure of a hoistway door electric contact to make proper contact when the door is closed. Breaking the glass with a small hammer, fig. 6,845, and depressing the normally open contact button short circuits the door electric contacts and allows the elevator to be operated. It is necessary for the operator to hold this button depressed while operating the elevator under emergency conditions. It is therefore necessary to install this release within easy reach from the car switch.

3. Overspeed slow down relay;
4. Phase failure protective relay;
5. Phase reversal protective relay.

Main Line Service Switch and Fuses.—These are mounted in an accessible location in the elevator machine room and are usually enclosed in a metal cabinet, preferably with an externally operated knife switch, and with a mechanical interlock making it necessary to open the knife switch before the cover can be opened to inspect or replace fuses.

Circuit Breakers and Overload Relays.—Circuit breaker protection of individual elevator motors is not very often used inasmuch as the National Electrical Code requires fuse protection of elevator motors even when circuit breakers are used.

Frequently, however, in addition to the service fuses, overload relays are used in order to secure protection against overloading of the elevator itself The overload relays are set below the fuse rating so as to prevent the blowing of fuses.

The overload relays are sometimes made to reset automatically with the return of the operating switch handle to neutral, so that after an overload it is unnecessary to go to the elevator machine room to again place the elevator in operating condition.

Overspeed Slow Down Relay.—Some builders include in their electrical equipment a voltage relay so connected that *an overspeeding of the elevator in either direction will cause the relay to act and thus automatically retard the speed*. This relay is set to act at a speed below that at which the overspeed governor is set.

Phase Failure Protective Relay.—All *a.c.* elevator installations on which the elevator motor may be continuously connected to the lines, such as hand rope and push button controlled elevators, include some form of phase failure protection.

Otherwise, upon the failure of a phase, the motor may be stalled on the single phase condition, and burn out. The protective relay is usually a poly-phase, shunt wound relay with a control circuit contact to maintain the control circuit of the elevator controller so long as the phases are all alive. The failure of any phase causes the relay to open the controller circuit and thus disconnect the motor from the supply lines.

Phase Reversal Protective Relay.—Many State electrical codes now require a phase reversal protective relay on all poly-phase *a.c.* installations. Frequently the phase failure and phase

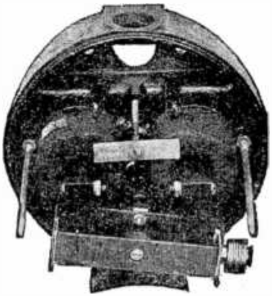


FIG. 6,847.—Cutler Hammer phase failure and reversal relay. ***It prevents*** the motor being started if the phases be accidentally reversed. This means that the elevator car cannot be started in a direction opposite to that which the operator expects it to move. The relay will also stop the motor in case of phase failure due to the opening of the supply line at any point, providing the motor is carrying a sufficient load to cause overheating when running single phase. The relay will not operate until the load increases to a harmful point or until an attempt is made to start the motor after stopping. This relay should be arranged to operate through a main magnetic contactor. The principle of operation is similar to that of an induction disc watt meter. A mercury switch opens and closes the control circuit and is so arranged that it makes the relay very sensitive to phase unbalancing, and yet the entire construction is rugged and dependable. Standard relays can be used without modification on either two or three phase circuits. No transformers are required on any circuit up to and including 550 volts. A change of voltage or frequency merely means the change of two small coils.

reversal relays are combined in one device. The reversal of phases immediately opens the controller circuit and prevents the elevator motor being connected to the lines until the relation of the phases is corrected.

TEST QUESTIONS

1. *What are terminal limit switches used for?*
2. *Describe the overtravel limit switches.*
3. *What is a slack cable switch and how does it operate?*
4. *Describe the construction of door safety switches.*
5. *Of what does a compensating cable switch consist?*
6. *What is the operation of buffers and air cushions?*
7. *How are the main line service switch and fuses mounted?*
8. *Are circuit breakers and overload relays often used?*
9. *What is an overspeed slow down relay?*
10. *When should a phase failure protective relay be used?*
11. *Are phase reversal protective relays necessary?*

CHAPTER 159

Gas and Electric Hoists

A hoist represents a class of machinery possessing wide utilities, for besides general hoisting work, there are other special duties to which it is adapted. Its development has been brought about chiefly by builders of this class of machinery being brought into touch with contractors, miners, bridge erectors, freight handlers on ships, docks, etc., resulting in a machine well adapted to the requirements.

There are a number of terms relating to hoists which are here given and which will be found helpful in understanding the subject.

Aerial dump.—An improved type of conveyor having low sides, and open at one end. The form facilitates the handling of material by a cableway.

Boom fall rope.—The rope which operates the vertical movement of the boom of a derrick.

Boom swinging gear.—A device for operating a radial or boom swinging derrick. It consists of a drum, or two spools on which the boom swinging ropes are simultaneously wound and unwound.

Bull wheel.—On radial derricks, a large wheel at the base of the derrick consisting of a circular flange made of structural T iron to which the boom swinging ropes are attached.

Clam shell grab.—A term used to describe a form of bucket used in dredging, excavating, and conveying loose material such as coke, sand, etc.

Cone.—An iron cone shaped cap used in logging operations to assist the log to pass over obstacles when skidding.

Derrick swinging ropes.—The two ropes which control the radial position of the derrick, or by means of which the derrick is made to revolve.

Differential brakes.—Band brakes, in which both ends of the band are pivoted to the rocker but at different distances from the center of the load held, tending to turn the rocker in the direction to apply the brake.

Dock wheels.—Small cast iron wheels fitted to hoists and forming a running gear, for use on docks or places where it is necessary to move the hoist frequently.

Drum.—A revolving flanged cylinder, to which the hoisting rope is attached.

Drum spring.—A spiral steel spring which pushes the drum out of contact with the friction woods when the friction pressure is released by the friction lever.

Dumping block.—A form of block consisting of a small and large wheel. A piece of chain inserted in the hoisting rope at the right point causes the small wheel to revolve which raises the back end of the skip, and allows the load to *dump*.

Foot brake.—A band brake for controlling the movement of the drum.

Fixed drum.—A type of drum in use where only single loads have to be handled.

Friction lever latch.—A device consisting of a thumb latch and detent, engaging with serrated teeth in a quadrant, by which the lever is held in any desired position.

Friction nut.—A large nut at the end of the drum shaft and attached to the side stand. The friction lever screw works in this nut and communicates motion to the friction pin.

Friction pin.—A steel pin which communicates lateral motion from the friction screw to the drum, bringing the latter into contact with the friction woods.

Friction screw.—A powerful steel screw located near the end of the drum shaft and operated by the friction lever. It communicates motion to the friction pin.

Friction woods.—A concentric layer of wooden blocks attached to the gear wheel, at the end of the drum, and furnishing the frictional contact between the two.

Guard bands.—Protecting wrought iron bands fitted over the gear wheels to prevent the rope or any obstruction getting in the teeth of the gear.

Locking levers.—On double friction drum engines designed for handling a boom derrick. When the friction lever is moved, for the purpose of throwing the drum into gear, the pin on the end of the friction lever presses against the curved part of the oscillating lever and releases the foot brake. When the lever is moved back, the operator places his foot on the foot brake for a moment, and the oscillating lever drops back into its original position, thereby locking the brake on the drum.

Loose drum.—A drum, free to revolve on its shaft, and which is thrown in or out of engagement with the driving shaft by means of a clutch.

Main hoist rope.—The rope which raises or lowers the load.

Operating levers.—Devices for operating the brake, friction, etc., in hoisting. They are usually assembled together and conveniently located for the engineer.

Orange peel grab.—A term used to describe a dredging device which when opened assumes the shape of an orange peel divided into four parts.

Outhaul rope.—In logging operations, an auxiliary rope, worked by a separate drum. It is used to carry the skidding rope out into the woods, which, by former methods had to be done with mules or men.

Post brakes.—A type of brake in use on reversible, mining, and hauling engines.

Radial ribs.—Cooling ribs placed outside of the drum friction surfaces to assist in carrying off the heat generated.

Shrouded ratchet ring.—A ring having ratchet teeth around its circumference and bolted to the drum flange. The outer edge of the ring is provided with a shrouded flange, thereby preventing the teeth being broken by the pawl, or the pawl slipping off.

Side stands.—Supporting frames usually of T shaped section and designed to carry both the drum and crank shaft bearings.

Skip.—An iron box with a bale holding from one to ten tons of ore or rock; used for hoisting and running between guides, or in inclined shafts to run on a track.

Sluing drums.—Two pony drums located on one shaft, and especially adapted for the operation of radial or swinging boom derricks.

Snaking and loading machine.—In logging, a hoist with rigging so arranged that the operations of hauling and loading may be carried on from separate booms independently and at the same time.

Stiff leg derrick.—A form of derrick fitted with wooden braces instead of guy ropes for support.

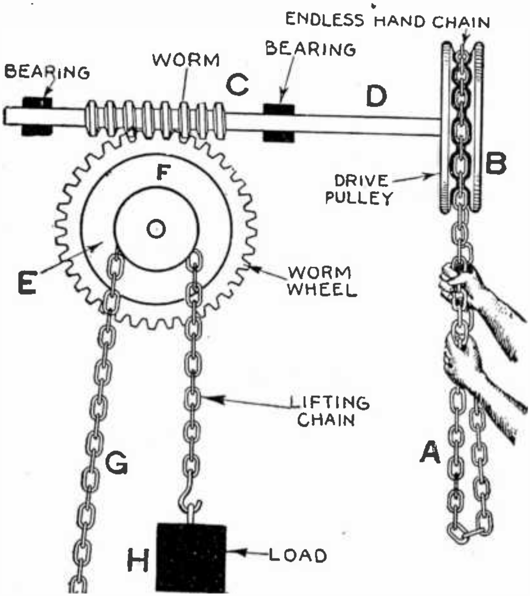


FIG. 6,848.—Elementary worm gear hoist. The hand chain A, is used for rotating the drive pulley B, which is connected to the worm by a shaft. The worm meshes with the worm wheel E, whose shaft is attached to a pulley over which passes the lifting chain G. The pulley F, has pockets for receiving the chain links so that the chain cannot slip in lifting the load H.

Tail sheave.—A pulley used in the "pull boat system" of logging.

Winch heads.—A short hoisting drum or spool having curved flanges, and attached to an extension of the drum shaft.

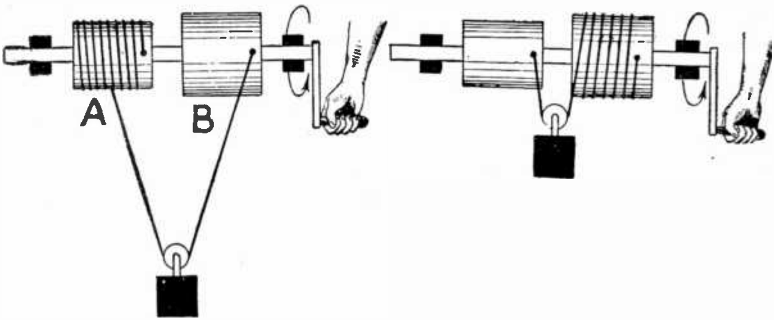
Classes of Hoists.—The great variety of hoisting work, calls for different kinds of engine designed to meet special conditions. They may be classified in several ways:

1. With respect to the power, as

   a. "Gas";
   b. Electric.

2. With respect to the transmission of power; as,

   a. Direct drive;
   b. Geared transmission.



FIGS. 6,849 and 6,850.—Chinese windlass illustrating the principle of the differential hoist. ***It consists of*** two drums, A and B, (one a little larger than the other) connected to a shaft and having the ends of a lifting cable attached to the drum as shown, so that in turning the crank the cable will simultaneously unwind on one drum and wind on the other. Fig. 6,849 shows the beginning of the lifting operation. As the crane is turned clockwise the cable winds on B, and unwinds on A, and since B, is larger in diameter, the length of cable between the two drums and load is gradually taken up, thus lifting the load. Evidently by making the difference in diameter of the two drums very small an extremely large leverage is obtained thus enabling very heavy weights to be lifted with little effort. The load will remain suspended at any point, *because the difference in the diameter of the two drums is too small to overbalance the friction of the parts*. Fig. 6,850 shows the end of the lifting operation.

3. With respect to the drum arrangement; as,

   a. Fixed drum;
   b. Loose drum;
   c. Single drum;
   d. Multi-drum;
   e. Cone drum.

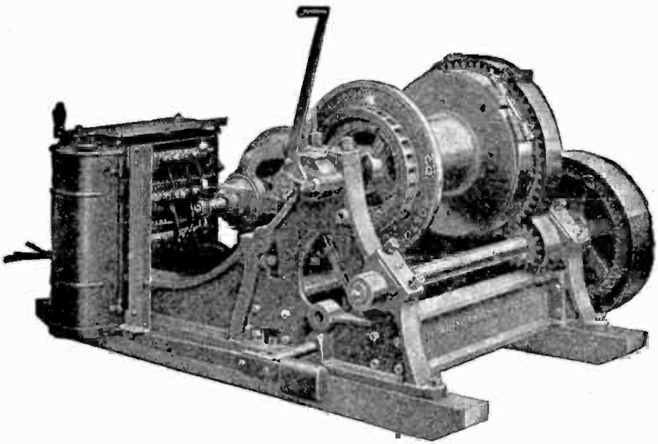


FIG. 6,851.—Mead-Morrison single drum *electric hoist.* This type is particularly adapted for hauling cars or hoisting elevators. It is found also on docks for hoisting and hauling of general cargo into warehouses, and in general building construction. It is equipped with slip ring motor and drum controller, but for many requirements the less expensive half high torque motor which has no controller is as well suited.

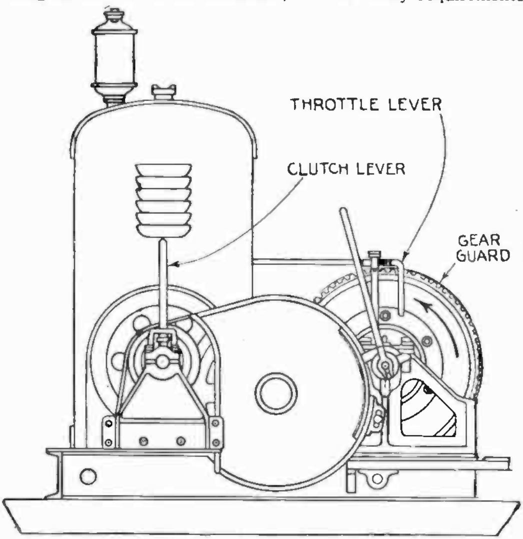


FIG. 6,852.—Novo gas engine driven hoist powered with four cylinder engine, radiator cooled. The engine has two fly-wheels, which approximates steam engine flexibility. With an engine equipped with two fly-wheels, when handling a concrete tower elevator, the engine may be throttled and the load will float to the proper stopping point without stalling the engine. This makes faster and more efficient hoisting.

4. With respect to the conditions of service; as,

   a. General service;
   b. Coal hoisting;
   c. Boom swinging,
      etc.

The Simple Hoist.—In its simplest form a hoist consists of a hoisting drum, having a friction brake and geared to a motor as in fig. 6,851 or to a gas engine, as in fig. 6,852, the assembly being mounted on one base.

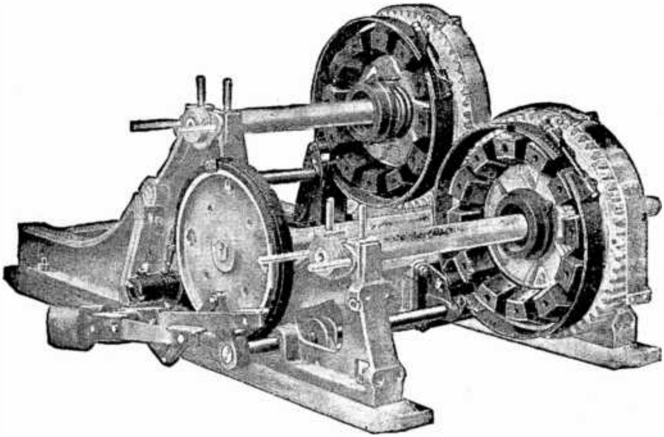


FIG. 6,853.—Mead-Morrison arrangement of frictions and brake for gasoline or electric hoists.

A friction brake is provided so that the drum may be prevented turning when desired. The power of the engine is applied in hoisting by means of a cable, fastened to the drum; the cable is wound upon the drum in hoisting the load, and unwound when it is lowered.

Drums.—Of the many types of drum there are two general classes: the *fixed*, and the *loose* drum. The fixed drum is found on some of the simpler machines designed for that class of work which requires only the operations of lifting or lowering, or where only single loads have to be handled.

The loose drum is the type mostly used and is so constructed

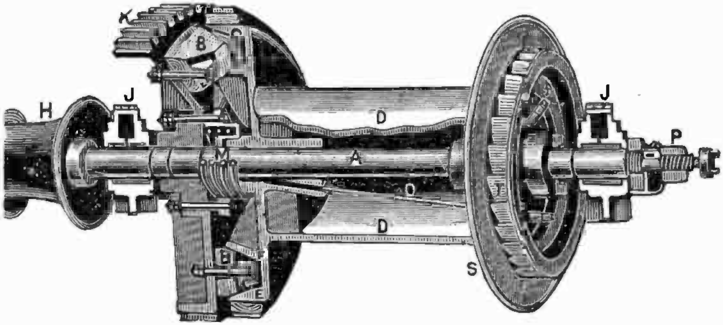


FIG. 6,854.—Sectional view of loose drum. The parts are: A, shaft; B, friction blocks; C, friction flange; D, drum; E and F, friction rings; H, winch head or spool; J, J, bearings; K, gear wheel; P, thrust screw; S, drum flange; T, ratchet teeth.

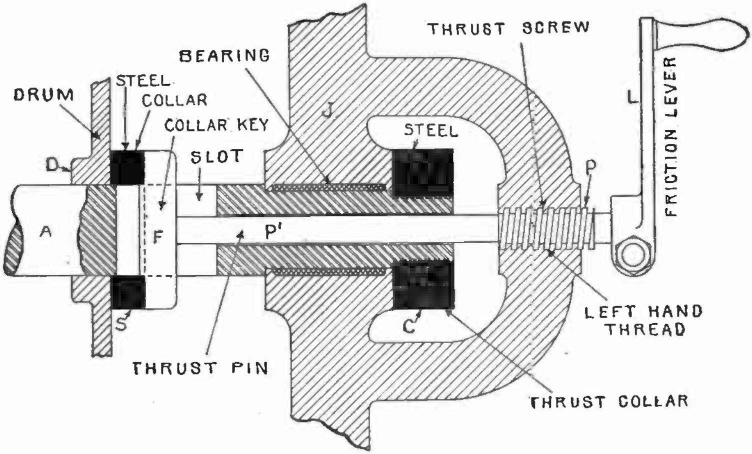
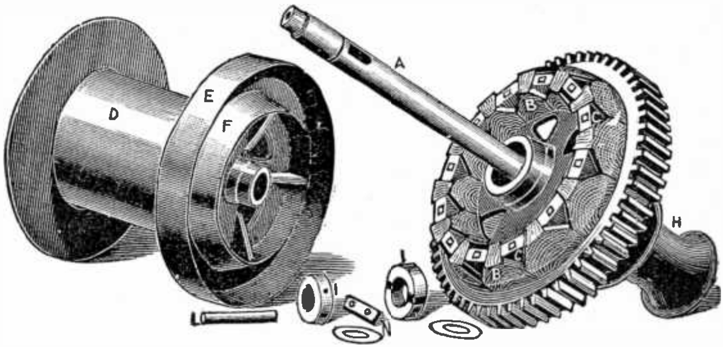


FIG. 6,855.—Sectional view of friction control on loose drum. When the friction lever is turned counter-clockwise, the left hand friction screw pushes the thrust pin to the left. The pin in turn pushes the collar key, collar, and drum in the same direction causing the latter to engage with the friction blocks.

that it may be thrown in, and out of engagement while the engine is in motion, by the action of *friction rings.*

Fig. 6,854 shows the principle of operation.

The drum D, is thrown into gear by a slight endwise movement on its shaft A, produced by turning a lever attached to the screw P, whose end is in contact with a hardened *thrust pin.* The action of this pin is best seen in the sectional view, fig. 6,855. When the engineer turns the friction lever toward him, the thrust screw, which has a left hand thread, pushes the thrust pin against a collar key, which works in a slot cut through the



FIGS. 6,856 to 6,862.—Loose drum and friction control before assembly. The parts are: A, shaft; B, friction blocks; C, block retainers; D, drum; E and F, friction rings forming a V groove on drum flange; H, winch head or spool; I, collar; J. thrust collar; L, thrust pin; N, washers.

shaft. The collar key, together with the collar, is, in turn, pushed against the drum, forcing it into contact with friction blocks to prevent any rotation on the shaft. These blocks consist of sections of hard wood B, bolted to the gear wheel K, which is keyed to the shaft. The adjacent flange on the drum has inclined rings E, F, which register with the bevel on the friction blocks, the endwise movement given the drum by turning the friction lever, bringing the rings into frictional contact with the blocks, thus preventing the drum turning on the shaft since the latter is keyed to the gear wheel K.

When the friction lever is turned clockwise to release the drum, the latter is pushed to the right out of engagement with the friction blocks by the spring M, allowing the drum to revolve freely on the shaft. The loose drum and parts are before being assembled shown in figs. 6,856 to 6,862.

Loose drums are usually fitted with band brakes in order to reduce the wear on the friction blocks. This is especially desirable for long descents, as in tall office building construction, the wear and heat generated being excessive.

Sometimes radial ribs are placed at the friction end of the drum to assist in dissipating the heat, by presenting additional surface for radiation, and inducing air currents.

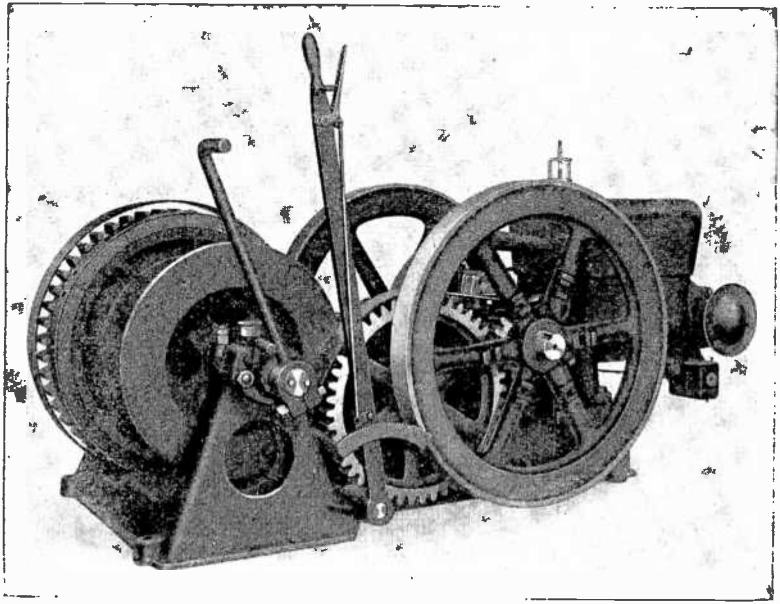


FIG. 6,863.—Fairbanks-Morse hopper cooled gas engine driven hoist. Ignition is by high tension magneto built in as a part of the engine itself and is mounted over the cam gear from which it is operated.

The pile driver illustrates a class of work in which the loose drum is most valuable. Instead of loosening the monkey from the rope and having to re-attach the two before the monkey can be lifted again, the rope remains permanently fastened, and the monkey, in falling, simply unwinds the rope, the drum revolving on the shaft in a reverse direction, and being again thrown into gear after the blow.

Foot Brakes.—When there is a winch head or spool, as H, fig. 6,854, it is necessary to have a band brake if the spool is to be used at the same time that the load is hanging on the drum. In fig. 6,864 is shown the usual type of brake which consists of a metal band lined with hard-wood segments, and embracing the external circumference of the drum flange.

The brake is operated by the foot, and, as shown, is of the differential type in which both ends of the band are pivoted to the rocker, but at different distances from the center of the brake shaft, so that the strain brought by the load held, tends to turn the rocker in the direction to tighten the brake. By crossing the ends of the band at the rocker, the rotation of the brake shaft is limited, so that the foot lever, when released, cannot be lifted by its counterweight above a fixed and convenient position.

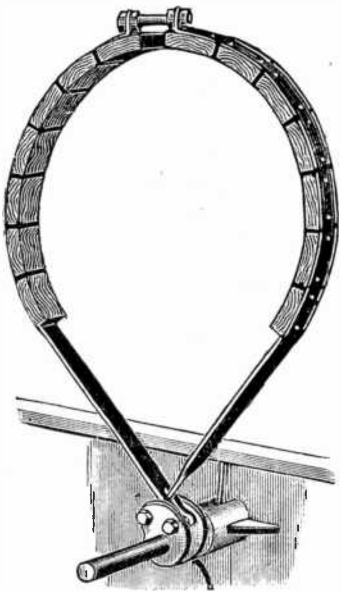


FIG. 6,864.—Band brake for holding the drum with load when disengaged from the friction. The metal band lined with hardwood segments tightly embraces the circumference of the drum when the brake lever is pressed down.

Double Drum Boom Swinging Hoist.—The multiplication of drums is a feature in the development of the hoisting engine, adapting it to service of a universal character, such as the working of a radial derrick where frequently several operations have to be performed at the same time. Fig. 6,865 illustrates a steam hoist adapted to this class of work.

The forward drum is for hoisting the load, and the other for raising the boom. Between the drums and winch heads are two spools for the derrick swinging ropes. With this arrangement, the operations of hoisting the load, raising and swinging the boom can go on simultaneously.

The winch heads are secured to the shaft by a sliding key having a sleeve upon which the swinging spools revolve.

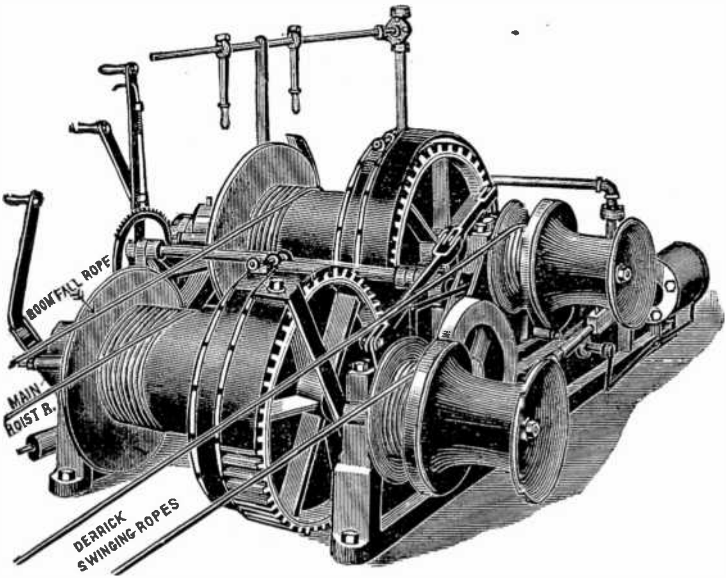


FIG. 6,865.—Double drum steam hoist with boom swinging gear for operating a radial derrick. The machine is so constructed that the operations of hoisting the load, raising and swinging the boom may go on simultaneously.

Friction adequate for the full power of the engine is used between the swinging spools and the winch heads. The frictional contact is produced by cams placed between the swinging drums and the frame of the engine; on the other side are anti-friction collars to take up the thrust.

The operating cams are connected by links to the end of a lever, which is carried on a shaft extending across to the side where the engineer stands, and where the vertical detent lever for operating the swinging device is placed.

In operation, a rope is wound on the bull ring of the derrick and secured to the same in the center, as shown in fig. 6,866. Each of the two ends is fastened to one of the two swinging spools, enough rope being wound on each to give the required amount of motion to the bull wheel. By throwing the lever forward, it engages the friction clutch on that winch, causing it to rotate and wind in the rope, which turns the boom in one direction, the other winch meanwhile paying out the rope.

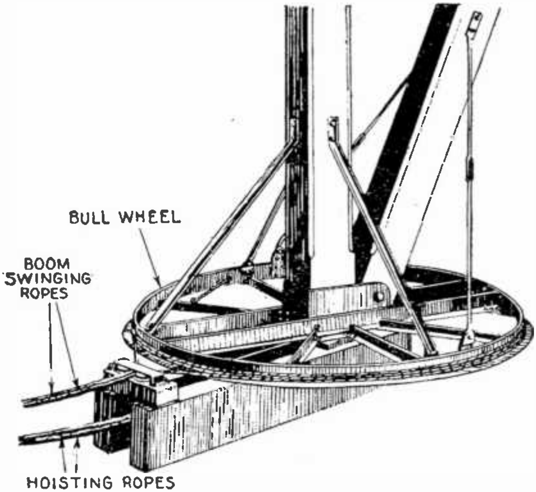


Fig. 6,866.—Base of a radial derrick, showing the bull wheel and boom swinging ropes, also the ropes for hoisting and raising the boom.

The construction of the cams permits this, as the same movement which engages one friction, disengages the other. By throwing the lever backward, the friction of the rear spool is engaged, and the forward spool released. Thus, the boom can be turned in either direction.

The cams operating the frictions are so constructed that when the operating lever is in its central position, there is enough frictional contact in the swinging spools to keep the ropes taut; therefore, when one spool is winding in the swinging rope, the other has sufficient friction to prevent the rope, which is paying out, overrunning.

The brake and friction levers for the drums are shown in figs. 6,867 and 6,868.

The friction lever of the rear drum, as shown in fig. 6,867, has an extension piece I with a pin, which moves upon the curved surface of an oscillating lever C. The latter has a notch at the lower end, engaging

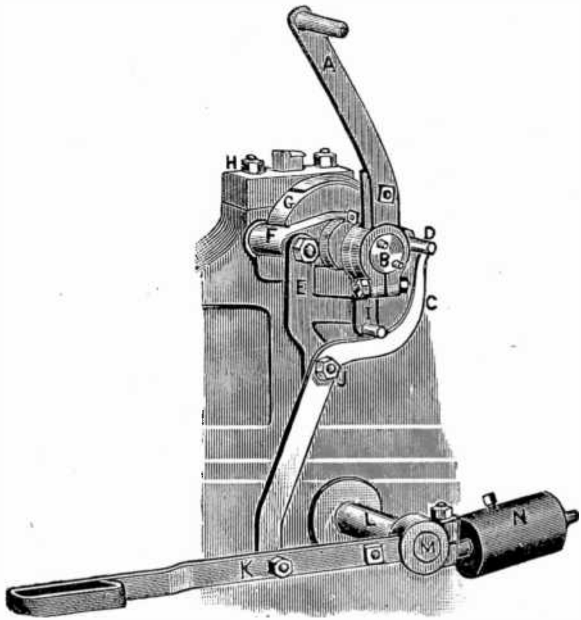


FIG. 6,867.—Lidgerwood brake and friction levers with safety attachment. When the friction lever A, is moved to throw the drum into gear, the pin I, on a projection of the friction lever presses against the curved part of the oscillating lever C, and releases the foot brake.

with a pin extending from the side of the foot brake lever. When the friction lever is moved, for the purpose of throwing the drum into gear, the pin on the end of the friction lever presses against the curved part of the oscillating lever and releases the foot brake.

The friction lever of the front drum, as shown in fig. 6,868, is arranged with a thumb latch and detent engaging with serrated teeth in a quadrant by which the lever is held in any desired position. The drum is thus securely locked, so that hoisting may go on without any further attention to this lever.

When the lever is moved back, the engineer places his foot on the foot brake lever for a moment and the oscillating lever drops back into its original position, engaging with the pin on the foot brake lever, and thereby locking the brake on the drum. It will be seen that this drum, with the boom hanging from it, is locked fast by the brake, the pawl being usually applied as an additional safeguard.

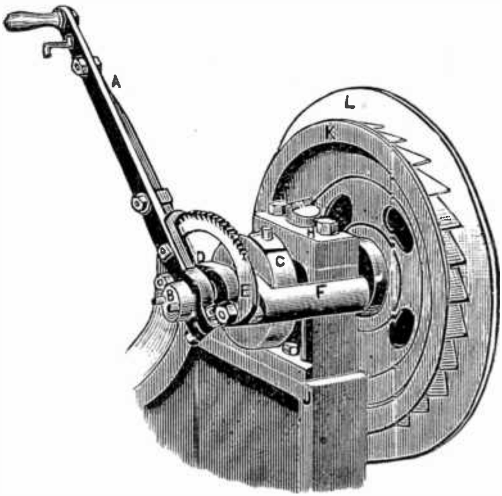


FIG. 6,868.—Lidgerwood friction lever on hoisting drum; a latch and quadrant hold the drum nny position.

Directions for Operating.—The engineer first throws in the front friction drum lever sufficiently to hoist the load. He is then free to handle the boom, either raising or lowering it with the rear drum.

When lowering the boom, he should do it both by the friction lever, and a slight pressure on the foot brake. This prevents the oscillating lever falling into place and locking the brake; it also allows control over the lowering speed of the boom, and as soon as it is lowered far enough.

full pressure is put on the brake lever, and the friction lever thrown out, when the oscillating lever falls into place and locks the brake fast. This use of the two levers in combination for lowering the boom provides against the possibility of the foot slipping off the foot brake.

It is important that the engineer keep the safety lever locked to the foot brake, and also the pawl applied at all times when the boom drum is not in use. The only exception to this rule is when working with a short boom and the time required to throw in the pawl is too valuable to lose. In such cases, the safety lever locked to the foot brake performs all that is required of the pawl and ratchet.

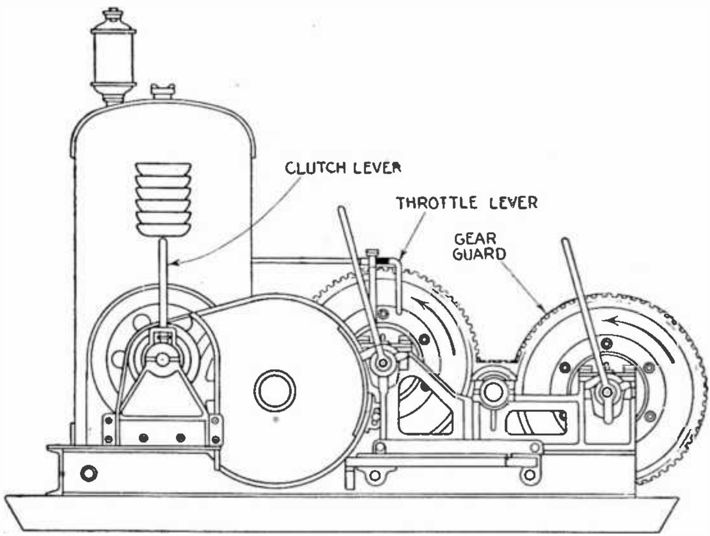


FIG. 6,869.—Novo double drum gas engine hoist powered with four cylinder radiator cooled engine. It will handle two large material elevators. Some contractors have this hoist fitted with an 18 in. or 22 in. diameter drum to handle concrete tower bucket with high speed and a standard drum to handle "Chicago" derrick or miscellaneous steel or platform elevators.

The use of the safety lever locked to the foot brake is desirable with a long springy boom, in chaining or dogging rock after a blast, at which time it may not be known whether the rock, which it is intended to hoist, is free.

The effect of applying the strain for hoisting the rock is to spring the boom, and if the dogs fly loose, or the chain break, the boom springs back to its normal position, slackening for an instant the boom fall rope, which may throw out the pawl causing the boom to fall.

Hoisting for Deep Mines.—When mining is to be done at great depths, the problem of hoisting the ore becomes more difficult than that met with in ordinary mines. For instance, the variable dead weight of the rope must be taken into account, that is, when the cage is at the bottom, not only is its weight, and that of the one to be hoisted, but also the full weight of the rope, which diminishes as the cage ascends.

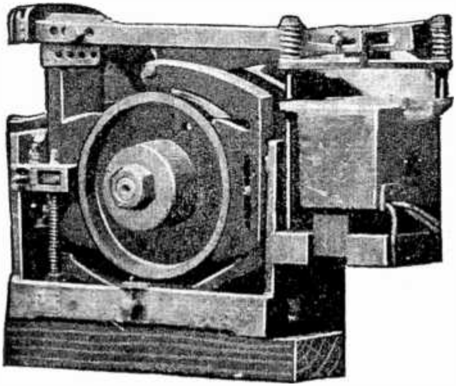


FIG. 6,870.—Novo automatic set solenoid brake.

The rope on the descending side becomes heavier as the cage goes down, with the result that it takes a great effort for the engine to start the cage or skip from the bottom, while as the ascending cage nears the top, the descending cage and rope may even more than balance the total weight of the former, so that the engine has no work to do during that period. This variable load, of course, results in poor economy, and prevents the use of compound engines. The difficulty is overcome by means of a *tail rope* of the same size and weight per foot as the hoisting rope.

The two ends of the tail rope are fastened to the bottoms of the two skips and at the bottom of the shaft the rope passes around a sheave placed in guides, or on a carriage, according to circumstances. This arrangement balances the hoisting rope, and the load on the engine is, therefore, at all times only the weight of the ore that is being hoisted. This counterbalancing is desirable, aside from the smoothness of operating, because the engine can be better proportioned for the work, resulting in greater economy.

Cone Drum Hoisting Engines.—A development of the single cylindrical drum with two ropes is the double cone drum as shown in fig. 6,871; this is another way of counterbalancing the variable weight of the hoisting rope. The theory of this

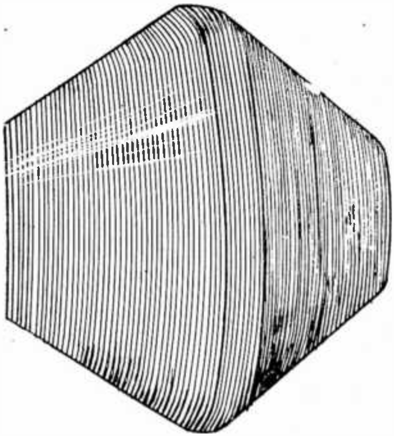


FIG. 6,871.—Allis-Chalmers cone drum. *A development* of the single cylindrical drum with two ropes is the double cone drum. This is another way of counter balancing the variable weight of the hoisting rope. The theory of this construction is that as the weight of the rope increases, the radius at which it acts correspondingly decreases, thus equalizing the work of the engine.

construction is that as the weight of the rope increases, the radius at which it acts correspondingly decreases, thus equalizing the work of the engine.

The dimensions of the drum must be proportioned for each particular case, and if used under different circumstances, the drum would fail to fulfill the purpose of its design.

For very deep hoisting in order to balance the great weight of rope, the central portion of the drum would become inconveniently large in diameter, therefore this portion is made cylindrical, and is used by both ropes. This arrangement, while it shortens the drum, makes it impossible to balance the weight of rope.

Reel Hoisting Engines.—The reel hoist is often used where it is not the intention to hoist always in balance, and where no tail rope or compensating device such as a conical drum can be used.

The greatest weight to be lifted by any hoist is when the loaded cage is at the bottom of the shaft, consequently all the rope is off the drum or reel. At this point, however, the reel begins to wind on its shortest radius. As the rope winds on the reel, the total load decreases while the leverage of the rope on the reel increases, thus keeping the load on the engine nearly uniform while lifting one cage unbalanced.

Moreover, the rope always leads straight to the head sheave instead of at a considerable angle as occurs when winding on a drum. This makes a compact arrangement which is an advantage in some cases.

Reel hoists are used mostly in the western part of America. As a rule, hoisting is done there from different levels, one car often being hoisted from one level while the car on the other deck may come from another level; under these conditions the hoisting cannot be done in balance.

Capacity of Hoisting Engines.—The horse power required to raise a load at a given speed is equal to

$$\frac{\textit{gross weight in lbs.} \times \textit{speed in feet per minute}}{33{,}000}$$

To this there should be added from 25 to 50 per cent for friction, contingencies, etc. The gross weight includes the weight of the cage, load, and rope. In a shaft with two cages balancing each thus, the net load is taken.

Limit of Depth in Hoisting.—Taking the weight of a hoisting rope, 1⅛ inches in diameter, at two pounds per foot, and its breaking strength at 84,000 lbs., it should, theoretically, sustain itself until 42,000 feet long before breaking from its own weight. But taking the usual factor of safety of 7, then the safe working length of such a rope would be only

$$42{,}000 \div 7 = 6{,}000 \text{ feet.}$$

If now a weight of three tons, which is equivalent to that of a cage of moderate capacity with its loaded cars, be hung

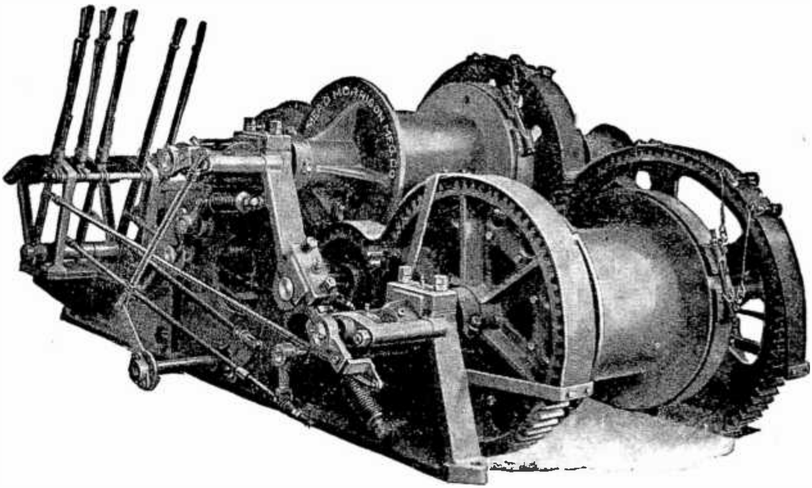


FIG. 6,872.—Mead-Morrison slack line hoist designed for slack line excavating. The motor is a continuous running, specially wound type that builds up torque as the load increases. Experience has demonstrated its superiority over the two speed motor in common use, both in efficiency and economy of operation. This hoist has only five levers for complete operation.

to the rope the maximum length at which such a rope could be used with the factor of safety of 7, is

$$6{,}000 - \frac{6{,}000}{2} = 3{,}000 \text{ feet.}$$

The limit may be considerably increased, by using: 1, special steel rope of greater strength; 2, a smaller factor of safety, and 3, taper ropes.

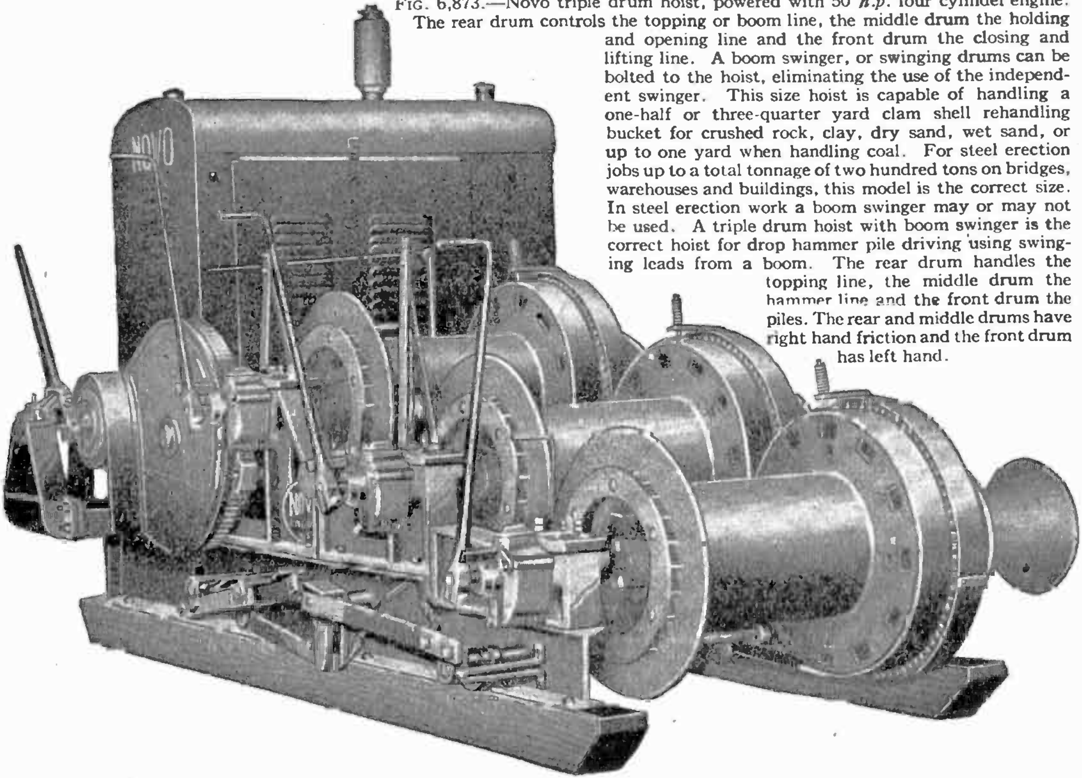


FIG. 6,873.—Novo triple drum hoist, powered with 50 *h.p.* four cylinder engine. The rear drum controls the topping or boom line, the middle drum the holding and opening line and the front drum the closing and lifting line. A boom swinger, or swinging drums can be bolted to the hoist, eliminating the use of the independent swinger. This size hoist is capable of handling a one-half or three-quarter yard clam shell rehandling bucket for crushed rock, clay, dry sand, wet sand, or up to one yard when handling coal. For steel erection jobs up to a total tonnage of two hundred tons on bridges, warehouses and buildings, this model is the correct size. In steel erection work a boom swinger may or may not be used. A triple drum hoist with boom swinger is the correct hoist for drop hammer pile driving using swinging leads from a boom. The rear drum handles the topping line, the middle drum the hammer line and the front drum the piles. The rear and middle drums have right hand friction and the front drum has left hand.

TEST QUESTIONS

1. *Define the various terms relating to hoisting machines.*
2. *Make sketch of an elementary worm gear hoist.*
3. *What are the various classes of hoists?*
4. *What is the construction of a Chinese windlass?*
5. *Of what does a simple hoist consist?*
6. *Name two types of drum and give construction of each.*
7. *What type drum is mostly used?*
8. *When is it necessary to have a foot brake?*
9. *Describe the construction and operation of the foot brake.*
10. *How is a radial derrick constructed?*
11. *What is the application of a two drum hoist?*
12. *Describe at length the operation of a hoist.*
13. *What are the requirements for deep mine hoisting?*
14. *Explain the operation of cone drum hoist.*
15. *Where are reel hoists used?*
16. *Give the formula for capacity of hoisting engines.*
17. *What is the limit of depth in hoisting?*
18. *How may the depth limit be increased?*

CHAPTER 160

Electric Cranes

Any appliance for lifting and moving loads is far superior to a gang of laborers, especially so in the case of very heavy loads.

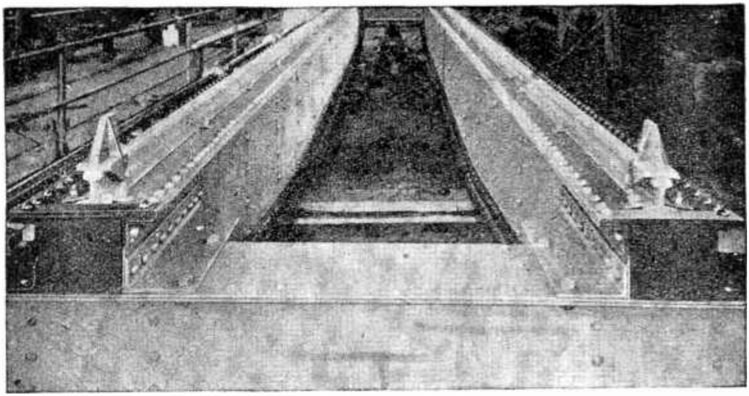


FIG. 6,874.—*Euclid crane construction 1. Double web box girder bridges.* The girders are reinforced by means of channel diaphragms at close intervals. The end trucks are of the box type, made up of heavy channels and plates. The illustration shows the way the girders are notched out and rest upon the top of the end trucks.

By definition, a crane is *a machine for lifting, lowering and moving a load in a horizontal direction*, as distinguished from a hoist which simply lifts and lowers a load.

The numerous and diverse conditions of service require a multiplicity of types, and accordingly cranes may be classified:

1. With respect to the character of the horizontal motion, as

a. Rotary
- swinging cranes
- jib cranes
- column cranes
- pillar cranes
- pillar jib cranes
- derrick cranes
- walking cranes
- locomotive cranes

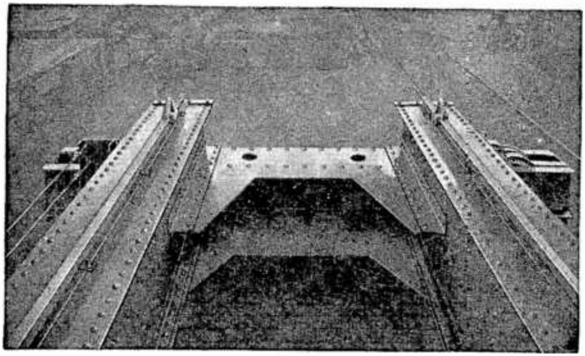


FIG. 6,875.—*Euclid crane construction 2. Gusset plates.* These are used to tie the girders to the end trucks, making it impossible for the crane to weave and get out of square on the runway.

b. Rectilinear
- bridge cranes
- tram cranes
- traveling cranes
- gantry cranes

c. Combination rotary and rectilinear.

In addition to these, there are some miscellaneous types known as

1. Sheer legs;
2. Transporters;
3. Telphers
   - cableways
   - mono-rail systems

The following definitions of the various types show the inherent features of each:

Bridge cranes.—Having a fixed bridge spanning an opening and a trolley moving across the bridge.

Column cranes.—Identical with the jib cranes, but rotating around a fixed column (which usually supports a floor above).

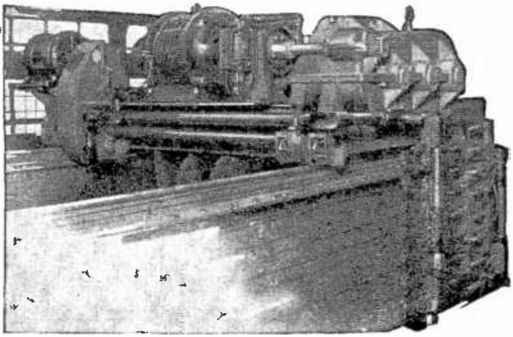


FIG. 6,876.—*Euclid crane construction 3. Heavy duty mill type trolley.* The two side housings are iron castings. The separator girt is made up of structural steel and steel castings.

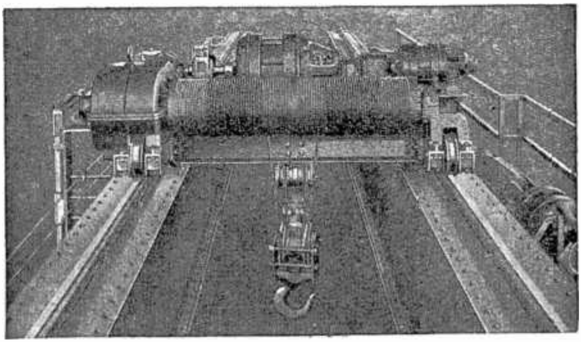


FIG. 6,877.—*Euclid crane construction 4. Another view of mill type trolley showing track wheel bearings.* The drum is scored right and left hand, so that the load is always equally distributed on both girders. This cut also shows the separator girt connecting the two side frames.

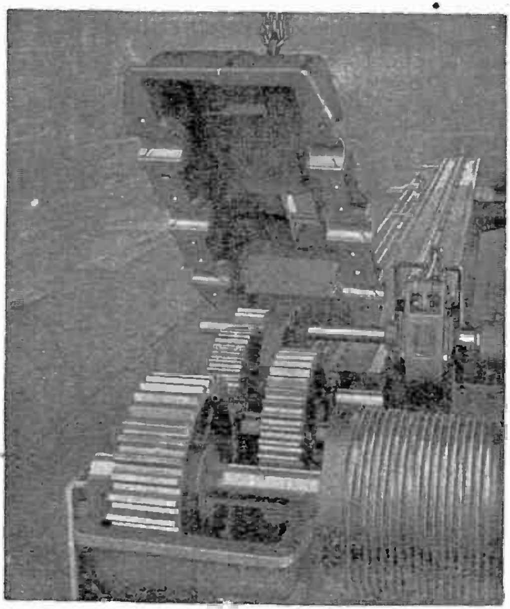


FIG. 6,878.—*Euclid crane construction 5. Hoisting gear train.* Wide face coarse pitch gears are used. The illustration also shows the shoe type electric brake mounted on the motor shaft and the Weston type mechanical load brake on the intermediate shaft.

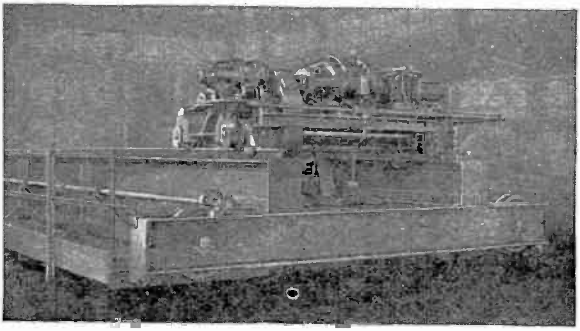


FIG. 6,879.—*Euclid crane construction 6. End truck construction and driving side of the crane trolle .* In design the line shaft bearings are closely spaced.

Derrick cranes.—Identical with jib cranes, except that the head of the mast is held in position by guy rods or stiff legs, instead of by attachment to a roof or ceiling.

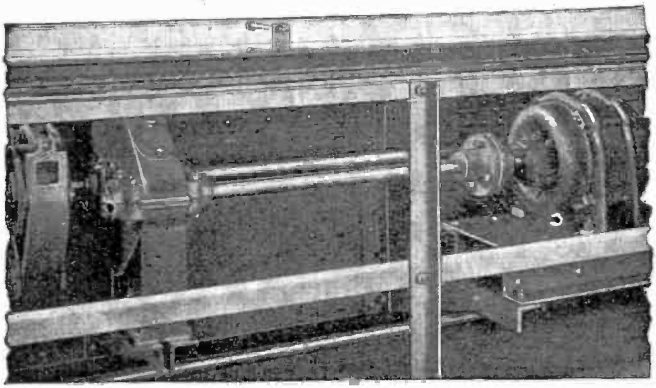


FIG. 6,880.—*Euclid crane construction 7. Bridge drive mechanism.* The illustration also shows the motor mounting between the bridge motor and the gear housing.

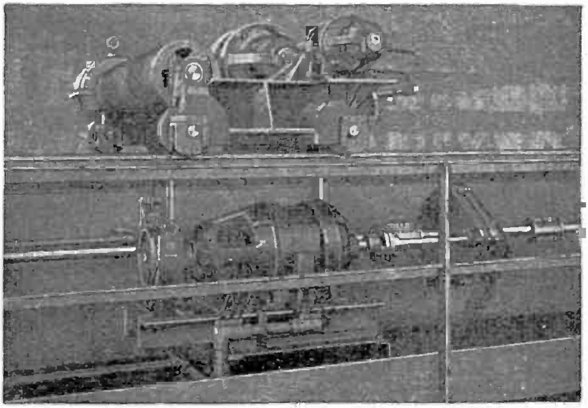
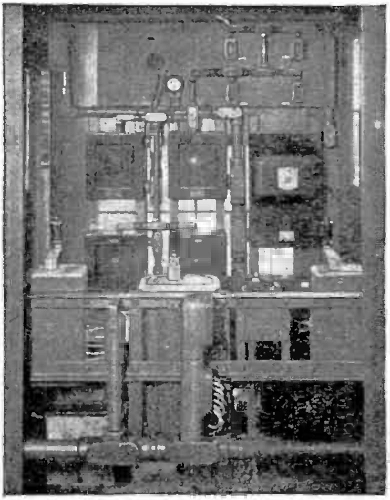


FIG. 6,881.—*Euclid crane construction 8. Side view of trolley, showing type of bridge drive gear case sometimes used.* The drive is oil tight. The shoe type bridge brake is operated by means of a foot pedal in the operator's cab. This brake is mounted on an extension of the motor shaft.



Gantry cranes.—The same as a traveling crane except that the bridge member is supported on structural legs of suitable height which are provided with wheels and suitable gearing, so that the crane may be propelled bodily along the tracks which are on the ground.

Jib cranes.—Having rotation and a trolley traveling on the jib.

Locomotive cranes.—Consisting of a pillar crane mounted on a truck, and provided with power capable of propelling and rotating the crane, and of hoisting and lowering the load.

FIG. 6,882.—***Euclid crane construction 9.*** *Interior view of crane cab.* All instruments are enclosed in metal cabinets and all the wiring in metal conduit with porcelain outlets. A fully enclosed safety type main line switch is provided, arranged so it can be padlocked in open position to insure safety of men working on crane.

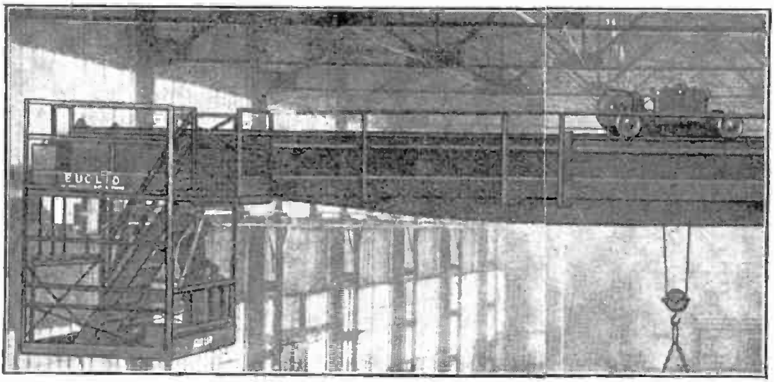


FIG. 6,883.—***Euclid crane construction 10. Box girder type crane*** having moderate duty trolleys in place of the mill type trolley. The trolley is shown in detail in figs. 6,884 and 6,885.

Pillar cranes.—Having rotation only, the pillar or column being supported entirely from the foundation.

Pillar jib cranes.—Identical with the last, except in having a jib and trolley motion.

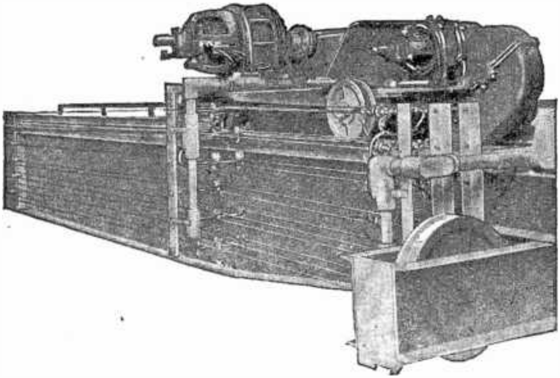


FIG. 6,884 —***Euclid crane construction 11.*** *Moderate duty trolley.* All the hoist mechanism is located in a one piece housing. This housing rests upon two heavy saddle type steel castings. This entire trolley is machined to jigs and all parts are interchangeable. It is used regularly up to 5 tons capacity and intermittently up to 15 tons.

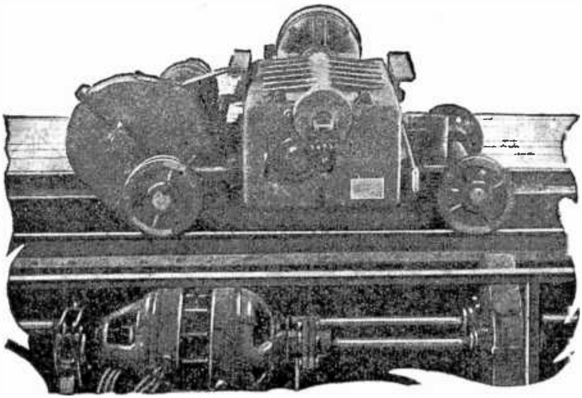


FIG. 6,885.—***Euclid crane construction 12.*** *Another view of moderate duty trolley.* The illustration also shows the disc type electric brake that is located on the end of the motor shaft.

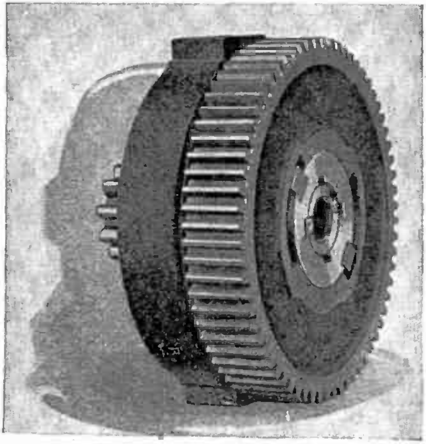


FIG. 6,886.—*Euclid crane construction 13. Multiple disc automatic load brake.* The center plate is stationary. The brake is fully released during the hoisting movement and automatically sets when the hoist motor comes to a stop. The load can be lowered only by reversing the motor.

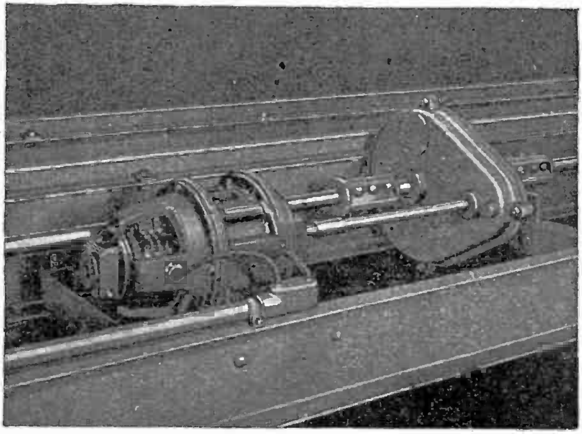


FIG. 6,887.—*Euclid crane construction 14. Bridge drive mechanism* used on I-beam girder cranes. A channel and plate structure, extending from one of the I-beam girders to the outrigger channel, forms a rigid and substantial support for the bridge drive motor. The driving pinion and gear are enclosed in oil tight housing, shown revolving in an oil bath.

Rotary bridge cranes.—Combining rotary and rectilinear movements and consisting of a bridge pivoted at one end to a central pier or post, and supported at the other end on a circular track, provided with a trolley moving transversely on the bridge.

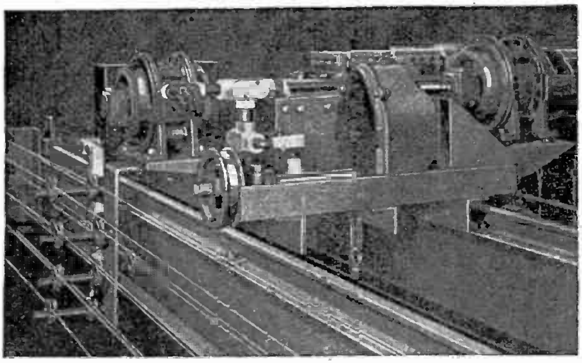


FIG. 6,888.—***Euclid crane construction 15.*** *Trolley drive mechanism* used on small capacity cranes. The gear train for the trolley drive is housed in one oil tight compartment, revolving in an oil bath. The illustration also shows the method of mounting the controllers and rheostats on the trolley when the service conditions make such an arrangement desirable.

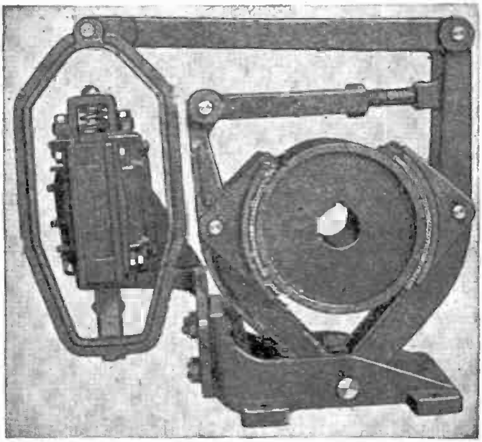
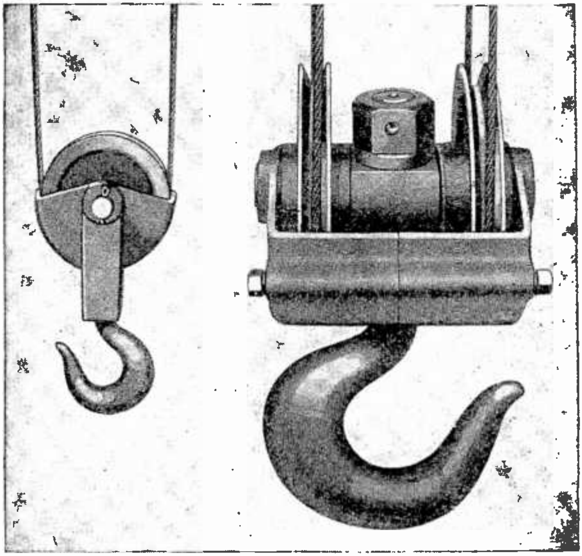


FIG. 6,889.—***Euclid crane construction 16.*** *Electric brake.*

Swinging cranes.—Having rotation, but no trolley motion.

Tram cranes.—Consisting of a truck, or short bridge traveling longitudinally on overhead rails, and without trolley motion.

Traveling cranes.—Consisting of a bridge moving longitudinally on overhead tracks, and a trolley moving transversely on the bridge.



FIGS. 6,890 and 6,891.—*Euclid crane construction 17. Load block.* On the smaller sizes of cranes, the load block consists of a steel casting, bored for the sheave pin. The load hook is carried on a heavy lug formed in the base of the steel housing, In the larger sizes the sheaves are mounted on a steel trunnion, which is bored at the center for the shank of the hook. The entire load is thus carried on the trunnion, the hook block casing serving only as a housing for the sheaves. All lifting hooks are steel forgings.

Walking cranes.—Consisting of a pillar or jib crane mounted on wheels and arranged to travel longitudinally upon one or more rails.

Essentials of Rotary Cranes.—In this type of crane, the construction is such as will permit the load to be lifted, lowered, and moved radially. An example of rotary crane is shown in fig. 6,892, which illustrates the essential features of a locomotive jib crane.

The area served by a locomotive jib crane is equal to *twice the maximum radius of the jib*, and a length depending on the length of track laid.

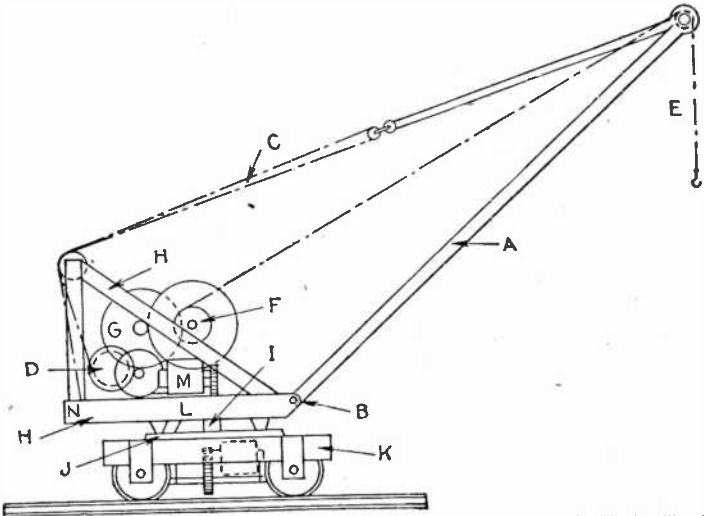


FIG. 6,892.—Electric locomotive jib crane. ***The essential parts are:*** A, jib; B, jib pivot; C, rope gear serving as a brace for jib, and which controls the radial position of jib D, jib shifting drum; E, hoisting rope leading from hook; F, hoisting drum; G, hoisting motor; H, framing; I, pin; J. turning or slewing wheel; K, truck; L. pinion; M, turning and propelling motor. As shown in the figure, the hook, which engages the load, hangs from the end of the jib A, which is supported by the piece B, and rope C, which leads to the drum D. By winding in or paying out the rope C, the radius of the jib in the horizontal plane can be increased or diminished. The rope for hoisting the load is brought over a pulley at the head of the jib and led to the drum F. Drums D, and F, are usually arranged to be driven from one motor G, clutches being so arranged that when the motor is in gear with the one drum, it is out of gear with the other. The jib and hoisting gear are carried by the framing H, which turns upon the pin I, the turning or slewing being accomplished by means of the wheel J, which is secured to the platform of the truck K, and pinion L, (carried by bearings in the framing H), which is driven by the motor M. It is usual for the framing to be capable of making a complete circle. The motor M, is also used to drive the truck along the rails. A vertical shaft driven from this motor passes through the pin I, and drives one or both of the axles by means of bevel gear. Clutches are provided so that the motor M, may be used for slewing or traveling. The load is balanced by the weight N. A foot plate for the operator is provided on the framing just in front of the balance weight, and the controllers and clutch levers are within easy reach.

The effective radius of the jib is equal to its projection on the horizontal plane passing through the pivot on the lower end of the jib.

The most economical position of the inclined brace in a jib crane is *that position in which the inclined brace intersects the jib at a distance from the mast equal to 4/5 of the effective radius of the jib.*

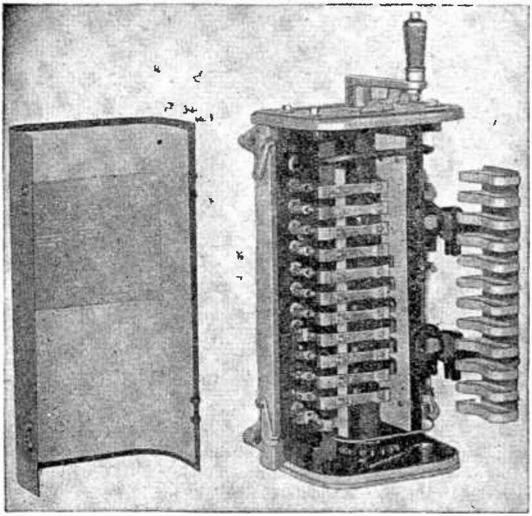


FIG. 6,893 and 6,894.—***Euclid crane construction 18. Controller.*** It is of the drum type with fingers of the non-stubbing type. Both finger tips and contact segments are reversible. *D.c.* controllers are provided with powerful blow out coils to prevent injurious arcing.

Essentials of Rectilinear Cranes.—This form of crane differs from the preceding type in that the load is moved linearly instead of radially. The essential features of rectilinear cranes are shown in fig. 6,895, which illustrates a rectilinear crane of the traveling type.

In construction, a pair of cross girders AA, known as the bridge, are supported on the end carriages BB. The wheels of the end carriages run on rails mounted on elevated structures or *gantries* CC. The purpose of the crane is to lift, transport, and deposit loads anywhere within an area a little less than the width between the gantries and of a length depending on the length of the gantries. Rails are laid on the cross girders AA, and a crab or trolley runs on these rails.

The trolley has two motions, each driven by its own motor.

The hoisting motion, for lifting and lowering the load, consists of the drum D, driven through suitable gearing by the motor E. To traverse the crab along the cross girders, the motor F, drives one pair of wheels through

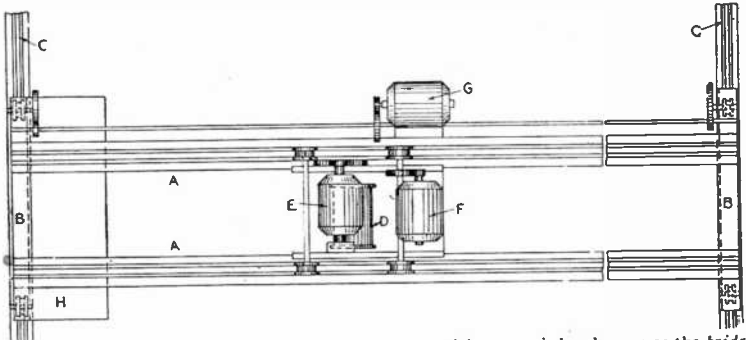


FIG. 6,895.—Electric traveling crane. *The parts are:* AA, cross girders known as the *bridge*; BB, end carriages; CC, elevated track structure or *gantries*; D, hoisting drum; E, hoisting motor; F, transverse propelling motor; G, longitudinal propelling motor; H, cage or operator's platform.

gearing. For the purpose of traveling the crane along the gantry, the motor G, is mounted at the center of one of the cross girders, and from each end of the motor, a shaft is led to drive one wheel in each of the end carriages. The traveling motor is mounted at the center of the cross girder to obtain an equal amount of twist in both parts of the shafting so as to avoid cross wind.

Essentials of Combined Rotary and Rectilinear Cranes.—A modification of the traveling crane, which combines the functions of the two classes, rotary and rectilinear, consists in pivoting one end of the bridge of a traveling crane and supporting the other end on a circular gantry as shown in fig. 6,896.

The illustration shows that most of the mechanism is identical with that of the traveling crane.

Essentials of Transporters.—By definition a transporter is *a lifting and transporting machine designed to carry loads between two fixed points.* It is used chiefly for handling comparatively light loads at quick speeds and employed largely for the conveyance of materials such as coal in bulk. For the latter service it is provided with an automatic grab instead of a hook. Fig. 6,897 shows the essential features.

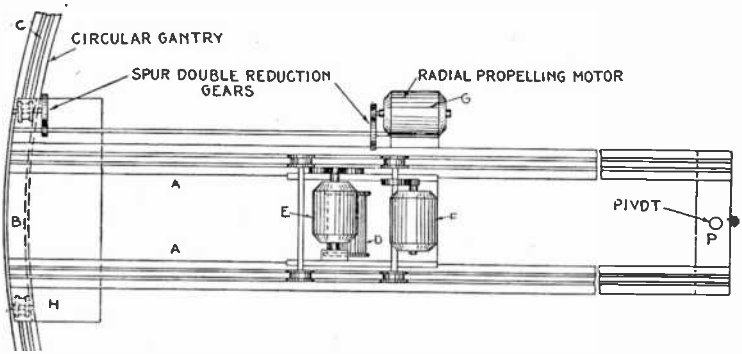


FIG. 6,896.—Electric combined rotary and rectilinear crane. *In construction* most of the parts are identical with those of fig. 6,895, and the letters on these parts are the same for each figure. This type differs from fig. 6,895, in the replacement of one gantry by a pivot P, and the other straight gantry by a circular gantry which may be either an arc or a complete circle as desired. One end of the bridge is pivoted at P, and at the other end, a section of the circular gantry is shown. The circular gantry may continue all the way around or only for a short arc, as may be desired. The figure clearly shows that the rotary motion is obtained by operating motor G, and the rectilinear motion, by motor F, while hoisting and lowering is effected by motor E.

A transporter requires from ½ to 1 minute to perform a complete cycle The weight of a grab load is from 1 to 1½ tons.

Crane Motors.—These are designed *for severe intermittent varying speed service.*

Such conditions of operation require very rugged construction in order to insure maximum reliability and minimum operating expense. The design should be such that all parts are readily accessible to permit the substitution of spare parts, with very little delay, in case of accident. The multiplicity of accompanying cuts illustrate very fully the characteristic features of crane motors.

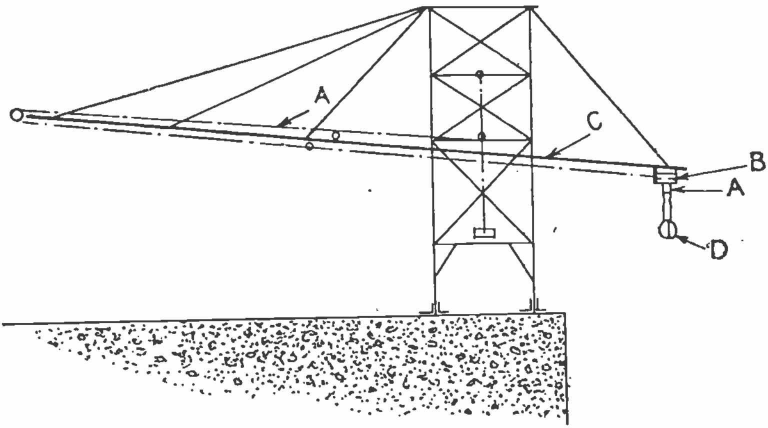


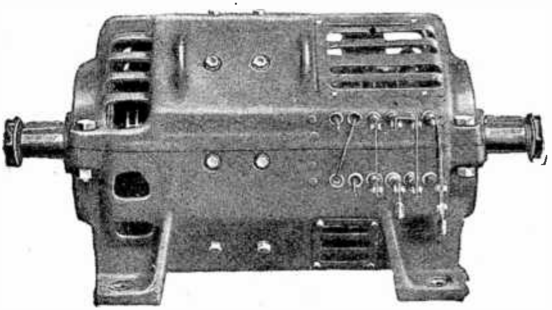
FIG. 6,897.—Electric transporter. ***The parts are:*** A, load rope; B, carriage; C, beam; D, grab. ***In operation,*** the grab being full, the electrically driven drum winds in the load rope A. The carriage B, being held by a trigger at the bottom end of the beam C, the winding in of the rope lifts the grab. When it is heaved right up to the carriage, it locks itself to it, and at the same time lets go the trigger. The carriage is pulled along the beam, but as the rope is now single purchase, the carriage is pulled along at double the speed at which the load was hoisted. On arriving at the top end, the carriage is held by a trigge and the grab is freed from the carriage. The motor is now reversed, and the grab, after being lowered a given distance, discharges its contents. The motor is again reversed, thus hoisting the grab up to the carriage, to which it locks itself and frees the trigger. On reversing the motor, the carriage runs down the beam, and at the botton end is caught by the trigger, while the grab is released and continues to run down till it plunges into the material, thus completing the cycle.

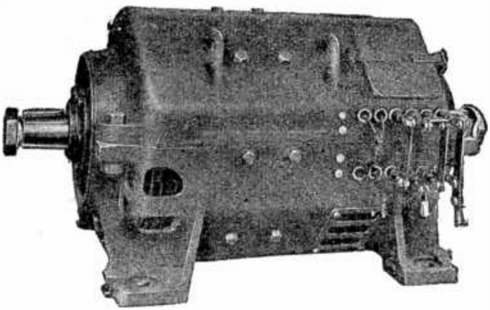
Power Required to Drive Cranes.—The power required to drive the different parts of cranes is determined *by allowing a certain friction percentage over the power required to move the dead load.*

On hoist motions 33⅓% is allowed for friction of the moving parts, thus giving a motor of ⅓ greater capacity than if friction were neglected.

For bridge and trolley motions, a journal friction of the track wheel axles of 10% of the total weight of the crane and load is allowed. There is then added an allowance of 33⅓% of the horse power required to drive the crane and load plus the track wheel axle friction, to cover friction of the gearing.

In selecting motors, the most important consideration *is the maximum starting torque which the motor can exert.*





FIGS. 6,898 and 6,899.—*General Electric crane d.c. motors 1. For main hoist.* Series wound, ventilated (fig. 6,898) or protected type (fig. 6,899) mill motors are used, having shunt wound spring set, shoe type, solenoid brakes, if solenoid brakes be needed. These types of motors are necessary on account of their ability to dissipate heat, but the motor should be protected from weather by a simple, sheet iron house, which provides for ventilation. ***Rack motion:*** Series wound, ventilated or protected type mill motors are used. They should be protected from weather in the same manner as hoist motors. Shunt wound, shoe type, spring set brakes for motor mounting are used in most cases. Automatic magnetic control, arranged either for plugging or dynamic braking for retarding the trolley, is used.

With alternating current motors, this is less than with direct current motors, requiring a larger motor, particularly on the bridge and trolley motions which require the greatest starting torque.

Automatic Electro-magnetic Brakes.—It is customary to fit the hoisting motion with an electro-magnetic brake. This may

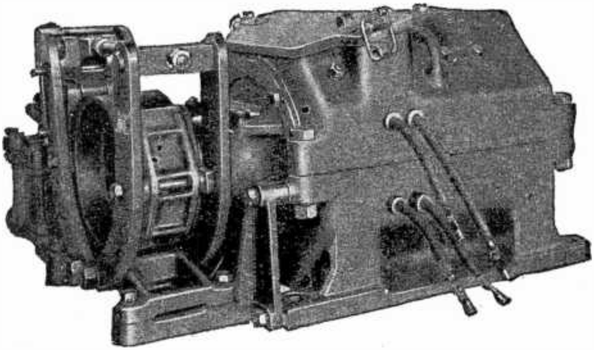


FIG. 6,900.—*General Electric crane d.c. motors 2. For boom hoist.* Series wound, totally enclosed, crane type motors with shoe type, series wound, spring set solenoid brakes and dynamic braking drum controller with low speed, heavy duty resistors are used.

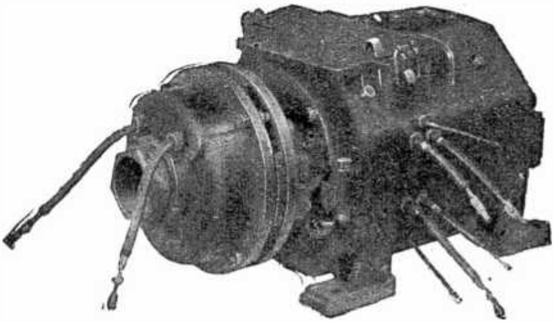


FIG. 6,901.—*General Electric crane d.c. motors 3. For bridge propelling.* Series wound, totally enclosed, weatherproof, crane type motors are used, equipped with shunt wound, weatherproof solenoid brakes of either the disc type or shoe type. The brakes are oversize in order to provide high torque for holding in a wind storm. Drum type controllers, suitable for either one or two motors, are used. These controllers have dynamic braking, slow down and creeping speed points to provide the maximum safety when propelling in a wind storm, and the ability to stop smoothly. This motor has the disc type brake.

consist of a band brake which is normally kept on by a spring or weight and released by an ironclad solenoid, or it may be a disc brake in which the discs are normally pressed together by a spring, an electro-magnet being provided to pull back the pressure plate and release the discs.

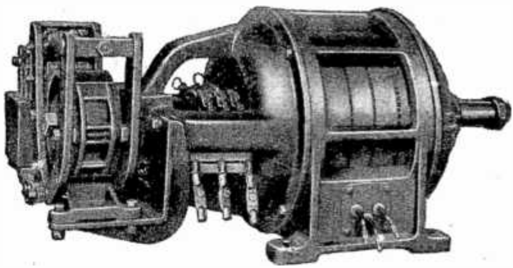


FIG. 6,902.—*General Electric a.c. crane motors 1. For main hoist.* Open motors are used for all except the most severe rapid service. For the latter service, mill type motors or large motors of mill type construction with outboard bearings are used. For very high speed hoists, running at 1000 ft. per min. and above, specially designed, low speed, high torque, low fly wheel effect motors, direct coupled to the hoist drum, are used. This construction eliminates gear losses, prevents wear and noise, and provides for the quick start which is consistent with the high rope speeds. For controlling small hoists running at approximately 100 ft. per min. drum type controllers and shoe type solenoid brakes are employed. Magnetic plugging controllers are employed on medium and high speed hoists. For some large high speed hoists, automatic magnetic controllers with dynamic braking are used, requiring either a separate motor generator set or preferably, where space permits, a direct coupled, direct current motor for separate excitation. For all sizes of hoists, where the bridge builder takes care of the necessary braking, plain reversible or non-reversible automatic magnetic control is used.

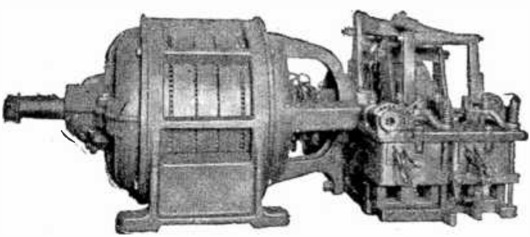


FIG. 6,903.—*General Electric a.c. crane motors 2. For boom hoist.* Open, crane type motors with solenoid load brakes and special rheostatic control are required. This permits the boom to be lowered by regenerative braking and stopped smoothly by the solenoid load brakes.

The coil of the solenoid or electro-magnet is in circuit with the hoisting motor, so that when current is switched on to the motor, the brake is released, and when it is switched off, the brake is applied. This makes an excellent safety device but as it can only be off or full on, it cannot be used to regulate the descent of the load when lowering.

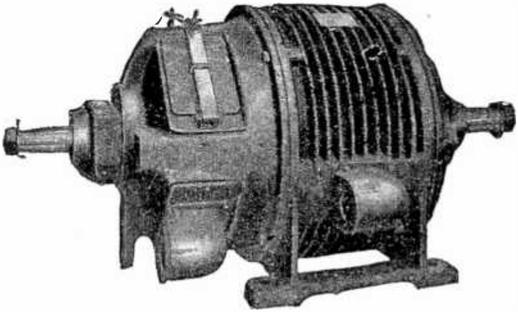


FIG. 6,904.—*General Electric a.c. crane motors 3. For bridge motion.* This requires open crane type motors with shoe type solenoid brakes in a sheet metal house for protection against weather or totally enclosed crane motors, with shoe type brake using a sheet metal housing for the brake. Totally enclosed, mill type motors with shoe type solenoid brakes, having a sheet metal housing for the solenoid brakes, are used in some cases, especially where duplicates of other equipment in a mill are desired. If one motor alone be used for propelling the bridge, it is advantageous to equip it with a multiple magnet solenoid brake so that one magnet can be used for giving a smooth stop and the other magnet for giving an extra high torque for holding in a wind storm. Where two or four motors are used for propelling the bridge, it is advantageous to equip the motors with solenoid brakes and, in stopping to set one-half of the solenoid brakes first to provide for a smooth stop and then to set the remainder of the solenoid brakes for holding against wind. Manual controllers, for either one or two motors, and equipped with necessary drift points for handling solenoid brakes as outlined above, are provided.

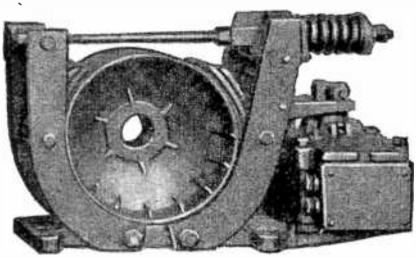


FIG. 6,905.—*General Electric shoe type spring set brake* for motor mounting.

In cases where the driver has access to the gear, as in locomotive jib cranes and derricks, an addition may be made to the electro-magnetic brake in the form of a hand or foot release lever, by which the brake can be released or its pressure regulated. Loads are then hoisted by the motor, and are allowed to run down by their own weight, the speed of descent being regulated by the brake.

Where the driver operates the gear from a distance, the arrangement just described is not practicable, and some automatic or electrically controlled arrangement must be used to check the speed of descent of the load.

Automatic Mechanical Brake.—A common arrangement is the automatic mechanical brake. The brake is usually of the

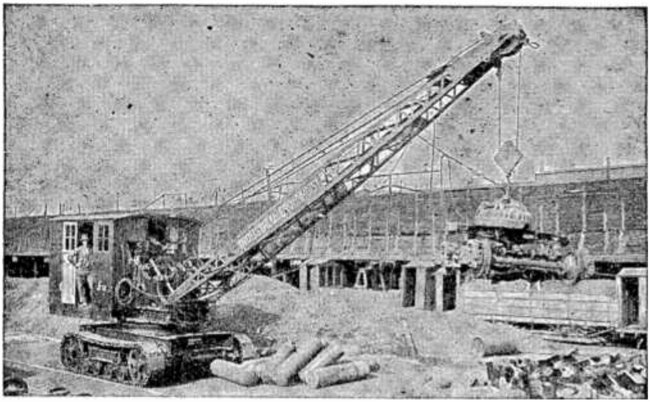


FIG. 6,906.— Brownhoist electrically operated crawler crane equipped with *lifting magnet.*

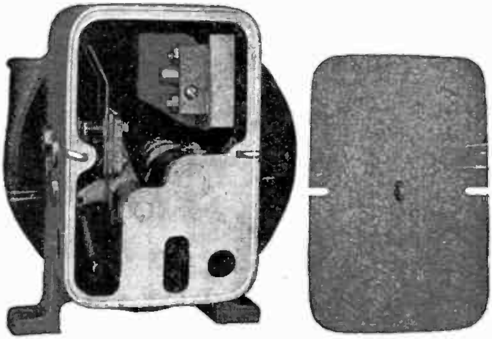
disc type, and is arranged to allow the gear to run freely in the direction of hoisting, but holds it from running in the opposite direction, being applied by a screw, or it can be arranged to be operated automatically by the load.

The brake is released by running the motor in the direction for lowering. As the motor releases the brake, the load tends to put it on again; consequently the speed of descent depends upon the speed of the motor, and this can, of course, be regulated by the driver by means of the controller.

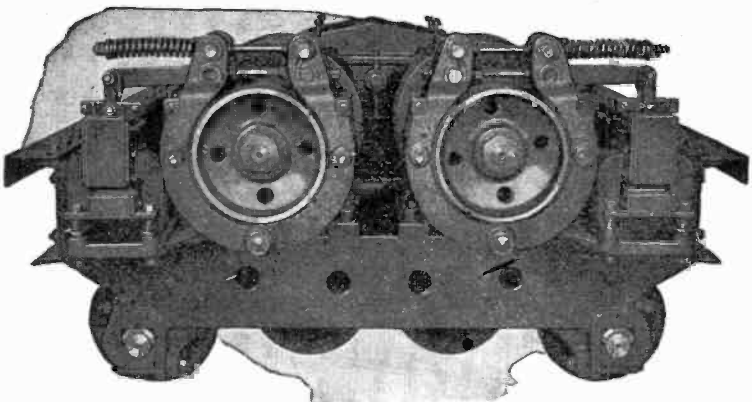
Eddy Current Brake.—This type of brake is only used to a limited extent.

It consists of a wheel, generally of copper or other metal of low electrical resistance, which is arranged to rotate between the poles of an electro-magnet. The wheel is driven by the descending load, and eddy currents are generated in it, which give rise to a retarding torque.

The eddy currents and the consequent torque are regulated by varying the strength of the magnet by means of a regulating switch and resistance.



FIGS. 6,907 and 6,908.—Milwaukee limit switch with cover removed showing internal mechanism.



FIGS. 6,909.—Milwaukee shoe type solenoid motor brake. The shoes are lined with asbestos.

Rheostatic Brake.—For this form of braking, the controller is provided with several positions on the lowering side, called *brake points.*

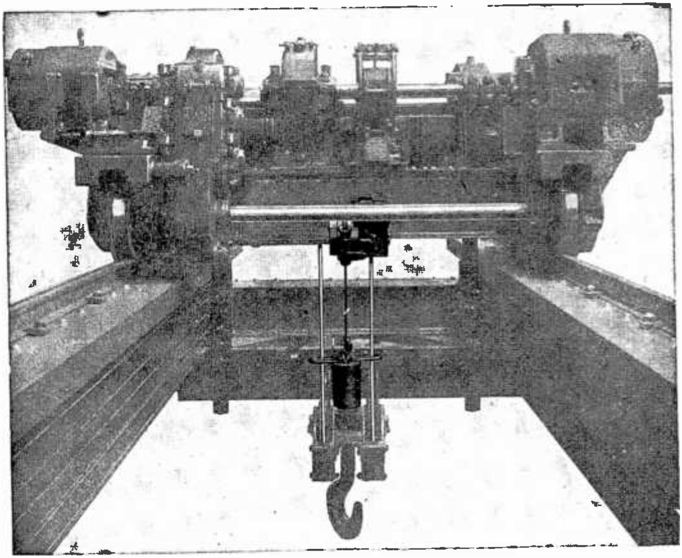
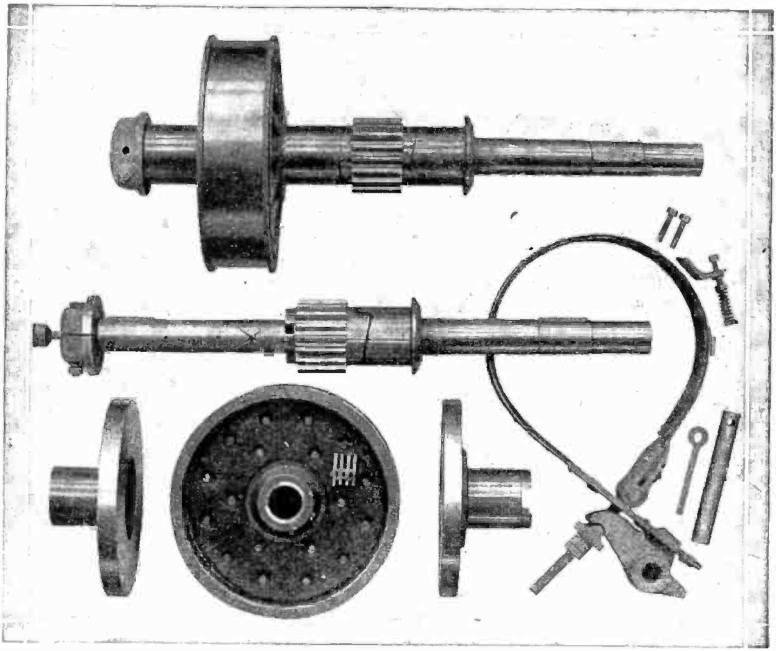


FIG. 6,910.—Milwaukee limit switch applied to two motor trolley. *To prevent overhoisting* and breaking of sheaves or other parts of the hoisting mechanism the hoist motor line is opened automatically by the limit switch when the hook reaches its highest safe position. The switch is arranged with a quick break mechanism which prevents it slowly or partly opening at the contacts. It is connected in series with the operating coil of a contactor mounted on the switchboard. This contactor opens the hoist motor circuit in the hoisting direction. When the limit switch has been tripped the operator can immediately lower his hook by simply reversing his controller. When the hook has been lowered below the tripping point the switch automatically resets.

In these positions the controller alters the connections of the motor to those of a series dynamo, so that it generates current when driven by the descending load, the energy being absorbed by the controller resistance. The speed of lowering is regulated by varying the resistance.

Regenerative Control.—Instead of a series motor, a shunt wound motor may be used to drive the hoisting motion.

A shunt motor has the advantage that its speed can be efficiently regulated over a fairly wide range by inserting resistance in its field circuit. By this means considerable variation of speed in lifting and lowering may be obtained without the necessity of having variable speed gear in the hoisting train, and when lowering, the shunt motor, if overhauled by a load, becomes a dynamo and feeds current back to the circuit, thus automatically controlling the speed of lowering. This system has been in use to a limited extent for some years.



FIGS. 6,911 to 6,921.—Milwaukee mechanical load brake disassembled. Trolleys operating on alternating current are equipped with a mechanical load brake. This brake serves a double purpose with the aid of the motor brake. It sustains the loads after being hoisted and also controls the speed in the lowering direction. The load is, at all times, under complete control of the crane operator and cannot be lowered faster than the speed of the motor permits since the mechanical brake will automatically retard the speed of the load in lowering should it become excessive. It is automatic in action and is operated by running the hoist motor in the lowering direction. The brake is of the Weston disc type equipped with a differential retaining band and discs fitted with asbestos friction linings.

Collector Gear.—To convey current from the mains to the moving crane a collector gear, generally similar to that used for electric tramway work, is employed. For overhead cranes copper

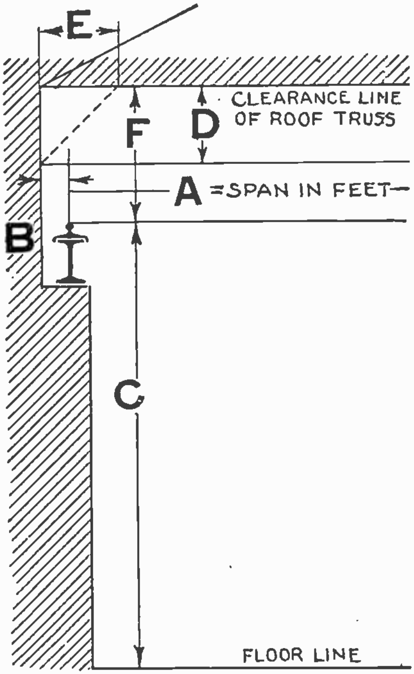
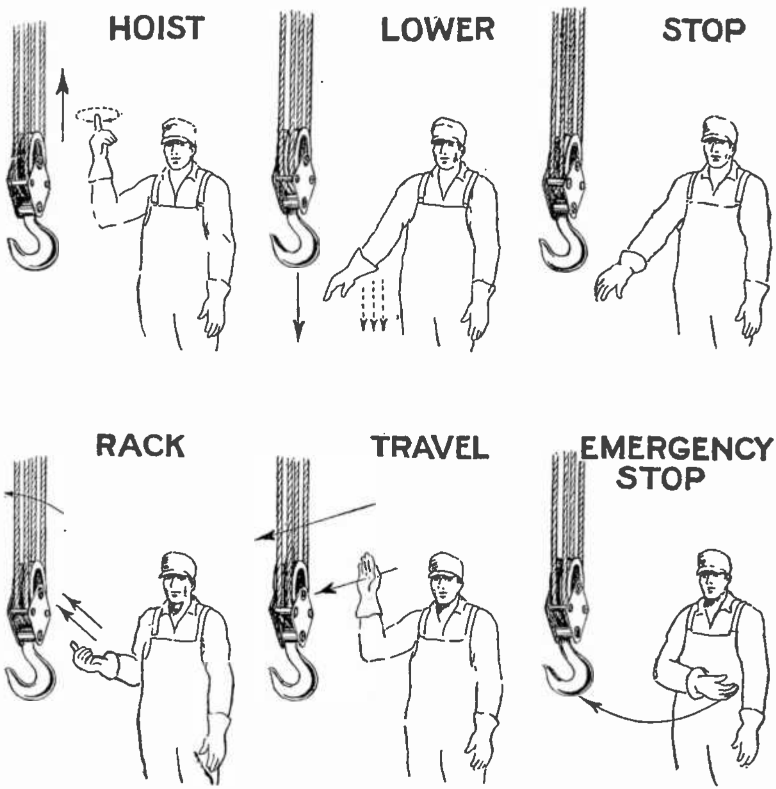


FIG. 6,922.—Section of shop showing information required in selecting a crane. ***Load,*** maximum in net tons; ***speed,*** if special for any function be preferred; ***style,*** outside or inside service; ***current data,*** whether *d.c.* or *a.c.*, giving voltage cycle and phase; ***clearance dimensions,*** A, span; B, end clearance; C, distance from top of runway rail to floor; F, overhead clearance.

wires about one-quarter to three-eighths inches in diameter are stretched along the gantry, being supported at the ends by globe strain insulators. Trolley wheels or slides, mounted on the end carriage, make contact with these wires.

From the trolley wheels or slides, insulated cables are led to the switches and controllers, and to another set of trolley wires on the cross girders. Contact with these wires is made by sliders or trolley wheels on the crab, from which cables are led to the motors.

For locomotive jib cranes overhead or underground collector gear is used similar to that used for tramway cars. As derrick cranes only swing backward and forward through a portion of a circle, collector gear is not



FIGS. 6,923 to 6,928.—Crane signals for operator's hoisting movements.

necessary. Connection from the supply mains to the moving part of the crane can be satisfactorily made by means of flexible armoured cable.

Controllers.—The class of controller most commonly used for crane work is that known as the drum, or tramway type.

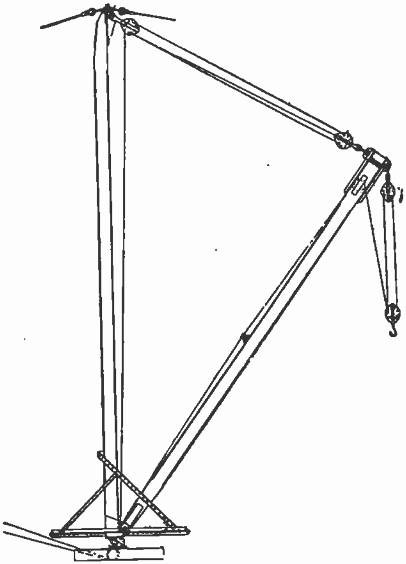


FIG. 6,929.—Guy derrick with bull wheel and swinging gear. *In construction,* all the fittings except the foot irons and sheaves are made of forgings or structural shapes. The foot block and mast step are made with a ball and socket universal joint. Uneven setting or a settling of the derrick supports cannot make this joint pinch or retard the swinging of the boom. A back lock makes it impossible for the mast to be lifted clear of the step. The spider is made of buckled plates. The regular set of iron for a guy derrick includes the mast head block, two sheaves in the foot block, one sheave in the mast step, and one sheave in the boom end.

In these controllers the wires and cables are brought to a series of fixed contacts, usually arranged in a straight line.

A series of corresponding contacts are attached to a revolving drum, the various combinations of connections for hoisting, lowering, etc., being obtained by rotating this drum into different positions.

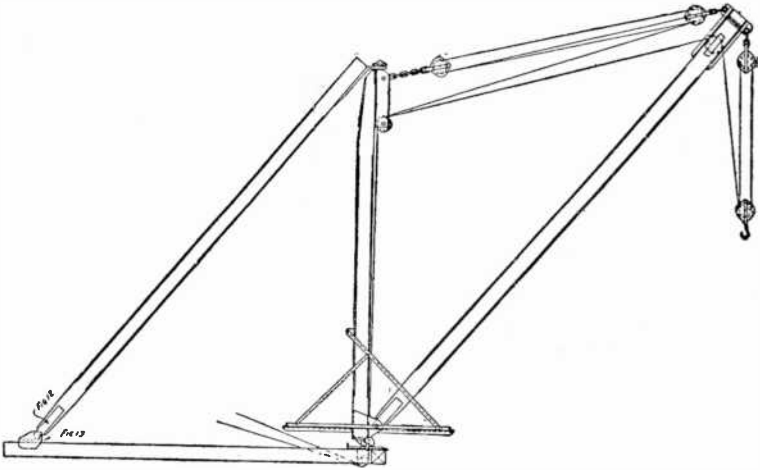
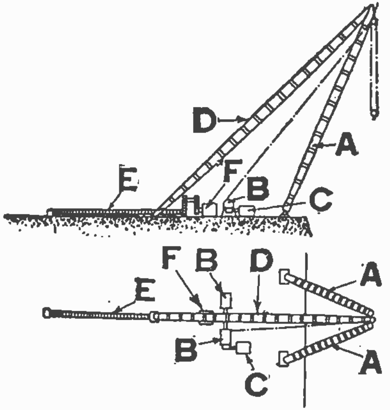
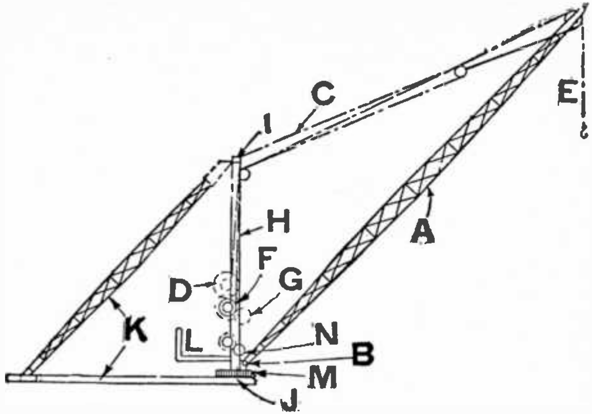


FIG. 6,930.—Stiff leg derrick with bull head and swinging gear. This type derrick has, as its name implies, rigid timbers or "legs" in place of guys. *In construction,* the goose neck irons for the stiff legs are made very heavy at the bend and bent close in to the mast top. The back or stiff leg connections to the sills allow the stiff legs to be set at any angle. They require no framing. When it is desired to rig these derricks with the fall line down the boom, one of the mast top sheaves is put in the mast step. The length of the boom should be approximately 1½ times the length of the mast.

NOTE.—***Power required for traveling cranes and hoists.*** Ulrich Peters, in *Machinery,* November, 1907, develops a series of formulæ for the power required to hoist and to move trolleys on cranes. The following is a brief abstract. Resistance to be overcome in moving a trolley or crane bridge. P_1 = rolling friction of trolley wheels, P_2 = journal friction of wheels or axles, P_3 = inertia of trolley and load. P = sum of these resistances = $P_1+P_2+P_3=(T+L)\left(\frac{F_1+F_2d}{D}+\frac{V}{1{,}932t}\right)$ in which T = weight of trolley, L = load, F_1 = coefficient of rolling friction, about .002 (.001 to .003 for cast iron or steel); F_2 = coefficient of journal friction, = .1 for starting and .01 for running, assuming a load on brasses of 1,000 to 3,000 pounds per square inch; (F_2 is more apt to be .05 unless the lubrication be perfect); d = diameter of journal; D = diameter of wheels; V = trolley speed in feet per minute; t = time in seconds in which the trolley under full load is required to come to the maximum speed. Horse power = sum of resistances × speed in feet per minute ÷ 33,000. Force required for hoisting and lowering: Fh = actual hoisting force, F° = theoretical force or pull, L = load, V = speed in feet per minute of the rope or chain, c = hoisting speed of the load L, c ÷ V = transmission ratio of the hoist, e = efficiency = $F^{\circ} \div F^{b}$. The actual work to raise the load per minute = FhV = Lc = $F^{\circ}V \div e$. The efficiency e, is the product of the efficiencies of all the several parts of the hoisting mechanism, such as pulleys, windlass, gearing, etc. Methods of calculating these efficiencies, with examples, are given at length in the original paper by Mr. Peters.



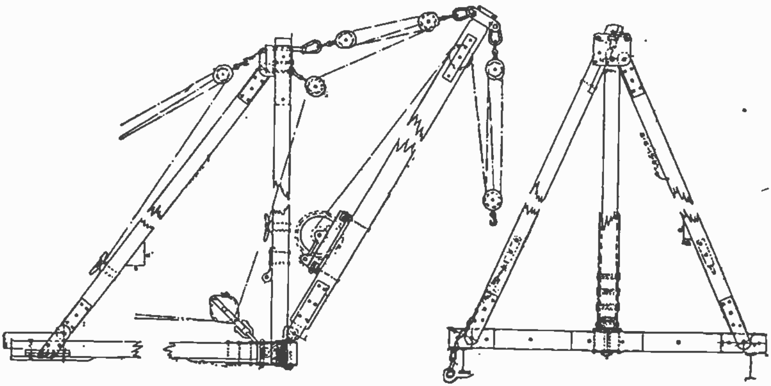


FIGS. 6,931 and 6,932.—Sheer legs. This is a type of lifting appliance used for handling extremely heavy loads such as ship's boilers and heavy guns. The load rope passes over a pulley at the head of the legs A, and is led to the winding drum B, which is driven by the motor C. The bottom of the back leg D, is traversed by a screw E, driven by the motor F, so as to traverse the load in or out. Occasionally a second hoisting drum and motor are provided to handle light loads at quick speeds. It will be noted that with this type of crane, loads can only be picked up and deposited along a horizontal line which is a continuation of the center line of the screw.

FIG. 6,933.—Electric derrick crane. The load hangs from the end of the jib A, which is supported by the pin B, and rope C, which leads to the jibbing drum D, by which the jib can be lowered. The load rope E, is led to the drum F. Drums D and F, are driven by motor G. A clutch is provided by which the drum D, may be put in or out of gear with drum F. When D, is out of gear, the drum F, is used to lift or lower the load. When the two drums are clutched together they run in opposite directions, so that when drum D, is hoisting the jib, drum F, pays out the load rope, and vice versa. Thus, whether the jib is being lifted or lowered, the load remains steady, and simply runs in or out in a horizontal line. The jib and the motors and gearing are carried by the vertical mast H, which turns in bearings I, J, in the framing K. The driver's platform L, is also attached to the mast, and the various controlling switches and levers are placed on this platform. To slew the mast and jib, a toothed wheel M, is fastened to the framing and gearing. With this is provided a pinion, the shaft of which is carried in bearings on the mast, and is driven by the slewing motor N. This type of crane will serve an area having a radius equal to the maximum horizontal radius of the jib, and forming a segment of a circle embracing an arc of rather less than 270 degrees.

Derricks.—By definition a derrick is *an apparatus for lifting and moving heavy weights.* It is similar to the crane, but differs from it in having the boom, which corresponds to the jib of the crane, pivoted at the lower end so that it may take different inclinations from the perpendicular.

The weight is suspended from the end of the boom by ropes or chains that pass through a block at the end of the boom and thence directly to the *crab*, a winding apparatus or motor at the foot of the post. Another rope connects the top of the boom



FIGS. 6,934 and 6,935.—Jinniwinks or so called "A" frame derrick. This differs from the ordinary stiff leg derrick in that it has in place of a boom, two inclined timbers, fastened to a horizontal cross piece and a stiff leg fastened to a second horizontal member projecting backward at right angles with the first. It is thus made with the minimum amount of framework, thus securing lightness with resulting ease of moving and erecting as well as security and rapidity of anchoring down.

with a block at the top of the post, and thence passes to the motor below.

The motions of the derrick are:

1. A direct lift;
2. A circular motion around the axis of the post;
3. A radial motion within the circle described by the point of the boom.

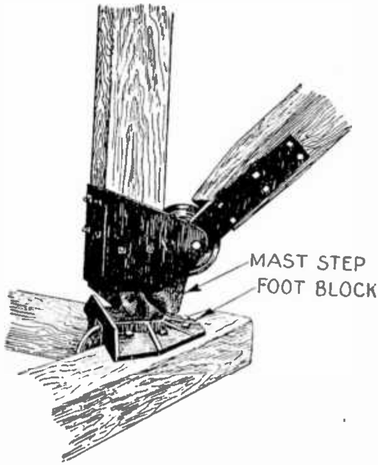
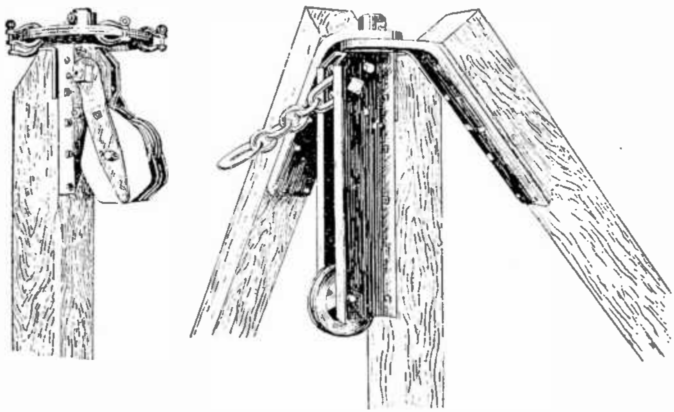
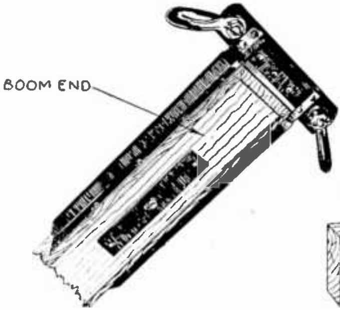
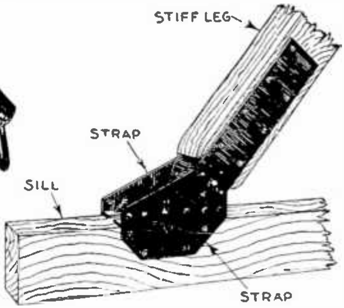


FIG. 6,936.—*Derrick fittings: 1. foot block and mast step irons*, showing lock at the rear of the ball and socket joint. There are two sheaves in the foot block and one in the mast step. The sheave in the mast step is not required for stiff leg derricks. Special foot blocks and mast steps are required for handling clam shell or orange peel buckets and other three line work.

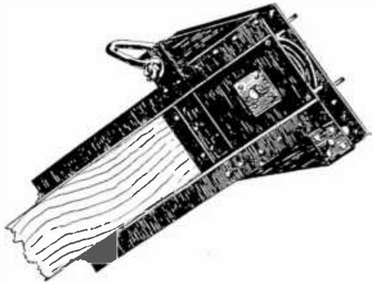


FIGS. 6,937 and 6,938.—*Derrick fittings: 2. mast top irons*. Fig. 6,937, irons with spider plate for guy derricks; fig. 6,938, irons with goose necks for stiff leg derricks. Iron cone complete with block, pin, shackles, back plate and bolts as shown.

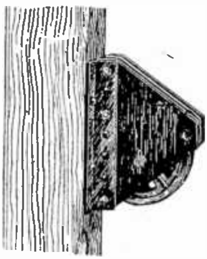


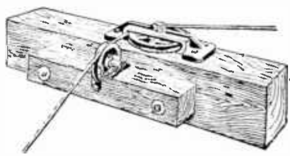


FIGS. 6,939 and 6,940.—*Derrick fittings:* 3. *boom end* for general work and *stiff leg connection* to sill with stiff leg straps.



FIGS. 6,941 and 6,942.—*Derrick fittings:* 4. *boom idler* for guy derricks and *boom end* for operating clam shell or orange peel buckets. The hole on lower side is for a shackle pin which can be used to attach upper block for a fall with several parts.





FIGS. 6,943 and 6,944.—*Derrick fittings:* 5. *mast brackets* used with derricks operating clam shell and orange peel buckets, and *guide sheaves* for bull wheel line.

On shipboard a derrick is a spar raised on end, with the head steadied by guys and the heel by lashings and having heavy weights. The accompanying illustrations show various types of derrick in general use.

Telpherage.—This word is defined as: *Automatic aerial transportation as by the aid of electricity, especially that system in which carriages having independent motors are run on a stout wire conducting an electric current.*

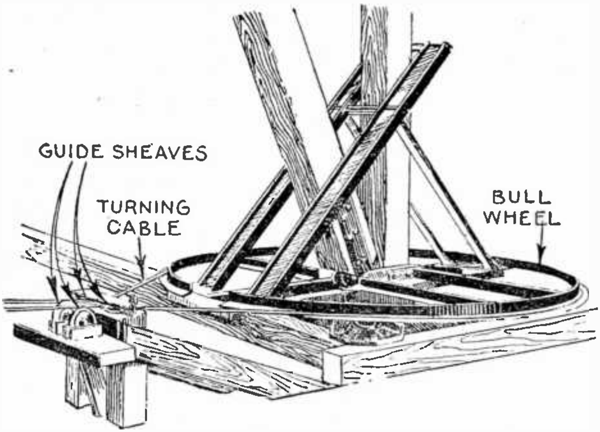


FIG. 6,945.—***Derrick fittings:*** 6. bull wheel and guide sheaves. The wheel is made in halves and may be conveniently erected without unstepping the mast. The ring is a heavy angle iron with the vertical leg rolled with an appreciable outward flare which eliminates any tendency for the line to climb. An inverted movable section of the ring is placed under the boom which makes it a full circle. The braces which drive the boom are made of steel beams, and sills of heavy angles.

Telpherage is a name introduced by the late Professor Fleeming Jenkin to designate a system devised by him, by which the transmission of a vehicle by electricity to a distance is effected independently of any control exercised from the vehicle; it is an aerial electric railway.

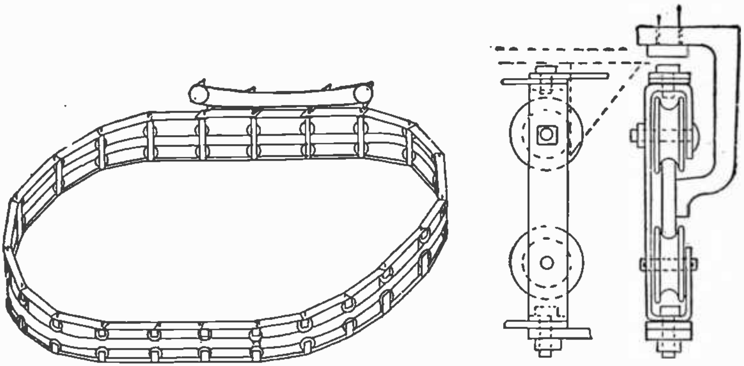
Telpherage properly includes those systems employing a wire or cable for a track, but the term is erroneously applied to systems using a rail. There are two divisions of telphers:

1. Automatic;
2. Non-automatic.

The automatic type comprises those *which are driven by electric motors, the control being a part, or remote from the telpher.*

The original telphers were automatic, the telpher being placed in the middle of the train. They are employed for handling coal, ore and bulk material.

Non-automatic telphers are those *which are controlled by an operator who travels with the load and who operates both the telpher and hoists from a cab or case which is attached to the telpher or carriage.*



FIGS. 6,946 to 6,948.—Delta continuous trolley system.

Non-automatic telphers are employed for bulk material, like the automatic telpher, and are also used for the hoisting and conveying of miscellaneous material, boxes, cases and barrels, the package freight of railways and the mixed cargoes of steamships.

A telpher is suspended from one or more wheels in tandem, of which one or all are driven by the electric motor or motors.

In the minimum head room two ton type designed for railway and steam ship terminals the vertical space from the underside of the roof girders to the bottom of the hoist hook is 4 ft. 9 in. (144.8 cm.). The width of the hoist is 3 ft. 3 in., and 4 ft. 8 in. to the limit line for 10 degrees swing. From the center of the rail to the inner limit of the telpher and hoist is 16 inches.

Energy in the form of either direct or alternating current is communicated to the motors by conductors which lie parallel with the track, the contact being made by shoes or wheels.

Sometimes storage batteries suspended from the telpher or the carriage are employed. On steep grades the telpherage traction, in some installations, has been assisted by supplementary cables, either fixed or movable.

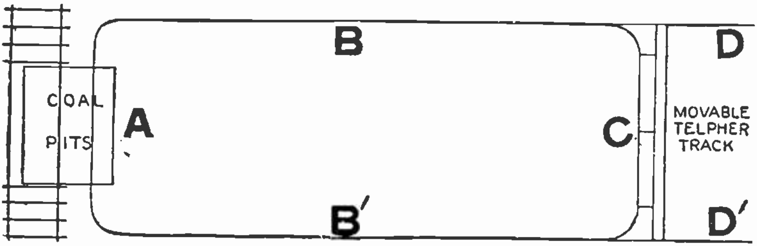


FIG. 6,949.—Typical arrangement of mono-rail tracks. The track is supported on brackets attached to buildings, or is supported on A bents. Supports under straight track are spaced 20 feet apart, and on curves, the spacing is 8 feet. For long spans, cables or trusses are used. The tracks may be either fixed or movable. *In the figure,* the side tracks BB′, are fixed, but C, is movable, being attached to a traveling bridge. The speed of this bridge is from 300 ft. to 900 ft. per min. The motor driving this bridge would have a load factor of .16. The telpher train is passed from these side tracks B′, by means of a gliding switch upon the movable track C. This track therefore may be placed anywhere over the area between the fixed side tracks. The telpher returns by means of the track B′; to its starting point A. By the operation of this movable track all the spaces can be served; this operation is called transferage. The minimum allowable radius of curves is 8 ft.

Telpher Motors.—The sizes of motor for telphers and hoists will depend upon the class of work to be done; the motors for telpher tractors vary from 5 to 15 *h.p.* and for the hoists, from 3 to 75 *h.p.*, the loads being from 500 lbs. to 30,000 lbs. The load factor for the tractor motor is .25 and for the hoisting motor .16. The driving wheels and the motors may be connected by gears or by chain drive. The maximum service efficiency of the motors is that corresponding to the efficiency obtained between one-half and three-quarters full load. The motors are of slow or medium speed.

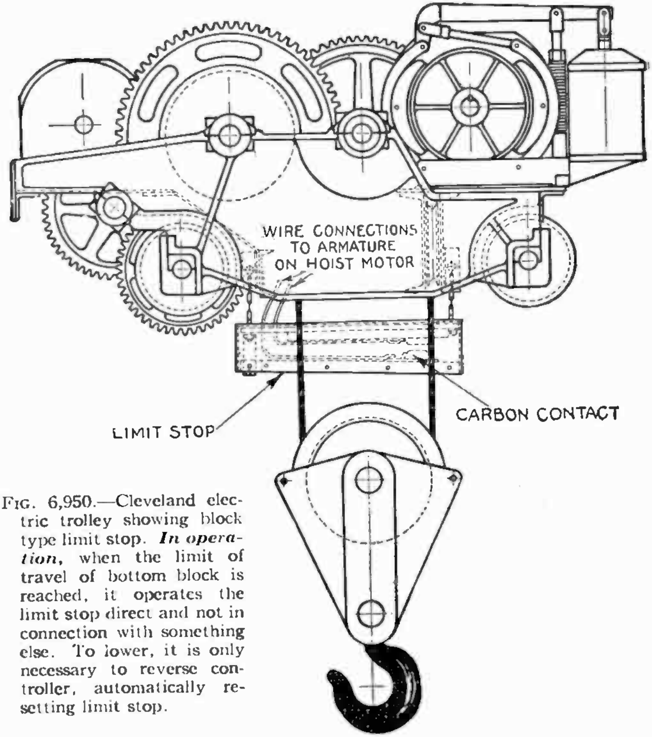


FIG. 6,950.—Cleveland electric trolley showing block type limit stop. *In operation*, when the limit of travel of bottom block is reached, it operates the limit stop direct and not in connection with something else. To lower, it is only necessary to reverse controller, automatically re-setting limit stop.

Direct current 250 volt or 500 volt series wound motors are preferable for tractors and hoists though alternating current motors afford satisfactory results. The motors should be dust and weather proof, and should have a 50 per cent. reserve in their rating. The average combined efficiency of the motors and gearing, for the tractor and hoist, is from 65 per cent to 75 per cent.

Brakes.—The mechanical type of telpher brake is used and the hoist brake is of either the electro-mechanical or electro-dynamic types. Spur gears and chain drive on the tractor transmit the power from motor to track wheels, and either spur or worm gear is used to transmit power to the hoisting drum.

Trackage.—Telphers either run in one direction on a closed track circuit, or to and fro over a single line. On the single line the automatic telphers reverse themsleves on completing their trips.

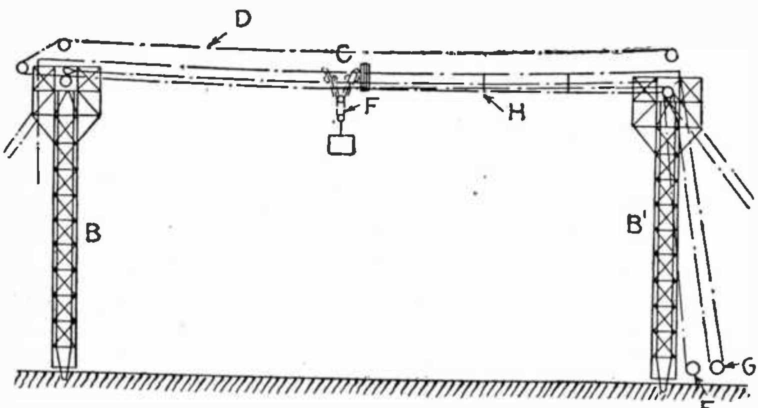


FIG. 6,951.—Cableway. The essential elements of construction are BB', towers; C, cable; D, hauling rope; E, hauling rope drum; F, hoisting rope; G, hoisting drum; H, hoisting rope slack carriers.

Essentials of Cableways.—The term cableway may be defined as a rectilinear *hoisting and conveying apparatus supported by a cable.*

The elements of construction are shown in fig. 6,951. A strong steel wire rope or cable is stretched between the towers BB'. On this rope runs the carriage C, pulled backward and forward by the hauling rope D, which is operated by the capstan drum E. One end of the hoisting rope F, is secured to the carriage, and is led round the various pulleys shown and to the hoisting drum G.

The slack of the hoisting rope, when paying out, is supported by the carriers H. These carriers are dropped by the carriage when running from B to B′, and are picked up again when returning from their position, being determined by buttons of different size arranged on the rope. Loads are hoisted and lowered by drum G, driver E, being held by its brakes.

To travel the load, the two drums are clutched together. Driver E, then hauls the carriage along, while drum G, takes in or pays out the hoisting rope, so that the vertical position of the load is unaltered.

A cableway will take up and deposit loads anywhere along a line directly underneath the main cable, and by means of switch blocks it may be made to serve an area having a width of about 15 feet or so each side of the cable.

TEST QUESTIONS

1. *Give definition of a crane.*
2. *How are cranes classified?*
3. *Describe the various types of crane.*
4. *What are the essentials of the rotary crane?*
5. *What is the most economical position of the inclined brace in a jib crane?*
6. *What are the features of rectilinear cranes?*
7. *Make a sketch of an electric traveling crane.*
8. *What are the essentials of combined rotary and rectilinear cranes?*
9. *What is a transporter?*

10. *How long does it require a transporter to complete a cycle of operation?*
11. *What are the requirements for crane motors?*
12. *How is the power required to drive cranes determined?*
13. *What is the friction allowance for cranes in power calculations?*
14. *What is the most important consideration in selecting motors?*
15. *Describe the construction of automatic electro-magnetic brakes.*
16. *How is the coil of the brake solenoid connected?*
17. *What is the usual type of automatic mechanical brake?*
18. *How is the automatic mechanical brake released?*
19. *Are eddy current brakes extensively used?*
20. *How is the controller arranged for rheostatic brake?*
21. *Describe the method of regenerative control.*
22. *How is the collector gear arranged?*
23. *Describe the term* telpherage.

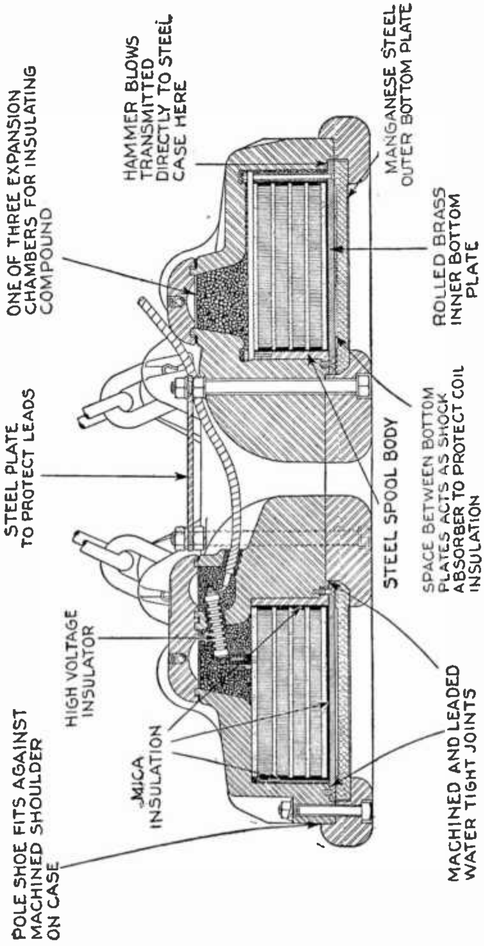


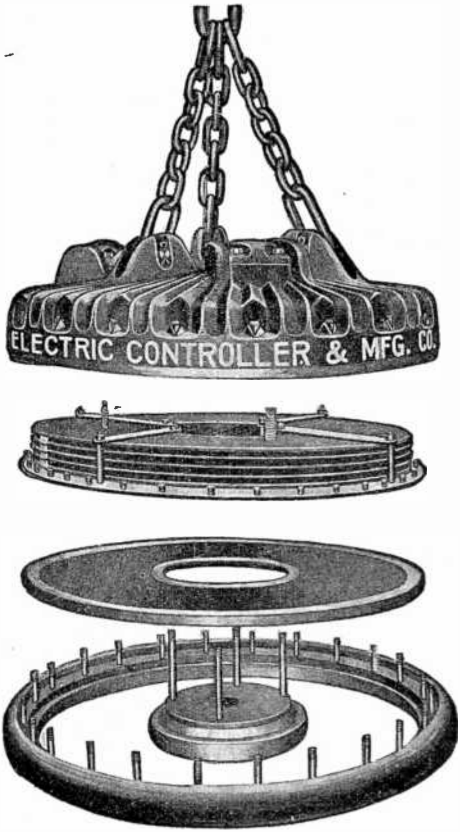
FIG. 6,952.—Electric Controller lifting magnet; sectional view showing construction.

CHAPTER 161

Lifting Magnets

Lifting magnets are used in connection with power operated cranes and hoists, for lifting magnetic material, especially where such material must be handled in bulk. They are especially useful in and around foundries, steel mills, etc., for lifting such materials as pig iron, metal plates, billets, scrap iron, steel castings, rails, "skull crackers" and, in fact, anything except non-magnetic metals, such as brass and copper.

The magnet is energized by *d.c.* and it greatly facilitates handling material of the classes mentioned, because the parts to be lifted are easily gripped or released by the magnet and quite a number of pieces can be lifted at one time, especially in the case of small billets, plates, etc. No time is required for adjusting hoisting tackle to the part or parts to be lifted, and



FIGS. 6,953 to 6,956.—Electric Controller lifting magnet disassembled showing coil wound on spider, outer bottom plate of manganese steel and renewable pole shoes held with through bolts.

FIG. 6,957.—Electric Controller lifting magnet. View showing separate terminal boxes for each lead and ribbed housing.

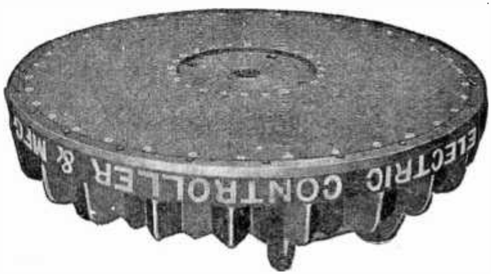
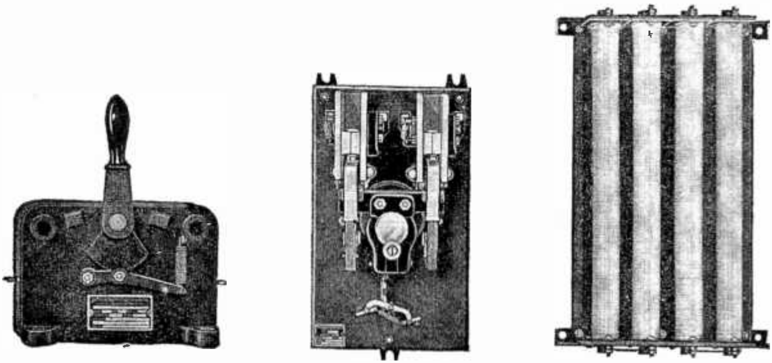


FIG. 6,958.—Electric Controller lifting magnet showing bottom plate to render the magnet moisture proof. The inner brass bottom plate hermetically seals the coil cavity.

in handling pig iron, scrap, etc., the parts to be moved need not be arranged in piles.

All that is necessary is to lower the magnet onto the material, switch on the current and transport the magnet with its load by means of the crane to the place where the material is to be deposited.

In foundries, blast furnaces, and rolling mills, magnets are often used for lifting and transporting metal which is too hot to be touched with the hands.



FIGS. 6,959 to 6,961.—Electric Controller lifting magnet control device. It is of the contactor type and provides for quick release of the load and for safety to the operator as he handles only the lever of a small master switch which controls a double pole magnetic contactor, which in turn opens and closes the circuit to the lifting magnet. The contactor is designed to break the highly inductive arc with minimum wear on the contacts. A resistor is supplied for limiting the flow of reverse current in the "drop" position. The master switch should be mounted conveniently for the operator but the magnetic contactor and resistor may be located at any distance from it. When operating the magnet, the master switch lever is moved to the lift position after the magnet has been lowered on to the stock pile. Two or three seconds should be allowed to permit the magnetism to build up to full strength before hoisting the load. To drop the load, the lever is moved to the drop position. The load is at once released and the lever should then be returned to the off position and left there until the magnet is again lowered onto the stock pile.

Classification.—There are several types of magnets, classified according to the nature of the material for which they are designed to lift.

1. Pig magnets.

For material of irregular shape, piled indiscriminately.

2. Plate magnets.

   For lifting straight shapes from orderly piles.

3. Bi-polar magnets.

   For handling irregular and regular shapes.

4. Special magnets.

   Designed for some special class of material.

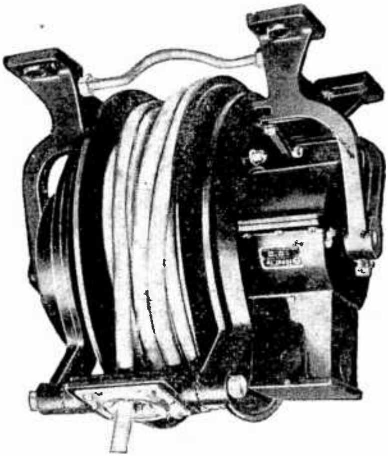


FIG. 6,962.—Electric Controller lifting magnet rope take-up. Spring operated rope reels of the type illustrated are recommended for keeping the magnet rope taut. The reel pays out and winds up the rope keeping the correct tension on it at all times. These reels will accommodate from 40 to 150 ft. or more duplex rubber covered flexible magnet rope.

Pig Magnets.—This type is provided with a central cylindrical pole and a concentric outer pole, with a magnetizing winding inserted in an annular slot or space between the two poles. These magnets are designed to give fields of deep penetration by reason of the powerful magnetizing winding and wide spread poles.

Plate Magnets.—For this service the magnet is rectangular in shape and has two parallel outer poles of like polarity, and a common central pole on which is wound the magnetizing coil. This type of magnet is designed to give a field of small penetration, the magnetizing winding being relatively less powerful, the poles closer together, and the steel section lighter than in the case of a pig magnet.

The lifting capacity per inch of face, in contact with a single layer of material not less than 1¼ in. thick, is 500 lbs.

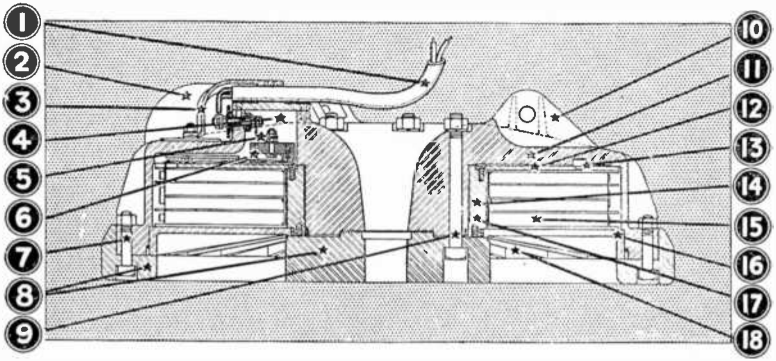
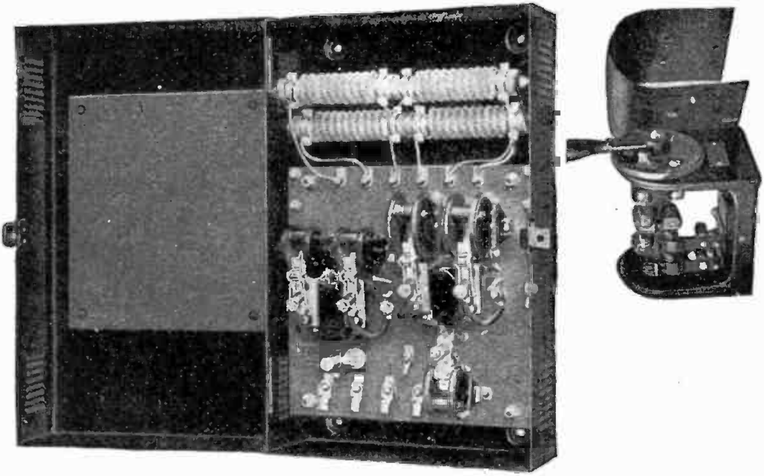


FIG. 6,963.—Cutler Hammer lifting magnet sectional view showing construction. *The parts are:* 1, leads, protected by 5 ft. of steam hose; 2, protecting flange for terminal box; 3, terminal hood; 4, terminal cavity; 5, coil terminal studs; 6, flanged outer pole shoe; 7, heat treated alloy steel through bolts; 8, inner pole shoe; 9, through bolt; 10, suspension lugs; 11, magnet case; 12, top plate of coil spool; 13, dowel; 14, core of spool; 15, magnetizing coil; 16, coil shield; 17, tapped eye bolt hole; 18, heavy protecting ribs.

Bi-polar Magnets.—This type, sometimes called *rail magnet* usually consists of a pair of vertical triangular shaped poles connected by a horizontal yoke which carries the magnetizing winding. Magnets of this type are adapted principally for handling plates and straight shapes but as they have a much deeper penetration than plate magnets, they can also be used for handling miscellaneous materials, such as pig iron and scrap iron; hence, bi-polar magnets are used in cases where the



FIGS. 6,964 and 6,965.—Cutler Hammer lifting magnet controller and master switch. To protect the operator and equipment from the hazards of high induced voltage, provision must be made in the controller to keep the voltage down to a safe value. This can be done only by providing a circuit in which the coil energy can be dissipated. The control system is designed to keep the voltage low, and a reverse connection is provided to expedite demagnetization and cause quick release of the load. When the master switch handle is moved to the off position, the magnet discharge voltage is kept low by shunting a low value of resistance in two parallel paths across the magnet terminals by means of a lower contact on the magnetic lift switch which closes at the same instant the upper contact opens the magnet circuit. As the operator moves the master switch handle to the drop position, the drop switch closes, thereby opening its lower contact and closing its upper contact. The opening of the lower contact opens one of the two parallel discharge paths, leaving the other to prevent high induced voltage. The closing of the upper contact provides a reverse circuit to the magnet. The upper contact on the lift switch is open only 1/16 in. when the lower contact touches. This keeps down the arc when the circuit opens. Even when the circuit is opened accidentally, such as a trolley jump, the switch drops open and provides a discharge circuit so quickly that the induced voltage is not high. The correct proportioning and connection of resistors protects the operator, the magnet, the controller and all interconnected equipment by keeping voltages low. The new lifting magnet controller automatically reverses current momentarily when load is dropped.

NOTE.—The master switch (fig. 6,965) carries only the pilot current controlling the magnetic switches. The lines to the magnet are not connected to the master switch. It has three positions—lift, off and drop, marked on the brass indicating plates. In the lift position, the lift switch is closed, connecting the magnet across the power lines. In the off position, both magnetic switch coils are out of circuit and the magnet discharge circuit is made. In the drop position, the drop switch is closed, reversing the circuit through the magnet. A spring return is provided from the drop position to off so that the magnet will not be left in circuit accidentally.

principal work consists of handling straight parts and where it occasionally is necessary to handle pig or scrap iron.

The bipolar or rail magnet has been used extensively for handling rails, pipes, billets, structural materials, and in general, straight pieces of considerable length as compared to the width and thickness. This type has been exploited as the rival of the circular pig magnets, but the results of tests do not seem to indicate its superiority for general work.

In general, however, it cannot compete with the circular type; besides being of smaller capacity, its shape makes it liable to incur very severe torsional strains which are liable to prove detrimental to its life. It has also been found very liable to stick to the sides and bottoms of steel cars on the clean up lifts.

Lifting Capacity of Magnets.—The weight that a magnet of given size can lift depends upon the form of the material and the evenness of the surfaces which must be gripped by the magnet. It might be possible to lift 20,000 lbs. or more, under favorable conditions, and only 1,000 lbs. or less, under adverse conditions, the same magnet being used in each case.

For instance, when there is a solid mass of steel or iron and a surface which affords a good magnetic contact, naturally, a much greater weight can be lifted than when there are a number of pieces which not only cling to the magnet but to each other, or in case the material is of such a form that a comparatively small surface is in contact with the magnet poles.

TEST QUESTIONS

1. *Name the various uses made of lifting magnets.*
2. *What kind of material cannot be handled?*
3. *Give a classification of lifting magnets.*
4. *Describe a pig magnet and a plate magnet?*
5. *What is the construction of a bi-polar magnet?*
6. *What is the lifting power of magnets?*
7. *Upon what does the lifting power of magnets depend?*

CHAPTER 162

Gas Engine Principles

The term gas engine is generally understood to mean *an internal combustion engine using natural gas or the vapor of gasoline for fuel as* distinguished from "oil" engines or those using kerosene or heavy low grade oils, the latter class including the Diesel engine.

Working Cycles.—The term "cycle" as applied to an engine, is defined as a *series of events which are repeated in regular order, constituting the principle of operation*. These several events comprise the transformations which take place in the working medium, or, with reference to the gas engine, the distribution and behavior of the fuel mixture in passing through the engine.

The gas engine derives its energy from the heat, generated by the combustion within its cylinder, of a *mixture of fuel* in the form of a gas or spray mingled with air in proper proportion to form an explosive.

The mixture is admitted to the engine intermittently, and the amount supplied at each admission is known as the *charge*.

The combustion of each charge takes place under pressure attained by *compression*—a result of the inward movement of the piston after the charge is admitted and all valves closed.

The effect produced by igniting the mixture after compression is commonly called an *explosion*, which is simply a quick burning or rapid combustion of the mixture.

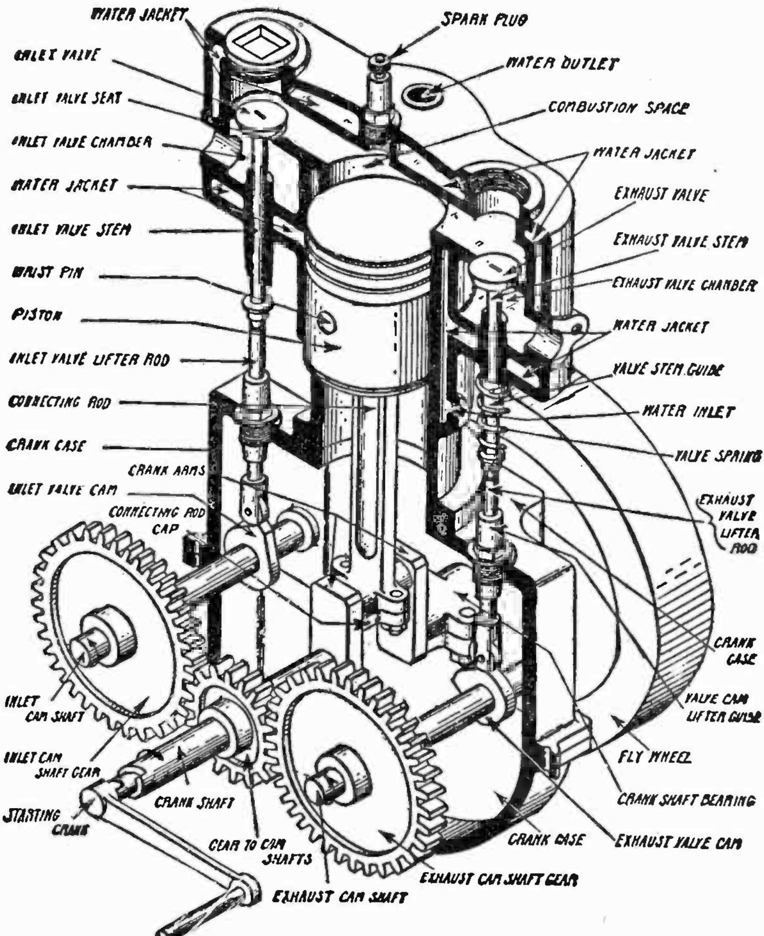


FIG. 6,965.—Sectional view of a four cycle gas engine, showing the valve gear and other working parts. Both inlet and exhaust valves are mechanically operated. The location of the valves diametrically opposite each other requires a separate cam shaft for each. These cam shafts are geared to the engine crank shaft and they make one revolution to every two of the engine. When the inlet valve is operated by a spring and the engine suction, only one cam shaft is necessary, as shown in fig. 6,967.

This sudden explosion causes a high degree of heat within the combustion chamber, resulting in considerable initial pressure, and gives to the piston an *impulse*, which decreases in intensity while the piston advances to make the *power stroke*, by reason of the expansion of the gases.

The products of combustion are finally *exhausted* from the cylinder. The period of exhaust occurs partly before the piston completes the power stroke, known as *pre-release*, and partly on the return stroke, known as *release*.

Expressed briefly, the cycle of a gas engine embraces:

1. Admission;
2. Compression;
3. Ignition;
4. Pre-release;
5. Release.

In the operation of a gas engine, the number of strokes required to complete the cycle varies with the type of engine.

According to the number of strokes required to complete the cycle, gas engines are divided into two general classes.

1. Two stroke cycle;
2. Four stroke cycle.

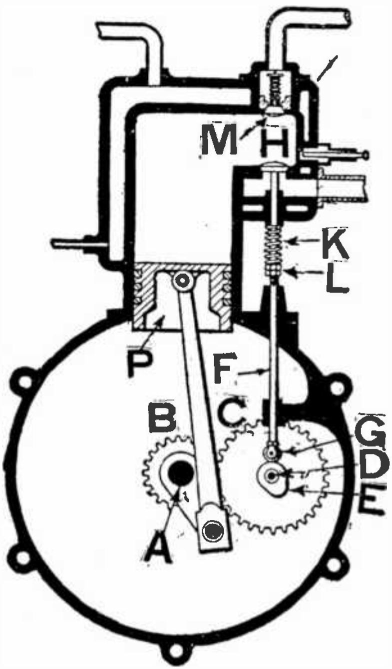
In referring to these two classes, the word stroke is usually omitted (being understood) and the classes designated as, briefly:

1. Two cycle;
2. Four cycle.

The four cycle engine being more generally used than the two cycle, is the more important and will accordingly be considered first. Fig. 6,966 shows the general arrangement of parts of a one cylinder four cycle engine with both valves operated mechanically, and fig. 6,967, a four cycle engine with spring inlet valve gear.

In four cycle operation the four strokes required to perform the cycle are known as:

1. First stroke (outward) *admission*;
2. Second stroke (inward) compression (or *suction*);
3. Third stroke (outward) *expansion* (or *power*);
4. Fourth stroke (inward) *exhaust*.

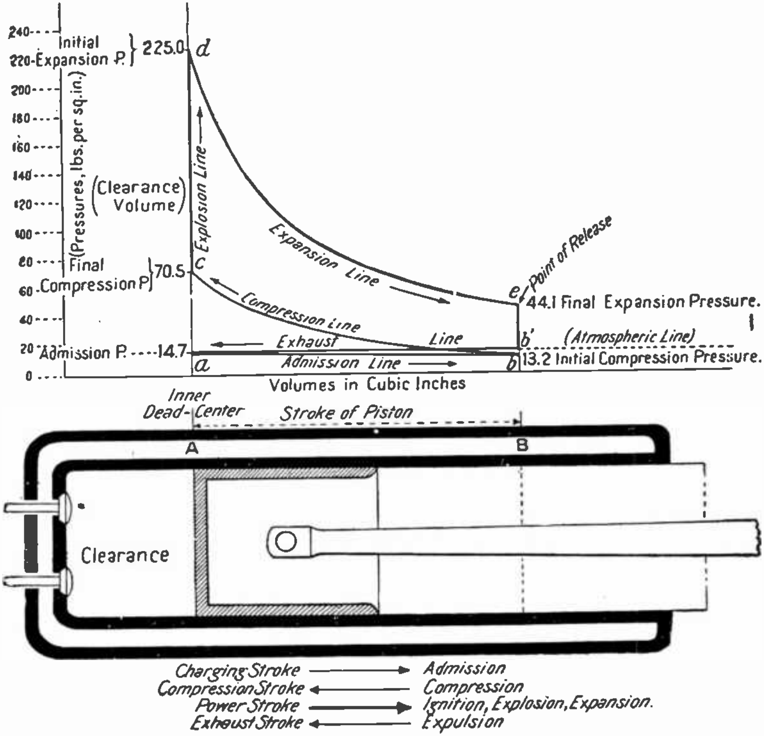


How a Four Cycle Engine Works.—The cylinder detail and *indicator diagram*, figs. 6,968 and 6,969, will serve to give a clear idea as to the "*distribution*" of the *working medium** within the cylinder due to the various "*events*" which take place during the cycle.

*NOTE.—The term ***working medium*** means the ***explosive mixture*** consisting of gasoline vapor and air in the correct proportion.

FIG. 6,967.—Four cycle gas engine with spring inlet valve gear. The figure shows a spring actuated inlet valve M, and a mechanically operated exhaust valve H. The latter is opened when the cam E, revolves and raises against the roller G, which is on the bottom of the lifter rod F. The rod F, extends upward and rests against the bottom of the stem of the valve H, although between the two or at their point of contact are nut and lock nut L, for lengthening or shortening the lifter F, and so to vary the time of opening or closing of the valve. The spring K, is compressed or squeezed together when the valve is opened and immediately the cam E, travels around and allows the roller G, to fall; this spring exerts its pressure and closes the valve. The intake valve M, is automatically opened by the suction of the engine.

Fig. 6,968 shows a theoretical indicator diagram of a four cycle engine; the assumed values for temperature, volume, and pressure, however, do not correspond to the maxima and

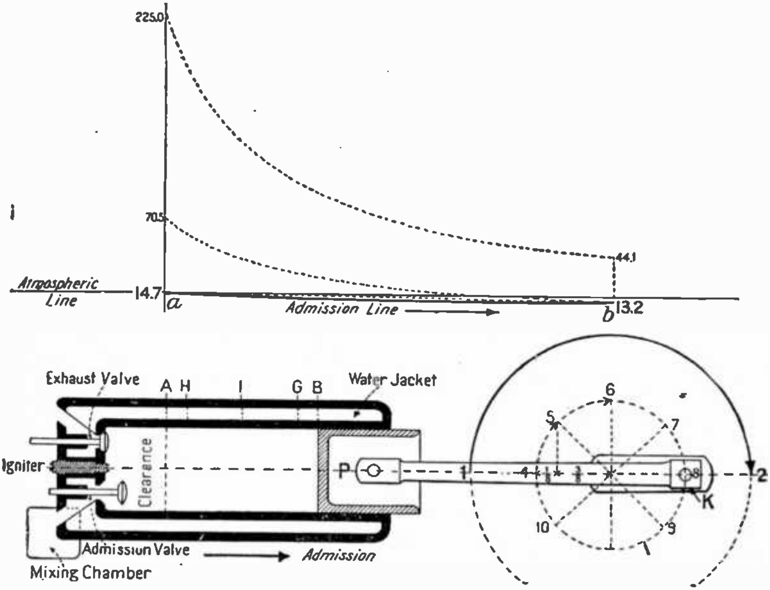


FIGS. 6,968 and 6,969.—***Theoretical indicator diagram*** of a four cycle gas engine. The assumed values for temperature, volume, and pressure are a fair average of those occurring in the cylinder under actual working conditions.

minima of such as may be derived from theoretical computations, but represent values which are a fair average of those occurring in the cylinder of a gas engine, operating under actual conditions.

In the diagram, the cycle begins at *a*, with the piston at A. During admission, the piston moves to B, the conditions within the cylinder during the movement being *ab*. This line is drawn below the line of atmospheric pressure, because, due to suction, the pressure in the cylinder is less than that of the atmosphere. At B, the inlet valve closes, thus completing admission.

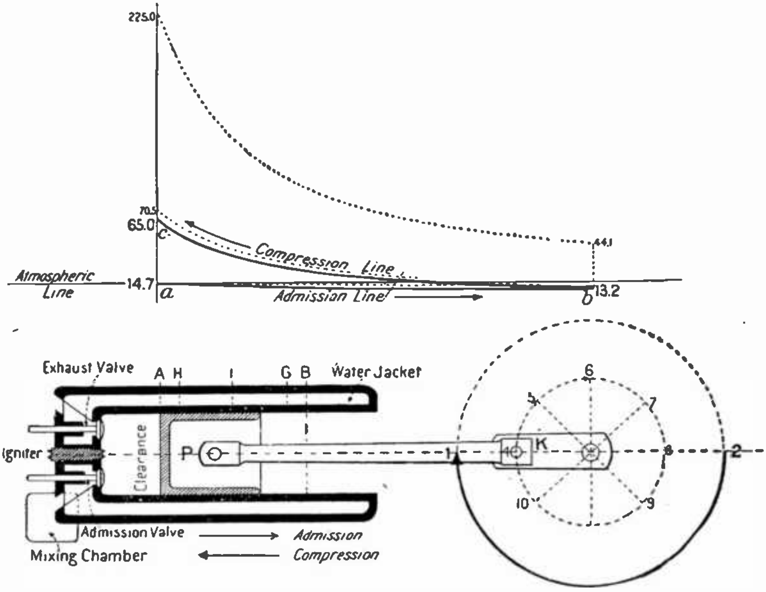
The piston now returned from B, to A, compressing the previously admitted charge into the clearance or combustion chamber; the curved line *bc*,



FIGS. 6,970 and 6,971.—***Admission stroke.*** The admission line *ab*, sags below the theoretical on account of frictional resistance encountered by the incoming charge. The uniform rotary motion of the crank causes great variations in the speed of the piston at different points of its stroke, the speed of the piston being more rapid while the crank passes from 5 to 7, and from 9 to 10, than while it passes from 10 to 5, and 7 to 9. The movement of the incoming charge as it flows from the carburetor through the manifold and valve opening is opposed by frictional resistance which increases with its speed. Hence, the increasing speed of the piston during the first part of the stroke causes an increase of speed of the charge, this in turn involves a drop of pressure within the cylinder corresponding to the greater suction required to overcome the excess frictional resistance. Thus, it is seen that the admission line falls below the dotted line during the first part of the stroke, and since in the latter part of the stroke the reverse conditions obtain, the admission line gradually approaches the dotted line.

shows the gradual increase in pressure, due to compression, from about a pound below atmospheric pressure to 70½ pounds at the end of the stroke. At this instant ignition of the compressed charge takes place, and the pressure suddenly jumps to 225 pounds, corresponding to the initial expansion.

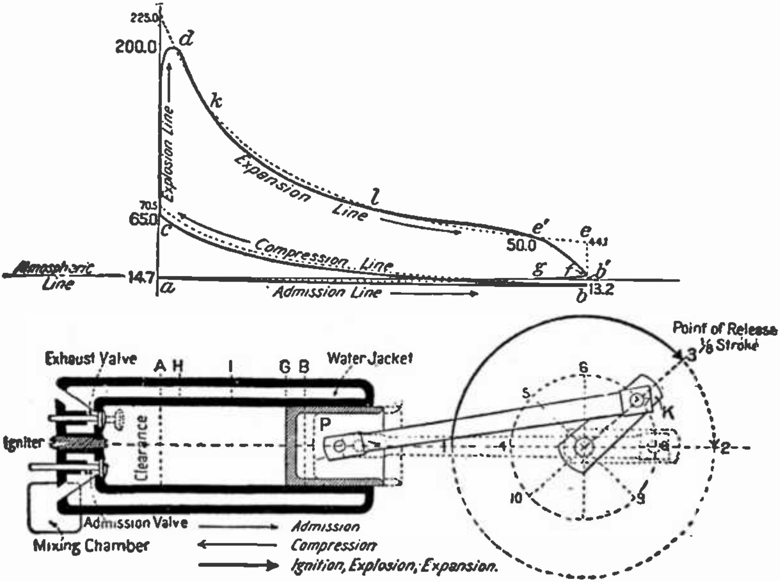
The piston again moves outward from A, to B, making the power stroke; the products of combustion expand with the increasing volume displaced by



FIGS. 6,972 and 6,973.—***Compression stroke.*** At or near the end of the charging stroke the admission valve closes and the energy of the fly wheel moves the crank from position 2 to 1 (fig. 6,973), which, in turn, pushes the piston from B. to A, thus compressing the charge into the clearance space. This results in raising both the pressure and the temperature of the charge. The gradual increase of pressure in the cylinder due to compression is indicated by the full compression line. The working conditions within the cylinder are such that the compression does not take place according to any law. There is a marked variation of the actual compression line *bc*, from the theoretical (dotted line).

the moving piston, and the pressure gradually falls, as indicated by the curved expansion line *de*. As shown, the pressure falls from 225 lbs. to 44.1 lbs. at the end of the stroke. At this point the exhaust opens and the pressure suddenly drops to that of the atmosphere, shown by the line *eb'*.

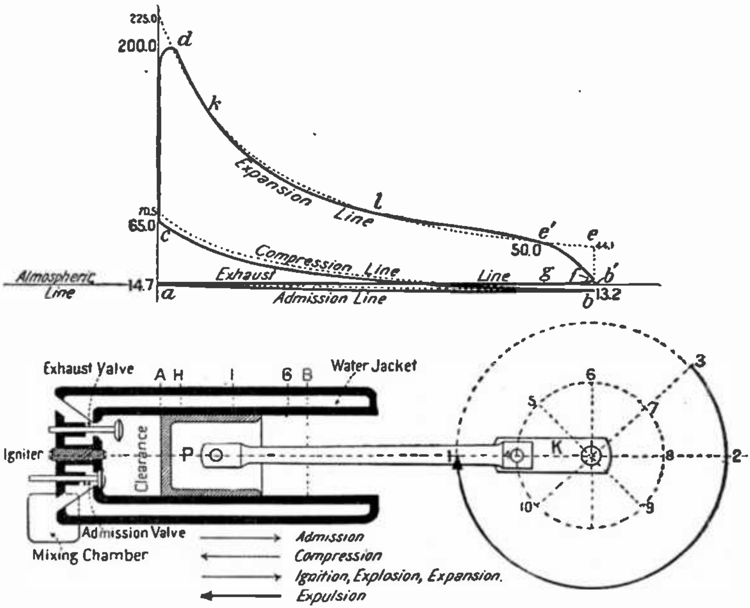
During the final stroke of the cycle from A, to B, the exhaust valve remains open and the burnt gases are expelled from the cylinder at approximately atmospheric pressure, as represented by the line *ba*, thus completing the cycle.



FIGS. 6,974 and 6,975.—***Expansion or power stroke.*** In the diagram, the position of the explosion line indicates that the spark in this instance was retarded to the end of the compression stroke and that the combustion was almost instantaneous, the maximum pressure attained being 200 lbs., corresponding to an initial expansion temperature of 2,195° Fahr. It should be noted that the theoretical pressure is 225 lbs., as shown by the dotted line. On account of late ignition the actual pressure of combustion obtained is less than the theoretical. A movement of the piston from A, to H, takes place during the explosion, hence, this increase of volume, together with the effect of the comparatively cool cylinder walls, prevents the maximum pressure reaching the theoretical value; this is shown by the curved portion of the explosion line at *d*, fig. 6,974. When the piston has reached the point H, (figs. 6 974 and 6,975) corresponding to *d*, the products of combustion expand, driving the piston forward toward B, at the expense of its own internal energy. the crank in the meantime revolving to the point 3. During the first part of the stroke, the temperature of the products of combustion is higher than that of the cylinder walls, hence, the gases are unduly cooled with a resulting fall of pressure in excess of that due to adiabatic expansion. During the latter part of the expansion (from *l* to *e'*, fig. 6,974) the reverse conditions obtain, that is, the products of combustion absorb heat from the cylinder walls, resulting in an excess of pressure above that due to adiabatic expansion. *Pre-release* begins at e' and continues to b'.

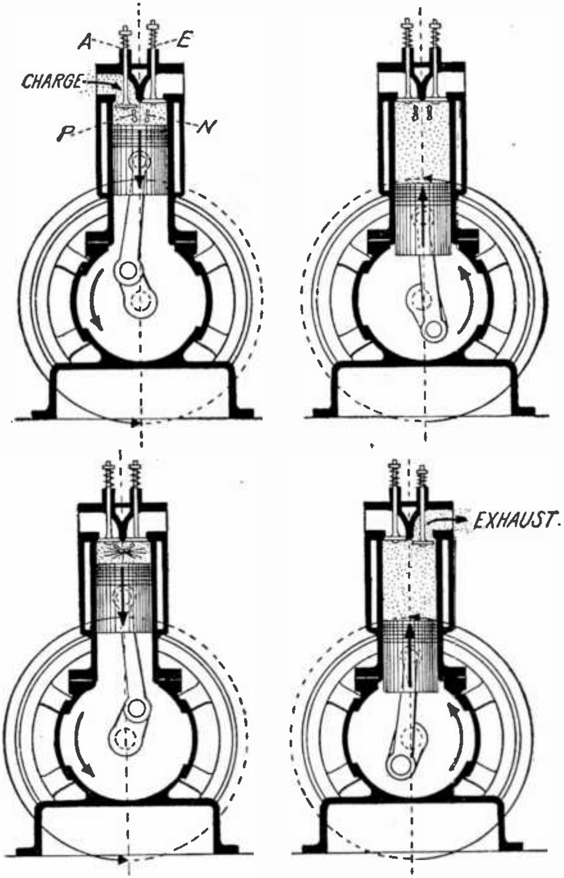
Ques. Could an engine operate according to the theoretical diagram of fig. 6,968?

Ans. *No*; the operation of any actual engine *can only approach* the conditions indicated in the diagram, since it is limited by mechanical and physical restrictions.



FIGS. 6,976 and 6,977.—***Exhaust stroke.***—During this operation, the indicator pencil will trace a line *ga* which will either coincide with, or lie above, the atmospheric line according to the following conditions: 1. If the exhaust valve be properly set and there be no wire drawing the pressure will be reduced to that of the atmosphere when the piston reaches the point G, on its return stroke, and the exhaust line traced by the pencil will coincide with the atmospheric line. 2. If the exhaust valve be set so as to release at too high a pressure, and there be wire drawing, the pencil will trace a line which will lie above the atmospheric line at a distance corresponding to the resulting back pressure.

In nature, nothing can take place *instantaneously*; that is, an *interval of time* is necessary for a physical change to take place, hence there can be no vertical lines as *cd*, or *eb'*, on a working diagram. Again, time is required for the opening of the exhause valve, involving that it *begins to open* before the end of the stroke, that is before the point *e*, is reached; this gradual opening of the valve is accompanied by a gradual instead of an abrupt reduction of pressure. Numerous other causes tend to produce variations between the actual and ideal diagrams.



FIGS. 6,978 to 6,981.—The *four cycle* method of operation. Fig. 6 978, *admission* stroke; fig. 6,979, *compression* stroke; fig. 6,980, *power* stroke; fig. 6,981, *exhaust* stroke. A, is the admission valve: E. exhaust valve; N, negative electrode; P, positive electrode of igniter.

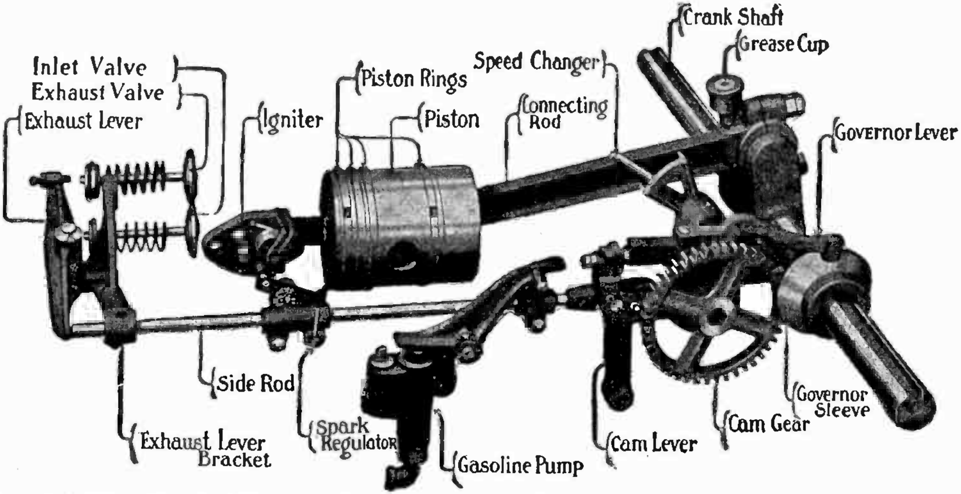


FIG. 6,982.—Working parts of a typical one cylinder four cycle gas engine.

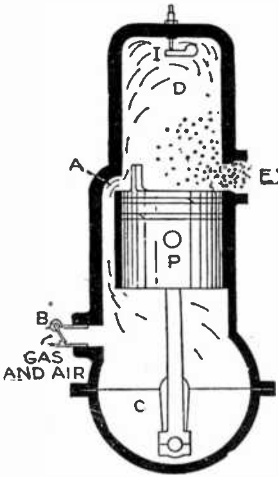
Pre-release.—In fig. 6,976, it will be noticed that there is a gradual drop of the expansion line at *e*′. This is due to the opening of the exhaust valve before the end of the stroke or pre-release of the products of combustion to exhaust.

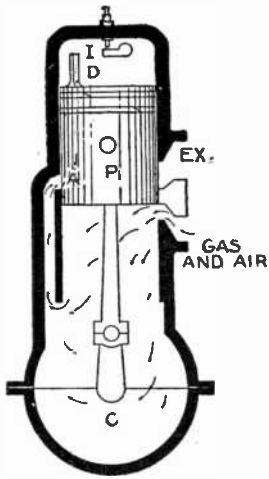
The exhaust valve opens before the end of the stroke in order that the pressure may be reduced to a minimum at the beginning of the exhaust stroke.

An interval of time is required for the valve to open, during which a corresponding movement of the piston takes place.

Accordingly as in fig. 6,976 the pressure does not fall abruptly at *e'*. The valve *begins* to open at *e'*, presenting at first a very small opening for the exit of the burnt gases; this offers considerable resistance, which results in a gradual fall of pressure, as indicated by the line *e' b'*.

The operation of the valves and valve gear of an actual engine during the cycle illustrated in fig. 6,968, is shown in figs. 6,978 to 6,981.





FIGS. 6,983 and 6,984.—Two cycle engine illustrating difference between the ***two port*** and ***three port*** types. Fig. 6,983, two port engine; fig. 6,984, three port engine. In the three port engine when the piston is at top of stroke a vacuum is created in base (see fig. 6,984). Inlet port, marked *gas and air*, is opened, allowing a charge to enter crank case. When piston starts down, this port is closed. The mixture of gas and air in crank case C, is then compressed by the downward motion of piston. Transfer point A, is opened, allowing gas and air which has been mixed in crank case to pass into cylinder. On the downward or explosion stroke the exhaust port opens slightly before transfer port and the exhaust or burned gases are passing out as a fresh charge is coming in through transfer port. To prevent this incoming charge passing across piston and into exhaust port a baffle plate D, is placed on top of piston which deflects a charge of incoming gas to top of cylinder. Piston comes up again closing exhaust port and transfer port and mixture is exploded. In the two port type, fig. 6,983, a check valve is used in place of the third port as shown.

The accompanying diagrams, figs. 6,970 to 6,977, show the events during the four strokes of the cycle more in detail.

How a Two Cycle Engine Works.—This type of gas engine is used chiefly for small powers, especially for marine service. The essential difference between it and the four cycle type is that the four operations of admission, compression, impulse, and exhaust, comprising the working cycle, are performed in one revolution instead of two.

There is then, one impulse for each revolution. From this, it follows that the weight is much less than that required for the four cycle engine.

The necessary mechanical features for two cycle operation are:

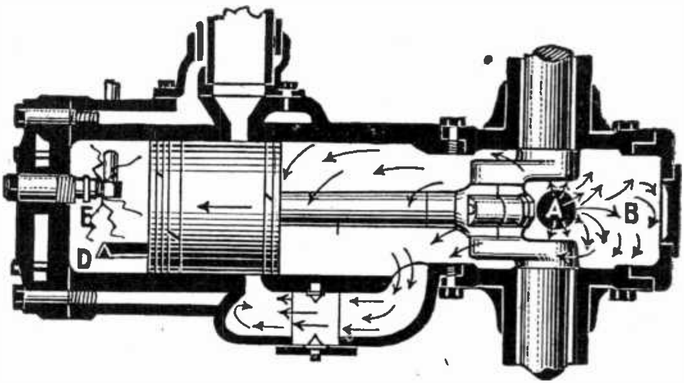


FIG. 6,985.—The two cycle engine: ***first stroke.*** The inward stroke of the piston induces a charge of the mixture at A into the crank case B, and compresses the previously admitted charge into the cylinder D; the subsequent ignition takes place at E.

1. An enclosed crank case fitted with a valve arranged to open and admit fuel gas at the front, instead of at the rear of the piston, on the inward, instead of the outward stroke, as in the four part cycle.

2. Inlet and exhaust ports located at points near the extreme outward position of the piston, so as to be uncovered during the outward stroke.

3. A by pass tube connecting the interior of the cylinder with the crank case, so as to admit fuel gas at the proper point in the cycle.

Ques. In the operation of a two cycle engine, what occurs during the first stroke?

Ans. The piston moves inward and draws in a charge of the explosive mixture into the enclosed crank case. During the operation the charge previously admitted to the cylinder is compressed and ignited as the piston nears the end of the stroke as in fig. 6,985.

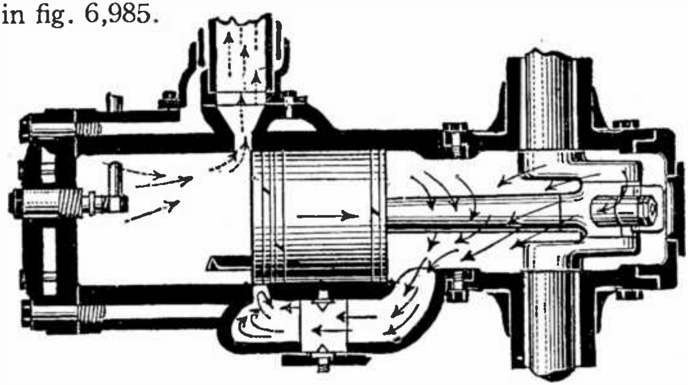


FIG. 6,986.—The two cycle engine: *first part of second stroke.* The outward stroke of the piston uncovers the exhaust port, thus releasing the burnt gases in the cylinder, and simultaneously compressing the previously admitted charge in the crank case.

Ques. What occurs during the second stroke?

Ans. The pressure caused by the explosion of the charge drives the piston outward, and slightly compresses the mixture drawn into the crank case during the previous stroke as in fig. 6,986.

Near the end of the stroke the piston uncovers the exhaust port and the burnt gases are exhausted. During the remainder of the stroke the piston

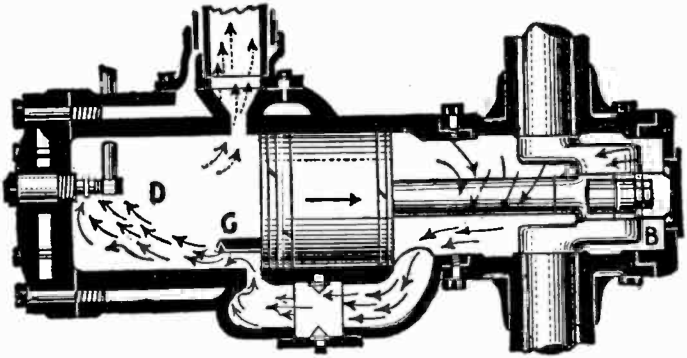


FIG. 6,987.—The two cycle engine. *end of the second or outward stroke.* The gases compressed in the crank case are admitted to the cyl nder space D, through the open inlet port, and sometimes past the screen or deflector, C. The passage between the cylinder and the crank case is controlled by a butterfly valve, which here, is shown open.

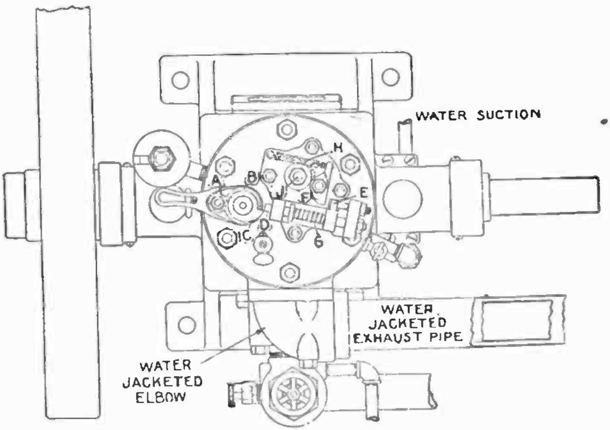


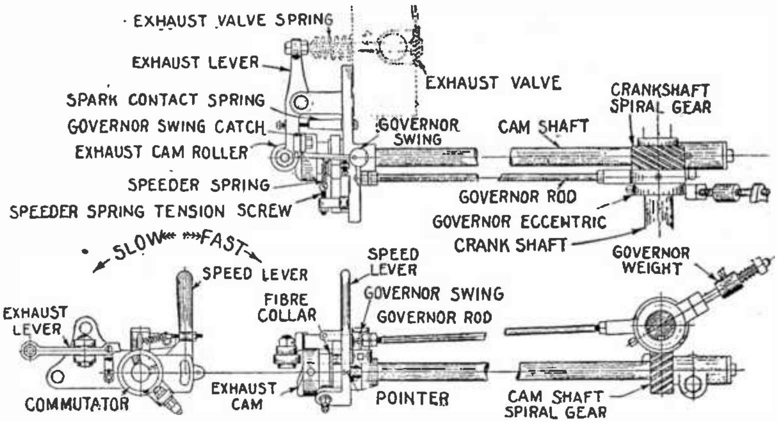
FIG. 6,988.—Plan of Fay and Bowen two cycle engine. ***In construction,*** the smaller gear A, is attached to the igniter shaft, and turns with it. The gear drives a larger gear B, the teeth of which show around and below the cam C. ***In operation,*** as the igniter shaft turns, this larger gear B, turns the cam C. The cam C, pushes back the plunger D, and as the plunger D, slips off the point of the cam C, its other end or hammer E, strikes the movable electrode F, breaking the electric current, and producing a spark. In the line drawing, the relation of the electrodes and sparking points *inside* of the firing chamber is indicated by dotted lines, the spring H, brings the movable electrode F to its place again, when the plunger D, backs off for the stroke.

uncovers the admission port, as in fig. 6,987, and the new charge, previously compressed in the crank case, is admitted to the cylinder, being deflected upward to the head end of the cylinder by a screen or "deflector plate" set in the end of the piston.

The "inrush" of the new charge helps materially to clear the cylinder of the burnt gases from the previous charge. The object of the deflector plate is to prevent the entering charge passing out through the exhaust in place of the burnt gases.

Ques. Which type of engine is the more economical?

Ans. The four cycle engine.



FIGS. 6,989 to 6,991.—Governor and valve mechanism of Domestic, type F, engine.

Ques. Why?

Ans. With the cycle extended to four strokes, there is more time for admission and exhaust; since these events take place at separate intervals, no chance is given for any of the charge to escape past the exhaust valve while open.

Owing to simultaneous admission and exhaust in the two cycle engine, *pre-release* of the burnt gases must take place earlier than in the four cycle engine, resulting in a loss of power which is avoided in the latter. The inefficiency of admission and exhaust of the two cycle engine becomes more marked at high speeds.

Ques. For what service is the two cycle engine extensively used?

Ans. For marine use, especially to propel boats of small size.

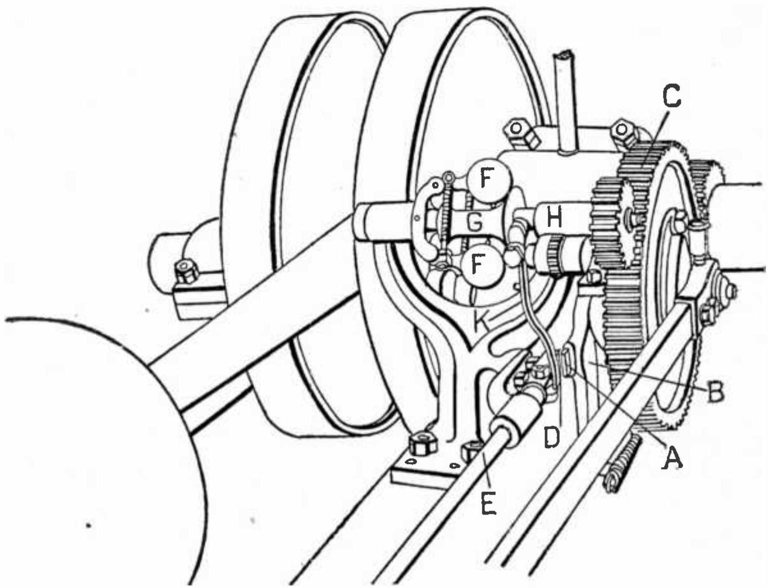


FIG. 6,992.—Foos hit or miss governor. ***In operation,*** at normal speed, the blade A, on the fuel lever B, operated by a cam on the gear wheel C, strikes the notched finger D, on the end of the push rod E, causing the fuel valve to open and admit a charge into the cylinder at each revolution of the cam. As the speed increases, the governor balls F, move outward, causing the spool G, to push against the roller H, carried on the upper end of the governor lever K. This action causes the lower end of the lever to move inward and push the notched finger D, out of its normal position, so that the fuel lever blade A, fails to hit it, and thus allows the fuel valve to remain closed. The fuel supply being thus cut off, the speed decreases and the governor balls return to their original position, releasing the pressure on the lower end of the governor lever and allowing the notched finger D, to resume its regular position under the pressure of a spring. It will be understood in this connection, that centrifugal fly ball governors operating on the hit or miss principle may be attached horizontally to a transverse secondary shaft as in the foregoing case, or they may be placed vertically at the side of the cylinder and receive their motion from a longitudinal secondary shaft through the medium of bevel gearing.

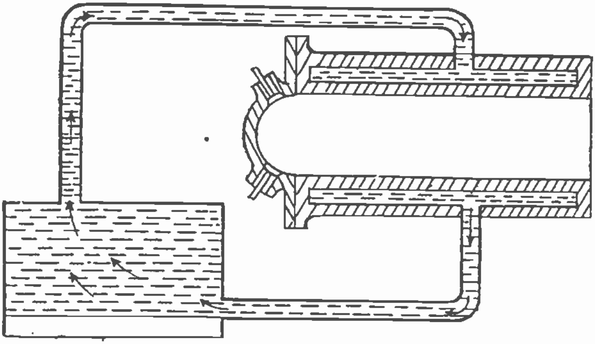
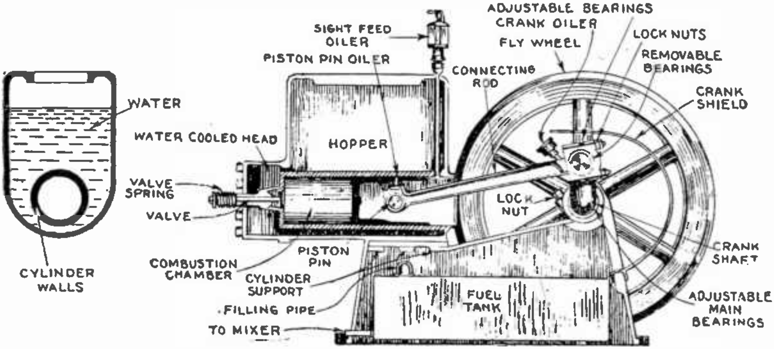


FIG. 6,993.—Diagram of a gravity water circulation system for a gas engine cylinder. As indicated by the arrows, the water from the tank enters the jacket of the cylinder at the lowest point, and being there subjected to the heat of the cylinder walls, rises to the level of the tank water; thus maintaining a continuous circulation.



FIGS. 6,994 and 6,995.—Sectional views of Fuller and Johnson gas engine cylinder showing open jacket or "hopper" method of cooling. The hopper consists of a large vessel surrounding the cylinder, which holds a sufficient quantity of water to adequately cool the cylinder. The water circulation is by gravity.

NOTE.—*The successful operation* of the two cycle engine at high speeds will depend on adequate provision for râpid exhaust. A prominent gas engine authortiy remarks: "The two cycle engine, at best, is the next thing to an impossibility." By this statement, he means that the act of admitting inflammable fuel mixture into the cylinder, already filled with flaming gas, without igniting it, involves something closely approaching a contradiction in physical conditions. Were it not for the fact that the burning gases actually exhaust faster than the new mixture is admitted under impulse of their inherent expansion, the ignition of the new charge would seem to be nearly inevitable.

Ques. Why is this?

Ans. On account of its light weight, simplicity, and small space, as well as low cost of construction.

Ignition.—The timing of the spark *should be varied to suit the running conditions.*

In general, ignition should occur a little before the end of the compression stroke, in order that the explosion will take place at practically constant volume, and attain the maximum pressure at the beginning of the stroke; early ignition is essential in some instances to secure complete combustion before the exhaust valve opens.

TEST QUESTIONS

1. *Define the working cycle of a "gas" engine.*
2. *What is the difference between a two cycle and a four cycle engine?*
3. *Could an engine operate according to a theoretical diagram?*
4. *Describe the construction of a four cycle gas engine.*
5. *How does a two cycle engine work?*
6. *What is the difference between a two port and a three port two cycle engine?*
7. *Describe at length the operation of a two cycle engine.*
8. *Which type of engine is the more economical and why?*
9. *For what service is the two cycle engine extensively used?*

NOTE—*Continued.*

By deflecting the incoming mixture to the rear end of the cylinder, it follows the rapidly expanding exhaust, coming into contact with it only when the expansion has so far reduced the temperature that the danger of pre-ignition is averted.

10. *Describe the operation of a governor.*
11. *How is overheating prevented?*
12. *How should the timing of the spark be varied?*

CHAPTER 163

Ignition Principles

Most treatises on ignition begin with an explanation of electrical principles and considerable space is thus taken up, which, if confined to the main subject, would be of greater value to the reader, assuming that he has an elementary knowledge of electricity.

The author suggests that the student first study the electrical principles as given in the first volume of this series before taking up the subject of ignition.

Electric Ignition Methods.—All the various systems of electric ignition in general may be divided into two classes:

1. Low tension, or *make and break.*
2. High tension, or *jump spark.*

The low tension system is electrically simple and mechanically complex, while the high tension system is electrically complicated and mechanically simple.

Low Tension Ignition.—In this method there is a device known as an *igniter*, placed in the combustion space of the engine cylinder. This consists of two electrodes, or spark terminals, one of which is stationary and the other movable.

The stationary electrode is insulated, while the other having an arm within the cylinder and placed conveniently near is capable of being moved from the outside so that the arm comes into contact with the stationary electrode and separates from the latter with great rapidity.

The sudden breaking of the circuit produces an electric arc caused by the inductance, that is, by the "inertia" or tendency of the current to continue flowing after the separation of the contact points.

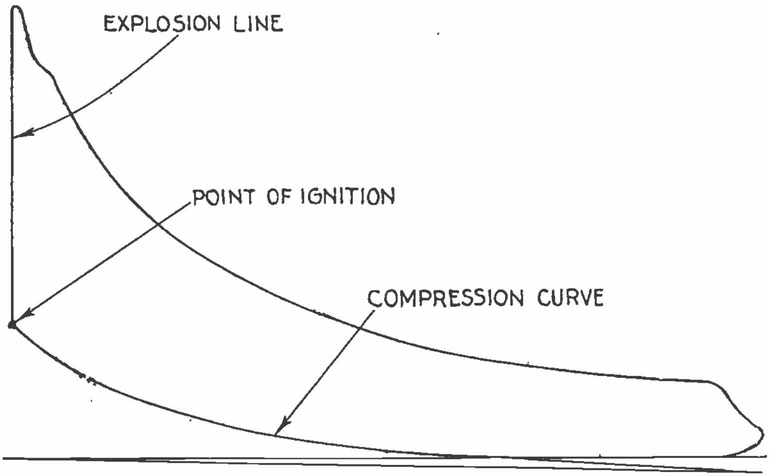


FIG. 6,996.—Indicator card for gas engine illustrating the *point of ignition*." It will be noted that compression continued to the end of the stroke, before the compression curve made an abrupt change into a nearly vertical line, the point of ignition, that is, the piston position at the instant of ignition, the nearly vertical "explosion" line with the high peak coming almost to a point, denotes a strong mixture and a quick explosion.

The current may be derived from either a primary battery, storage battery or low tension magneto.

While it is possible to produce an arc by simply breaking a battery circuit, it is necessary in order to have an *arc* of sufficient intensity and duration to introduce into the circuit a *primary induction coil* consisting of a long iron core wound with a considerable length of low resistance insulated copper wire. When a magneto is used, the coil is not necessary as the armature winding serves the same purpose. A magneto furnishing either direct or alternating current may be used; the voltage will depend on the armature speed and the strength of the magnets.

Iridium or platinum is used for contact points of the electrodes, as these metals resist the oxidizing effect of electricity and heat better than others.

In low tension ignition a considerable interval of time is required for the current to rise to its full value and the time of separation of the electrodes should not be sooner than the moment when the maximum current strength has been attained. When a magneto is used the current strength increases with the speed, hence the contact interval can be shorter at high speeds than when a battery is used.

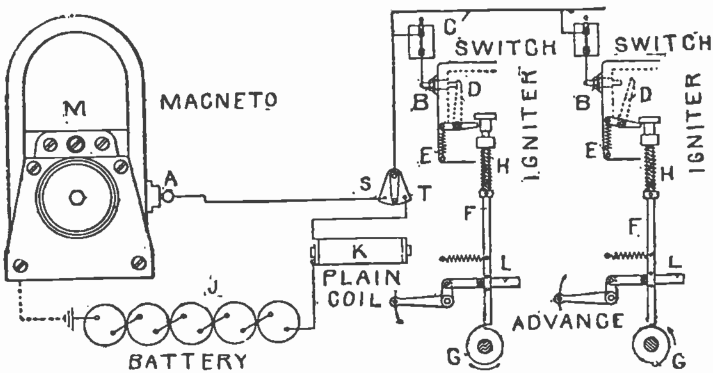


FIG. 6,997.—Method of low tension or make and break ignition. *In operation*, as the nose of the cam G, passes rod F, the latter suddenly drops by the action of spring H. The head of the rod, which has been raised by the cam somewhat above the arm of D, will in its descent strike D, a blow which abruptly breaks contact between D and B, thus producing an arc. When not acted upon by the head of the rod F, D, is held in contact with B, by the spring E. The system is explained in detail in the text.

The principles of operation of a low tension ignition system are illustrated in fig. 6,997.

At the instant the circuit is broken by the separation of the contact points, the self-induction thus set up in the coil K, opposes any rapid change in the current strength, hence, the current continues to flow momentarily after the circuit is broken, resulting in producing an *arc*. The action is the same as though the current possessed the property of "inertia," that is, time and resistance both are necessary to bring it to a state of rest. This inertia effect is intensified by the action of the induction coil. When a magneto is used, the armature windings serve the same purpose.

The timing of the spark is accomplished by the adjustable guides L, which serve to vary the horizontal position of the lower ends of the rods F, and thus vary the instant at which their ends pass the nose of each cam.

In make and break ignition it is necessary in order to produce a good arc, that the "break" or separation of the contact points of the igniter should take place with **extreme rapidity,** that is, the

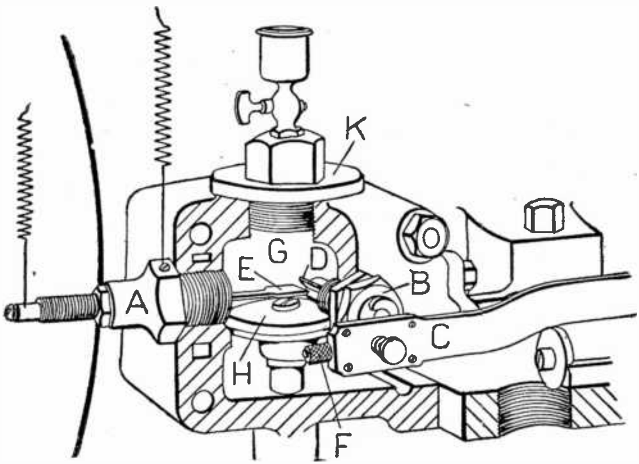


FIG. 6,998.—***Wipe contact*** igniter. It consists of two independent electrodes, the stationary electrode A, and the movable electrode B. When the latter is revolved by the motion of the igniter rod C, the revolving blade D, is brought into contact with the spring E, at each rotation, and produces the spark. In this arrangement the break is more effective than in the hammer break type, and gives a larger spark with a given battery capacity, while at the same time, the wiping contact of the two parts prevents the accumulation of burnt carbon or scale on their edges, and thus serves to keep the contact surfaces bright and clean. On the other hand, it possesses the drawbacks incident to the use of a spring which is exposed to the extremely high temperatures developed within the cylinder. The use of flat springs is particularly disadvantageous as it is very difficult to temper them uniformly, and they are consequently liable to break without warning. Furthermore, the wear of the electrodes is excessive. The moment of ignition can be adjusted while the engine is running by turning the thumb screw F, on the end of the igniter rod, and this screw is used also to retard the impulses at starting, thus preventing the engine moving backward. The igniter is located in the inlet chamber G, directly over the head of the admission valve H, and either one of the electrodes can be reached for inspection or removal, independently, by simply removing the cap K.

spring H (fig. 6,997) should be sufficiently strong to cause the shoulder of rod F, when it falls, to strike the igniter arm a decided blow, thus quickly snapping apart the contact points.

Ques. State some disadvantages of low tension ignition.

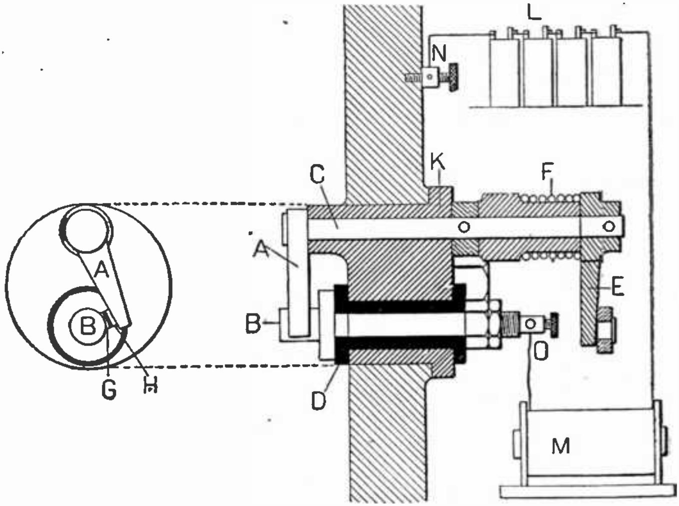


FIG. 6,999.—***Hammer break*** igniter. ***It consists of*** two metallic terminals A and B. The terminal A, is mounted on a movable shaft C, while B, is stationary and ***insulated*** from the cylinder wall by the lava bushing D. A suitable cam rod, attached to the crank E, provides the means for rocking the terminal A, so as to bring it in contact with the terminal B, ***and then quickly separate*** the terminals to produce the spark. The helical spring F, provides a semi-flexible connection between the shaft C, and the crank E. The contact points of the two terminals are tipped with two small pieces of platinum G and H, and both terminals are mounted in the removable plug K, which is usually inserted through the wall of the cylinder head, so that the igniter points extend into the compression space of the cylinder. In the circuit is a battery L, and primary spark coil M. ***In operation***, when the igniter terminals are brought together, the circuit is closed through the battery and the spark coil, and when the terminals are ***quickly separated***, the self-induction of the coil causes an electric arc between the igniter terminals which ignites the charge.

Ans. Mechanical complication, excessive noise, wear of the igniter points, and possible leakage through the igniter.

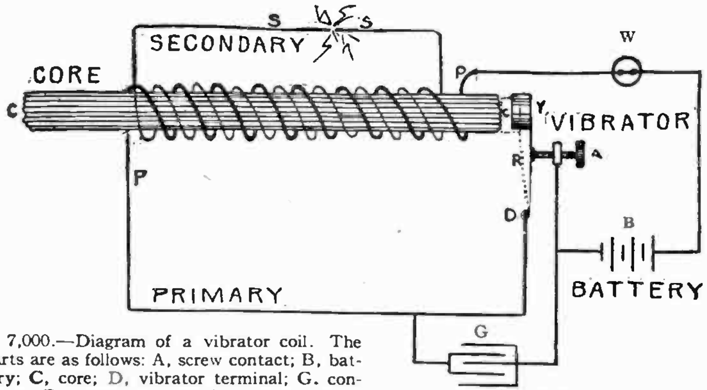


FIG. 7,000.—Diagram of a vibrator coil. The parts are as follows: A, screw contact; B, battery; C, core; D, vibrator terminal; G. condenser; P, primary winding; S, secondary winding; W. switch; Y. vibrator. When the switch is closed, the following cycle of actions takes place: 1, the primary current flows and magnetizes core; 2, magnetized core attracts the vibrator and breaks primary circuit; 3, the magnetism vanishes, inducing a momentary high tension current in the secondary winding; 4, magnetic attraction of the core having ceased, vibrator spring re-establishes contact; and 5, primary circuit is again completed and the cycle begins anew.

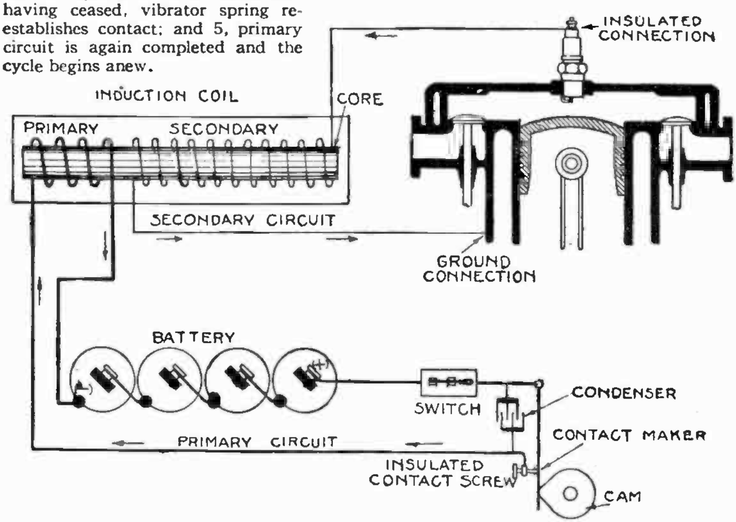


FIG. 7,001.—Diagram illustrating the principles of high tension or jump spark ignition. The nose of the cam in revolving engages the contact maker which completes the primary

Ques. For what service is low tension ignition especially suited?

Ans. For marine service especially in open, off shore fishing boats, such as Cape Cod dories, Sea Bright skiffs, etc.

High Tension Ignition.—In this method of producing a spark, a device called a *spark plug* is employed.

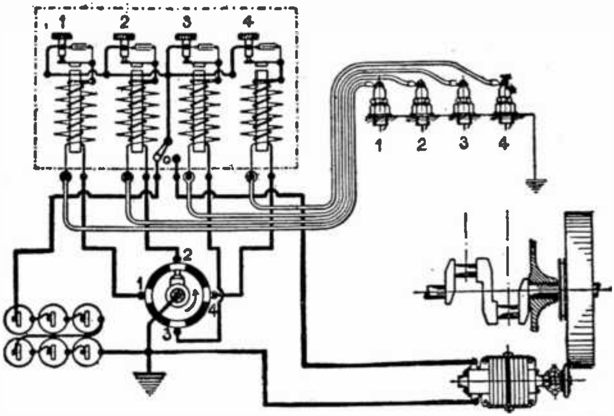
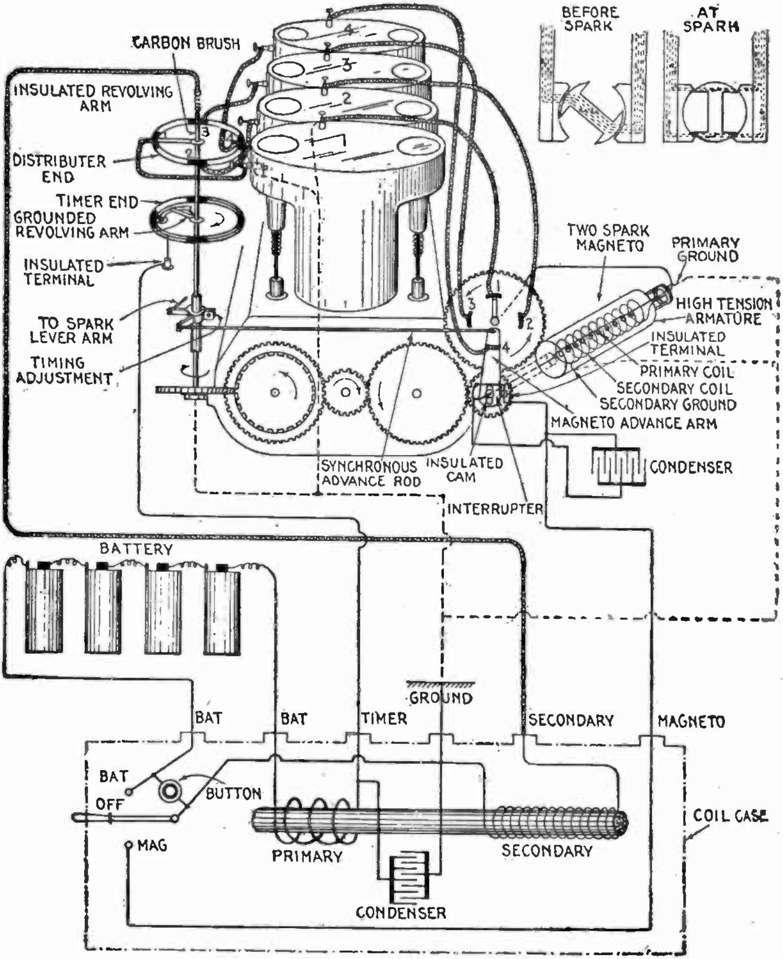


FIG. 7,002.—Wiring diagram of a dual jump spark ignition system for a four cylinder four cycle engine. A dry battery and low tension magneto form the two sources of current supply. The primary, or low tension circuit is shown by heavy lines, the secondary or high tension circuit by fine lines and the leads to spark plugs by the double lines. The dotted rectangle represents the outline of a four unit dash coil.

This consists of two stationary electrodes, one of which is grounded to the engine cylinder and the other insulated. The points of the electrodes are permanently separated from each other by about $^1/_{32}$ of an inch, the space

FIG. 7,001.—*Text continued.*
circuit and allows current to flow from the battery through the primary winding of the coil; this magnetizes the core. The primary circuit is now broken by the action of the cam and magnetic changes take place in the coil which induce a momentary high tension current in the secondary circuit. The great pressure of this current forces it across the air gap of the spark plug and as it bridges the gap a spark is produced. The arrows indicate the paths of the currents.



FIGS. 7,003 to 7,005.—Double ignition consisting of a two spark high tension magneto system and a battery synchronous ignition system with engine driven distributer. Fig. 7,003, elementary diagram of connections; fig. 7,004, position of magneto armature just before time of spark; fig. 7,005, position of armature at time of spark.

between the points being known as an *air gap*. This space offers so much resistance to the flow of an electric current that a very high pressure is required to cause the current to burst through the air gap and produce a spark, hence the term "high tension ignition."

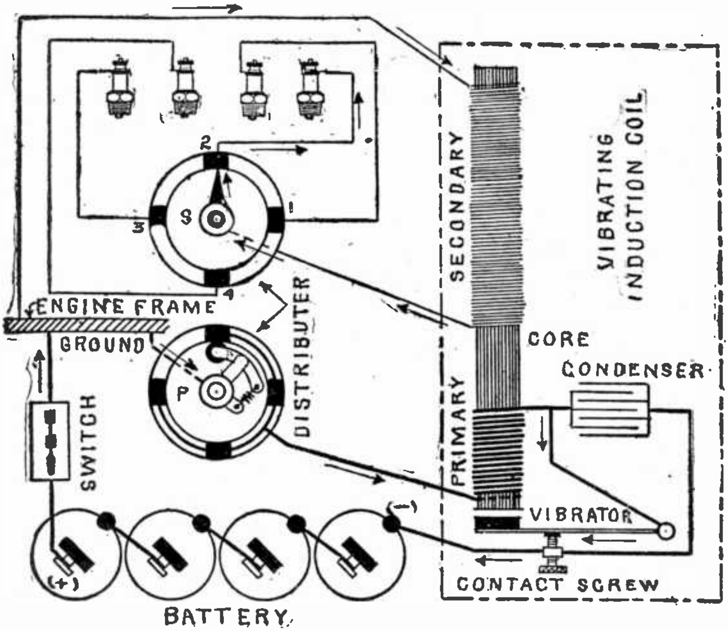


FIG. 7,006.—Diagram illustrating the principles of synchronous ignition. ***For clearness*** the primary and secondary elements of both the coil and the distributer are shown separated. When the primary rotor of the distributer completes the primary circuit, current from the battery flows and the vibrator operates, making and breaking the current with great frequency. A high tension current, made up of a series of impulses, is induced in the secondary circuit and distributed by the rotor arm during its revolution to the several cylinders in the proper order of firing.

Since the spark jumps from one electrode to the other, this method of igniting the charge is also known as the *jump spark* system. The spark itself is properly described by the prefix ***high tension*** or *secondary*.

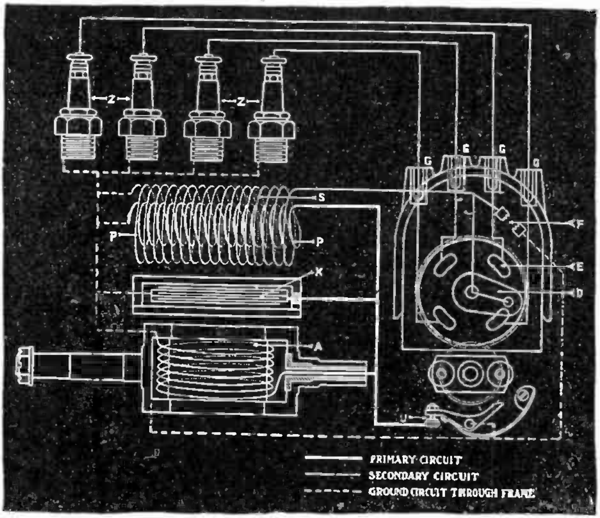


FIG. 7,007.—Circuit diagram of a ***magneto*** with ***self-contained coil.*** A, is the armature winding; P, primary —; S, secondary of transformer; D, distributing brush carrier; **E**, contact segments; F, safety spark gap; G, terminals to plugs; U, interrupter; Z, spark plugs. ***In operation,*** alternating current flows from the armature having two points of maximum pressure in each armature revolution. As the current leaves the armature, it is offered two paths: 1, the shorter through the interrupter U, to the ground, and 2, the longer through the primary P, of the induction coil to the ground. A third path through the condenser K, is only apparently available; it is obstructed by the refusal of the condenser to permit the passage of the current, as the condenser will merely absorb a certain amount of current at the proper moment, that is at the instant of the opening of the interrupter. The interrupter being closed the greater part of the time, allows the primary current to avail itself of the short path it offers. At the instant at which the greatest current intensity exists in the armature, the interrupter is opened mechanically so that the primary current has no choice but must take the path through the primary P, of the induction coil. A certain amount of current is at this instant also absorbed by the condenser K. This sudden rush of current into the primary P, of the induction coil, induces a high tension current in the secondary winding S, of the coil which has sufficient pressure to bridge the air gap of the spark plug. The sharper the rush of current into the primary winding P, the more easily will the necessary intensity of current for a jump spark be induced in the secondary winding S. ***The distribution of the current*** in proper sequence to the various engine cylinders is accomplished as follows: the high tension current induced in the secondary S. of the induction coil is delivered to a distributing brush carrier D, that rotates in the magneto at half the speed of the crank shaft of the engine. This brush carrier slides over insulated metal segments E, there being one for each cylinder. Each of these segments E, connects with one of the terminal sockets that are connected by cable with the spark plugs as shown. ***At the instant of interruption*** of the primary current, the distributing brush is in contact with one of the metal segments E, and so completes a circuit to that spark plug connected with this segment. Should the circuit between the terminal G, and its spark plug be broken, or the resistance of the spark plug be too great to permit a spark to jump, then the current

In the production of the spark two distinct circuits are necessary: 1, a low tension or *primary* circuit, and 2, a high tension or *secondary* circuit. The current which flows through the low tension circuit is called the *primary current*, and that which it *induces* in the high tension circuit, the *secondary current*.

In order to obtain the high pressure required to produce a spark, a device known as a *secondary induction coil* is used which transforms the primary current of low voltage and high amperage into a secondary current of high voltage and low amperage, that is, the quantity of the current is decreased and its pressure increased.

The general principles upon which high tension or jump spark ignition is based are as follows:

An automatic device is placed in the primary circuit which closes and opens it at the time a spark is required. When the circuit is closed, the primary current flows through the primary winding of the coil and causes a secondary current to be induced in the secondary winding. The spark plug being included in the secondary circuit opposes the flow of the current by the high resistance of its air gap. Since the pressure of the secondary current is sufficient to overcome this resistance, it flows or "jumps" across the gap and in so doing intense heat is produced resulting in a spark.

Sometimes the spark is obtained by keeping the primary circuit closed except during the brief interval necessary for the passage of the spark at the plug points. A secondary spark, then, may be produced by either open or closed circuit working, that is, the primary circuit may be kept either opened or closed during the intervals between sparks.

The automatic device which controls the primary current to produce a spark by the first method is called a *contact maker*, and by the second method, a *contact breaker*. A closed primary circuit with a contact breaker is used to advantage on small engines run at very high speed as it allows time for the magnetism or magnetic flux in the core of the coil to attain a density sufficient to produce a good spark. The word *timer* is usually applied to any device which controls the primary current, when it controls both the primary and secondary currents, as in *synchronous ignition* it is called a *distributer*.

FIG. 7,007—*Text continued.*

might rise to an intensity sufficient to destroy the induction coil. To prevent this what is known as a safety spark gap is introduced. This will allow the current to rise only to a certain maximum, after which discharges will take place through this gap. *In construction*, the spark discharges over this gap are visible through a small glass window conveniently located.

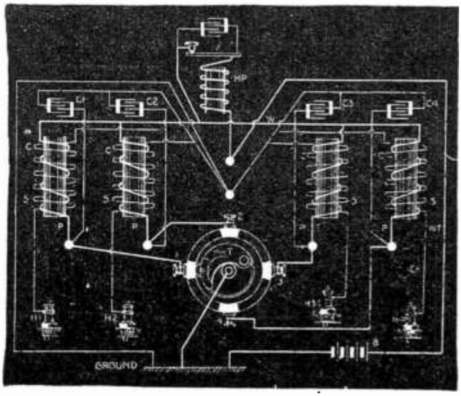
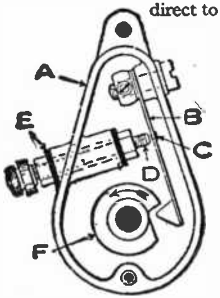


FIG. 7,008.—Circuit diagram of a master vibrator coil. B, is the battery; C, the unit coils; C1, C2, etc., the condensers; P, the primary windings and S, the secondary windings; H1, H2, etc., the spark plugs; T, the timer; MP, the master primary; V, the vibrator; W, the common primary connection; 1, 2, etc., the stationary contacts of the timer. The primary windings are all united in parallel at the top by a wire W, and with the lower ends connecting respectively with the segments of the timer E. The primary winding MP, which operates the vibrator V, is in series with this winding, the wire WT, connecting from the battery and passing directly through the master primary MP. The four condensers C1, C2, C3 and C4, are in parallel with the primary windings. Each of the secondary windings S connects direct to the spark plugs, designated respectively H1, H2, H3 and H4.



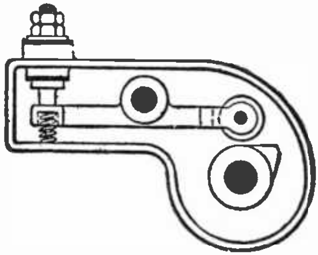


FIG. 7,009.—A contact maker and mechanical vibrator or *trembler*. The case A, is usually attached to the gear box of the engine; B, is the blade; C, a platinum contact point; D, an insulated adjusting screw; E, a bushing with insulation; F, the operating cam. As this cam revolves, the weight on the end of blade B, drops into the recess on the cam, causing the blade to vibrate and make a number of contacts with D, thus producing a series of sparks when in operation.

FIG. 7,010.—A contact breaker. This device keeps the circuit closed at all times except during the brief interval necessary for passages of the spark at the plug points. Used to advantage on engines running at very high speeds, as it allows time for the magnetic flux in the core of the coil to attain a density sufficient to produce a good spark.

TEST QUESTIONS

1. *Name two general classes of ignition systems.*
2. *What is the principal device used in low tension ignition?*
3. *Does low tension ignition take place on making or on breaking the contacts of the igniter?*
4. *Name two sources of current for low tension ignition.*
5. *What other name is sometimes given to low tension ignition?*
6. *What metal is used for the contact points of an igniter?*
7. *Draw a diagram of a low tension ignition system with battery and magneto current sources.*
8. *What is the most important requirement in the operation of an igniter?*
9. *Describe the various types of igniters.*
10. *State some disadvantages in low tension ignition.*
11. *For what service is low tension ignition especially suited?*
12. *How is ignition produced in the high tension system?*
13. *What other name is sometimes given to high tension ignition?*
14. *What is the difference between an arc and a spark?*
15. *Draw a diagram of a vibrator coil.*
16. *Make sketch illustrating the principles of high tension or jump spark ignition.*
17. *Describe the construction of a spark plug.*
18. *What is understood by the term* synchronous ignition?
19. *Draw a diagram of a magneto with a self contained coil, and describe at length its operation.*

20. *How does a master vibrator coil work?*
21. *How many coils are required for synchronous ignition of a four cylinder engine?*
22. *How does a contact maker work?*
23. *Describe the construction of a contact breaker.*

CHAPTER 164

Timing

The system or process by means of which the opening and closing of the valves and the moment of ignition are regulated in an internal combustion engine is called timing.

Accordingly, timing consists of two distinct operations:

1. Timing the valves.
2. Timing the ignition.

The timing of the valves is an expression analogous to "valve setting" in regard to a steam engine.

Ques. How is the timing of the valves effected?

Ans. By arranging the cams which operate the valves, so that successive firing cylinders are on opposing cranks.

Ques. Explain this by referring to the four cylinder engine detail in fig. 7,011.

Ans. Naming the cylinders from right to left, 1, 2, 3, 4, and assuming that cylinder #1 has just completed a power stroke, the next cylinder may be either #2 or #3, the third one must be #4, and the final one may be either #3 or #2, depending on which fired second.

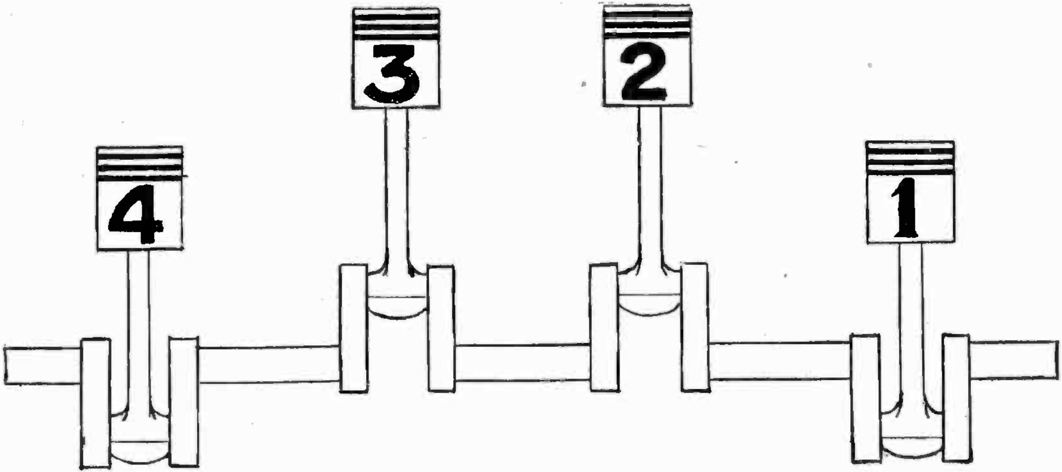


FIG. 7,011.—Sequence of cranks of a four cylinder gas engine.

Ques. How is the firing order usually expressed?

Ans. The engine fires 1, 2, 4, 3, or it fires 1, 3, 4, 2.

Ques. What else governs the firing, in so far as balance is concerned?

Ans. The adjustment of the ignition mechanism must follow the same rotation as governed by the cam rotation.

Ques. Explain the best method of ascertaining the timing, as regards the firing of the successive cylinders.

Ans. The engine should be turned over slowly by hand. By watching the lifting of the inlet or exhaust valve stems, the point of ignition will come about one-half turn after the seating of the inlet valve on each cylinder.

Ques. What governs the ignition?

Ans. The timing device.

Ques. How is the timer adjusted?

Ans. The engine should be turned slowly until the inlet valve of cylinder #1 seats. It is then given an additional half turn; if the timer be fastened to the cam shaft by a set screw, the latter may be loosened and turned around until contact is made with one of the points, and the set screw tightened. The wire leading to spark coil #1 is connected to this point and the secondary wire of this coil to spark plug on cylinder #1. The engine is now slowly given another half turn, during which it should be noted which inlet valve seats; it should be that of cylinder #2 or #3. The primary wire of the second spark coil, is connected to the binding screw of the timer point now in contact, and the secondary wire of this coil to the cylinder which has been found to be in action. The remaining cylinders are then tested in the same manner.

Ques. Should not the spark coils and cylinders whose numbers correspond be connected together?

Ans. For convenience spark coils are commonly connected in rotation, no matter what the firing order may be.

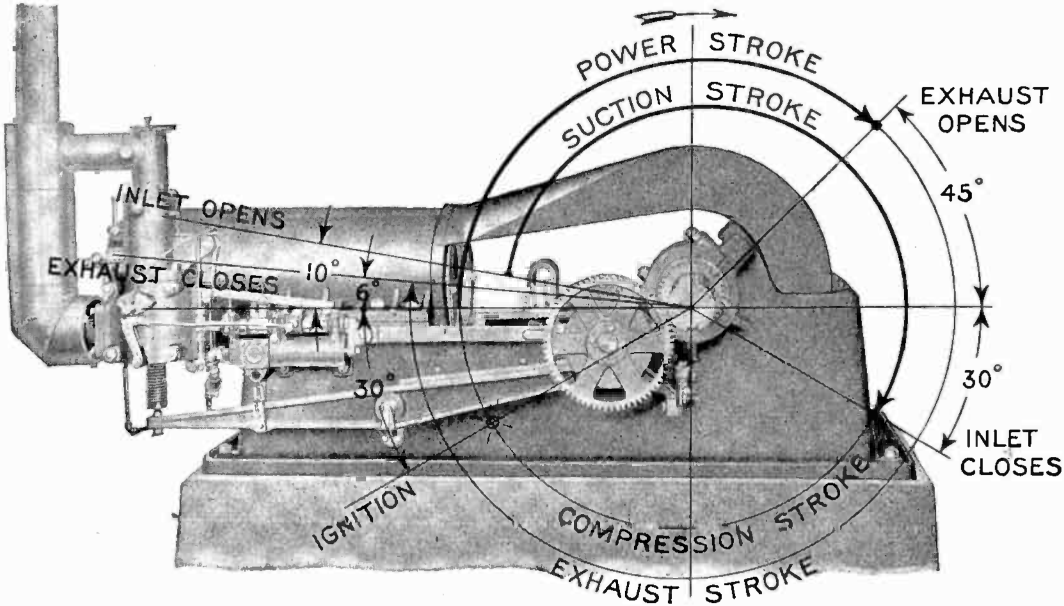


FIG. 7,012.—Charter oil engine with superimposed timing diagram. The valve mechanism is operated by two to one gears. The crank pin makes two complete revolutions to one revolution of valve gearing. This one revolution of gear completes the cycle of operations. The engine runs ahead in the direction shown by arrow. The direction of rotation cannot be reversed. A careful comparison between figs. 7,012 and 7,013 will show the relation of the cycles, rotation of crank pin, fig. 7,012, and the pressures in the cylinder, fig. 7,013.

Ques. Would this method hold good on all engines?

Ans. No. Only on those equipped with jump spark ignition.

Ques. How should a "make and break" spark be timed for firing?

Ans. The engine is turned over until the inlet valve of cylinder #1 seats, then given another half turn until piston

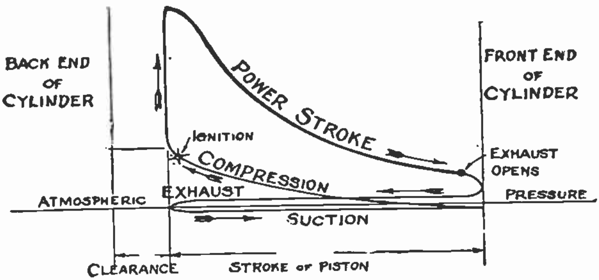


FIG. 7,013.—Charter oil engine indicator card or graphic representation of the pressures in the engine cylinder on the back end of piston. It is practically correct except that the exhaust and suction lines are shown at exaggerated differences from atmospheric pressure.

#1 is at the top. The "snap release" is now adjusted on the sparker until the contact breaks; the same method applies to the other cylinders, determining their succession as before.

Ques. Why must the position of the piston be determined more accurately than with the jump spark in a make and break spark engine?

Ans. As a rule, a make and break device has not such a wide range of advance, and if the retarded spark should not take effect at the dead center, the spark could not be sufficiently advanced for the highest speed.

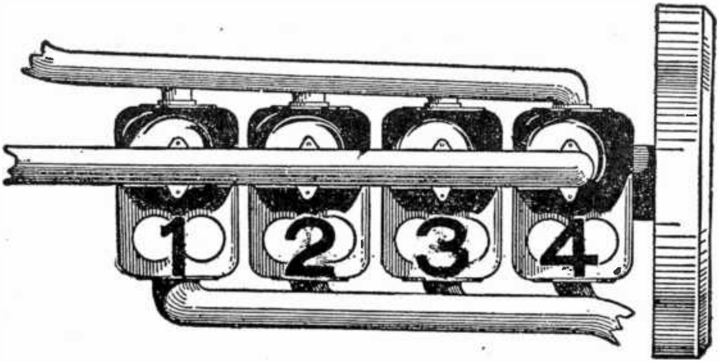
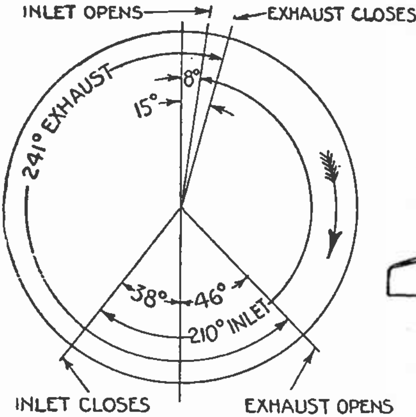
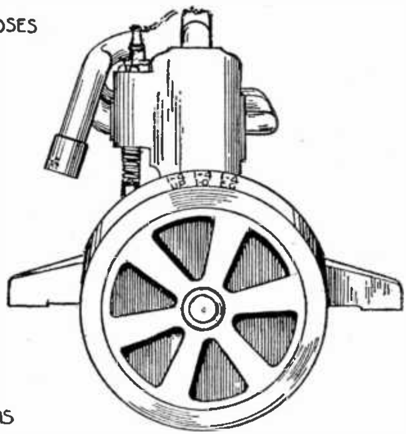


FIG. 7,014—Top of four cylinder engine showing numbering of cylinders.





FIGS. 7,015 and 7,016.—Valve timing diagram and fly wheel markings. ***The timing of valves*** is an operation which should be undertaken with caution and carried out with accuracy, and by a person competent to do such work. The usual markings on the rim of the fly wheel are as follows:

1-4 up means, pistons of cylinders 1 and 4 are on top center.
2-3 up " " " " 2 " 3 " " " "
1-4, I-0 means, inlet valve of cylinder 1 or 4 opens.
1-4, I C " " " " " 1 " 4 closes.
1-4, E 0 " exhaust " " " 1 " 4 opens.
1-4, E-G " " " " " 1 " 4 closes.
2-3, I-0 " inlet " " " 2 " 3 opens.

FIGS. 7,015 and 7,016—*Text continued.*

2-3, I-C	"	" "	"	"	2 " 3 closes.
2-3, E-O	"	exhaust"	"	"	2 " 3 opens.
2-3, E-C	"	" "	"	"	2 " 3 closes.

The firing order is 1-3-4-2.

The dimensions here given apply to a certain engine, the principles to any. ***According to the diagram,*** the intake valve opens when the fly wheel is 8 degrees past upper dead center and closes when it is 38 degrees past the lower dead center.

The exhaust valve opens 46 degrees before the lower dead center, and closes again 15 degrees past upper dead center; thus the inlet valve opens and closes late, whereas the exhaust valve opens early and closes late.

The fly wheel being eighteen inches in diameter, the following table gives the measurements in inches, of the valve operation when laid out on the rim of the fly wheel:

Diameter of fly wheel	18 in.
Inlet valve opens late	$1\frac{1}{4}$ in.
Inlet valve closes late	$5\frac{31}{32}$ in.
Exhaust valve opens early	$7\frac{15}{64}$ in.
Exhaust valve closes late	$2\frac{23}{64}$ in.

To determine whether setting of the valves is correct, proceed as follows, beginning with cylinder number one:

Open the priming cocks over all exhaust valves, to make the turning of the fly wheel easier.

Turn the fly wheel to the left until the mark *1-4 UP* is in line with the punched guide mark on number 4 cylinder, as shown. Now pistons 1 and 4 are at their highest points in their cylinders, or on upper dead center. About one and a quarter inch to the right of the mark *1-4 UP* you will notice the mark *1-4, I-O*. Turn the fly wheel to the left until this mark is lined up with the guide mark on the engine. At this point the inlet valve of either cylinder 1 or cylinder 4 should begin to lift.

If the lift should occur in cylinder 4, turn the fly wheel one complete revolution, until the mark *1-4, I-O* again appears on top and in line with the guide mark. Now watch or feel the inlet valve stem; it should just begin to lift from its seat.

To determine the closing point of the same inlet valve, turn the fly wheel, a little more than a half revolution, until the mark *1-4, I-C* appears on top. With the fly wheel in this position, the inlet valve should be closed and there should be just enough space between the top of the valve lifter and the toe of the valve stem so that a thin visiting card can be placed between them. At the factory, stem and lifter are set so that the distance between them is exactly twelve thousandths of an inch; this clearance is necessary to compensate for the expansion of the valve stem, when it becomes hot during the operation of the engine.

If adjustment be necessary, loosen the lock nut on top of the valve plunger and screw the adjusting nut up or down, as required.

If the play between plunger and valve stem be too great, the result will be noisy operation; if the adjustment be too close, it may prevent the valve seating fully.

Next, test the exhaust valve, again bringing *1-4 UP* to the top, and turning the fly wheel to the left until the mark *1-4, E-C* appears in line with the guide.

After testing the closing of the exhaust valve of cylinder number 1, test its opening by revolving the fly wheel until the mark *1-4, E-O* comes to the top. Then go carefully over the valves of cylinder number 4, and of numbers 2 and 3.

A slight variation of the fly wheel markings to the right or left of the guide mark is permissible, but it should not be greater than a quarter of an inch.

The dead center of an engine may be determined as follows: At some easily accessible place near the rim of the fly wheel, a pointer is fastened to the frame of the engine. At the top of each cylinder there is, usually, a plug or pet cock, which should now be removed. Next, having procured a smooth stick of wood, or a thin iron rod which will fit loosely through the hole in the top of the cylinder, it is inserted into the cylinder so that it rests upon the piston. The stick should be kept vertical. The engine is turned so that the stick appears to be in the highest position. and a mark made on the stick with a pencil at the edge of the hole. Another pencil mark is made about ¾ or 1 inch from the first mark. Now the engine is turned until the second mark corresponds with the edge of the hole, and a mark is made on the fly wheel corresponding with the pointer which has been fastened to the frame. The engine is turned over past the bottom center, until the mark again registers with the edge of the hole; at this point a mark is made on the fly wheel corresponding to the position of the pointer. With a pair of dividers or a flexible rule, the distance between these marks is bisected and marked. This latter mark is turned to the pointer, and cylinder No. 1 is on its exact top center.

Ques. Would the top centers of the other cylinders have to be found the same way?

Ans. No, the other centers may be found from the first obtained mark on the fly wheel, thus: in a four cylinder engine #4 would have the same mark as #1. For #2 and #3, another mark will have to be placed directly opposite the one of #1 and #4. In a six cylinder engine, one of the remaining cylinders would have a mark corresponding with the first, while a mark for each pair of the other cylinders would have to be placed at 120 degrees from the first mark, commonly spoken of as "placing them on thirds."

Ques. To what type of engine do the above explained methods apply?

Ans. To engines that are supplied with an ignition battery or an ignition dynamo.

Ques. In what way do engines equipped with a magneto differ from those equipped with a battery?

Ans. The magneto itself has to be "in step" with the engine.

Ques. Is there a difference between the timing of a high and of a low tension magneto?

Ans. There are certain points in the revolution of a magneto when the intensity of the spark is greatest; this should be taken advantage of whether it be a high or low tension magneto.

Ques. How should a low tension magneto with make and break mechanism be adjusted?

Ans. The sparking mechanism is adjusted the same as if a battery or dynamo were used, adjusting the various cylinders independently. The magneto, however, must be adjusted so that the most intense spark takes place at the moment of 'break" of the contact.

Ques. Explain a simple and practical way of timing a magneto.

Ans. If the engine has been equipped with a magneto, the drive gears are marked on their rims so that with the marks on the different gears corresponding with each other, the magneto is in step with the engine. In such a case, if the gears have been shifted, it is a simple matter to replace them. If, however, no marks be present, the wires are connected to the terminals, and one of the valve chambers opened so that the spark points can be seen. The engine is now turned rapidly over by hand, and the spark noted. Marks are made on the gears with a pencil so this position can be found again if necessary. The idler gear is now shifted a couple of teeth, and this position indicated with a different mark; the engine is again turned and the spark noted. This process is repeated, shifting the gears a couple of teeth each time. The mark corresponding with the best spark should be selected and a permanent mark put on the gears.

Ques. What is important to observe when attaching a magneto to an engine?

Ans. That the drive and driven gears be keyed to their shafts, after the right position is found.

Ques. When the magneto has been timed to give the best spark at the top center, will advancing the spark lever make any difference?

Ans. The spark would not be as intense if the speed of the engine remained constant, but as the spark is advanced for high speeds only, the increased speed of the magneto will more than make up the deficiency and produce an even better spark.

Ques. Is the speed at which the magneto is driven important?

Ans. As there are two dead points during each revolution of the magneto, it should be geared so that none of the dead points correspond with the sparking periods.

Ques. How may a low tension jump spark magneto be timed?

Ans. When equipped with a multiple unit coil and timer, the same rules as applied to a battery equipment will be applicable, but the magneto may be timed the same as for the make and break engine, by turning and testing the spark. The spark plugs may be taken out and laid on the cylinder, with the cables connected, thus making the spark visible.

Ques. When a distributer is used, will there be any other points to observe in timing?

Ans. The distributer must be timed so that the rotor contact registers with one of the terminals for the spark cables for each cylinder before the spark is to take place. The contacts must follow the regular firing order of the cylinders.

Ques. If the magneto be equipped with a self-contained coil, would this make any difference in timing?

Ans. The same rules hold true, the only difference is in the wiring.

Ques. How is a high tension magneto timed?

Ans. The cables must be connected to the spark plugs in the regular firing order of the cylinders to determine the order of sparking of the plugs. They may be laid on the cylinder heads while the magneto is being turned over. The gears must be shifted one tooth at a time until the spark takes place at the right time, which is at about the top center when retarded.

Ques. How is the speed of a magneto determined?

Ans. By the number of cylinders, as well as the cycle of the engine.

Ques. What would be the proper speed of a magneto for a four cylinder, four cycle engine?

Ans. Since there must be four explosions for each two revolutions, and as each revolution of the armature produces two sparks, there must be one revolution of the armature for each revolution of the engine.

Ques. What would be the magneto speed for a three cylinder, two cycle engine?

NOTE.—The subject of ***Magneto Timing*** is taken up in great detail in Chapter 163 following:

Ans. Since three explosions take place per revolution, the armature must make one and one-half revolutions for each turn of the crank shaft.

Ques. If the cam shaft gears should be shifted, how would this affect the engine?

Ans. It would throw the entire valve motion, as well as the ignition device, out of time.

Ques. What is most important to observe before starting to time?

Ans. To examine the valve gear to ascertain whether the valves open and close at the proper time.

Ques. If the valves be out of "time," what is the proper way to proceed?

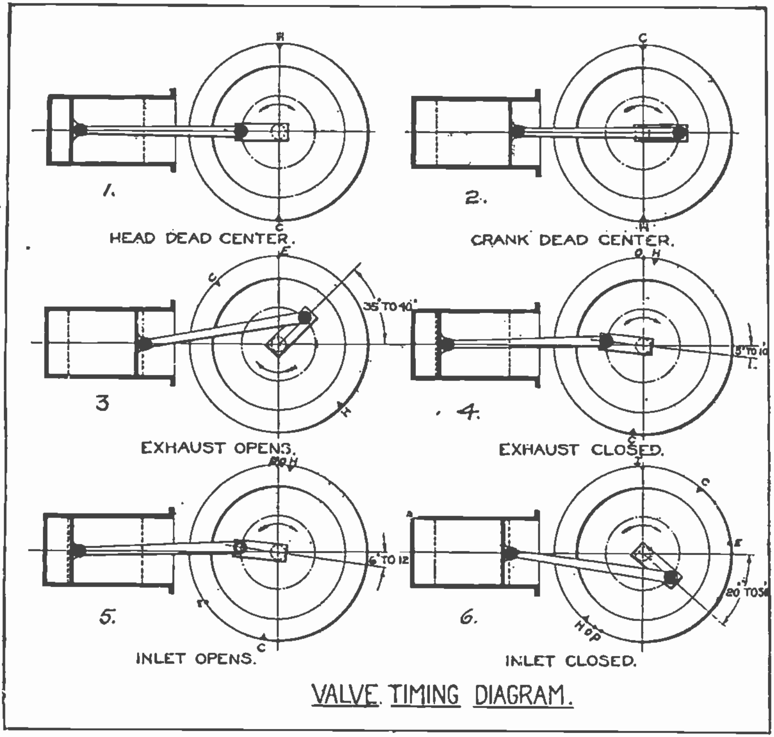
Ans. First examine the valve stems and push rods for lost motion, which should be no more than the thickness of heavy paper.

Ques. If this lost motion in the valve stems and push rods has been taken care of, should the gears be disturbed?

Ans. No, the engine should again be turned over and the valve action observed, when it will be found that the valves open earlier and close later.

Ques. Why should lost motion affect the valve action thus?

Ans. Referring to figs. 7,028 to 7,030, it will be seen that the cam raises the roller, including the push rod, to its full height. If however, there be a space, equal to the clearance indicated by the dot and dash circle, between the push rod and the valve stem, the push rod has to raise an amount equal to the clearance before it has any effect on the valve, and the cam has turned



FIGS. 7,017 to 7,022.—Valve timing diagrams, showing timing of valves for one cylinder engine. At 1, an engine is shown at the head center, and at 2, the same engine is shown at the crank center, the rotation being indicated by the arrow. At 3, the position of the crank at exhaust opening is shown, which varies from 35° to 40° from the bottom center of the power stroke in various engines. At 4, the exhaust closes about 5°-10° beyond the top center of the exhaust stroke. At 5, the inlet opens about two degrees after the closing of the exhaust, and at 6 the inlet valve closes and compression commences. Now, if by turning the engine over, the exhaust valves be found to seat at or before the dead center, it is plain that it closes 5°-10° too early, and must have opened the same amount too early. Also, if the inlet valve should be found to open on or before the top center, it must also have closed too early, and thus prevented the engine taking a full charge.

into position 1, and, after passing position 2, is commencing to close, the lost motion would affect it in the opposite way, as shown at 3, thus reducing the time of opening materially.

Ques. If after taking care of the lost motion, the valve mechanism is found to be out still, what will be the next step?

Ans. To change the position of the cam shaft drive gears with respect to the driving gear until the correct timing is obtained.

Ques. What is meant by the valve being late?

Ans. The valves open and close late as compared to the movement of the piston. This is explained in figs. 7,017 to ,7022.

Ques. Is the operation of the exhaust and inlet valves dependent upon each other?

Ans. If all of the valves be operated by the same cam shaft, the valves are bound to be "in step" with each other, providing there is no excessive lost motion, but if one of the valves be early or late, it is evident that they are all out of time.

Ques. What might happen if the exhaust and inlet valves be operated by separate cam shafts?

Ans. Both sets of valves may be out of time with each other, and at the same time being out of time with the pistons, or one set may be in time with the pistons, while the other set is cut of time.

Ques. Could an engine run under any of the above named conditions?

Ans. The valves may all be considerably out of time, and the engine will still run but at the expense of reduced power, increased fuel consumption, and excessive vibration.

Ques. How is improper timing detected?

Ans. By unsteady action, especially at the higher speeds.

Ques. If the valves be out of time, and there be no lost motion, what must be done?

Ans. One of the pistons, say, 1, in fig. 7,023 is put on top center, a space amounting to about 5° to 10° is then marked off on the fly wheel rim and the engine turned ahead until this

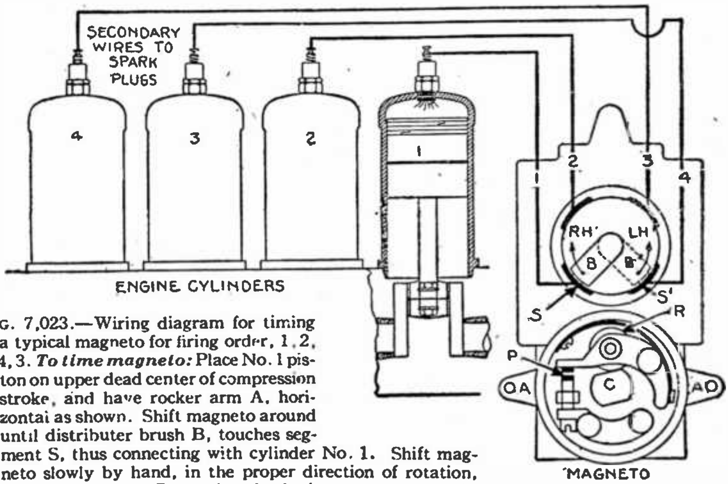
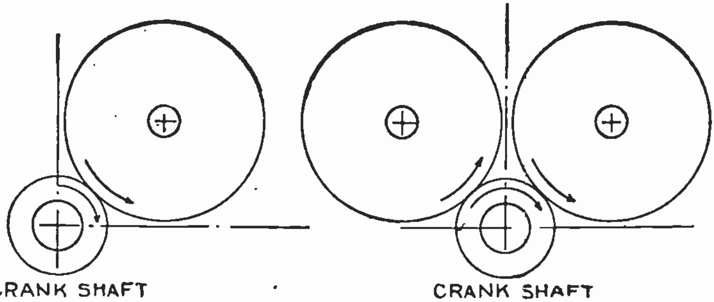
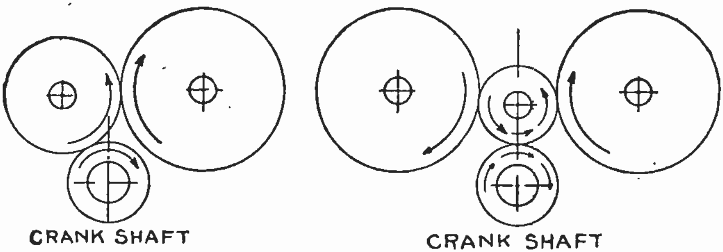


FIG. 7,023.—Wiring diagram for timing a typical magneto for firing order, 1, 2, 4, 3. *To time magneto:* Place No. 1 piston on upper dead center of compression stroke, and have rocker arm A, horizontal as shown. Shift magneto around until distributer brush B, touches segment S, thus connecting with cylinder No. 1. Shift magneto slowly by hand, in the proper direction of rotation, until the contacts P, are just beginning to separate At this point secure magneto shaft to gear or coupling with set screws. When one cylinder is timed, proceed to connect the others as follows: Ascertain the firing order of the engine, then crank engine slowly and connect plug cable from next cylinder that fires to distributer segment No. 2 and so on until all the plug cables are connected. The secondary connections on the hard rubber distributer block are numbered in consecutive order, 1, 2, 3, 4, etc. These numbers do not refer to the engine cylinders, and it is necessary to determine the order in which the cylinders fire and connect secondary cables accordingly. Replace parts on the magneto and start the engine to test the setting. See that all nuts and connections are tight, also that retainer spring has been replaced. There should be a tendency for the engine to kick back slightly when starting, and if it do not, advance magneto until it does kick slightly. To advance, shift coupling against direction of rotation. To retard, shift coupling with direction of rotation. Shift slightly each time until correct position is obtained. Pin magneto shaft to gear or coupling with taper pin, do not depend on a set screw, as it will surely work loose in time.

mark comes even with the center pointer; the gears of the exhaust cam shaft are then shifted so that the exhaust cams just allow the valves to remain clear of their seats. The engine is then turned ahead about 2°, and the inlet valve shaft shifted until the inlet valve commences to raise.



FIGS. 7,024 and 7,025.—Diagram showing rotation of cam shafts with a direct gear device.



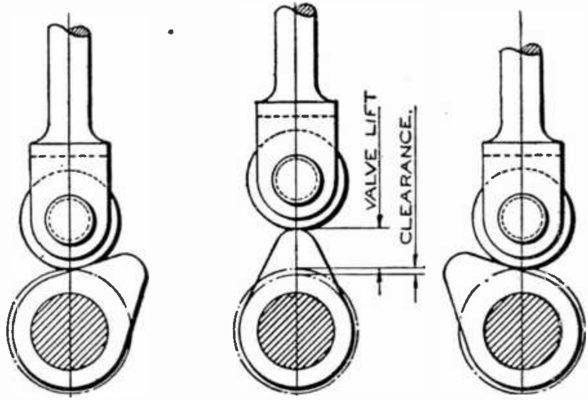
FIGS. 7,026 and 7,027.—Diagram showing rotation of cam shafts when an intermediate idler is used.

Ques. When shifting the cam shaft to make the valves earlier or later, should it be turned respectively, with, or against the direction of rotation of the crank shaft?

Ans. That depends upon the gearing.

If the cam shaft gears mesh directly into the crank shaft pinion, the cam shafts revolve in an opposite direction to the crank shaft, and to make the valves earlier, the cams must be turned in the direction followed by the cam shafts, which is opposite that of the engine.

Most engines have an idler gear between the crank shaft and the cam shaft gears; in such case the cam shafts revolve in the same direction as the crank



FIGS. 7,028 to 7,030.—The successive positions of a valve lifting cam.

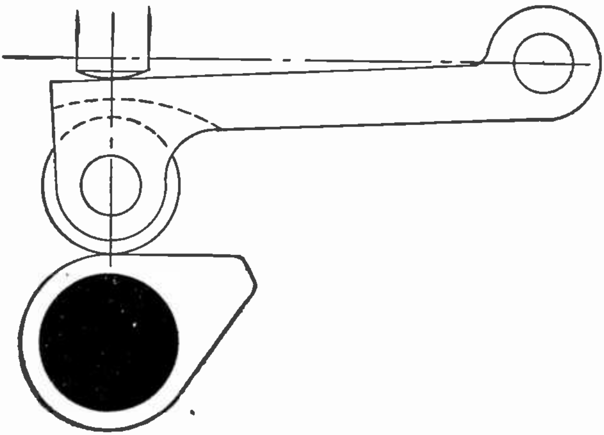


FIG. 7,031.—Valve cam device with roller mounted on cam. This design is frequently used to reduce the side-thrust upon the push rod.

shaft, and the cams shift *with* or *opposite* the engine to make them respectively early or late. This is illustrated in figs. 7,024 to 7,027.

Ques. If all valves be driven from one cam shaft, is it possible that one or more of them may be timed correctly, while the others are out of time?

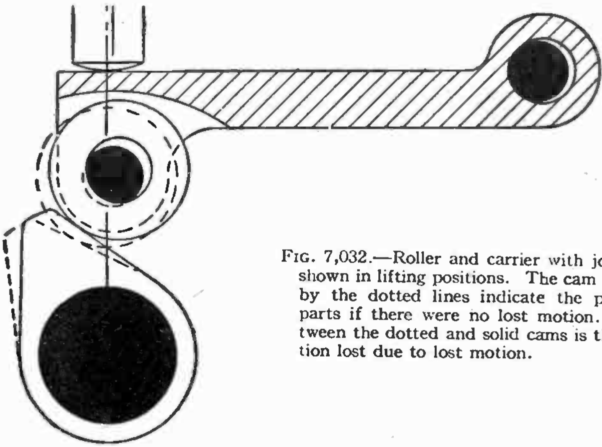


FIG. 7,032.—Roller and carrier with joints badly worn shown in lifting positions. The cam and roller shown by the dotted lines indicate the position of these parts if there were no lost motion. The angle between the dotted and solid cams is the angle of rotation lost due to lost motion.

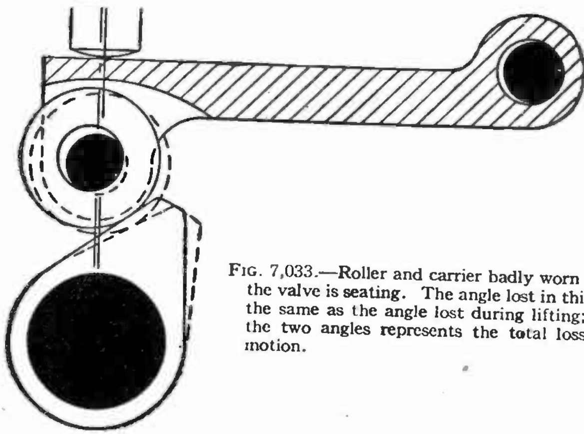
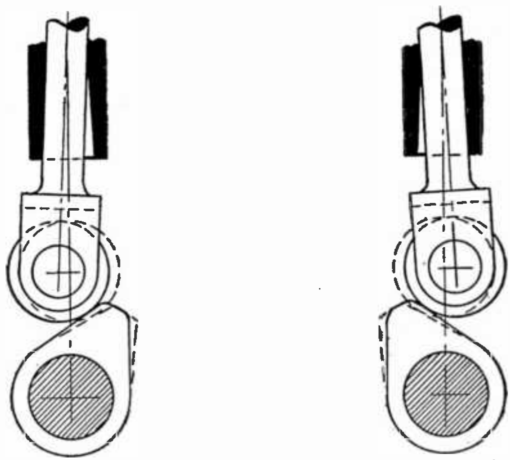


FIG. 7,033.—Roller and carrier badly worn shown while the valve is seating. The angle lost in this case is just the same as the angle lost during lifting; the sum of the two angles represents the total loss in angular motion.

Ans. On some engines the cams are made independent of the cam shaft, and are keyed to the latter, hence it is possible that, in overhauling the engine, some of the cams may have been replaced wrongly.

Ques. Is this possible if the cams be forged with the shaft?

Ans. Although the cams cannot be shifted out of time with each other, it is possible that the surface of some may be worn



FIGS. 7,034 and 7,035.—Valve push rod with roller shown in lifting and seating position, showing the serious defects of a worn push rod bushing. The dotted cams and rollers indicate the position these parts would have with the same amount of lift if there were no lost motion.

more than others, or on such engines where the cams act upon rollers carried by the end of the push rod, as in figs. 7,028 to 7,030, or by a carrier as in fig. 7,032, the roller and pin may be worn to such an extent as to make proper timing impossible, without removal of the worn parts.

Ques. Could this lost motion be taken care of when adjusting the lost motion between valve stems and push rods?

Ans. No, between valve stem and push rod only the lost motion in the direction of the valve travel can be adjusted. The lost motion in the rollers, the carrier suspension, or the push rod bushings, acts in a direction at right angles to the valve travel, and affects the timing in the manner shown in figs. 7,032 to 7,035.

TEST QUESTIONS

1. *Of what does timing broadly consist?*
2. *How is the timing of the valves effected?*
3. *Explain valve timing by referring to a four cylinder engine diagram.*
4. *How is the firing order usually expressed?*
5. *What else governs the firing, so far as balance is concerned?*
6. *Explain the best method of ascertaining the timing, as regards the firing of the successive cylinders.*
7. *What governs the ignition?*
8. *How is the timer adjusted?*

9. *Should not the spark coils and cylinders whose numbers correspond be connected together?*

10. *How should a make and brake spark be timed for firing?*

11. *Explain a simple and practical way of timing a magneto.*

12. *Is the speed at which the magneto is driven important?*

13. *How is a high tension magneto timed?*

14. *If the cam shaft gears should be shifted, how would this affect the engine?*

15. *If the valves be out of time, what is the proper way to proceed?*

16. *What is meant by the valve being late?*

17. *What might happen if the exhaust and inlet valves be operated by separate cam shafts?*

18. *How is improper timing detected?*

19. *When shifting the cam shaft to make the valves earlier or later, should it be turned respectively, with, or against the direction of rotation of the crank shaft?*

20. *If all valves be driven from one cam shaft, is it possible that one or more of them may be timed correctly, while the others are out of time?*

21. *Is this* (Question 20) *possible if the cams be forged with the shaft?*

22. *Could the lost motion mentioned in the last question be taken care of when adjusting the lost motion between valve stems and push rods?*

23. *Make sketch of valve push rods and roller showing serious defects of a worn push rod bushing.*

CHAPTER 165

Timing Magnetos

The timing diagrams and illustrations of magnetos which appear in this chapter, were furnished by the Robert Bosch Magneto Co.

The word *timing* means that *the mixture or gas is ignited or fired at a moment when the piston is in a position in the cylinder where the most power will be obtained from the engine.*

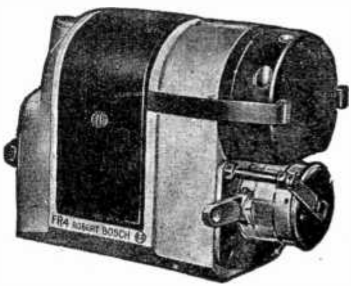


FIG. 7,036.—Bosch magneto.

FIG. 7,037.—Bosch distributer.

At this position of the piston, the ignition apparatus must be at the point of firing, that is, of producing the *arc* in the case of low tension or make and break ignition, or the *spark* in the case of high tension or jump spark ignition.

The exact point or place on the piston stroke for securing maximum power depends on the size of the engine, on the speed the engine runs and also on the load on the engine.

NOTE.—What is the difference between an *arc* and a *spark?*

To make the spark occur at the right moment for different loads, some engines are provided with a device to shift the time at which the igniter plug shaft is snapped.

Low Tension Magnetos.—Some engines using make and break ignition are equipped with a low tension magneto instead of (or in addition to) batteries.

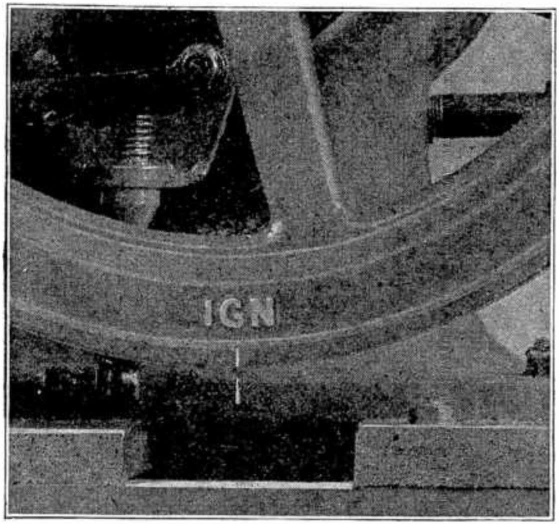


FIG. 7,038.—Ignition timing marks on fly wheel and base of McCormick-Deering gas engine. So long as the timing gears inside the crank case are properly meshed, the timing of the spark cannot vary greatly. There is provision, however, for an ample range of adjustment. The best point for the spark to occur is indicated by a notch on the fly wheel under the letters IGN, and a notch on the base of the engine. The spark should occur when these two notches are in line on every second revolution of the fly wheel. The point at which the magneto trips can be advanced or retarded slightly as shown in fig. 7,044.

A low tension magneto may have the same appearance as a high tension magneto such as is used on trucks and tractors together with spark plugs. However, a high tension magneto cannot be used with a make and break igniter plug. Neither can a low tension magneto be used with spark plugs, nor can one be changed over to the other type.

There are two types of magneto classified according to the motion of the armature, as:

1. Rotating or revolving;
2. Oscillating.

The first or rotating type is one in which the armature revolves, driven by a gear or coupling. Belt drive cannot be

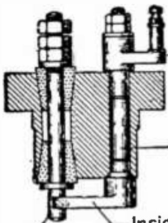


FIG. 7,039.—Igniter for low tension or make and break ignition. By means of mica or stone washers, the stationary pin is electrically insulated from any part of the igniter plug. Through the igniter plug runs a shaft. On the end of this shaft, reaching inside the cylinder is an arm long enough to strike the insulated stationary pin. On the outside end of the shaft is another arm (the outside arm). The shaft can be turned far enough to cause the inside arm to strike and then leave the stationary pin. This turning motion is produced by a push rod working from an eccentric or from a cam. On a two cycle engine this cam is operated by the crank shaft and on a four cycle engine the cam is actuated by timing gears driven from the crank shaft. The stationary pin, the arms and the shaft are a part of the electrical circuit.

used. On the other type, the armature does not revolve. Instead, it is *oscillated*, that is, it is moved only a little way by means of a lever or cam, which is then suddenly released. A spring then causes the armature to move back very fast. It is on this fast return of the armature that the current is generated in the armature winding.

Timing of Low Tension Magnetos.—When a rotating (gear or coupling driven) low tension magneto is used, it must be remembered that, unlike a battery, it does not give a steady flow of current.

The *largest amount of current (enough to give a hot spark at the igniter plug) occurs at only two places in each turn.*

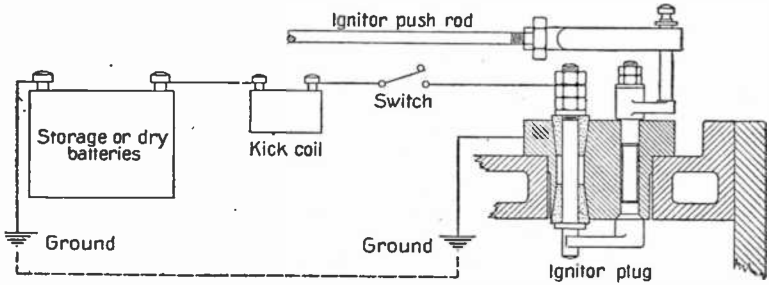


FIG. 7,040.—Low tension ignition system showing igniter and wiring connections.

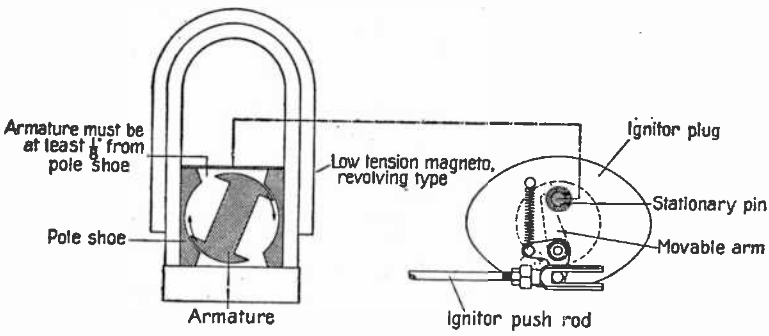


FIG. 7,041.—Timing diagram for revolving type low tension magneto.

The rest of the time the electric current is too small to be used for ignition. The same is true of the oscillating type. In this type, the magneto trip lever (which is fastened to the armature) and the armature itself, are held in a certain position by springs. Therefore, when timing a make and break (low tension) ignition system, using either the revolving (gear or coupling drive) or oscillating type of low tension magneto, *the magneto as well as the igniter plug must be timed.*

For timing a revolving low tension magneto, the crank shaft must first be turned to where the piston should be when the spark should occur.

Then the magneto must be set so that the movable arm of the igniter plug is snapping away from the stationary pin, when the armature is in the position shown in fig. 7,041.

For timing the oscillating type of low tension magneto the method as outlined for the revolving type is used, with this

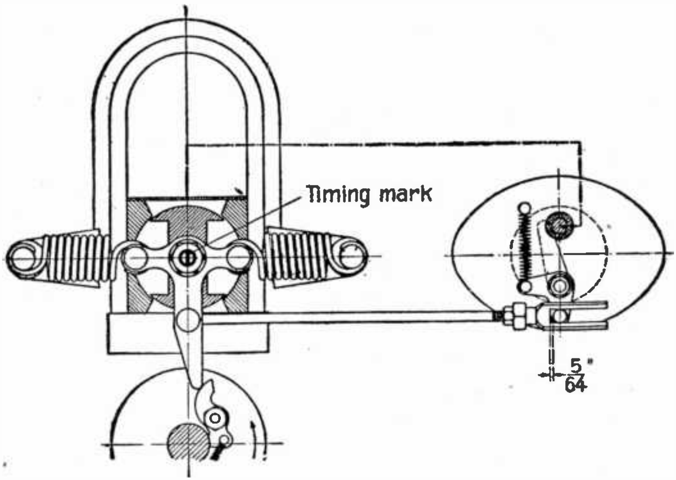


FIG. 7,042.—Timing diagram for oscillating type low tension magneto 1. Igniter shaft in contact with stationary pin.

exception, that during the time the magneto trip lever and the push rod connected to it are not in motion, *the igniter shaft must touch the stationary pin in the igniter plug and remain in that position during the time when the cam is moving the magneto trip lever and push rod as in fig.* 7,042.

The cam then causes the magneto trip lever to move the magneto armature to the position of line A, fig. 7,043. Then the magneto trip lever drops off the cam. The springs cause the armature to turn to the position shown by line B, fig. 7,043. At this point the push rod should strike the outside arm on the igniter plug, causing the inside arm on the igniter shaft to snap away from the stationary pin.

Variable Timing.—The words *advance* and *retard* mean the same as early timing and late timing of the spark. Naturally the best place to ignite or fire the mixture or gas in the cylinder *is the place where the greatest power will be obtained from the engine.*

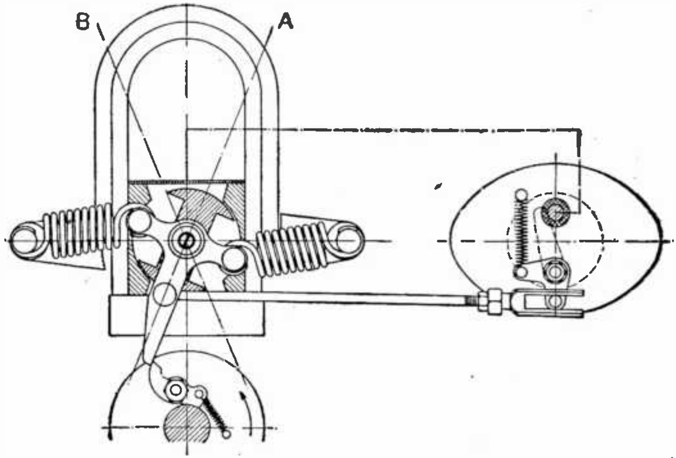


FIG. 7,043.—Timing diagram for oscillating type low tension magneto 2. Magneto trip lever near position of release.

The gas mixture in the cylinder is compressed in order to obtain greater power. However, a certain amount of time passes between the moment the ignition occurs, and the moment when all fuel is burned up. During this period of time, much power will be lost unless this loss of time is compensated for. This is done by allowing the spark to occur while the piston is still moving on its compression stroke.

The distance on the piston travel between the point where the spark occurs and the outer dead center is called the *advance*.

The amount of advance required varies with the different sizes of engine, the speed, the fuel used and the load. The advance is usually determined by the manufacturer of the engine.

The Advance and Retard Mechanism.—On engines using make and break ignition with the current supplied from a battery or from a low tension revolving magneto, the advance and retard device is built into the cam or mechanism that operates the igniter plug lever.

On the oscillating type of low tension magneto, the advance

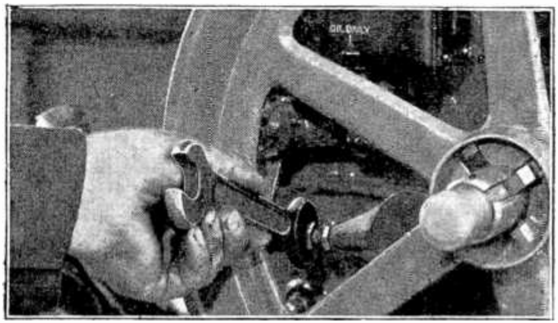
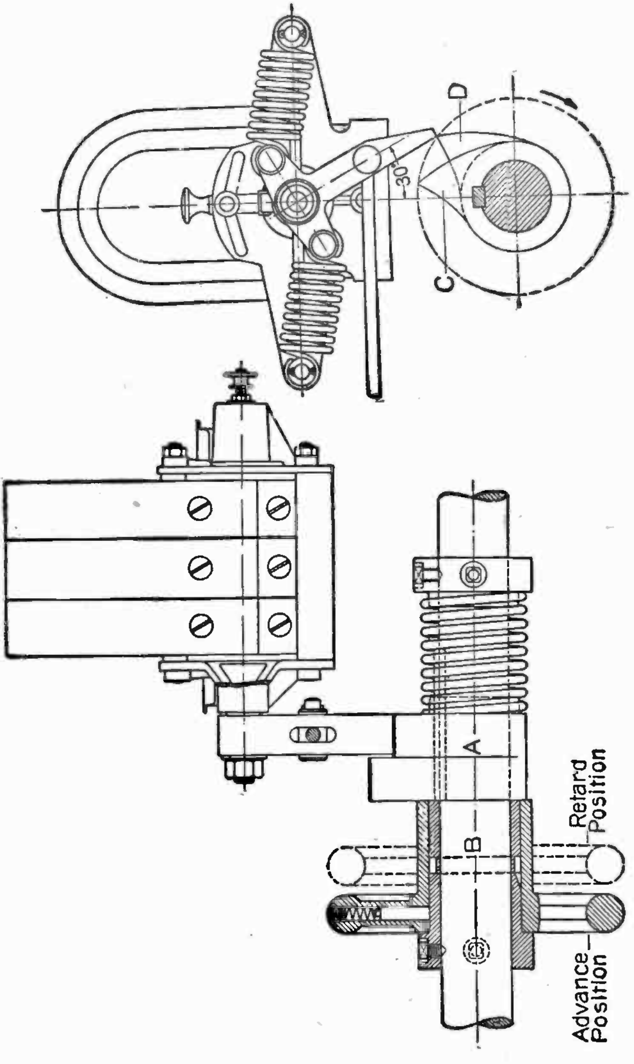


FIG. 7,044.—Method of adjusting point of ignition on McCormick-Deering gas engine. If the spark do not occur until after the notch under the letters "IGN" has passed the notch on the engine base, the rod which actuates the magneto bell crank should be slightly unscrewed from the eccentric strap, first loosening the lock nut shown at the right of the wrench. If the spark occur before the letters "IGN" have passed the notch, the lock-nut should be loosened and the magneto trip rod should be screwed farther into the eccentric strap. When the proper adjustment is obtained the lock nut should be tightened.

and retard device is usually at the cam itself, as shown in figs. 7,045 and 7,046.

In fig. 7,046, it is seen that the part which works the magneto trip lever can be shifted on shaft B, causing either one of the cams to operate the lever. When part A, is shifted so that cam C, operates the lever, it is in the retard position.

When part A, is shifted so that cam D, operates the lever, it is in the advance or running position.

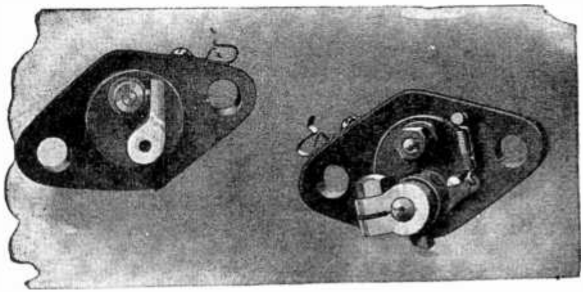


FIGS. 7,045 and 7,046.—Bosch variable advance and retard oscillating type magneto.

Too early a spark position (too much advance) *causes a knock in the engine and falling off in power.*

Too late a spark position (too much retard) *causes a hot engine and also a falling off in power.*

Another reason for having ignition with variable timing, particularly on the larger engines which are started by hand, is the necessity at the time of



FIGS. 7,047 and 7,048.—Charter oil engine igniter. The igniter lever is operated from the cross head; a spark shifter permits of two ignition positions, one to produce a late spark when the operator is starting the engine, and the other for early or running spark.

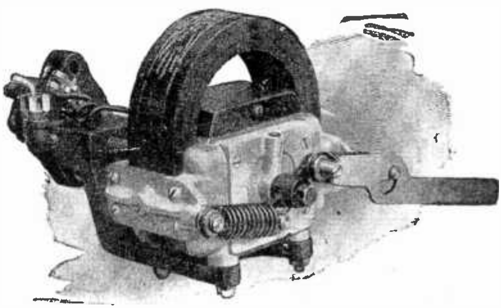


FIG. 7,049.—Charter oil engine oscillating magneto igniter. This type magneto does away with the use of a starting battery, spark coil and gear driven magneto. *It consists of* a make and break igniter on which a special magneto is mounted and which is tripped or oscillated to produce both the electric current and a quick snap or separation of the igniter points inside the combustion chamber. As a hot spark is produced in starting the same as when running, starting on the magneto is easily accomplished and without any auxiliary battery. In fact, a battery must not be connected with this type of magneto.

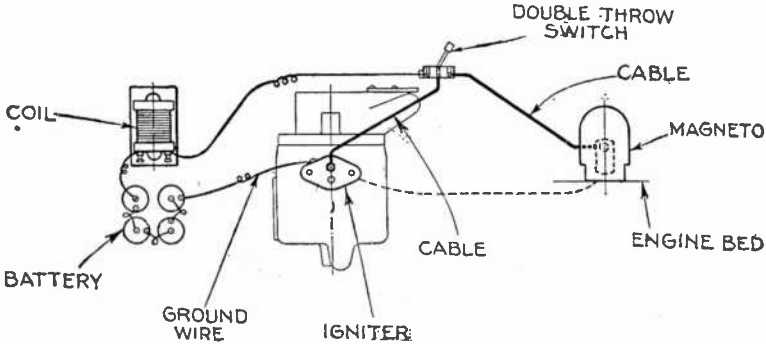


FIG. 7,050.—Charter oil engine wiring diagram for geared magneto and auxiliary starting battery. The geared magneto causes less wearing on the igniter points than the battery; its spark is of different characteristics, of somewhat higher voltage and less amperage or current, and therefore less tendency to burn and pit the points. However, magneto current has more tendency to break down the insulation, requiring that the wiring, connections and insulation around stationary electrode be kept in good order. If at any time the engine fail to run properly on the magneto while apparently satisfactory operation on the battery is obtained, don't tamper with magneto, but examine carefully connections at magneto, switch and éngine. Clean igniter insulations thoroughly.

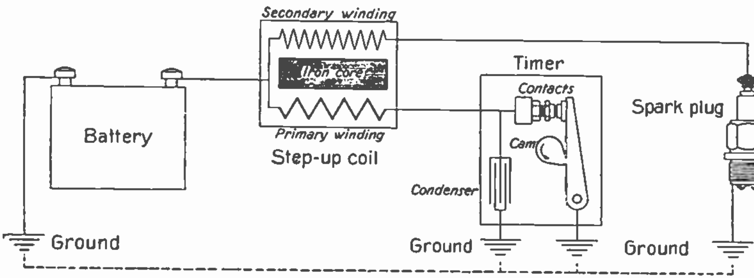


FIG. 7,051.—High tension battery ignition for one cylinder, illustrating use of *timer*. Assuming that the engine is running, the electrical circuit in a high tension ignition system using batteries is as follows: Current flows from the battery through the primary winding, across the timer contact points, back to the battery. This causes the iron core of the step up coil to become magnetized. The timer cam operated from the camshaft of the engine, causes the contacts to separate, stopping the current in the primary winding. This in turn causes the iron core to demagnetize and it is this demagnetization that causes a high voltage to be created in the secondary winding, a voltage high enough to jump across the spark plug gap. The batteries used with this system, whether dry cells or storage batteries, must be in good condition. Otherwise the spark at the spark plug will be too weak to fire the gas mixture.

starting, of allowing the spark to occur at outer dead center or better still, a little past dead center to keep the engine from kicking back (running the wrong way).

High Tension Ignition.—There are two general classes of jump spark ignition grouped with respect to the current, as:

1. Battery;
2. Magneto.

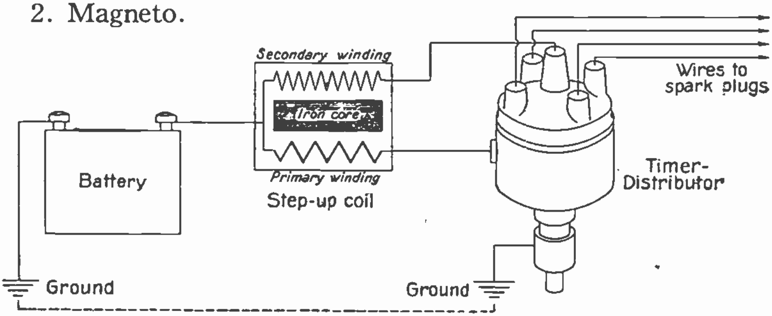


FIG. 7,052.—High tension battery igniter for four cylinder engine, illustrating use of *distributer.* The distributer consists of 1, a head into which are molded as many metal segments as there are cylinders on the engine. These segments are electrically connected with the spark plugs in the proper cylinders; 2, a rotating current conducting arm which is operated from the same shaft as the timer cam and which is electrically connected with the center terminal of the distributer head and the high tension terminal of the coil. When this rotating arm is turned, an electrical connection is established through the segments in the distributer head between the high tension terminal of the coil and the spark plugs.

For magneto ignition, the high tension magneto is available in various constructions. Those for single cylinder engines can be either revolving or oscillating. Those for two, three, four, six and eight cylinder engines are furnished in revolving types only and are called multiple cylinder magnetos.

The revolving type high tension magneto can be had with or without an impulse coupling. The impulse coupling is a device to make starting easy. More will be said about this later.

Operation of High Tension Magneto.—This type magneto creates a current *by revolving, or partially revolving (oscillating) an armature between poles of permanent magnets.*

The two windings (primary and secondary) are wound on the armature. This eliminates the necessity of a separate step up coil. On the armature is mounted an interrupter (timer).

Over the interrupter is placed a housing, carrying the cams that cause the interrupter (timer) points to separate. The housing is movable, thereby providing the means of variable timing (advance and retard). At its interrupter end the armature also carries the condenser.

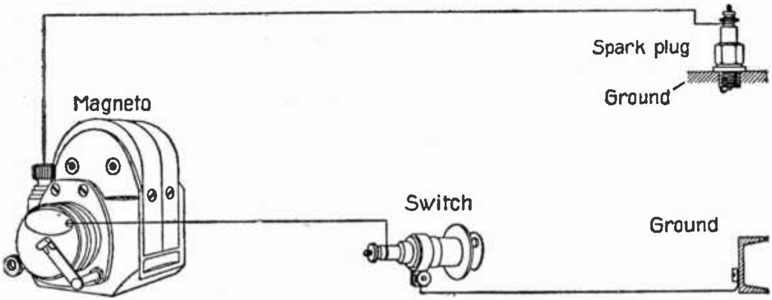


FIG. 7,053.—Bosch high tension magneto for *one* cylinder engine. For this service the revolving high tension magneto does not require a distributer because the high tension current is conducted directly to the spark plug from the secondary winding by way of a slip ring (collector) and a brush holder. A one cylinder magneto has only one cam in the interrupter housing.

Timing High Tension Magnetos.—In timing a single cylinder high tension magneto, *the engine must first be turned to the correct late firing position, usually the outer dead center, or a little past at the end of the compression stroke.*

The timing arm on the interrupter housing is put in its full retard position, as far as it will go in the direction in which the magneto revolves. The magneto armature is then turned until the interrupter contact points just start to open. In this position it is then connected to the engine drive shaft by putting together the magneto driving coupling or by meshing the driving gears as the case may be.

In timing a multiple cylinder magneto, that is, for a 3, 4 or 6 cylinder engine, or for a 2 cylinder engine using a half type, it is necessary in addition to the timing just described, *to have the distributer brush touch the segment connected with the spark plug in the cylinder which has its position set at its late firing position.*

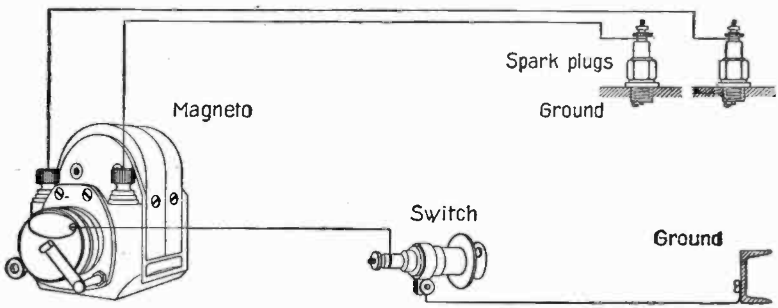


FIG. 7,054.—Bosch high tension magneto for *two* cylinder engine. Where the engine cranks are 180° apart, there is sometimes used what is called a half type magneto. This is a four cylinder magneto which has a distributer. Two of the distributer terminals are connected with the spark plugs. The other two, however, are either grounded or the current passing through them is allowed to jump the gap to ground.

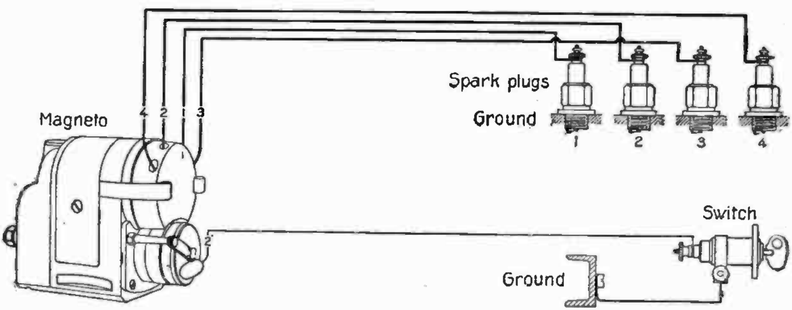


FIG. 7,055.—Bosch high tension magneto for *four* cylinder engine. For three, four and six cylinder engines the magneto must have a distributer. The difference in the magneto used for engines having more than two cylinders lies in the ratio of the gears that drive the distributer brush holder and the number of segments in the distributer head or plate. This makes it necessary to construct a special magneto for each of the various multiple cylinder engines. For this reason multiple cylinder magnetos cannot be changed one into the other. For example, a six cylinder magneto cannot be arranged for use on a four cylinder engine or vice versa.

Two Spark Magnetos.—Some magnetos are constructed so as *to produce two sparks simultaneously.*

This means that the magneto fires two spark plugs at the same time in each cylinder. This type of magneto enables more power to be obtained from a given size of engine than if only one spark plug were used in each cylinder. It is particularly valuable for engines of the larger sizes. The construction of two spark magnetos is practically the same as that of single spark magnetos, with the exception of the slip ring (collector ring) the slip ring brush holder, the distributer disc and the distributer rotating brush holder.

Fig. 7,056, shows the method of wiring a two spark magneto for a four cylinder engine. A switch is shown for cutting off the ignition, also for

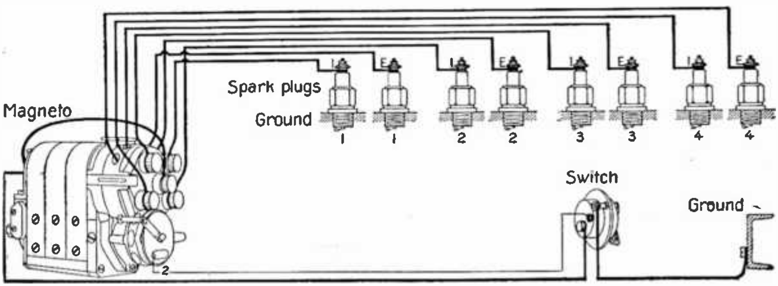


FIG. 7,056.—Bosch high tension two spark magneto for four cylinder engine.

cutting out one set of plugs. Two spark magnetos are furnished for 3, 4, and 6 cylinder engines, also for two cylinder engines using half type magnetos.

Impulse Couplings.—For use on high tension magnetos there has come into general use what is known as an impulse coupling.

This is a mechanical device to snap the magneto over at the time of starting. Its mechanical snapping action speeds up the magneto armature so that a very hot spark is generated when the impulse coupling is operated. This causes the engine to start much easier. It is possible to obtain magnetos with impulse couplings for engines of any number of cylinders.

High Tension Oscillating Magnetos.—There is another type of high tension magneto for single cylinder engines, the high tension oscillating magneto. The magneto itself is practically the same as the single cylinder revolving type with the exception of the armature construction.

The mechanical operation of a high tension oscillating magneto is identical with the operation of a low tension oscillating magneto, the method of drive being the same. An igniter push rod is not used on the high tension magneto, which operates on the jump spark principle.

TEST QUESTIONS

1. *Define the word timing with respect to ignition.*
2. *Upon what does the exact point of ignition depend for securing maximum power?*
3. *Name two types of low tension magneto.*
4. *Describe the operation of rotating magnetos and oscillating magnetos.*
5. *Describe in full detail the method of timing a low tension magneto.*
6. *Draw sketches showing 1, low tension system with battery and 2, with magneto.*
7. *Describe the method of timing an oscillating type low tension magneto.*
8. *What is understood by* variable timing?
9. *Describe the construction of the advance and retard mechanism on engines using make and break ignition.*
10. *What occurs with too early a spark?*
11. *When the spark is too late, what happens?*

12. *Name two general classes of high tension ignition.*
13. *Draw a diagram showing high tension ignition with battery and distributer.*
14. *Describe the operation of a high tension magneto.*
15. *Explain at length the timing of a high tension magneto.*
16. *What is a two spark magneto?*
17. *Describe the construction of an impulse coupling.*
18. *How does a high tension oscillating magneto work?*

CHAPTER 166

Growler Testing

Ques. What is a growler?

Ans. An audible testing device for armatures.

Nearly always when an armature stops generating, the trouble is due to either a ground, a short circuit or an open circuit. A ground and a double open circuit can be spotted with a pair of test points connected to an ordinary light bulb. A short circuit, or short, cannot be found with test points, and this is why armatures which show up faultless, with test points, will not generate when installed on the car.

Ques. What kind of faults will a growler indicate in dynamos and starter ammeters?

Ans. Grounds, short circuits, open circuits, reversed coils, etc.

Ques. How does a growler work?

Ans. The alternating current which is used sets up vibrations at the contact surfaces between armature core and growler poles resulting in a buzzing or growling noise, hence the name "growler."

Every armature no matter if it be good or bad, when placed on a growler with current turned on will growl, and this noise is no indication as to the condition of the armature.

NOTE.—*The growler selected* to illustrate growler testing in this chapter was made by the *Allen Electric & Equipment Co.* of Kalamazoo, Mich.

A growler with an armature in place and current turned on is very similar to a transformer; the iron of the growler in contact with the steel body or core of the armature, forming an all metal path or core, for the magnetic circuit.

The growler winding is the primary which takes current from the power line, and the winding on the armature is the secondary, in which current is

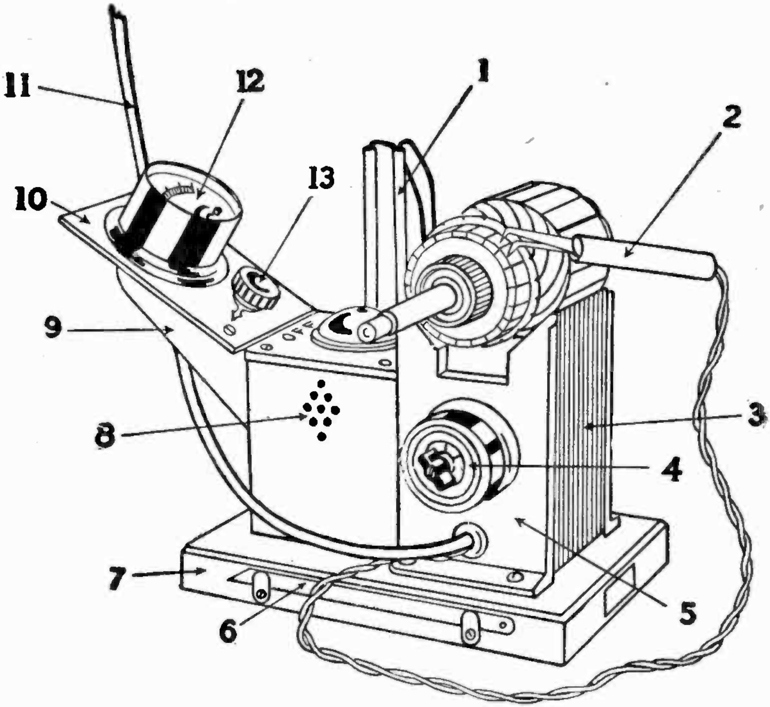


FIG. 7,057.—Allen growler with armature in position for testing. *In construction*, there is a U shaped piece of soft iron or electric steel, called the core, around one section of which is wound many turns of insulated copper wire. The upright legs are called the poles, and the armature to be tested is placed in the open end of the U in contact with the two poles, as shown. *The parts are:* 1, Long test points with insulated handles; 2, Contact fingers held in Bakelite tube; 3, Laminated core; 4, Operating switch, no open contacts or knife switch to shock operator; 5, End frames; 6, Hack saw blade for testing; 7, Base; 8, Holes to see tell-tale light; 9, Housing to protect rheostat and meter; 10, Panel carrying rheostat and meter; 11, Extension cord; 12, Ammeter with zero adjustment 13, Adjustable triple wound rheostat.

induced by the alternating action of the magnetic field developed in the iron core. If the armature winding be in proper condition, there is no current flow in the armature coils. If, however, the armature be short circuited, or has a short, a heavy current is induced in the short circuited coil, which strongly attracts a hack saw blade.

When to Use Growler.—All armatures of charging dynamos or starters which do not operate properly should be tested with a growler. This refers to armatures that are properly wound and to those which were improperly rewound or have been poorly repaired.

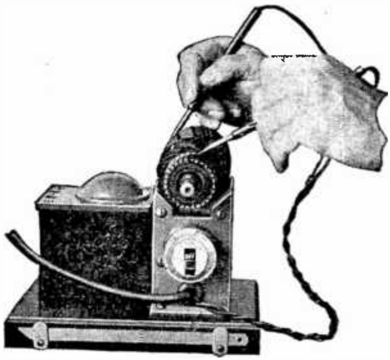


FIG. 7,058.—***Test for grounds.*** Place armature on growler and plug in the socket but do not turn on current. Use hand test points, touching one to steel shaft or steel core of the armature and the other to the copper commutator. If there be no ground the lamp will not light. If the lamp light, there is a ground. The test prods will show up the grounded spot by making it burn or smoke. The ordinary test lamp points carry about ¼ ampere current which is enough to go through a ground and light the lamp. This indicates a ground, but does not locate it.

Precautions in Using Growler.—If left *with current on and no armature in place, a growler will soon burn out.*

With an armature in place, the iron part of the armature bridges the poles of the growler and makes a complete magnetic circuit. This complete circuit tends to push back, on incoming current, as it were, making the effective current small.

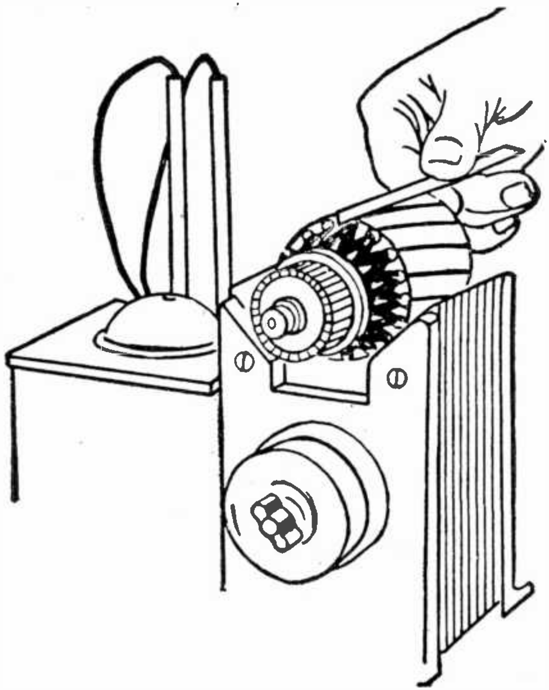


FIG. 7,059.—*Tests for s orts.* With armature in growler, turn on current. Note that this will also light tell tale lamp, precaution against leaving the growler running. Hold flat piece of steel, hack saw blade, in loose contact with top surface of armature, and, holding the blade, rotate the armature under it. In case of shorted coil, blade will be attracted to this coil. Turn off switch and mark the shorted coil. Test all armatures with hack saw blade even when using meter test as final check. First put armature in place, then turn on growler. Turn rheostat back to off position. Hold the hand contacts on the commutator so they touch the adjacent bars about half way up the side of the commutator. (See 2, fig. 7,057.) Adjust the rheostat so that the meter reads about half way. Holding the contacts on these two bars, rotate the armature slightly one way and then the other. This will increase or decrease reading. Note that there is a place where reading is the highest for each pair of bars, and when the reading is highest adjust rheostat so the meter reads an even number. Move the contacts to the next pair of bars and rotate the armature with contacts in place. If everything be satisfactory, this pair of bars will give the same reading on the meter as the first pair when in the same position. Move contacts down to next pair and so on all around. If there be no fault in armature, meter readings on every pair of bars will be the same. A shorted coil will give a *low* reading, and an open circuited coil will give *no* reading. This method is quicker and gives much more satisfactory readings than when the contacts are held in a fixed position with a clamp or when a spacing finger is used on the core slots.

When armature is removed, growler loses its ability to push back, and heavy current flows through it which soon burns out the insulation on the windings.

Troubles That May Develop in Armatures.—In general when an armature stops generating, the trouble is due to either a ground, a short circuit or an open circuit; that is, a *ground* results when there is contact between steel and copper somewhere in the armature; a short circuit or short when copper

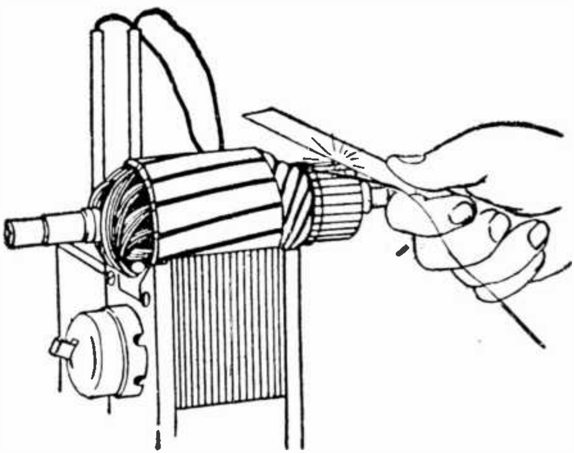


FIG. 7,060.—*Test for open.* This must be made after testing for ground and short. With armature in growler, turn on switch and short circuit each bar of commutator against the adjacent segment with hack saw blade while rotating armature. Each bar should give strong flash. Weak flash means an open circuit, if armature test clear of shorts and grounds as previously described. *In testing,* adjust contact fingers on adjacent commutator bars and rotate armature. An open coil will give *no* reading on meter.

touches copper; and an open circuit or open when a wire is loose or broken. Test for faults in the order given:

1. Ground;
2. Short;
3. Open.

Causes of Grounds.—These may occur in either the commutator or the winding. The following are the causes of grounds:

In the commutator:

1. In front end, caused by carbon and copper dust deposit which starts current leaking. This leakage develops heat which blackens the mica and turns it into a conductor.

2. Behind risers caused by dust deposit or from soldering wires in with acid, or even solder may run down behind risers.

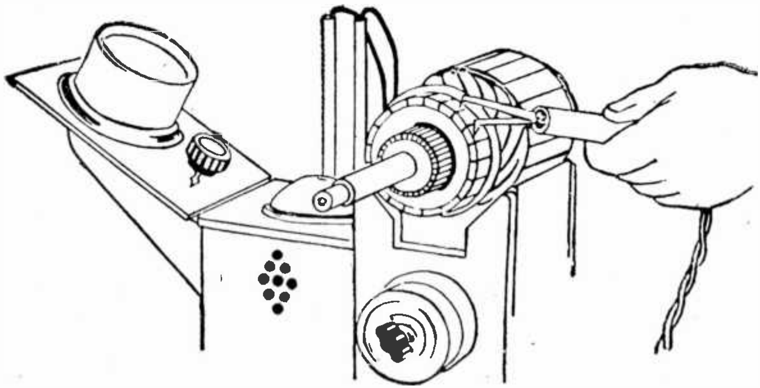


Fig. 7,061.—*Test for reversed current.* A reversed coil will give the same reading as a correctly connected coil, when read from bar to bar. To test for a reversed coil, place fingers on every other bar, adjust rheostat and test around. A reversed coil will neutralize the reading of a good coil and together they will give a very *low* reading.

3. Sometimes ground develops inside commutator caused by defective mica or defective assembling of commutator.

In the winding:

4. At end of core, generally caused by leaving weak spot in insulation at this point when winding. Under heat and vibration this spot breaks down and causes ground.

5. Laminations coming loose and cutting into wires.

6. Armature rubbing on pole faces, driving laminations into wires.

Remedy for Grounds.—When ground is caused by carbon dust, or solder behind riser, it can often be cleared. If armature core laminations be loose or misplaced by rubbing on pole face, the only remedy is a new armature.

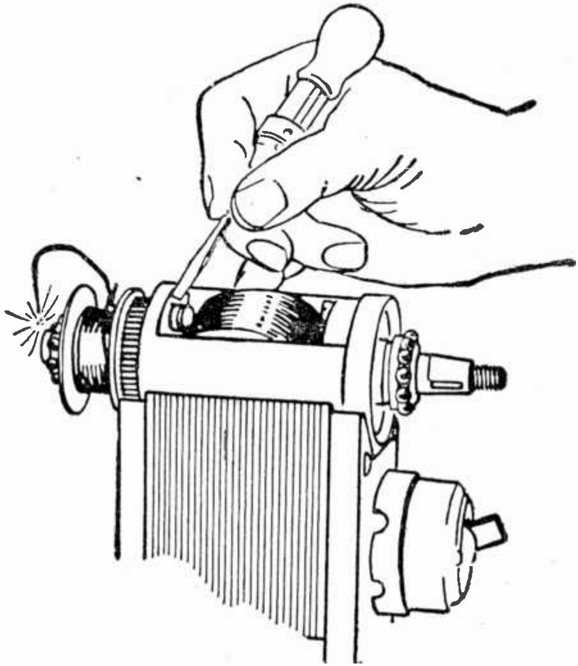


FIG. 7,062.—*To test magneto armatures.* A growler gives a very good magneto armature test. Place magneto armature in growler and with piece of wire arrange spark gap. If armature have make and break attached, operate this with finger and it should produce spark at the gap. If breaker be not attached, short the primary on and off with screw driver, as shown.

NOTE.—*To test starter armatures.* Starter and single commutator motor generator armatures have only one or two turns of wire on each coil, and as a result they do not give very strong indications on growler for shorts. Tests are the same, with exception of open circuit test which will not show up by flashing the commutator. Opens in these jobs will nearly always occur in commutator, and can be detected by inspection or with the meter. Test double commutator (Delco) armatures for ground on each commutator and then test from one commutator to the other. Lamp should not light. After this test, inspect for shorts and opens as if these were two separate armatures.

Causes of Shorts.—These, like grounds may occur in either the commutator or the winding. The following are the causes of shorts:

In the commutator:

1. Solder or soldering acid getting down behind commutator and bridging commutator segments.

2. Carbon dust packing into the undercutting of commutator and bridging segments.

3. When slight short occurs, current starts to flow through short, causing heat. With this condition mica becomes black and conducts current. Heavier current causes more heat until finally short is sufficiently heavy to conduct enough current to burn out coil.

In the winding:

4. Insulation damaged on wires while winding, leaving weak spot which under heat and vibration breaks down.

5. Careless handling weakens insulation causing it to break down.

6. Chafing of insulation due to vibration.

7. Overheating chars and weakens insulation so that it breaks down.

Remedy for Shorts.—If coil insulation be not burned out, troubles 1 and 2 can be remedied by cleaning away foreign material which is causing trouble. If insulation on winding be gone, the only remedy is rewinding the burned out coil or entire armature.

Causes of Open Circuits.—The following causes of open circuits should be noted.

At the commutator:

1. Poor or faulty soldering gradually gets dirty, making for poor connection and causing heat. Windings oxidize and no longer make connection, causing an open.

2. Overloading which causes overheating, melting out solder and resulting in an open.

3. Either commutator or core loose on shaft. This causes vibration at point where windings enter commutator which will in time crystalize and break wires.

In the armature:

4. Caused mechanically by armature rubbing on some part inside frame such as projecting bolt or some part that may work loose and cut wire.

5. Caused by ground or short burning through a wire and causing an open.

TEST QUESTIONS

1. *What is a growler?*
2. *What kind of faults will a growler indicate in dynamos and starter ammeters?*
3. *How does a growler work?*
4. *When should a growler be used?*
5. *Mention an important precaution to be taken when using a growler.*
6. *Describe the tests for grounds.*
7. *Describe the tests for shorts.*
8. *What are the troubles that may develop in armatures?*
9. *Describe the test for opens.*
10. *What are the causes for grounds:* 1, *in the commutator;* 2, *in the winding?*
11. *Give remedy for grounds.*
12. *Describe the testing of magneto armatures.*

13. *How is a starter armature tested?*
14. *What are the causes for shorts: 1, in the commutator; 2, in the winding?*
15. *Give remedies for shorts.*
16. *What are the causes for open circuits: 1, at the commutator; 2, in the armature?*

CHAPTER 167

Battery Testing

The author has presented the storage battery including its care and maintenance at such great length in volume III, it is unnecessary to go into the subject further here.

However, a few points relating to battery testing in general, will be of interest.

Usually a battery is brought in to be "charged" when the car owner cannot start his car, or his lights are so dim he can't drive at night, or he is having trouble of some kind and remembers he has a battery which may need charging.

In general, all that a normal battery needs is water and a recharge. However, some batteries will not take a proper charge; a cell may be short circuited, the plates bad, the separators worn out, or it may be just deterioration from long usage and old age.

It is poor business to put a battery on charge without giving it a high rate discharge test as soon as it is in condition to give results.

A battery may be so fully discharged that it will not give a reliable high rate discharge test. Such a battery must be put on charge for several hours before it can be tested.

However, every battery should be given the high rate discharge test in the presence of the owner, if possible. If the battery do not take a charge, there is the cost of current and loss of time for which the customer will not pay without an argument, and it doesn't pay to win an argument and lose a customer.

The equipment needed is a good shop hydrometer and a high rate discharge battery tester with accurate meters. All battery engineers agree that an open voltage test is worthless. A battery must be working, either charging or discharging, to give reliable voltage readings.

The following method of battery testing is based on practice used by many successful battery men:

1. When the electrolyte covers the plates, make a hydrometer test for gravity. If all the cells read below 1.175 put the battery on charge for several hours. This battery is too weak to give accurate results on a high rate discharge test.

2. If the electrolyte be low, fill with distilled water to the proper level and put on charge for several hours to mix the electrolyte and bring the gravity to 1.200.

3. If all three cells read over 1.200, make a high rate discharge test at once.

4. If 2 cells show a gravity of 1.200 or over and the third cell is off 50 points or more on the hydrometer, look for trouble. Make the high rate discharge test at once.

5. When the gravity of any 2 cells in the battery on charge passes 1.200, remove and make a high rate discharge test.

CHAPTER 168

Battery and Dynamo Testing

In order to quickly locate troubles in starting, lighting and ignition systems, a repairman should be equipped with the proper apparatus, otherwise his efforts to locate and correct faults will be more or less hit or miss and unsatisfactory.

An electrical testing unit or "*trouble shooter*" suitable for the work should be available.

Preliminary to Testing.—As starting the car is a battery's hardest task, it is generally in starting that a battery first shows signs of weakness. Therefore, the battery, starting motor and wiring will all be considered together in the first tests. Assuming that the dynamo is operating properly, there are three troubles liable to occur in the battery dynamo circuit:

1. Any or all cells of the battery may lack capacity to do the required work.
2. There may be an open circuit or poor connection somewhere which interposes resistance so that there is no current or not enough to operate the starter.
3. There may be a ground or *short* that either keeps the battery drained or diverts the current from the starter.

Before proceeding with tests to locate battery troubles, the following points should be considered:

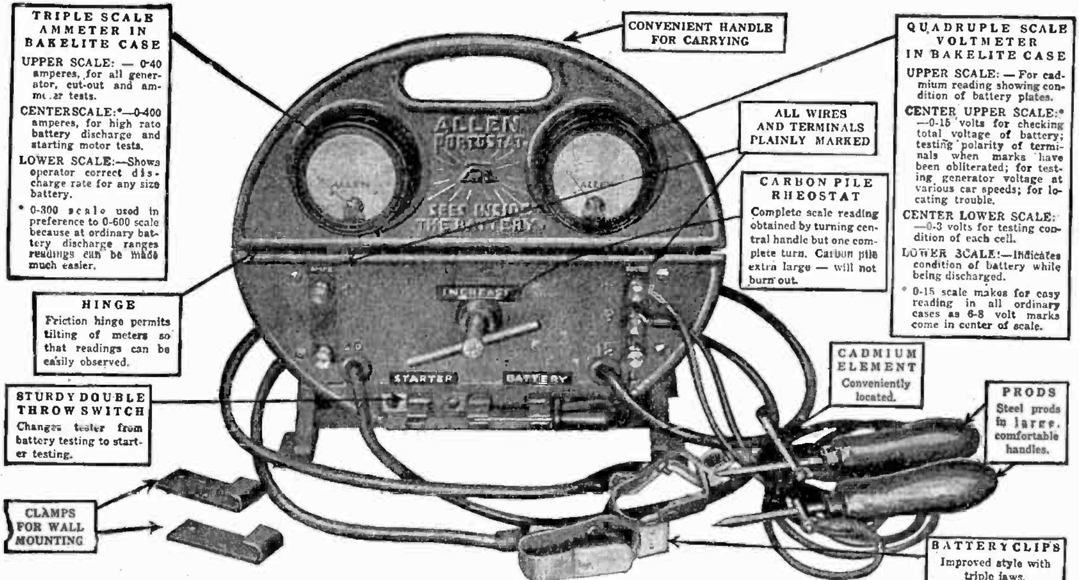


FIG. 7,063.—Allen trouble shooter or testing unit. It is used for completely testing the dynamo and starter, quickly locating and informing the operator what and where the trouble is, also for checking the wiring, ammeter, switches, ignition circuits, etc.

Points Relating to Batteries.—The normal voltage of each cell in a battery is about 2 volts, whether the battery be fully charged or nearly empty. For this reason a battery may be almost empty, yet when the lights are switched on they burn brightly (because the light load is so small that it does not affect the voltage).

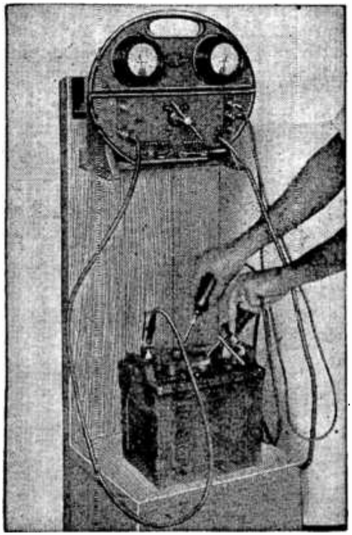


FIG. 7,064.—Allen trouble shooter installed for shop testing.

However, as soon as the starter is operated the lights go out, indicating that the voltage is practically gone. For this reason, when testing with a volt meter only, the results are of little value in determining the condition of the battery. The true condition of the battery does not become apparent except when its voltage is taken while the battery is being discharged at a high rate.

Battery Testing.—There are so many different ways of testing that the following method is given primarily to familiarize the operator with the working of a trouble shooter. Use a good battery for the first test.

Proceed as follows:

1. Inspect the battery cells and if any be dry, fill to proper level with distilled water. Leave the vent caps off.

2. Open the main switch on the trouble shooter, back off the rheostat handle and connect the heavy leads to the battery posts of the right polarity.

3. Attach prod with red handle to plus terminal and prod with black handle to 3 volt terminal of trouble shooter.

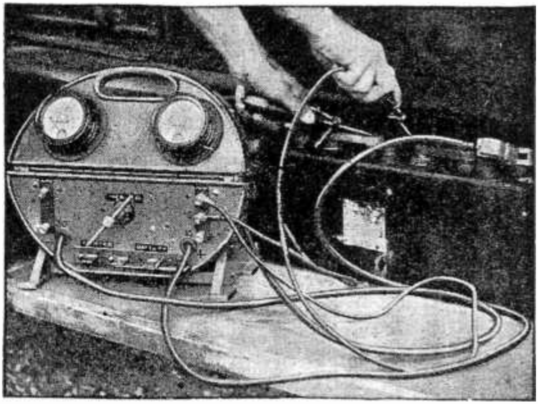


FIG. 7,065.—Making battery test with Allen trouble shooter.

4. Close main switch to battery side and turn rheostat handle to right until discharge rate of battery reads on ammeter at rate of 30 amperes per positive plate in each cell, 11 plate battery 150 amperes; 13 plate battery, 180 amperes, etc., as in fig. 7,065.

5. Now while discharging at this rate, prod each cell, red prod always on positive post and black prod always on negative post. If battery be in satisfactory condition, voltage should read 1.5 or better for each cell.

The following procedure should be followed:

1. Check each cell with hydrometer, if necessary add distilled water and charge to get reading. If any cell read low, 1.150 or less, it will not be possible to secure reliable reading until they are charged. At this point open circuit voltage readings may be taken on each cell or not, as the operator desires.

2. Put each cell on discharge at proper rate as indicated above. If any cell bubbles or foams on discharge, it indicates a short circuit in that cell due to buckled plates, defective separators, etc. Voltage readings on this

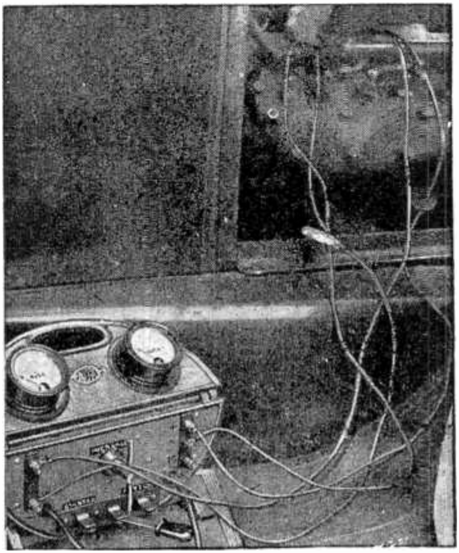


FIG. 7,066.—Testing dynamo with Allen trouble shooter.

cell will read very low or even in reversed direction. Take readings on each cell with volt meter. If voltage of any cell fall rapidly or read reversed, that cell has lost capacity due to falling away of material from positive plates, sulphating, etc.

3. If it be not possible to get correct discharge rate no matter how far rheostat handle is turned, set it as high as possible and make reading to find defective cell. If impossible to get battery to discharge, all cells

testing high in voltage, there is an open circuit or loose connection somewhere. Move the clips to be sure they make a good contact, and pry on the straps to see if they be loose.

4. If any cell read more than .1 below its neighbors, look for trouble in that cell. This test must be made with battery at least 25% charged. Note that a good battery will show low readings in some cells while being rapidly discharged.

Caution. In shooting trouble in a battery, before opening it up always test with hydrometer, before using trouble shooter.

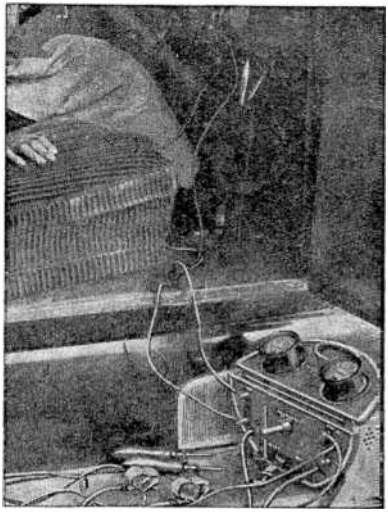


FIG. 7,067.—Testing ammeter with Allen trouble shooter.

Cadmium Test.—This *when properly made* will show the amount of charge of the positive and negative plates of each cell individually. In other words, it is possible to have the positive plates of a cell charged more than the negative plates. In such cases, when the battery is being discharged, the negative plates would be discharged first and this would cut down the total capacity of the battery.

In making cadmium test, battery should be either charging at normal rate, or discharging at about 8 hour rate. Cadmium stick is on negative prod of trouble shooter and should be inserted in the cell. Positive prod of trouble shooter should then be placed on positive terminal of battery and reading of positive plates taken. Leave cadmium in battery cell and move prod to negative post. It should be noted that there are many factors in cadmium testing which must be considered in order to make the readings of practical value. See the storage battery chapters in volume III of this series.

Testing Starter Circuit.—The student in learning how to use a trouble shooter should first use the apparatus on a car operating properly to become familiar with the correct method of using the outfit.

Prelimimary to testing:

1. Open main switch on trouble shooter and connect heavy leads to each side of starting switch, or connect one clip to live post of battery and other to starter terminal.

2. Connect prods to positive and to 15 volt binding posts on trouble shooter.

3. Now close main switch to starter side. This will complete circuit through trouble shooter to starter and if starter be in satisfactory condition, engine will turn over. The amperes are read in the ammeter and should run from 100 to 200 for average cars.

In testing proceed as follows:

1. Remove the heavy clips and operate starter by placing a weight on starter switch. Using test prods, prod lead posts of battery and read the voltage. Now hold one prod on terminal stud of starting motor and other prod on starter frame, which gives actual voltage at starter. The difference between battery voltage and starter voltage is loss. If this loss be over 1 volt, there is a possibility of loose connections, defective starting switch or that wiring is too small.

NOTE.—*When cranking an engine* a battery which is in good shape shows about 5 volts at its own posts, but voltage measured at starting motor will be slightly less, probably about 4½ volts due to loss in wiring and connections. The better the connections are, the less the loss; the higher the voltage at the starter, the stronger the starter.

NOTE.—*In the case of a very cold engine* the current draw, 400 to 500 amperes, will cause such a drop or loss in voltage that there will remain only about 3 volts at starter terminal.

2. Change prods to the positive and 3 volt binding posts on trouble shooter and operate starter. Hold one prod on the car frame near grounded post of battery, and other prod on grounded post of battery. There will be a small reading result. Now take readings from live post of battery to starting switch, from one side of starting switch to the other, from switch to starter terminal, and from frame of starter to spot on frame of car near grounded connection of battery. When all these readings are added to voltage reading taken at starter, the total should equal total voltage of battery. If any reading be too high, such as battery to grounded connection, open it up, clean surfaces, pull up tight and see if this do not reduce reading. It will also be found that installing larger cable, good starter switch, and cleaning and tightening all joints will reduce loss and increase the output of the starter. The same thing applies inside the starter itself. A clean commutator, clean brushes of the right grade, set at the right tension, and all connections tight will reduce the loss and increase the output.

Dynamo, Cut Out and Ammeter Testing.—The cut out here referred to is the discriminating cut out or reverse current circuit breaker. The reason for this device and its principles of operation should be understood.

In testing, proceed as follows:

1. Provide an extra pair of wires with a small battery clip on one end of each, and attach other ends of wires, one to positive and one to 30 amperes terminals of trouble shooter.

2. Remove one wire from rear of ammeter on car and clip one wire from trouble shooter to ammeter post and other wire from trouble shooter to ammeter wire just removed.

3. Connect prod wires to positive and 15 volt terminals on trouble shooter. Now hold one prod on frame and other prod on terminal of dynamo, and start the car reducing engine speed to minimum.

4. Increase speed slowly and note voltage build up until it reaches between 7 and 8 volts. At this point cut out should close, as will be indicated by ammeter needle giving a slight jump and coming back to about

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NOTE.—*The battery* must be in condition to operate the starter through the wiring and switch. The wiring and starter should be maintained at the highest efficiency, so as not to handicap the battery when the battery efficiency is not quite up to par, such as happens when it is under-charged due to an extra amount of cranking, when it is unusually cold, or when it has given up the best part of its service life.

1 or 2 amperes charging rate at same time voltage drops back to about 6. Now increase engine speed slowly and amperes will increase until reading reaches high point corresponding to about 25 miles per hour car speed. A higher engine speed will reduce the charging rate.

Now reduce engine speed. As speed is reduced, the ampere reading will become less and less until it shows a discharge of 1 or 2 amperes when cut out will open. While making this test ammeter in car can be checked against trouble shooter. To get reading on discharge side, stop engine and turn on lights.

The foregoing will give operator check on operation of dynamo, cut out and ammeter:

To locate trouble in wiring, connect prods to 0 and 15 volt terminals of trouble shooter and use same method as outlined under starting motor test. Turn on the horn, lights, or whatever is not operating and check out the circuit with the prods until the point of trouble is located.

TEST QUESTIONS

1. *What is a trouble shooter?*
2. *Assuming dynamo to be operating properly, name three troubles liable to occur in the battery dynamo circuit.*
3. *Mention a few points relating to batteries.*
4. *Give the general procedure in testing batteries.*
5. *Describe the cadmium test.*
6. *What does the cadmium test show?*
7. *What precautions should be taken in making the cadmium test?*

8. Give the general procedure in testing the starter circuit.

9. Describe in detail the method of testing discriminating cut out or reverse current circuit breaker.

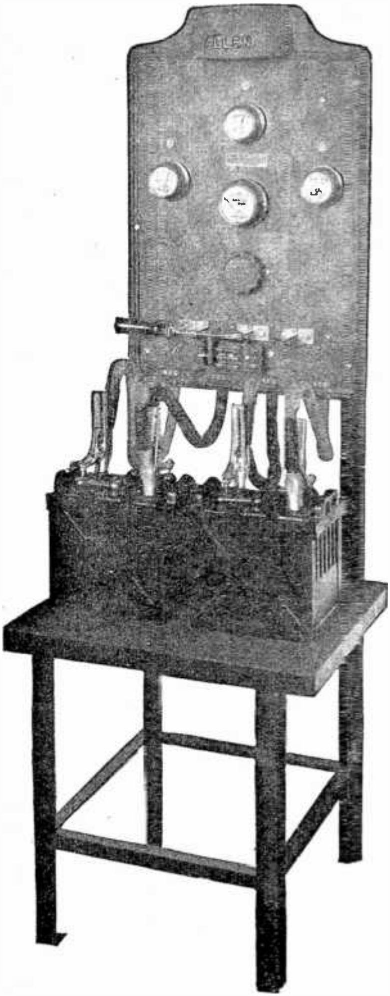


FIG. 7,068.—Allen panel test battery merchandiser. The purpose of this apparatus is to show the exact condition of each cell in the customer's battery, and to prove to the customer that the analysis is correct by making a direct comparison between his battery and a new battery of the same capacity. The three 3 in. volt meters are plainly marked to indicate a charged or partly charged condition of the battery; it is easy for car owners to understand the readings, and the reason it is necessary to have a new battery or a recharge. The 4 in. ammeter is marked with plate readings to indicate the proper discharge rate for all sizes of batteries. The switch is designed to carry both the high ampere discharge currents, and the volt meter circuits simultaneously. The rheostat control handle is large in size, and is finished in copper color to match the meters, switch and panel. There are two carbon piles, instead of the customary one, which gives more satisfactory operation in every way. The Allen volt amp. clips eliminate the necessity of having to use six separate clips, in order to get a reading of each cell of the battery at the same time. The knife blade contact arm reaches the straps of all types of batteries, including all the older, and the latest types. The clips remain cool even though prolonged high discharge rates are used, and the danger of making wrong connections and damaging the meters through overload is eliminated.

CHAPTER 169

Test Stand Testing

The term *test stand* is used to denote a testing outfit suitable for testing dynamos, starters, distributers, coils, magnetos, etc., in the shop.*

1. Dynamos

Charging Dynamos.—If, when on the car, the negative side of the battery be grounded, connect the + lead from the dynamo jacks No. 6 to the insulated terminal of the dynamo, and ground the — lead to a bare metal part of the dynamo.

If the positive side of the battery be grounded, reverse the leads. To determine which way to drive the dynamo, clockwise or counter-clockwise, motorize it, as instructed below, and then drive it in the same direction. A manual of wiring diagrams will be of great help in checking up on the correct operation of dynamos and ignition units.

Locating Dynamo Troubles.—Remove brush holder cover, and examine for dirty commutator, short brushes, brushes sticking in brush holder, and end play for worn bearings.

Run the dynamo as a motor, using battery current of the same voltage. Note the number of amperes it takes running as a motor, the action of the ammeter needle, and the speed of rotation of the armature.

*NOTE.—The test stand selected to illustrate this mode of testing is manufactured by the *Allen Electric & Equipment Co.*, Kalamazoo, Mich., and the author is indebted to this Company for the instructive illustrations shown in this chapter.

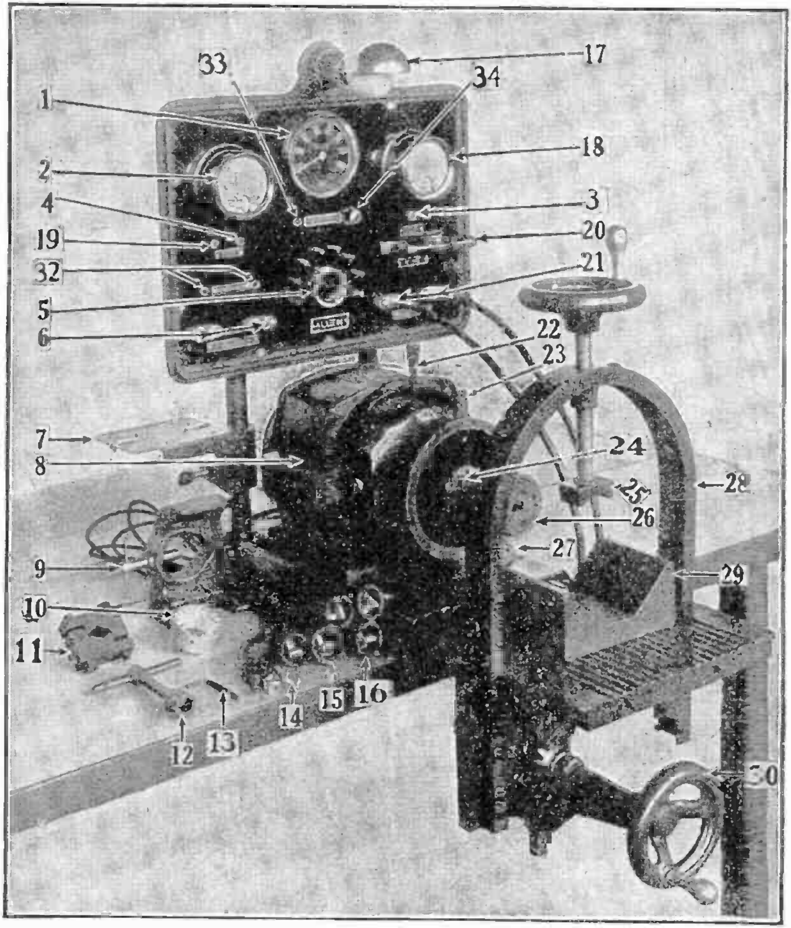


FIG. 7,069.—Allen universal test stand. The key numbers here given are used in the descriptions of tests. ***Key numbers:*** 1, tachometer, 400, 4,000 *r.p.m.*; 2, 0-20, volt meter; 3, independent volt meter test jack; 4, condenser switch; 5, adjustable multiple spark gap; 6, generator test plug-in jacks; 7, clamp plate for ooil tests; 8, motor switch; 9, distributer clamp; 10, Ford and Chevrolet gear type coupling; 11, compression coupling, universal for straight shafts and most hex nuts; 12, T socket wrench for compression coupling; 13, Allen set screw

To Motorize a Dynamo.—Place the dynamo in the V block on the elevating table. If rectangular, lay it on the table. Do not hook up to test stand motor. Fig. 7,071 shows connections for a dynamo with grounded negative. If the dynamo have a grounded positive, reverse these connections.

Close battery switch No. 20. The dynamo should rotate as a motor and draw from 4 to 7 amperes at 6 volts, running freely.

If armature do not rotate, it indicates armature trouble.

If armature rotate but draws too many amperes, it usually shows armature trouble.

If the ammeter needle fly off the dial, it usually indicates a grounded brush holder.

If the armature stop when certain segments come under the brushes, it shows an open circuit in the armature.

If the ammeter needle keep swinging and armature do not rotate at a constant speed, look for armature trouble.

If dynamo will not motorize, or otherwise show trouble, take it apart and test each unit separately.

If it motorize, and appear to be in proper condition proceed with tests.

Dynamo Troubles.—These occur in armature, fields, brush holder and brushes, and may be divided into electrical troubles and mechanical troubles.

FIG. 7,069—*Text continued.*

wrench; 14, independent voltage plug and test leads; 15, jumper connection; 16, generator and ignition test leads; 17, 110 volt test lamp socket (lamp not included); 18, combined 30-0-30 and 600-0-600 ammeter; 19, plug-in jack connects to breaker No. 24 mounted on front of motor; 20, battery switch, controls all circuits; 21, starter test plug-in jacks and leads; 22, speed and rotation control lever; 23, rotary spark gap and shifting handle; 24, standard breaker for ignition testing; keep points separated when not in use; 25, clamp screw pad; 26, silent drive motor coupling, rubber cushioned; 27, rotary spark gap lead; 28, hold down clamp, quick adjustment; 29, V block, takes all round generators including both types of Buick motor generators; rectangular generators are set directly upon elevating table; 30, elevating wheel, convenient to operate; 31, 110 volt test prods in holder on post of instrument panel, not shown; 32, ignition test plug in jacks; 33, rheostat control switch; 34, rheostat control knob.

Armature Troubles.—The following are the various electrical and mechanical armature troubles:

Electrical Troubles.

1. Grounds.
2. Short circuits.
3. Open circuits.

Mechanical Troubles.

1. Dirty or burned commutator.
2. Oily commutator.
3. Commutator out of round.
4. Bent shaft.
5. High mica.
6. Worn bearings.

Tests for Armature Troubles

Test for Ground.—Place one of the 110 volt test points on the copper commutator, and the other on the steel shaft or steel core. Bulb No. 17 should not light.

If it do, the armature is grounded and must be replaced.

Tests for Shorts and Opens.—These require a growler. See chapter on Growler Testing.

Field Troubles.—The following are the various electrical and mechanical field troubles:

Electrical Troubles.

1. Grounds.
2. Short circuits.
3. Open circuits.

Mechanical Troubles.

1. Wrong field connections.
2. Reversed coils.

Tests for Field Troubles

Tests for Grounds.—Place one of the 110 volt test points on one of the field terminals, and touch the other test point

NOTE.—If commutator be dirty or oily, clean with gasoline and rub with 00 sand paper. Commutator out of round will make the brushes jump off the commutator, especially at high speed. Turn down commutator. High mica keeps the brushes jumping off the commutator and wears down the brushes. To remedy, undercut the mica. Worn bearings permit armature to rub on pole shoes, makes dynamo noisy, and results in shorts and grounds. Replace with good bearings.

against the case. Bulb No. 7 should not light. If the bulb light, the coils are grounded.

To locate which field winding is grounded, loosen field pole screws from one field coil and push it away from frame. Test for ground.

Then loosen screws and push away the next field winding and so on, until the grounded winding is located. Be sure to examine the insulation around the field terminal where it comes through the case.

Tests for Short Circuits.—Insert two leads No. 16 in dynamo jacks No. 6 and attach one lead to each of the field winding terminals. Close switch No. 20 and note the number of amperes shown on the ammeter. Consult the data manual for the proper current draw for that particular type of dynamo field winding.

If current draw be high, there is a short circuit. To locate, insert voltage plug No. 14 in volt meter jack No. 3 and with the No. 14 clips read the voltage drop across windings. The voltage drop should be the same for all coils, and the low reading one is the shorted coil. Replace this coil.

Test for Open Circuit or Poor Connection.—If ammeter reading be low, look for a poor or dirty connection in the wires between two field coils. Clean and resolder. An open or broken wire will give no reading on the ammeter. Find the broken connection, clean and resolder.

Wrong Field Connections.—Dynamo will motorize backward. Reverse the field leads to brush holder.

Field Coils Reversed.—Connect leads from dynamo jacks No. 6 to the field terminals. Close battery switch No. 20. Bring a small compass near each pole on the outside of the dynamo.

The compass should indicate alternate North and South poles. If one field coil be reversed, two or more consecutive poles will have the same polarity. Reconnect the field coils properly.

Brush Holder and Brush Troubles.—The following are the electrical and mechanical troubles usually encountered:

Electrical Troubles.

1. Grounded brush holder.

Mechanical Troubles.

1. Brushes stuck in brush holder.
2. Brushes worn too short or glazed.
3. Weak brush springs.

To test brush holder, touch one of the 110 volt test points to an insulated part of the brush holder and the other test point to the grounded portion of the brush holder. If the bulb light, the brush holder be grounded. Replace. Brushes sometimes stick in the brush holder, due to dirt or wrong size and fail to make contact with the commutator. Be sure they are free to move. Glaze on brushes may be sanded off with fine sand paper, or if worn short, should be replaced.

Brush springs must have proper tension. If too stiff, brushes will wear quickly, and tend to heat the commutator. Too little spring tension will tend to decrease the dynamo output and increase the dynamo voltage, and may burn out the dynamo.

All data manuals give the proper spring tension for dynamo brushes. Test the springs with a 5 lb. spring balance.

Setting Brush Holder on Neutral.—After the dynamo is reassembled loosen the screws which hold the brush ring in place. *Raise the movable third brush off the commutator.* Lay dynamo in V block and connect, same as for motorizing.

Close switch No. 20. By shifting the brush holder with main brushes on the commutator, the armature can be made to rotate in either direction. A neutral point will be found where the armature will not rotate either way, even when the shaft is rocked with the fingers. This is the exact neutral.

In practice, the brush ring is generally set with a little lead so that when started with the fingers, the armature will turn very slowly in the same direction as the dynamo rotates. Now tighten brush screws.

How to Hook Up a Dynamo.—1. Lay round dynamo in V block on elevating table. If rectangular lay it on the table.

2. Clamp compression coupling No. 11 squarely on armature shaft or hex nut as shown in fig. 7,070.

3. Turn the motor coupling so that the holes in the rubber block are horizontal. With the two pins on dynamo coupling No. 11 horizontal, raise or lower the table until the pins slide into the holes. Clamp dynamo firmly and turn couplings with fingers to make sure dynamo turns freely, is square with the motor coupling and not too close.

4. Plug two leads into dynamo test jacks No. 6. Clip the + lead to the insulated dynamo terminal and ground the − lead to the dynamo frame. If

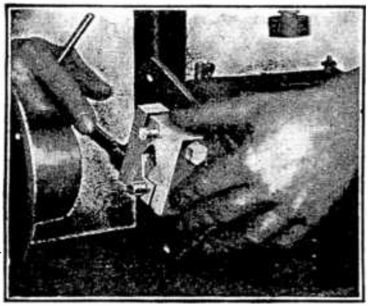


FIG. 7,070.—Adjusting compression coupling.

on the car the + post of the battery is grounded, reverse the above connections, as shown in fig. 7,071. On a two wire dynamo connect the leads so that dynamo motors in proper direction. If the dynamo has a shunt field terminal connect this terminal to the main dynamo terminal with a piece of bare clean copper wire, or else through a regulator.

Testing a Dynamo.—1. Close battery switch No. 20. The dynamo should run as a motor. The ammeter will register higher than when running free because the dynamo is driving the motor.

If dynamo motor backward, reverse the field leads in the dynamo. It must rotate in the same direction as it will be driven on the car.

2. Make sure the coupling runs smooth and true, with about ⅛" space between motor coupling and dynamo coupling. Raise or lower the table for final adjustment.

3. Lock elevating table in place with lock nut under the right side of elevating table.

4. With motor control lever No. 22 in a central position, turn on motor switch No. 8, and slowly move control lever No. 22, so as to drive the dynamo in the proper direction.

5. As the motor speed is increased, the ammeter needle should move toward zero and cross over to the "charge" side. The charging rate should increase as the motor speeds up until the tachometer shows a speed of 1,600

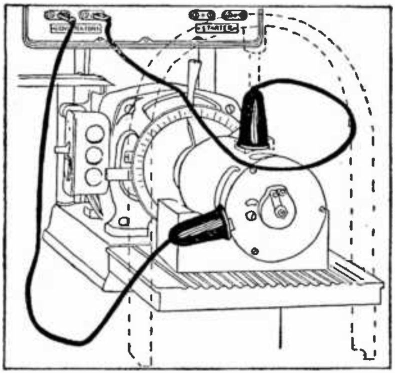


FIG. 7,071.—Dynamo connections.

to 1,800 *r.p.m.* for most dynamos. At higher speeds the charging rate usually drops off. If it drop too much, look for weak brush springs, short brushes, commutator out of round or in rare cases a flying ground or short.

To Test Delco Motor Generators.—1. In general, there will be three terminals. The largest one and the frame (ground) are the starter terminals. The two smaller terminals and the frame (ground) are the generator field terminals. Connect the two small terminals together with a clean bare copper wire and this wire becomes the insulated terminal for test purposes.

2. Attach one generator test lead from No. 6 to the copper wire and the other to the frame of dynamo (ground), as shown in fig. 7,072.

3. There is usually a motor brush lifting mechanism. Shift this to raise the motor brushes off the commutator. On the Lincoln motor generator slip a fibre plug into the mechanism after raising the motor brushes. The large heavy brushes are for the motor.

4. Adjust motor generator on test stand the same as any ordinary generator.

5. Close battery switch No. 20 and test just like any other dynamo.

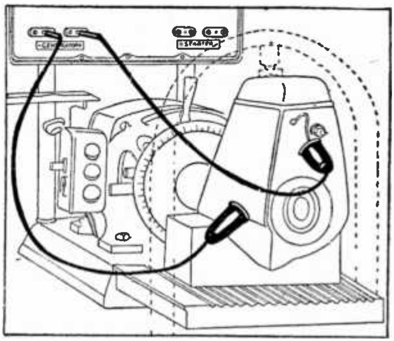


FIG. 7,072.—Buick motor generator connections.

To Test Other Motor Generators.—Most other types of motor generators have a single armature winding and are tested the same way as a straight generator. For 12 volt units use a 12 volt battery.

2—Discriminating Cut Outs

(Reverse Current Circuit Breakers)

A discriminating cut out or reverse current circuit breaker (usually called *cut out*) is *an electrical check valve*.

In operation, at 7½ volts, the points should close and permit the generator current to charge the battery. When the dynamo is idle, the cut out points should open when the battery discharge reaches from 1 to 3 amperes, and stop the battery from further discharging into the generator.

Cut Out Troubles.—These may be electrical or mechanical as follows:

Electrical.

1. Open circuit in shunt winding.
2. Poor ground connection.

Mechanical.

1. Points badly pitted.
2. Points not making contact.
3. Improper spring tension.
4. Wrong air gap.

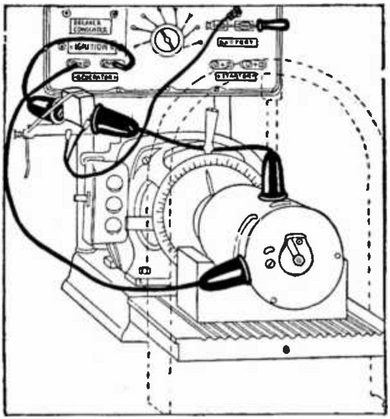


FIG. 7,073.—Independent cut out connections.

To Test Cut Out.—1. A cut out usually has two terminals, marked G, for dynamo and B, for battery connections. Some older types have a third terminal for ground connection. If terminals be not marked, test with 110 volt test points. When cut out points are open, Batt terminal is insulated from both G, terminal and ground, and bulb will not light. Test points placed on Gen terminal and ground should light bulb, and with *a.c.* will cause points to vibrate.

2. Clamp cut out on coil test plate No. 7. Be sure that B and G, terminals do not touch the plate.

3. Hook up a good generator.

4. Connect one lead from jacks No. 6 to Batt terminal of cut out. Connect a lead from Gen terminal of cut out to insulated terminal of dynamo. Ground the other lead from No. 6 to frame of generator. Insert voltage plug No. 14 in volt meter jack No. 3. Connect one of the No. 14 wires to dynamo terminal of cut out and ground the other to plate No. 7, as in fig. 7,073.

5. Close battery switch No. 20. If volt meter read backward, reverse connections of No. 14 wires.

6. Remove cut out cover. Press points of cut out together and generator should motorize.

7. Separate cut out points. Start the motor, driving the dynamo slowly in the same direction it motorized. Slowly increase the generator speed, the volt meter will begin to read. At 7½ volts (15 volts on a 12 volt system) the points should click shut and a charge show on the ammeter. Points should make good contact, there should be no sparking, and the volt meter reading should be practically zero.

8. Slow down the motor. The ammeter will come to zero and then begin to show a discharge. At from 1 to 3 ampere discharge the cut out points should click open.

Adjustments of Cut Out.—There are three adjustments to a cut out:

1. Points must be clean, must meet squarely, and when closed, the air gap between the coil core and the movable arm should be from .005″ to .010″.

2. Set spring tension so that points will open at from 1 to 3 ampere discharge.

3. If points close at less than 7½ volts, increase air gap.

4. If points close at more than 7½ volts, decrease air gap. If adjustments 3 or 4 change the spring tension, readjust it. If cut out will not adjust for correct operation, replace it.

Important: If cut out do not close, keep the generator voltage below 20 volts, or the volt meter may become damaged.

To Test Cut Out on Dynamo.—1. Mount dynamo with cut out attached in regular way.

2. Connect leads from test jacks No. 6, one to battery terminal of cut out and the other to the dynamo frame (ground).

3. Insert volt meter jack No. 14 in jack No. 3. Connect one of the No. 14 leads to the insulated dynamo terminal or the dynamo terminal of the cut out and ground the other lead to the dynamo frame. If volt meter read backward, reverse the No. 14 leads, as in fig. 7,074.

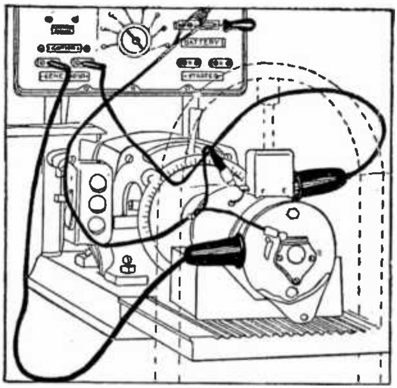


FIG. 7,074.—Discriminating cut out or reverse current circuit breaker on generator.

4. Remove cut out cover and close battery switch No. 20. Motorize dynamo and make the same tests and adjustments as when testing an independent cut out.

Important: If cut out do not close, keep the dynamo voltage below 20 volts, or the volt meter may become damaged.

3—Starting Motors

Locating Starting Motor Troubles.—Remove brush cover, and examine for dirty or burned commutator, short brushes, brushes sticking in brush holder, bent shaft and worn bearings.

To Test Starting Motors.—These should be tested for free running and for torque as follows:

1. *Free running test*. Place starting motor in V block. Plug heavy leads into starter jacks No. 21. Connect one lead to insulated terminal and the other to the starter frame (ground), as in fig. 7,075. Close battery switch No. 20, and motor should rotate at high speed and draw between 35 and 90 amperes. Any good data manual gives the no load amperes for various starting motors. Volt meter should read not less than 5 volts, if battery be in good condition. If motor howl, draw more current than it should, and do not run at high speed, look for bad bearings.

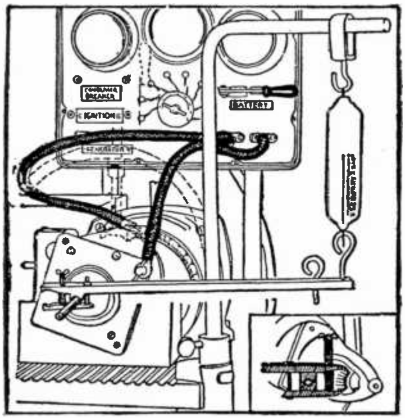


FIG. 7,075.—Torque test connections.

2. *Torque test*. The torque test measures the cranking power of the starting motor. Torque is the pull in pounds at the end of a 12 inch torque arm. Clamp the starting motor firmly in V block with shaft away from the test stand motor. Place the scale support arm in the opening in the front center of the elevating table and hang the scale on it. Clamp the torque arm firmly on the starter shaft so motor cannot rotate (or the bendix gear) as shown in fig. 7,075.

For a round shaft connection, attach the torque arm scale to the outside hook. For a bendix drive connection attach the scale to the inside hook. Arrange the scale support arm so that the torque arm is about 1" higher at the scale than at the motor. Plug heavy leads in starter jacks No. 21 and connect one to the insulated terminal of the motor and the other to the starter frame (ground) as in fig. 7,075.

Connections must be clean and tight. Be sure there is a good battery on the test stand. In this test the voltage wanted is that at the motor and not at the battery. Accordingly insert volt meter plug No. 14 in jack No. 3, and connect No. 14 terminals, one to the insulated terminal and the other to the frame (ground).

Important: Check direction of rotation of starter beforehand and swing the scale support arm to the proper side so the torque arm will *pull* on the scale and not kick back. A starter has plenty of kick at the end of a 1 foot arm, and can cause serious injury. Place fingers on torque arm while making test, so arm won't fly up when current is shut off. Close switch No. 20 and read lbs. torque, voltage of battery and ampere draw. Consult the data manual for the proper torque, voltage, and ampere draw for that particular motor.

Troubles in Starting a Motor.—The troubles usually encountered are:

1. Armature, grounded, shorted or open circuited.
2. Fields, grounded or open circuited, hardly ever shorted.
3. Brush holder, grounded.
4. Dirty or burned commutator.
5. Brushes too short or sticking in brush holder.
6. Brushes of improper grade.
7. Brush springs with improper tension.
8. Worn bearings or bent shaft causing armature to stick to pole pieces.

Tests for Armature Troubles.—These comprise tests for grounds, shorts and opens as in the following paragraphs:

Test for Ground.—Same as for dynamo armature.

Test for Short.—Same as for dynamo armature.

Test for Open.—Starter armature windings are of large size and an inspection will usually show up any loose wires at the commutator. Clean slots and wire, and resolder.

A dirty commutator may be cleaned with gasoline and 00 sand paper. An out of round commutator must be turned true. A bent shaft must be straightened or the armature replaced. Worn bearings must be replaced. See note on page 4,346.

Tests for Field Troubles.—These are as follows:

For Ground.—Same as for dynamo fields.

For Shorts.—This practically never happens.

For Opens.—Same as for dynamo fields. Look for loose connections where terminal leads are soldered to field leads. If loose, clean and resolder. See section on Dynamos.

Test for Brush Holder Troubles.—*For ground* test same as for dynamo brush holder.

Brushes must be free to move in brush holder. Short brushes should be replaced. With a small 5 lb. spring balance test the tension of brush springs. Check against data given in a standard manual.

Battery Ignition Systems.—A typical battery ignition system consists of a battery, breaker, coil, resistance wire, condenser, distributer and spark plugs, with suitable switches and wiring.

The function of the ignition system is to furnish the high tension spark necessary to operate the engine. Each cylinder on an automobile requires one spark every two revolutions.

For every revolution of the engine, a 4 cylinder car must have two sparks, a six requires three, and an eight requires four. Some engines have a maximum speed of 2,000 revolutions per minute (*r.p.m.*) while others make over

4,000 *r.p.m.* While under ordinary driving conditions an engine does not operate at maximum speed, a coil must be capable of supplying a good hot spark at maximum car speed. For example, a 6 cylinder car with a maximum engine speed of 3,600 *r.p.m.* requires at that speed, $3{,}600 \times 6 \div 2 =$ 10,800 sparks a minute.

Since the test stand has a 6 lobe cam, and gives six sparks per revolution, the test stand motor should be driven at $10{,}800 \div 6 = 1{,}800$ *r.p.m.* as shown on the tachometer.

A faulty breaker, condenser, coil or distributer, will fail to start the engine or cause misfiring, especially at high speed and under load.

To test a battery use a hydrometer and a high rate discharge test set. Spark plugs are inspected for carbon deposits, burned points, incorrect air gap, cracked porcelain, etc. Substitute a new spark plug.

4—Ignition Coils

A high tension coil must be capable of delivering a good spark at starting and at high speeds. In cold weather, the starting motor draws so much current from the battery that the effective voltage to the coil may drop to as low as 3 volts, and many coils will not give a spark hot enough to start the engine on such low voltage. This makes the car hard to start.

In the ignition test circuit on the test stand, is a rheostat No. 34, to reduce the battery voltage applied to the coil being tested and the exact voltage at which the coil begins to miss can be easily found. Further, many coils which are satisfactory at moderate speeds may cause misfiring at high speeds and every coil should be tested over the entire range of speeds.

Troubles in Ignition Coils.—Practically the only trouble in a coil is broken down insulation. A coil is either good or bad, and a test will show its operating condition. It is best to test a coil when it is hot as sometimes trouble shows up only when the coil is warm.

To Test a Coil.—Clamp coil on plate No. 7. Connect one lead from ignition jacks No. 32 to coil terminal marked Batt or Sw, and ground the other lead.

Connect lead from coil terminal marked Int, or Timer, to breaker condenser jack No. 19. Connect secondary of coil to one of the leads from the adjustable spark gap No. 5, which should be set to 5/16″.

Insert volt meter plug No. 14 in volt meter jack No. 3, and connect the two leads No. 14 to the metal plugs inserted in No. 32 jacks, as shown in fig. 7,076. Lower the breaker arm so that breaker points No. 24 make contact,

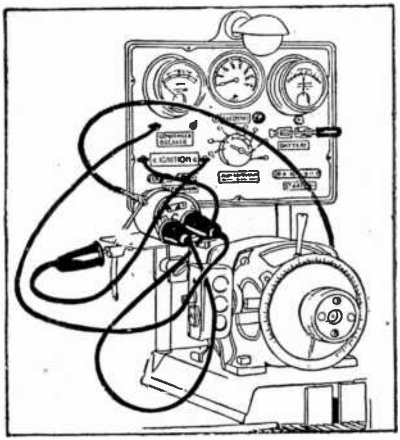


FIG. 7,076.—Coil testing connections.

and start the motor. Close battery switch No. 20. If coil have a condenser inside it, leave condenser switch No. 4, open. If not equipped with condenser, close switch No. 4. With rheostat switch No. 33, up, observe the sparks at various speeds.

Now with the switch No. 33 down, rotate the motor slowly and reduce the battery voltage by turning rheostat control knob No. 34. Keep reducing the voltage as shown on the volt meter, until the coil begins to miss.

To get low speed, it may be advisable to hold hand on the motor coupling No. 26. If coil do not give a good spark at about 3½ to 4 volts, close condenser switch No. 4. If a good spark be now obtained, condenser in coil is bad and coil should be replaced. If coil test satisfactorily on low voltage, throw switch No. 33 up, and speed up motor. The spark should be steady, strong and regular. If not, and the coil has a condenser in it, close switch No. 4. If a good spark be now obtained, condenser in coil is defective, and coil should be replaced. If closing switch No. 4, does not improve the spark, the coil windings are defective and coil must be replaced.

A broken or burned out resistance unit will prevent current getting to coil.

5—Condensers

There must be a good condenser in the primary circuit, coil or breaker points, to get a good spark.

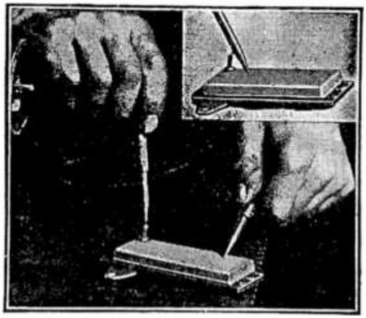


FIG. 7,077.—Testing condensers.

Condenser Troubles.—These are the troubles usually encountered: 1, Open circuit; 2, Short circuit; 3, Leaky condenser.

A defective condenser will cause heavy sparking at the breaker points.

To Test Condenser.—1. Place one of the 110 volt test points on the condenser terminal and the other against the case (ground). If lamp light, condenser is shorted. See fig. 7,077.

2. If not shorted, the above test, No. 1, will charge the condenser. Hold one of the 110 volt test points on the case (ground) and lean it over to touch the insulated terminal. There should be a short snappy spark. If *a.c.* be used try several times. If it do not spark, condenser is leaky or open circuited. Replace.

3. The best test, if condenser be not shorted, is to compare its operation against that of a good condenser with a good coil. Connect a good coil without an internal condenser, for test as under 2, Section 4, but do not use volt meter jack No. 3. Operate it, closing condenser switch No. 4, to make sure spark is good. Now with motor running, open switch No. 4, and connect with a jumper wire, the terminal of the condenser being tested to the coil terminal attached to breaker wire No. 19, and ground the condenser against a clean part of the test stand. If coil now give a good spark, condenser is faultless.

6—Breakers

The breaker opens the primary current so that a high secondary current may be induced in the secondary coil winding.

Trouble in Breakers.—Electrical troubles hardly ever occur except poor connection to condenser. The mechanical troubles are:

1. Breaker points dirty, pitted or badly worn.
2. Breaker points out of adjustment or out of alignment.
3. Spring tension weak.
4. Worn bushing on breaker shaft.

All these troubles are easily detected. Clean, true up or replace dirty pitted and badly worn points. Spring tension must be correct, especially so on high speed engines. Check with a 5 lb. spring scale against data in manual for any particular breaker. A worn bushing on breaker shaft can be detected by moving cam with fingers.

To Test Operation of Breakers.—1. Fasten breaker in clamp No. 9. Slip compression coupling on pinion or on shaft if pinion be too large.

2. Arrange breaker for driving, same as a dynamo.

3. Hook up a good ignition coil and connect as shown in fig. 7,078.

4. Be sure breaker points No. 24 are separated. Use lever on breaker cam for raising and lowering.

5. Connect lead from ignition test jacks No. 32 to coil terminal marked Batt or SW. Connect jumper wire from coil terminal marked Int. or Timer to insulated terminal of breaker. Plug lead into breaker condenser

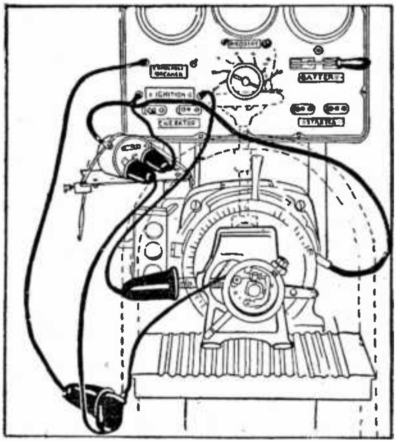


FIG. 7,078.—Testing a breaker.

jack No. 19, and connect it also to insulated terminal of breaker. Ground the other lead from ignition jacks No. 32, to clean bare metal. Connect rotary spark gap lead No. 27, to secondary terminal of coil.

6. If coil or breaker be equipped with a condenser leave condenser switch No. 4, open, if not, close switch No. 4.

7. Start test stand motor and drive breaker shaft in same direction as on the car.

8. Close battery switch No. 20. There should be as many sparks evenly spaced on the rotary spark gap ring as there are lobes on the breaker cam. 4 sparks for 4 lobe cam, etc. If the sparks be not evenly spaced, one or more cam lobes may be worn low, be out of true or have a burr on it, or the shaft may be bent. If the spark be poor, close condenser switch No. 4.

If a good spark be now obtained, condenser in breaker unit or coil is defective. Now operate the breaker at ½ maximum engine speed, to check for operation at maximum car speed. On the car, breaker operates at ½ engine speed. It should be noted that points set too far apart will cause missing at high speed.

To Check Automatic Spark Advance.—While testing breaker, run motor very slowly and shift the rotary spark ring handle No. 23, until one of the sparks occurs on the zero mark of the ring. Speed up the motor and if the breaker have an automatic spark advance, the spark will travel back or earlier. Read the number of degrees spark has advanced and check against specifications in data manual. At high speed the spark will be strung out. Take reading from the first good strong spark.

7—Synchronizing Two Arm Breakers

Some six and eight cylinder cars have two pairs of breaker points with six or eight lobe cams, and the two breaker arms must be set to open at the same instant. Other six and eight cylinder cars have two sets of breaker points with three or four lobe cams, and each breaker arm must be set so it opens alternately, exactly half way between two breaks of the other.

Synchronizing Two Arm Breakers to Open Together.—1. Adjust points to proper gap and spring tension and mount the breaker in clamp No. 9. Connect it with a good coil.

2. Connect same as for breaker test in Section 6, page 4,362, fig. 7,078. Connect secondary of coil to rotary spark gap. Be sure breaker points No. 24 are open. Separate the points on the adjustable arm with a piece of fibre and operate the motor slowly. Close switch No. 20. There will be as many sparks on the rotary ring as there are lobes on the cam. Bring the zero of the spark ring scale to one of the sparks.

3. Stop motor, remove fibre from points on the adjustable arm and place it between points on the fixed arm which have just been set. Start motor and move adjustable arm until its spark also falls on the zero. To check setting, operate with both sets of points working. With the fingers, lift first one arm, then the other, and the sparks should fall on the same spot.

Synchronizing Two Arm Breakers to Open Alternately.—Connect and operate same as above, but set the adjustable arm to bring the spark to the correct angle, 60° for six cylinders or 45° for eight cylinders. On Lincolns and other 60° V engines, the correct angles are 30° and 60°.

8—Distributers

The rotor brush arm and distributer cap connect the secondary current from the coil to the spark plugs at the proper time.

Troubles in Distributers.—Electrical troubles are rare. The mechanical troubles are:

1. Rotor brush worn.
2. Rotor brush arm cracked.
3. Distributer cap cracked.
4. Carbon path in distributer cap.

To Test Distributers.—1. If breaker be in good condition, assemble breaker distributer complete with rotor brush and distributer cap, and connect high tension terminal of coil to center of distributer instead of rotary spark gap. Connect leads from multiple spark gap No. 5, to the distributer terminals in proper order. Paper clips or screws are useful to place in terminal holes of distributers and the leads from No. 5, connected to them. If the spark plug wires be left in distributer cap, clip the leads to them.

2. Adjust multiple spark gap points No. 5, to about 5/16" gap.

3. Drive breaker in same direction as on car, close battery switch No. 20, and a spark should jump regularly across every gap connected to distributer head. If rotor brush be worn or leaky, or distributer cap be cracked or do not operate, replace them.

9—To Test Magnetos

The following instructions are for the more common types of magnetos. Some of the later magnetos give four sparks per revolution.

1. Chuck magneto same as a generator, using compression coupling. No. 11 over hex nut on magneto shaft. If table will not elevate high enough to set magneto directly on table, set it on a short piece of 2×4, or turn the V block on its side and set magneto on this.

2. Connect the rotary spark gap lead No. 27 to the collector brush of the magneto.

3. Start motor and drive magneto in proper direction. Two sparks spaced at 180° around the spark ring should be obtained. If unevenly spaced, check up on the stationary cam blocks. It may be necessary to shim one of them so that the points separate the same amount on each cam. When this is done, the sparks will be spaced an even 180° apart.

4. Now disconnect the rotary spark gap lead and connect the multiple spark gap leads to the distributor terminals in proper order, as in fig. 7,079.

5. Set the multiple spark gap points to approximately 5/16" and try out the magneto over its speed range, both with the breaker advanced and retarded. Note especially to see that good spark is secured at low speed.

To Test Magneto Armatures.—1. After removing armature from magneto, replace lead screw (breaker retaining screw) in armature, screwing in far enough to make good contact.

2. Place heavy insulator on coil clamp plate No. 7. Use a piece of dry board or a piece of bakelite or fibre.

3. Twist a piece of bare copper wire around collector ring.

4. Clamp armature on coil test plate No. 7, taking care to see that insulation is properly placed.

5. Connect a lead from one of the ignition test jacks No. 32 to the armature shaft. Connect the other ignition test jack No. 32 to some bare metal part (ground) of the stand. Plug a test lead in breaker jack No. 19, and connect it to the magneto lead screw. Connect one of the multiple spark gap leads to the wire twisted around the collector ring of the armature. Adjust the multiple spark gap points to approximately 5/16″.

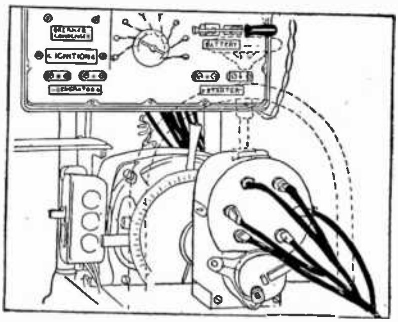


Fig. 7,079.—Magneto test connections.

6. Lower the breaker arm so that breaker points No. 24, will operate. Throw switch No. 33 down to put resistance in circuit.

7. Start motor and close battery switch No. 20. Observe the spark at various speeds.

8. If spark be weak, close condenser switch No. 4 and if spark be then good, a new condenser should be placed in the magneto armature.

9. Another common trouble is broken down collector ring. In this case, the collector ring must be replaced with a new one.

Operation and Maintenance Hints.—1. Do not use the test stand for any test unless it be connected to a good storage battery.

2. Use a 12 volt battery when testing 12 volt equipment, and vice versa.

3. Always have battery switch No. 20 closed when testing a dynamo or cut out, or the volt meter will be liable to burn out.

4. Always open battery switch No. 20 when not in use. If left open, test leads may touch and short the battery and burn out the ammeter and insulation.

5. If motor be connected with conduit or BX cable, do not touch the 110 volt test prods to the metal part of the test bench. This will blow a fuse in light line. Touching just one test prod will cause the lamp to light. This is due to the ground at the power house, and is in no way a fault of the test stand. Lay the part to be tested on a wooden bench or board before touching with test prods. If fuse be blown when test point touches frame, reverse the lamp connection in socket.

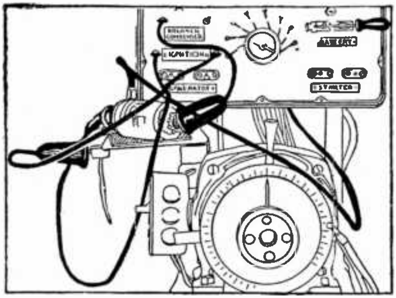


FIG. 7,080.—Testing magneto armature.

6. Study the instructions before making each test, all connections are fully explained.

7. If volt meter fail to read, see that contact points on jack No. 3, make proper contact and are not separated by particles of dirt.

8. If motor seem to lack power, see that it rotates freely and that it is connected for the proper line voltage.

9. If connected to a light line and the light dims when current is turned on the test stand motor, the line voltage is low. If connected to a power line with other heavy motors, the power line may be too small. Have the power company check the line voltage at no lead, when motor is running about 1,800 *r.p.m.* and when driving a dynamo at its maximum speed.

10. Try a good dynamo; the one on test may have tight bearings, or be defective.

TEST QUESTIONS

1. *Of what does a test stand consist?*
2. *How are dynamo troubles located?*
3. *Give directions how to motorize a dynamo.*
4. *Describe the various tests for armature troubles.*
5. *Give test for field trouble.*
6. *What are the brush holder and brush troubles?*
7. *Describe how to hook up a dynamo.*
8. *Give tests for Delco motor generators.*
9. *How is a discriminating cut out or reverse current circuit breaker tested?*
10. *Name the various cut out troubles.*
11. *Explain at length the testing and adjusting of cut outs.*
12. *How are starting motor troubles located?*
13. *Describe at length the method of testing a starting motor.*
14. *Give the various tests for armature troubles.*
15. *How are ignition coils tested?*
16. *Is it possible to get a spark without a condenser?*
17. *Name the various condenser troubles.*
18. *Describe the method of testing a condenser.*
19. *What are the troubles usually met with in circuit breakers?*
20. *How is the operation of a breaker tested?*
21. *Explain method of checking automatic spark advance.*
22. *How are two arm breakers synchronized?*
23. *Give various tests for distributers, magnetos, and mention a few maintenance hints.*

CHAPTER 170

Starting and Lighting Systems

The fact that electricity is used for the ignition system has resulted in displacing the early mechanical, pneumatic and gas starters, also gas lighting systems. The storage battery has been found adequate to meet the demands not only of starting and lighting systems but also ignition, notwithstanding the great amount of current used during starting and has accordingly largely displaced magnetos.

The essential parts of a starting system are:

1. Storage battery;
2. Dynamo;
3. Starting motor;
4. Discriminating cut out or reverse current circuit breaker.

There are three general classes of starting systems known as:

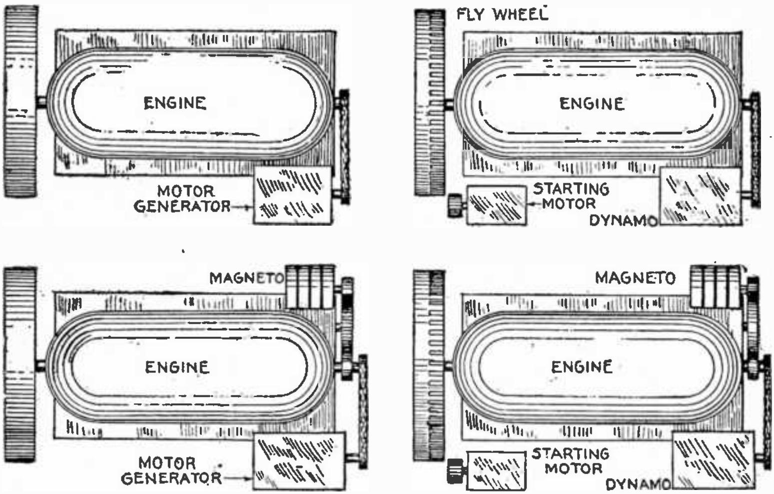
1. One unit;
2. Two unit;
3. Three unit.

One Unit Systems.—The term "one unit" as applied to an electric starting system means that *there is a motor and dynamo*

***combined** in one machine*, or motor generator, as it is called, the dynamo furnishing current for the starter, and for charging the storage battery.

Two Unit Systems.—This classification indicates that the *motor and dynamo are* ***separate units***, as distinguished from the one unit system.

There is another system, ill advisedly called two unit, consisting of a *motor dynamo, and a magneto.* The reason for this confusion is because



FIGS. 7,081 to 7,084.—Classes of starter systems. Fig. 7,081, one unit system; fig. 7,082, two unit system; fig. 7,083 so called two unit system; fig. 7,084, so called three unit system.

some dynamos are arranged to furnish current for ignition when not charging the battery, thus ignition has to be considered in the classification to distinguish the last mentioned system from the arrangement of three independent units.

Three Unit Systems.—This division comprises those systems which have a *motor, dynamo, and magneto* ***each separate.***

Here, each unit has a single function and is only electrically associated with the rest of the apparatus in the system. Thus, the dynamo supplies current for charging the battery, which in turn delivers current to the motor and ignition system at starting, and also to the lighting system, the magneto furnishing current for the ignition system, when the engine is running.

The term three unit system applies only to "starting, lighting and ignition systems," as distinguished from "starting and lighting systems."

Owing to the great increase in horse power now provided on automobiles and resultant multiplicity of cylinders, magnetos have been practically discontinued. This is due to the considerably extra cost of the magneto and the fact that the storage battery is very satisfactory for ignition service.

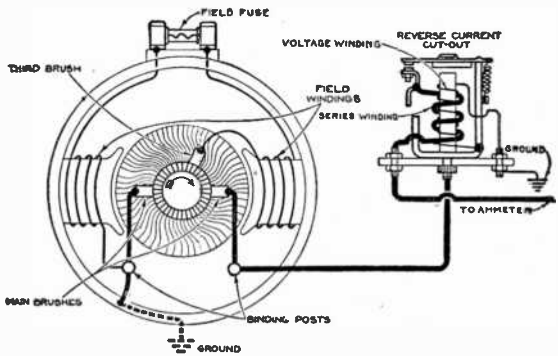


FIG. 7,085.—North East dynamo and cut out circuit. *In operation:* as soon as the contacts close, the circuit between the dynamo and battery is completed. The charging current then passes through the current (series) winding of the cut-out in the right direction to add to the magnetizing effect of the shunt winding and increases the core pull on the armature. As long as the dynamo voltage is equal to, or higher than the voltage at which the cut-out is adjusted to close, the contacts will be held together by the magnetic pull of the core. When the dynamo voltage drops below that of the battery, however, as is the case when the dynamo slows down, discharge current begins to flow back from the battery through the series winding. Since this discharge current flows in the opposite direction, it reverses the polarity of the series winding so that it works against the shunt winding. This weakens the magnetic pull on the contact armature to such an extent that the spring tension opens the contacts. In this way the circuit between the battery and the dynamo is opened and the battery is thus prevented becoming discharged when the dynamo is not running. The cut-out is automatic in its operation and, when properly adjusted, should operate indefinitely without attention.

Choice of Voltage.—The pressure used on the different lighting and ignition systems is six volts, and were it not for the problem of cranking, there probably would not be any reason to change.

The advantage of low voltage is that the circuits are easily protected from electrical leakage. Low pressure lamps are manufactured with less difficulty than those designed for higher pressure.

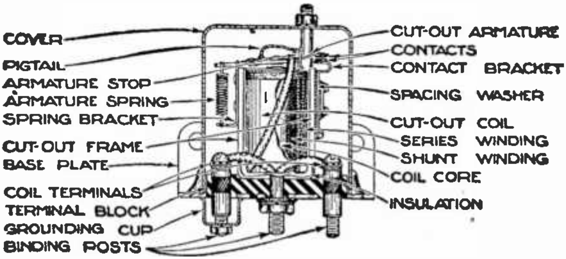


FIG. 7,086.—North East discriminating cutout. *It has* two contacts, one stationary and one movable, which are automatically closed or opened according to whether the generated voltage is above or below the voltage of the battery. The movable contact is carried by a hinged steel plate or armature, and is normally separated from the stationary contact by the spring attached to the opposite end of this armature. Directly beneath the contact armature is the magnetic core which serves to draw it down and bring the contacts together. This core is magnetized by the cut out coil which is wound on it. The cut out coil has two windings, a voltage winding with a great many turns of fine wire, and a current winding with a few turns of coarse wire. The voltage (shunt) winding is connected directly across the dynamo circuit and its strength depends upon the dynamo voltage. Whenever this winding is energized sufficiently by the dynamo voltage, it builds up enough magnetism in the core to overcome the spring pull on the armature. This draws the armature down and closes the contacts. The voltage at which this winding is able to close the contacts is determined by the degree of tension on the armature spring and by the air gaps between the armature and the core and between the contacts.

Voltage of Units.—The weight of six volt batteries is less than that of the higher voltage type. Were it not for these considerations, starting motors would be designed for high pressure, as they are smaller and consequently lighter. High voltage for the motor does not necessarily mean high voltage for the dynamo and lights.

Control.—In any electric system where there is a dynamo and a storage battery, two control elements are necessary for the proper working of the system:

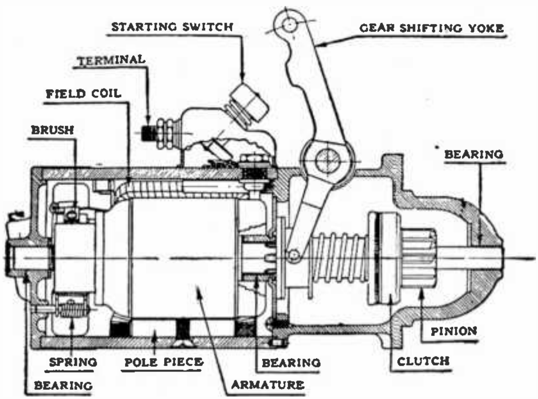


FIG. 7,087.—North East starter showing details.

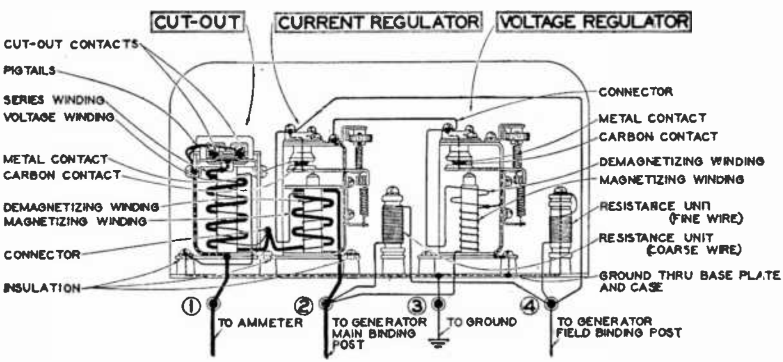


FIG. 7,088.—North East three element control unit.

1. Means for preventing reversal of current when the dynamo is charging the battery; 2. Means for limiting dynamo voltage.

When the engine is slowed down the speed of dynamo is also reduced, which causes the pressure induced in the armature to become less than the battery pressure against which it must force the current in charging, and accordingly, unless some automatic device be provided to break the circuit when such condition obtains, the current will reverse and flow out of the battery. This automatic device is called a *discriminating cut out* or *reverse current circuit breaker*, and consists of an electro-magnet connected

FIG. 7,089.—North East starting switch and cut out as used on Graham Bros. buses. Cut out 12 volt metal contacts. Shunt and series coils wound together.

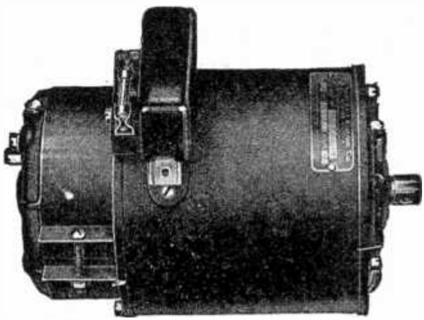


FIG. 7,090.—North East dynamo as used on Dodge Bros. vehicles.

in the dynamo circuit, which, when the dynamo generates sufficient pressure to charge the battery, will attract an armature and close the circuit between the dynamo and battery, and which will also open the circuit when the battery pressure becomes greater than that induced in the dynamo.

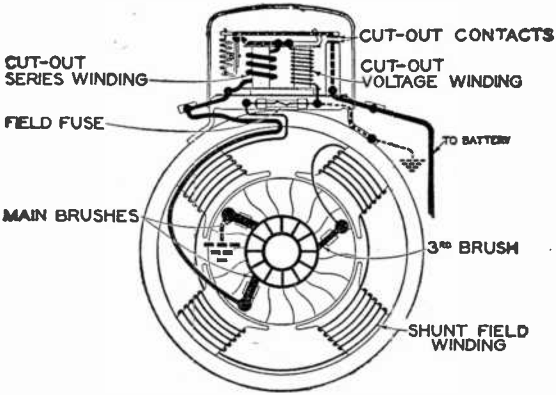


FIG. 7,091.—North East dynamo internal circuits; 6 volt, 4 pole, 3rd brush regulation, reaction type brushes, †CW, rotation. No binding posts. Grounded internally through main brush-holder. Dynamo lead connected to cut-out on field frame. Fuse 6 amps; mounted on base of cut-out. Cuts in 7.5 volts, 450 *r.p.m.* Standard output setting 15 to 16 amps (hot) at 1,200 *r.p.m.* Rated capacity 125 watts. This shows the internal circuits of fig. 7,090.

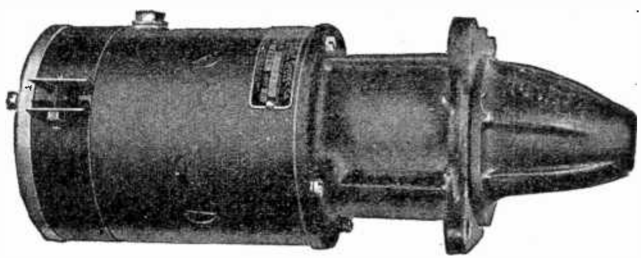


FIG. 7,092.—North East starting notor as used on Dodge Bros. cars, 6 volt, flange mounting. CW rotation, Bendix drive, right hand thread, 10 tooth pinion, 8-10 pitch, outboard bearing. 1 binding post only, located at commutator end of field frame, and milled flush with nut 21/64" above frame. Grounded internally through brush holder. Maximum torque (stalled) 13.5 pd. ft. at 550 amps. and 3.2 volts.

†NOTE.—Direction of rotation is determined from the drive end.

Again when the engine speeds up, the voltage increases and some form of regulator must be provided to prevent undue rise of voltage otherwise the battery would be charged at too high a rate.

This regulation may be effected: 1, mechanically; 2, electrically, or 3 thermally.

Dynamo Regulation Methods.—Owing to the variable speed of a charging dynamo some form of regulation is necessary to maintain:

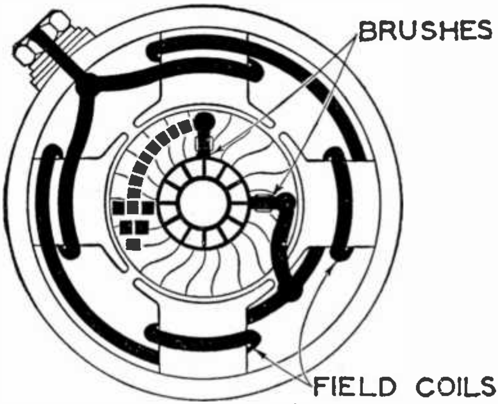


FIG. 7,093.—North East internal circuit of the starting motor shown in fig. 7,092.

1. Constant voltage;
2. Constant amperage;
3. Constant voltage and constant amperage.

To accomplish this regulation the following methods are used:

1. Electro-magnetic method;
2. Inherent method.

In the electro-magnetic method the resistance is cut into the

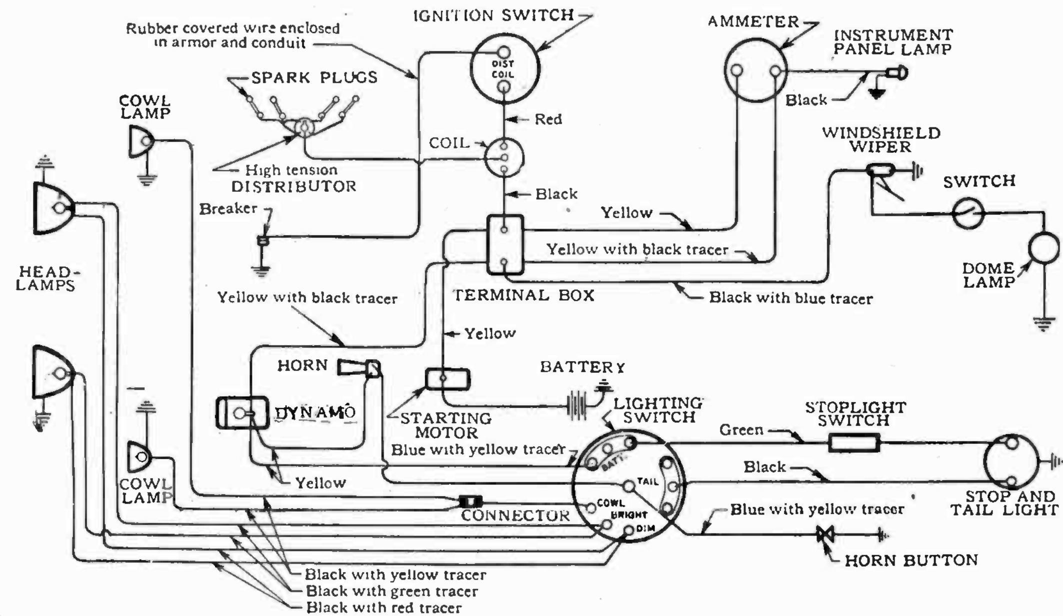


FIG. 7,094.—Ford model A wiring diagram of starting, lighting and ignition systems.

shunt field circuit automatically by an electro-magnetic device placed externally to the dynamo. This was formerly extensively used.

There are three systems operating on the electro-magnetic principles designed:

1. To regulate the current (amperage) so as to obtain constant current or amperage;

2. To regulate the voltage so as to obtain constant voltage, or pressure;

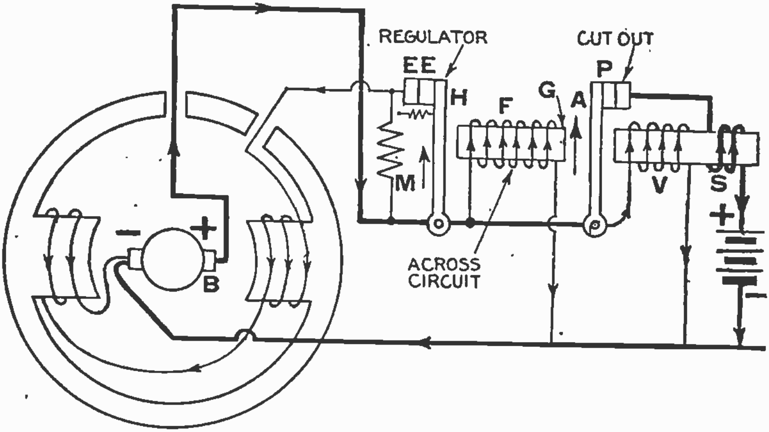


FIG. 7,095.—Electro-magnetic voltage regulation. ***In operation:*** the voltage generated by the dynamo will determine the opening of the points EE. The fine wire voltage winding F, of the regulator is so wound, that with a 6 volt battery, the dynamo voltage will reach about 7.5 to 8 volts maximum, and points EE, will remain closed; but on higher speeds and where the dynamo reaches a higher voltage than the maximum, then the core G, becomes magnetized sufficiently to draw blade H, to it, thus opening points EE, and cutting in resistance M, into the field circuit. This has the result of weakening the magnetic lines of force of the fields. When the dynamo speed is less than 8 or 10 miles per hour car speed, the dynamo voltage drops to less than 6.5 volts and the core G, loses its magnetism, and points EE, close again, thus cutting resistance M, out of the field circuit. This permits the magnetic lines of force to build up again in the fields. This action is repeated over and over as the speed of the engine and dynamo varies; and thus the blade H, vibrates back and forth.

3. To regulate both voltage and current so as to obtain constant current and voltage.

These are illustrated in figs. 7,095 to 7,097.

With the constant voltage regulation, fig. 7,095, the amount of current generated depends upon the battery voltage (if charged or discharged) and also on the load in the circuit, such as lamps.

Note that the charging circuit from the dynamo to the battery is not through the regulator winding. The voltage can be increased or decreased, where the regulator cuts in and cuts out, on many regulators of this type, by increasing the spring tension of blade H, for an increase of voltage and by decreasing for a lower voltage.

Evidently in fig. 7,096 showing electro-magnetic current regulation if the battery should be removed, or if the battery terminals be loose,.or some other open circuit should exist, there would be no current flowing through the regulator current coil F, and there would be no regulation of the dynamo. Thus, at high speeds, it could build up voltage to such an extent that it would damage the dynamo.

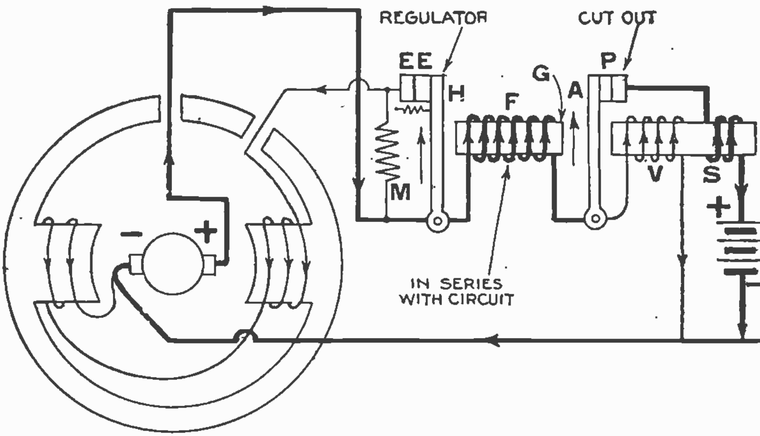


FIG. 7,096.—Electro-magnetic current regulation. ***In operation:*** when the engine speeds up, the dynamo builds up voltage. Again when the voltage of the dynamo is sufficient to cause the cut out points P, to close, which completes the battery charging circuit, the dynamo then charges the battery, and as the charging current flows through the regulator winding F, this will cause core G, to become magnetized, and when the maximum output of current from the dynamo (approximately 12 to 15 amperes) is passing through this winding, the blade H, will be drawn to core G, against the tension of the spring, thus opening points EE. This action inserts the resistance M, in series with the shunt field circuit, thus causing the voltage of the armature to drop and the charging current to decrease, because of the weakening of the shunt field strength, or magnetic lines of force. When this current decrease drops to about 10 amperes, the coil F, is wound with such a size wire and number of turns that the core G, loses its magnetizing force and the blade H, is released and closes the points EE, thus cutting the resistance M, out of the field circuit, and permitting the field strength to build up again to its maximum. The blade H, in actual practice, vibrates or opens and closes rapidly, so that the dynamo will not charge over 12 to 15 amperes. or 15 to 20 on some dynamos, at high speeds and thus the current output is constant, regardless of the voltage of the battery, whether charged or discharged.

If the battery be removed, open the field circuit by disconnecting the field wire. Usually there is a fuse in the field circuit which can be removed. To increase the charging rate, the spring tension of blade H, is increased, and to decrease the charging rate, the spring tension is decreased.

In fig. 7,097, it will be noted that if the cut out points should not close, or if the battery be disconnected, current will not flow through the current coil F2, and the dynamo will be dependent upon the voltage winding F1, for regulation. If the voltage winding should become disconnected, then the cut out points could not close; thus the charging current would not pass to the battery. If the battery be removed from the circuit, disconnect the shunt field wire at the regulator, so as to open the field circuit.

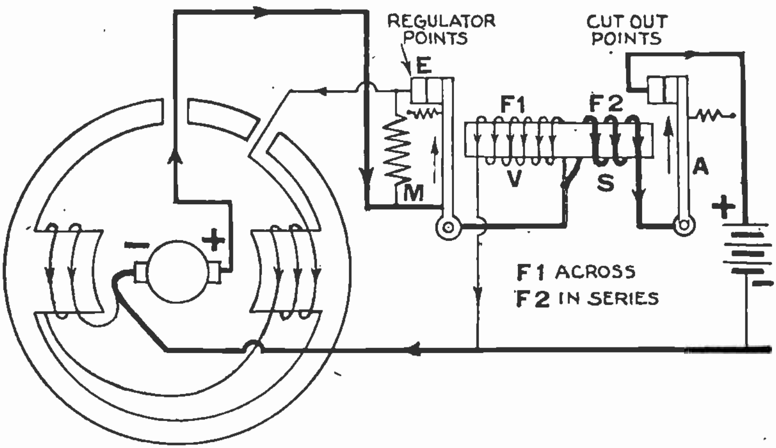


FIG. 7,097.—Electro-magnetic voltage and current regulation. *In operation:* when the voltage of the dynamo reaches about 6.5 volts, the current passing through the fine wire winding F1, is sufficiently magnetized to draw blade A, of the cut-out against the spring tension, which is so adjusted that the cut out blade A, is drawn to the core, and the cut-out points are closed. The charging current then passes through the cut-out winding F2, through the points, to the + terminal of the battery, in the usual manner. When the voltage or current reaches more than the output should be, the regulator blade, on the left, is drawn to the core against the tension of the spring which is adjusted higher than that of the cut-out blade. This action cuts resistance M, into the field circuit, as explained in figs. 7,095 and 7,096.

In the inherent method the dynamo is provided with compound (two) field windings, or a *third brush* is used. The third brush arrangement is used most.

The Delco and North East are examples of compound wound dynamos which also use a third brush regulation. The object of all the regulation methods is to decrease the current flowing through the shunt field winding at very high speeds of the dynamo, in order to reduce the strength of the magnetic field and to maintain a constant voltage, or constant current, or both.

In the third brush method of regulation, the third brush is always connected with one end of the shunt field windings, either the (+) or the (−) depending upon the direction of rotation of the armature and the side of commutator on which it is placed. In the example given above it is connected with the (+) side; thus the current leads from it into the field windings. The shunt field circuit is from the third brush (which is on the (+) side of the armature), through the field windings, to the (−) main brush.

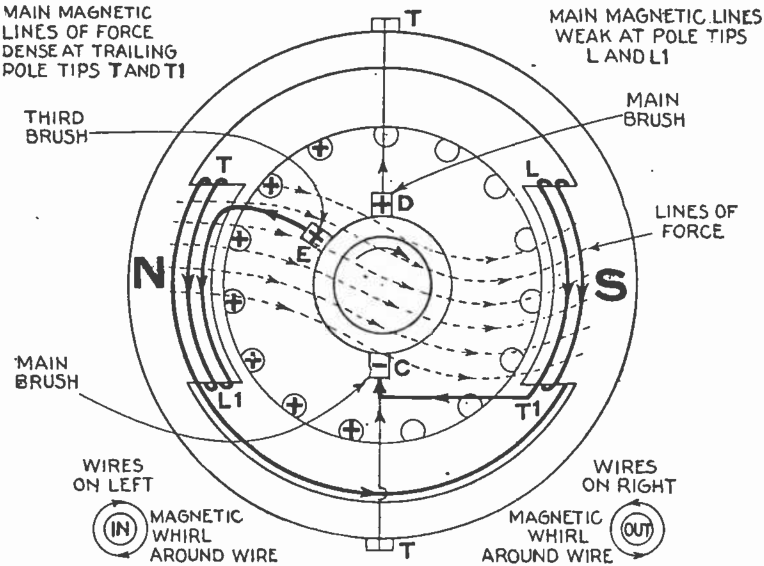


FIG. 7,098.—Third brush method of regulation. The maximum voltage and the maximum current generated are controlled by the third brush. The current which excites the field winding is drawn through this brush. By movement of the third brush, the amount of current passing through the field windings is changed, thereby changing the amount of magnetism in the field, and consequently changing the voltage and current induced in dynamo armature. The third brush is the adjustable one, adjustable brush arm can be moved in either direction, and is always connected direct to field windings only. The output of a third brush regulated dynamo can be increased by moving the third brush on the commutator in the direction of rotation of armature. To decrease move it in the opposite direction. It is important that all brushes be fully seated, especially the third brush.

The amount of current passing to the field windings is dependent upon the position of the third brush. Fig. 7,091 shows the third brush principle.

Voltage Regulation Explained.—The action of the voltage regulator in tapering down the charging rate as the battery becomes charged is easily understood if it be compared to the familiar float valve used in water tanks.

The amount of charging current that will flow through the battery at any time depends upon the difference between the reverse voltage of the battery and the voltage maintained by the dynamo, just as the flow of water into the tank will depend upon the difference between the back pressure of the water standing in the tank and the incoming pressure of the water from the pump.

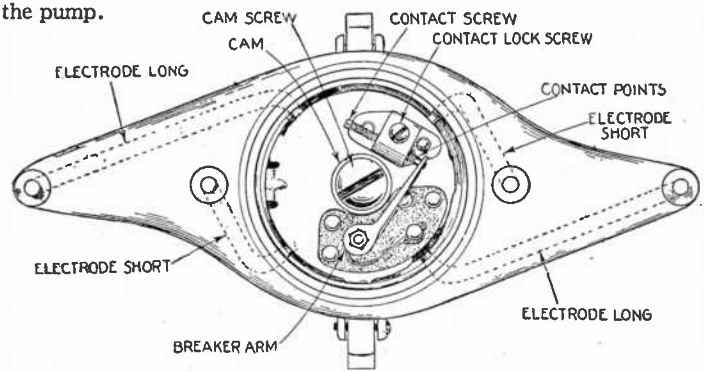


FIG. 7,099.—Top view of Ford model A distributor. The gap between the breaker points is set at .018 to .022″. The gap should occasionally be checked to see that the points are clean and properly adjusted. If the points be burnt or pitted they should be dressed down with an oil stone. *Do not use a file.* To adjust the points proceed as follows: 1, lift off distributor cap, rotor and body; 2, turn engine over slowly with starting crank until breaker arm rests on one of the lobes of the cam with the breaker points fully opened; 3, loosen lock screw and turn the contact screw until the gap is between .018 and .022″. A standard thickness gauge is used to obtain this measurement. When correct adjustment is obtained, tighten the lock screw. After tightening the lock screw, again check the gap to make sure the adjustment was not altered when the lock screw was tightened; 4, replace distributor body, rotor and cap.

In the electrical system the actual filling or charging voltage is always the difference between the dynamo or pumping voltage that the dynamo is allowed to maintain and the reverse voltage or back pressure of the battery just as the filling pressure in the water system is the difference between the pumping pressure and the back pressure of the tank; and the amount of charging current forced into the battery depends upon how great is the differential or charging voltage.

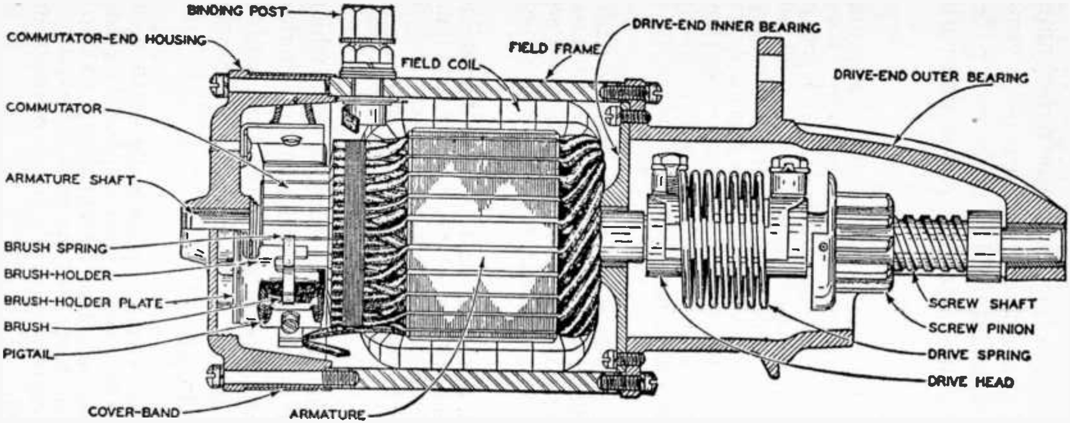


FIG. 7,100.—North East starting motor for Dodge cars showing Bendix drive.

In a 12 volt system the battery will develop a back pressure or reverse voltage of approximately 12 volts when it is only slightly charged, 13 volts as it becomes moderately charged and 14 volts when it is well charged. Assuming that the dynamo voltage to be limited by the voltage regulator to a maximum of 14.25 volts, the possible charging voltage will, in the first instance, be $14.25 - 12 = 2.25$ volts.

Further assuming that each unit of charging voltage is capable of sending 10 amperes into the battery, the charging rate is $2.25 \times 10 = 22.5$ amperes, providing of course there are no other regulating factors to limit the current.

As the battery comes up and its reverse voltage rises to 13, the charging voltage will then be reduced from the original 2.25 volts down to 1.25 volts and the charging rate will be cut down to 12.5 amperes.

Finally when full charge is reached and the reverse voltage comes up to its high value of 14, the charging voltage will be but .25 volt and the charging rate will come down to only 2.5 amperes.

Like the water system too, the voltage regulator never quite completely checks the flow of charging current, because a very low finish rate always has to be maintained to make up for the slight drains and losses that are unavoidable in connection with the battery.

Thus, where the voltage regulator is used, it begins to cut down the output of the dynamo as soon as the reverse voltage of the battery comes up toward the voltage control point and continues to taper it down until it is finally reduced at full charge to the minimum finish rate which will just keep the battery in proper condition. This variation in the charging rate should always be borne in mind when noting the ammeter readings during charge, and it should be remembered that the actual rate registered at any one time in all probability lies somewhere between the maximum initial rate and the minimum finish rate, depending upon how fully the battery is charged.

Whenever the engine is first started up, however, it should be noted that a relatively high rate will practically always be delivered at the outset because the slight decrease in reverse voltage that occurs when the battery is not on charge is enough to reduce the charging voltage below the control point of the regulator.

If the battery be well charged, this high initial rate will drop rapidly to the low finish rate after a few minutes' running. On the other hand if the battery should happen to be low, the high charging rate will continue until the battery is charged sufficiently to bring the regulator into action.

In addition to thus providing an ideal charging rate which safeguards the battery both against overcharge and undercharge, the voltage regulator also affords protection against possible over-voltage which might result from loose or open connections in the charging circuit.

Should faults ever develop in the wiring or in the battery which would tend to make the dynamo voltage rise above its normal range, the regulator will immediately come into action and control the voltage so as to keep it within safe limits. This protects the lamps and other parts of the system so that it is possible to operate the car temporarily in such an emergency until the wiring faults can be corrected.

Why Voltage Regulation Is Needed.—The output of a dynamo that is controlled by third brush regulation only, is maintained practically unchanged under all conditions, regardless of the state of charge of the battery. In fact the only effect the battery has upon the action of such a dynamo is to cause a slight increase in its output as the charge progresses.

As a result of this, the charging rate is not cut down as it should be upon completion of the charge to guard against overcharging, but continues at its maximum as long as the battery remains in a fully charged condition.

Fortunately this contrary tendency of the output is offset in part by the drooping characteristic which is more or less inherent in third brush regulation. Because of this characteristic the output always droops or decreases whenever the operating speed rises above the average traffic driving range.

Since continuous driving usually involves considerable high speed operation, the action of this drooping characteristic is ordinarily enough to provide reasonable protection against serious overcharging in passenger car and truck service where the fluctuations in the demand for current are not excessive and the mileage is moderate.

Where the variations in current requirements are more extreme and the daily mileage is high, as is the case in taxicab and motor bus service, it is almost impossible to maintain a satisfactory balance between charging rate and demand for current unless additional regulating features are introduced. In such service there is so much difference between the requirements at night when the lights are all in use, and in the daytime when almost no current is being consumed that a charging rate which is right for one time would be entirely incorrect for the other.

Furthermore, the continuous operation which is customary in this service magnifies any differences between charging rate and current consumption to such an extent that, if the charging rate be not exactly in accord with the requirements of the system at any one time, serious overcharging or undercharging is liable to result before anything can be done to counteract it. In this type of service, therefore, it is practically necessary to provide a form of output control which will not only protect the battery from overcharge but will at all times automatically accommodate the charging rate to the actual requirements of the battery according to the extent to which it is charged. This can be done to the best advantage by using voltage regulation.

Voltage regulation, however, only controls the output when the battery is well charged. For this reason some form of current regulation is also needed to keep the output within proper limits whenever the battery is too low to call the voltage regulator into action. This supplementary current control is usually supplied in the form of third brush regulation within the dynamo, but where the demands for current are very heavy a straight shunt wound dynamo is used and external current control is used in combination with the voltage regulator in the control unit.

With either of the forms of supplementary control just described the action of the voltage regulator is the same.

It limits the dynamo voltage so as to prevent it ever rising materially above the full charge voltage of the battery and thus tapers down the charging rate as the battery counter voltage rises on charge toward this point. As the battery becomes fully charged and its reverse voltage reaches

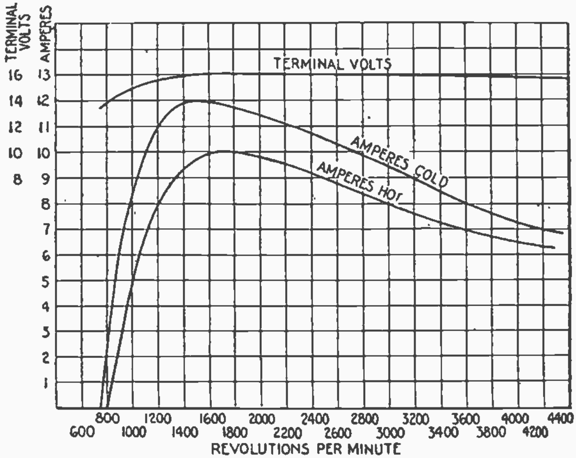


FIG. 7,101.—Typical charging curve with 3rd brush regulation.

the point at which the dynamo voltage is limited, the dynamo output is cut down to practically nothing. As a matter of fact, however, a minimum finish rate of only two or three amperes is still allowed to flow in order to keep the battery in a fully charged condition. This finish rate is so low that it can be continued indefinitely without danger of overcharging or even of boiling away the electrolyte through gassing.

On the other hand whenever the battery is drawn down below the point at which the dynamo voltage is limited, the voltage regulator ceases to act and the dynamo output tends to rise to the full value for which it is set.

During the time when the battery is low and the voltage regulator is not in action, the output characteristics of the dynamo are the same as if no regulator were used.

Where the dynamo is of the third brush type, the maximum value of the charging rate tends to increase gradually in the usual manner as the battery becomes charged, up to the point where the regulator comes into play and begins to reduce it. The output is also subject to the third brush droop at speeds above the average operating range.

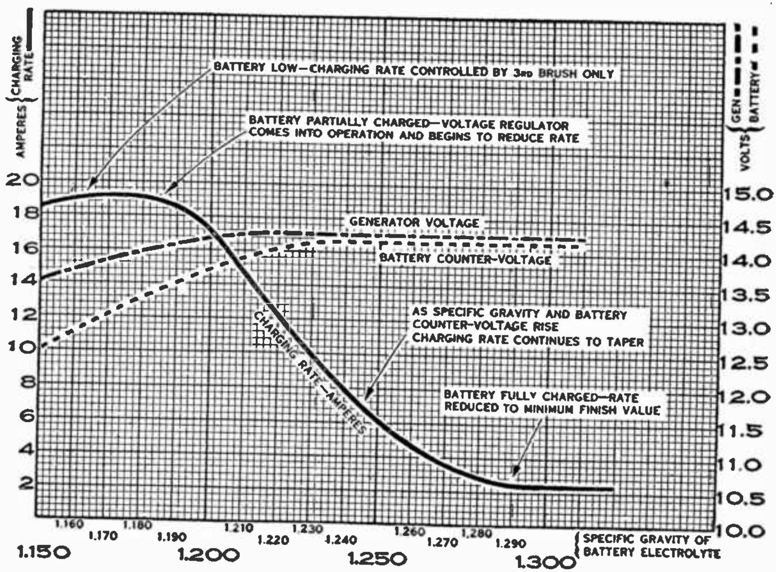


FIG. 7,102.—North East battery charging curves. When voltage regulation is used, the dynamo output gradually reduces as the battery becomes charged.

In the case of the straight shunt wound dynamo which has no internal regulation, the control of the output is taken over by the current regulator as soon as the voltage drops below the voltage regulator operating point. With this type of control the output remains constant at its full value through the normal operating range and is neither affected by the condition of the battery, up to the time when the voltage regulator begins to control, nor is it subject to any droop at speeds above average running as is the case with third brush regulation.

Because of this difference in the current control characteristics of these two classes of dynamos, extreme care should be exercised to see that the right type of control unit is always used.

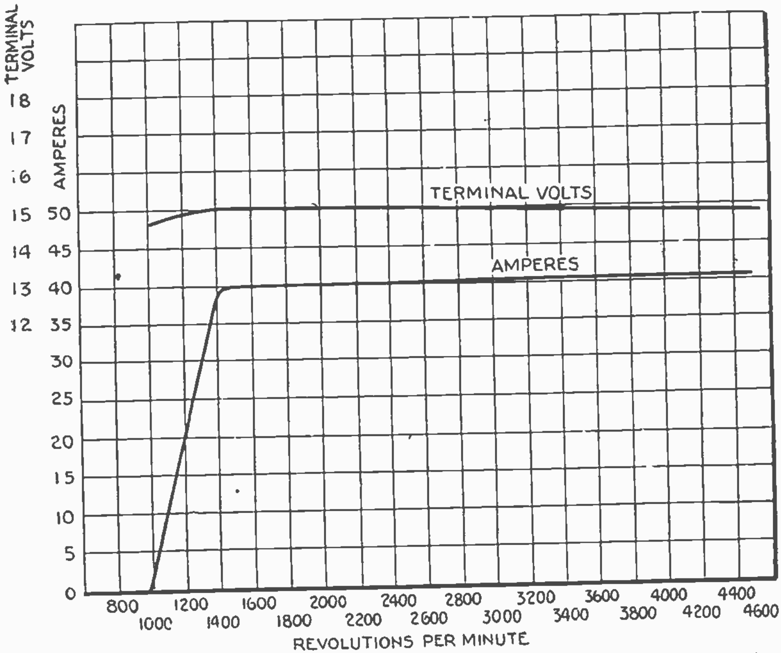


FIG. 7,103.—Charging curve of shunt wound dynamo with external current voltage regulation.

With the straight shunt wound dynamo (two brush type) the current voltage control unit must always be used.

With the third brush controlled dynamo, the plain voltage control unit should regularly be used, although it is permissible to use a current voltage unit temporarily in an emergency.

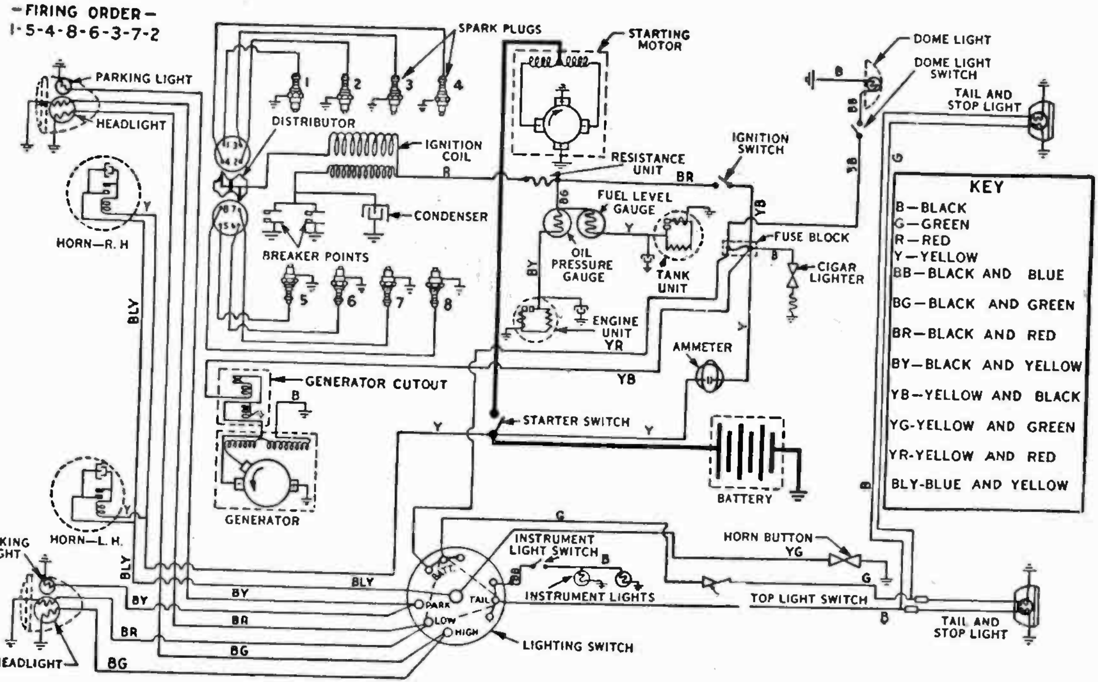


PLATE.—Wiring Diagram of electrical system as applied to *Ford (V-8)*. ***Generator:*** Current regulated by field brush

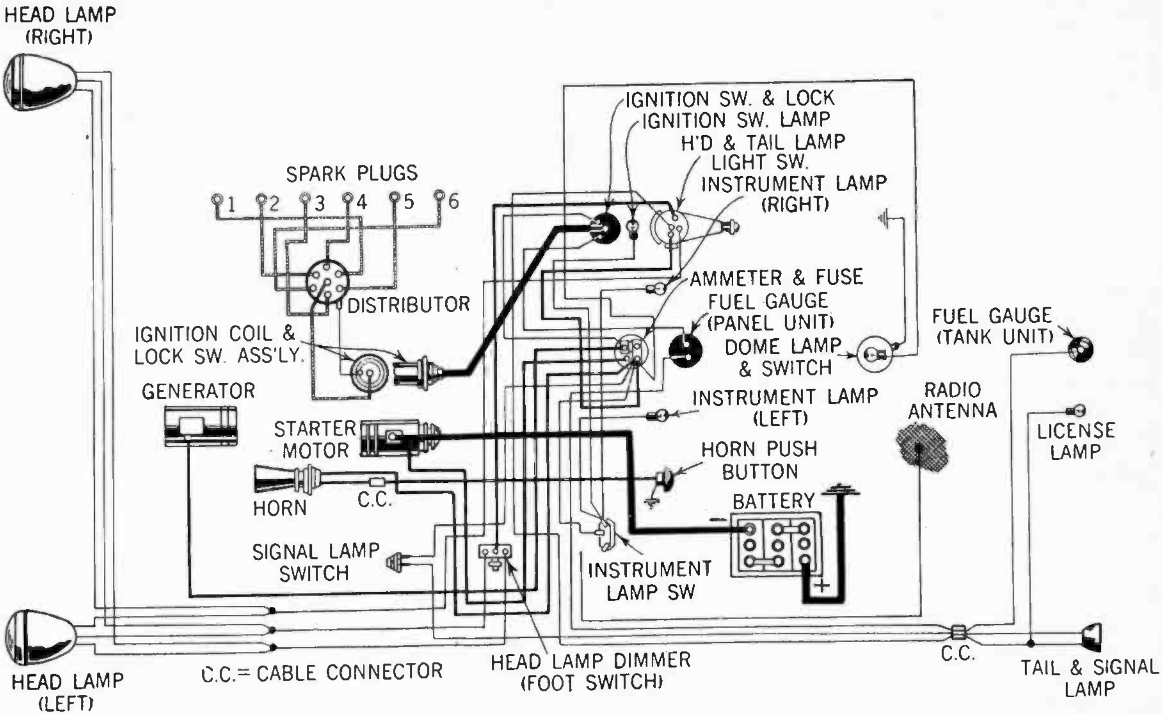


PLATE.—Wiring Diagram of electrical system as applied to *Plymouth* 6 cyl. 1936. ***Generator:*** Current regulated by movement of the third brush.

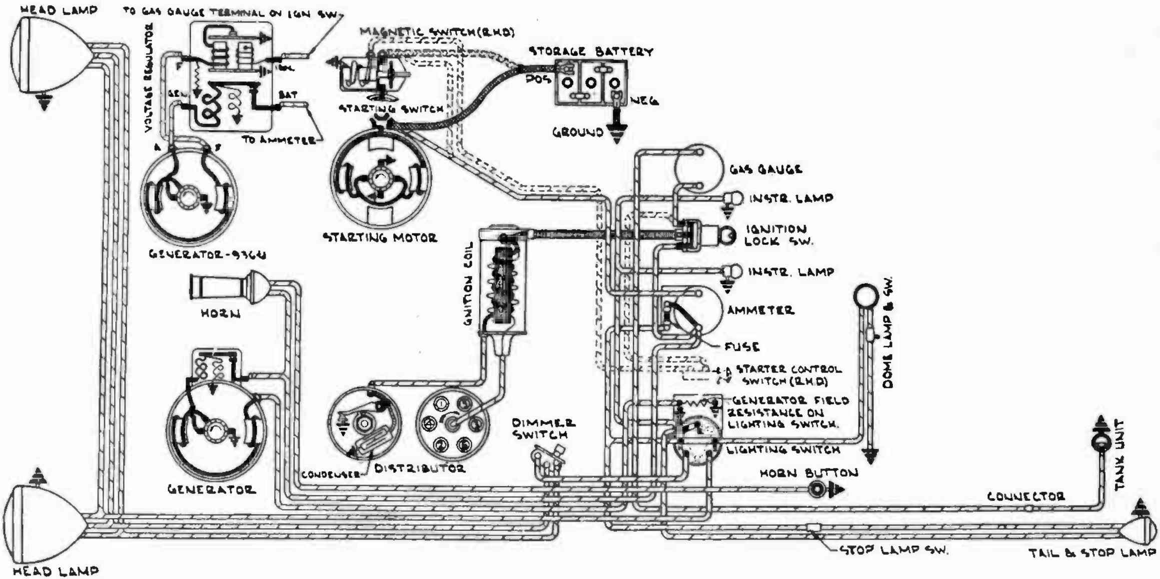


PLATE.—Wiring Diagram of electrical system as applied to *Chevrolet* 6 cyl. 1936 (Delco-Remy). ***Generator:*** Current regulated by third brush. Output controlled by field resistance on lighting switch. Rotation clockwise, viewing drive end. ***Starting Motor:*** Rotation clockwise, viewing pinion. ***Distributor:*** Rotation counter-clockwise, viewing drive end.

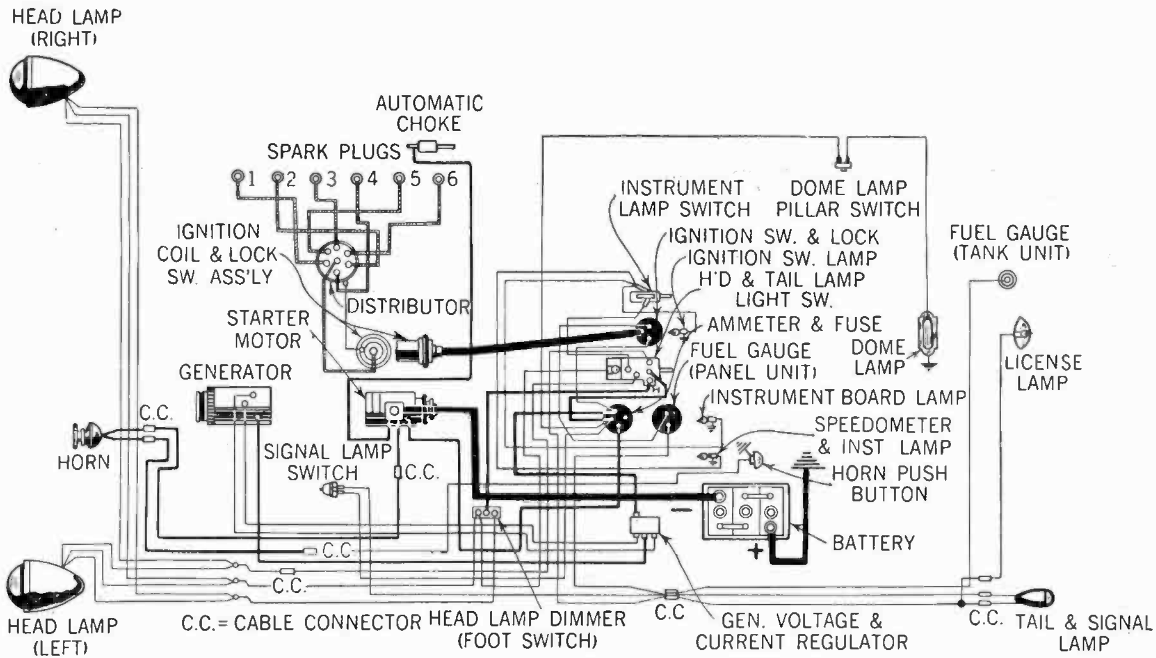


PLATE.—Wiring Diagram of electrical system as applied to *Dodge* 6 cyl. 1936. ***Generator:*** Shunt type, two brushes. Current regulated by external regulator unit. External voltage control.

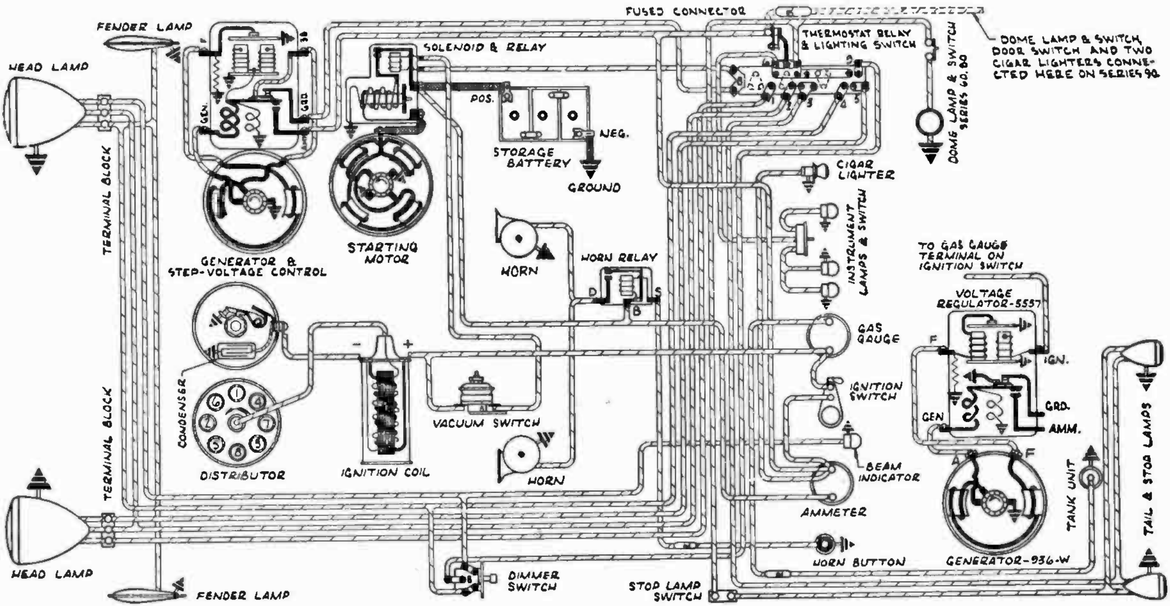


PLATE.—Wiring Diagram of electrical system as applied to *Buick* 8 cyl. 1936 (Delco-Remy). ***Generator:*** Current regulated by third brush. External voltage control. Rotation clockwise, viewing drive end. ***Starting Motor:*** Rotation clockwise, viewing pinion. ***Distributor:*** Rotation clockwise, viewing drive end.

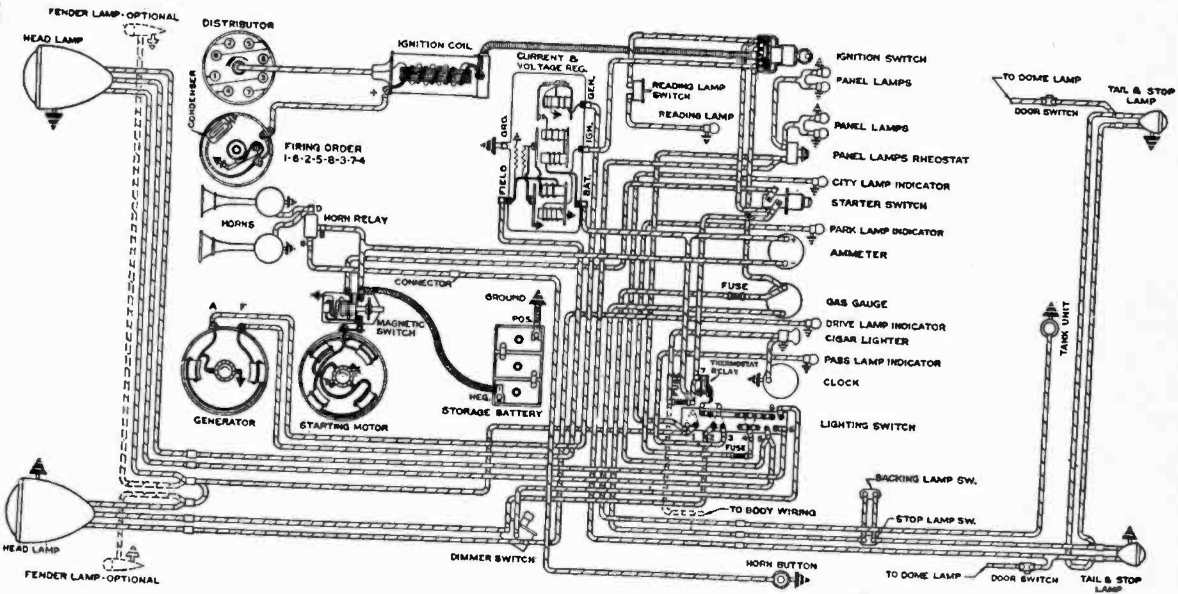


PLATE.—Wiring Diagram of electrical system as applied to *Packard* 8 cyl. 1937 (Delco-Remy). ***Generator:*** Shunt type. External current and voltage regulation. Rotation clockwise, viewing drive end. ***Distributor:*** Rotation counter-clockwise, viewing drive end.

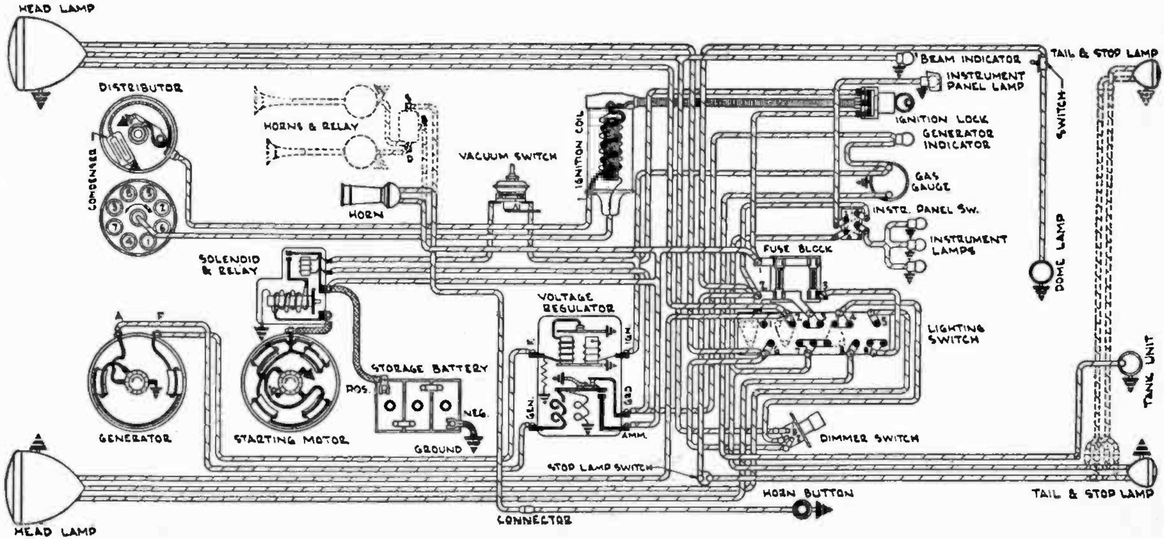


PLATE.—Wiring Diagram of electrical system as applied to *Pontiac* 8 cyl. 1936 (Delco-Remy). ***Generator:*** Current regulated by fixed third brush. External voltage control. Rotation clockwise, viewing drive end. ***Starting Motor:*** Rotation clockwise, viewing pinion. ***Distributor:*** Rotation clockwise, viewing drive end.

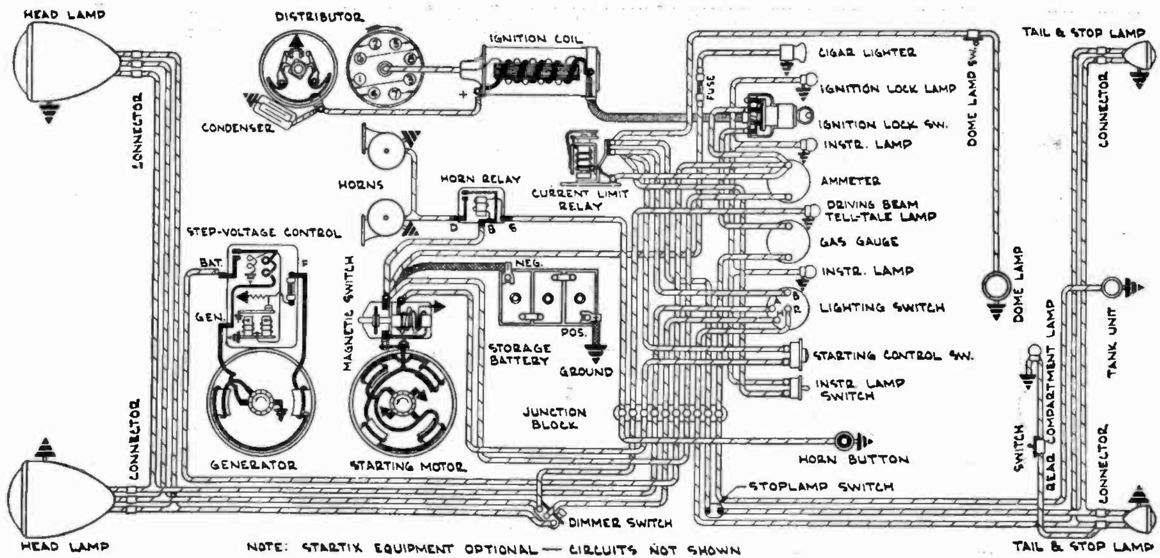


PLATE.—Wiring Diagram of electrical system as applied to *Studebaker* 8 cyl. 1936 (Delco-Remy). ***Generator:*** Current regulated by third brush. External voltage control. Rotation clockwise, viewing drive end. ***Starting Motor:*** Rotation clockwise, viewing pinion. ***Distributor:*** Rotation counter-clockwise, viewing drive end.

CHAPTER 171

Air Planes

An aeroplane may be defined as a *heavier than air flying machine;* it consists essentially of:

1. A body or frame (ill advisedly called fuselage or nacelle*) which carries:

2. The power plant, passengers, etc., and to which is attached:

3. The landing gear, or under carriage;

4. The wings (planes) and

5. Control devices.

The accompanying illustrations show the general construction of an air plane.

The Control.—An aeroplane in flight is subject to three motions, the same as a vessel in a rough sea.

1. Up and down motion;

In pointing upward or downward as in climbing or descending, similar to the angles of inclination taken by a vessel in riding a wave.

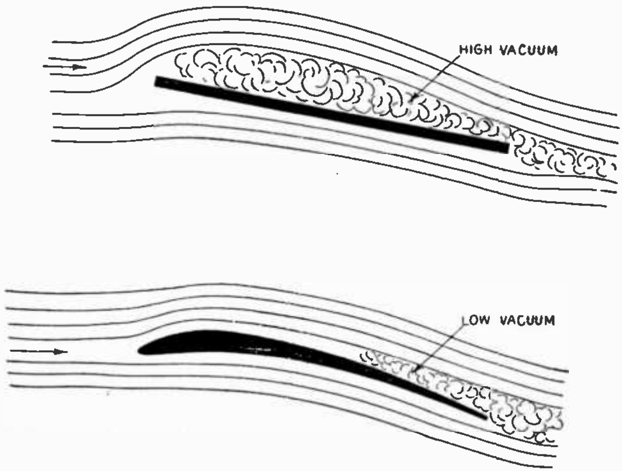
*NOTE.—The practice of introducing foreign terms in place of plain English cannot be too strongly condemned. There is no sane reason for such practice, in fact it reflects an egotistical desire to display a knowledge(?) of some other language.

2. Lateral motion;

Due to changing air conditions one wing may tip upward and the other downward tending to upset or turn over the machine, just as a vessel rolls from one side to the other in a rough sea.

3. Directional motion;

The machine may change its course either to right or left, as a vessel responds to the rudder.



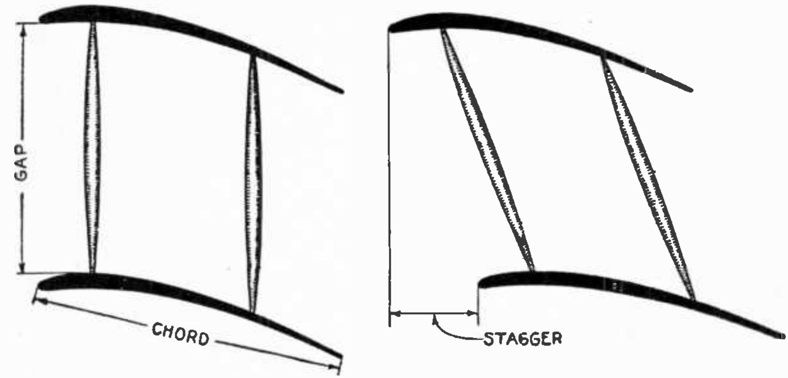
FIGS. 7,105 and 7,106 —Flat and curved wing surfaces and their effect on the air.

Because of these possible motions and in order that the operator may control the motion of the machine by causing it to assume any desired position it is necessary that there be provided controlling devices for each motion. These are respectively:

1. The up and down control;
2. The lateral or rolling control;

3. The right and left control.

These three controls are the *movable* controls as *distinguished* from the *fixed* controls or *stabilizers*.



FIGS. 7,107 and 7,108.—Method of connecting wings by struts and diagonal bracing, illustrating the terms *chord, gap and stagger*.

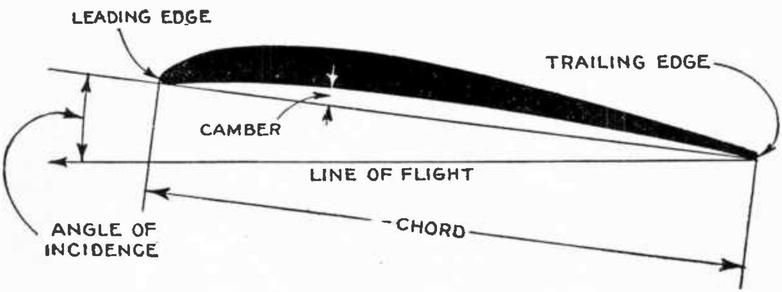


FIG. 7,109.—Wing main rib illustrating the terms *camber, chord, angle of incidence*.

The Up and Down Control.—At the upper end of the tail post where the upper longerons are attached is a transverse piece placed at right angles to the tail post, and to which the up and down control flaps or elevators are hinged as shown in fig. 7,110, one on each side of the post.

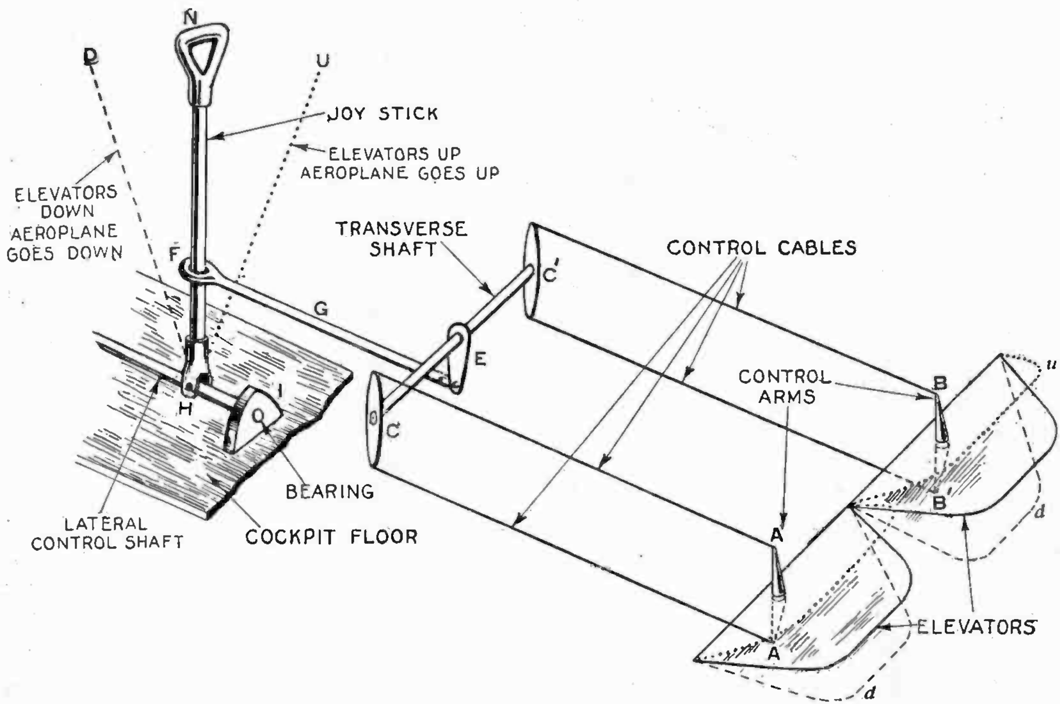


FIG. 7,110.—The up and down control, consisting of tail flaps or "elevators," hinged across the tail post and connected by suitable gears to the joy stick so that as the latter is moved in a fore or aft direction the elevators are respectively inclined downward or upward, causing the machine to change its angle of flight and respectively point downward (to descend) or upward (to climb).

Each elevator has two control arms AA′ and BB′, connected by cables to the arms C and C′, the latter being attached to a transverse shaft. Keyed to the center of this shaft is an arm E, which is connected to the joy stick at F, by the rod G.

The joy stick is pivoted at H, to the lateral control shaft, which is free to turn in the bearing I, giving virtually a universal joint at H.

In flight when the joy stick is in the vertical or neutral position N, the elevators are in a plane perpendicular to the tail post and do not tend to change the normal flying angle of the machine.

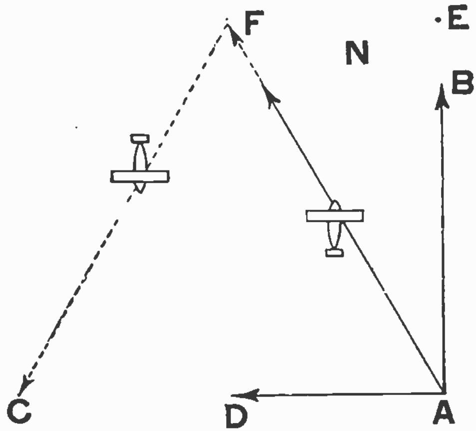


FIG. 7,111.—Effect of drift. Point A, represents the point of departure. E, is the point to be reached, and AD, is a side wind whose velocity compares with the velocity of the aeroplane as AD, is to AB. It will be seen from this that although the pilot's compass is indicating north, his true course is considerably west of north, along the line AF, and he will miss his objective, E, by many miles. If, upon failing to find his objective, the pilot turn about to return to his base, it is natural for him to steer south or in the direction from which he came. This would carry him along a line parallel with CF. In cases where it is important to arrive at or return to a given place, it is not difficult to appreciate the value of an instrument for determining deviation to offset drift.

Moving the joy stick fore or aft moves the elevators respectively up or down. Thus when the stick is moved forward to position D, the elevators are inclined downward to position *d*, giving an upward pressure on the elevators, steering the machine *down*. Again moving the stick aft to position U, deflects the elevators upward to position *u*, giving a downward pressure on the elevators and causing the machine to point upward.

Evidently if some means were not provided to resist somewhat the effect of the elevator control the machine would be so sensitive to the movement of the elevators as to become unstable or tricky, hence a fixed tail surface called the horizontal stabilizer is provided as shown in fig. 7,112. The effect of this fixed surface is to hold the machine in its normal flying angle, thus giving inherent stability so that when the elevators are moved this inherent stability must be overcome before the machine will alter its angle of flight. The machine is accordingly rendered less sensitive, that is, the stabilizer tends to damp out oscillations or "hunting" of the machine in responding to the movement of the joy stick.

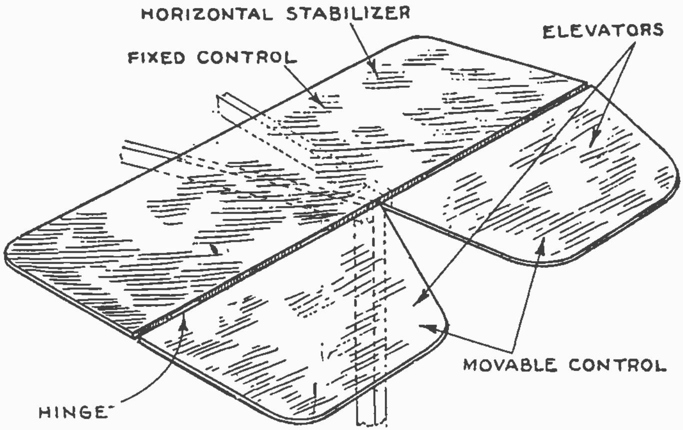


FIG. 7,112.—Horizontal stabilizer or fixed horizontal control surface to prevent sensitive response to the elevators. If the stabilizer be too large the machine becomes stiff and unduly resists the elevator control; if too small, it becomes tricky. *In practice,* it has been found that a stabilizer having an area of 6 to 8% of the wing area and placed from 2 to 2½ chord lengths back of the wing gives the best results.

The Lateral Control.—If in flight any disturbing condition should cause the machine to lose its equilibrium in a transverse direction, that is, unequal wind pressures may cause one wing to rise and the other to drop, the machine would roll over or upset, unless means were provided to overcome such tendency. Accordingly, each wing is provided with a hinged flap near its elevator as shown in fig. 7,113, being so connected to the joy stick by cables and pulleys that when the stick is moved to the right or left the flaps will be inclined *upward* on the side toward which the stick is moved and *downward* on the other side. The gearing between the joy stick and flaps is clearly shown in the figure so that its working is easily understood.

Now, if in flight, the left wings rise and the right wings drop, this may be overcome by pushing the joy stick toward the high side (that is, to the position marked L in the figure). This elevates the left flaps causing pressure on that side from above, and depresses the right flaps causing pressure there from below. The left side then is pushed down and the right side up, bringing the machine back in a horizontal position.

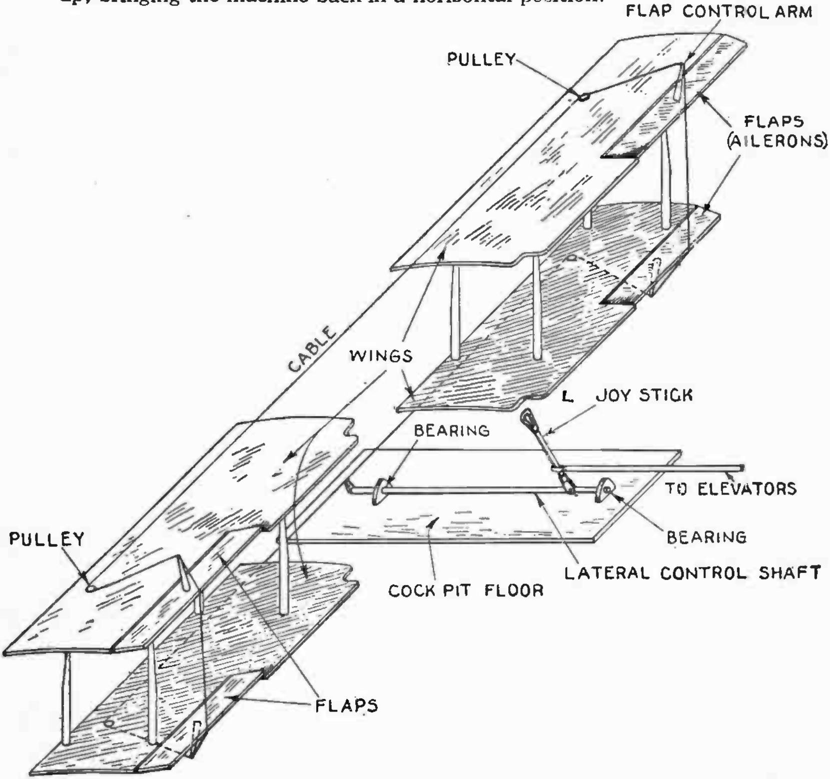


FIG. 7,113.—The lateral control. It consists of movable flaps, hinged to the trailing side of the wings at the ends as shown, and connected to the joy stick by suitable cable and pulley gearing. The gear is so arranged that the flaps on one side move in an opposite direction to those on the other side. On some machines only the top wing is provided with flaps.

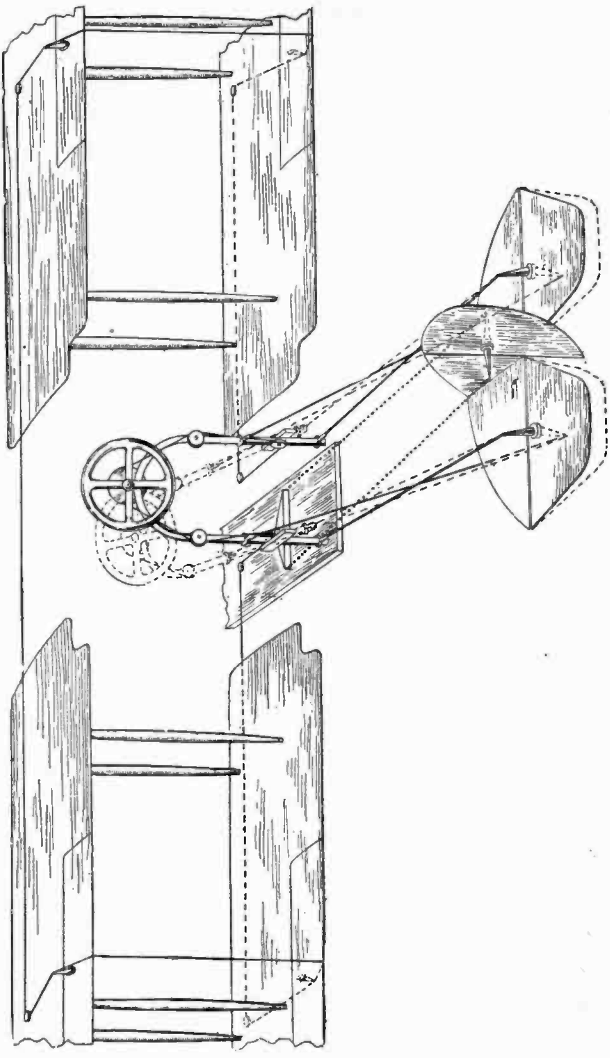


FIG. 7,114.—Wheel or "Dep" (Deperdussin) control. It works like the steering wheel of an automobile to control the ailerons or flaps, and is tilted fore or aft to operate the elevators. This type of control is adapted to slow acting and especially large machines where a geared down leverage for the wing flaps is necessary. On some machines the wheel is attached to a central post instead of the arch.

When the horizontal position is reached the joy stick is brought back to the vertical or neutral position. With the connection as shown the joy stick is naturally moved toward the side to be lowered.

Lateral Stability.—This may be defined as *the sideways balance of the machine*. There are several conditions which tend to turn a machine over sideways, or cause it to "skid." These are:

1. Excess wind pressure on one side;
2. Sudden gust of wind not in the direction of the line of travel;
3. Centrifugal force;
4. Propeller torque.

The means employed to overcome these disturbing conditions are:

1. Inclined wings;
2. Variable angle of incidence;
3. Center of gravity;
4. Side surface (so called keel surface);
5. Vertical stabilizers.

Inclined Wings.—To secure lateral stability, the wings are inclined upward from the frame to their tips as shown in fig. 7,115, the angle between the two wings being known as the dihedral and not the angle which the

NOTE.—*Warp control.*—In this method of lateral control, wires pass from the control stick or wheel through fan heads, low down on the body, to the rear outer strut of the warping section of the wing. There are various ways of attaching these warping wires. One method is to pass the wires through fan leads fitted at the bottom of the rear outer struts to different points along the warping section of the top plane. Only the top plane is warped, and may be warped along the entire length of the plane or only the outer section. Warp controlled machines are fitted with a compensating wire which is usually placed along the top of the upper plane leading from one warp section to the warp section on the opposite plane. By this means when one warp section is pulled down by the control device, the opposite warp section is pulled up by the compensating wire.

wings make with the horizontal as conveniently and erroneously stated by some writers.

The effect of inclining the wings in giving lateral stability is shown in figs. 7,118 to 7,123.

Now when the wings are inclined, the effective lifting surface is equal to the projected area, and as shown in fig. 7,118, when the machine is not inclined to either side, the projected area of each wing is the same, hence the lifting force on each wing is the same.

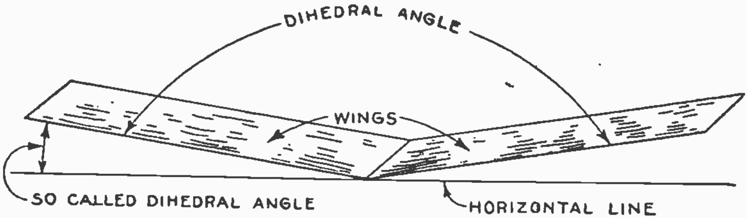
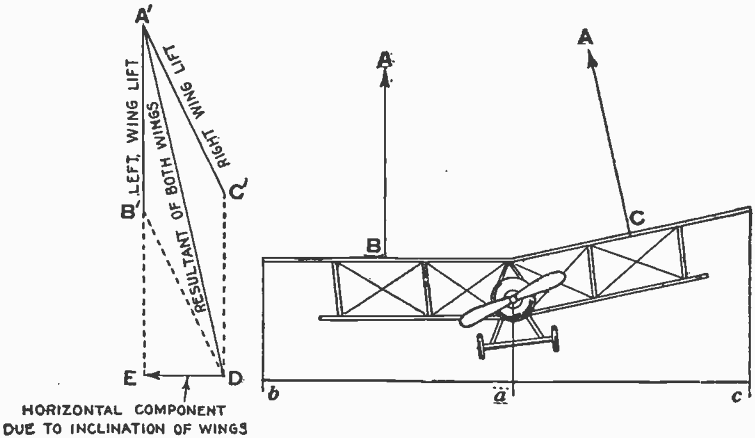
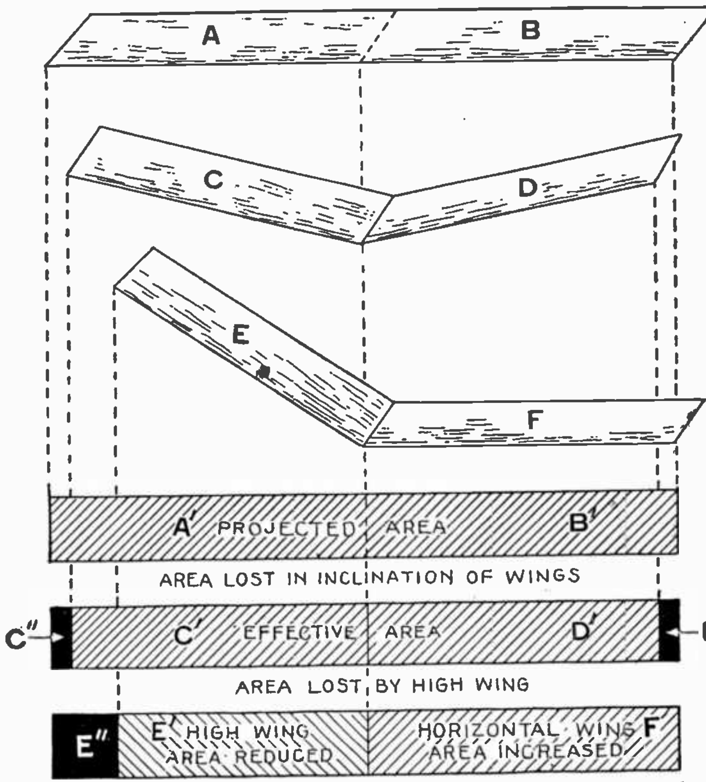


FIG. 7,115.—Inclination of the wings to the horizontal to secure lateral stability. The dihedral and so called dihedral.



FIGS. 7,116 and 7,117.—Inclination of wings causes a side thrust. Let AB, and AC (=*ab* and *ac*) equal lift of the two wings, then taking A'B' and A'C' equal and parallel respectively to AB and AC, completing the parallelogram, and draw A'D, the resultant. Since this upward pull A'D, is inclined to the vertical, there will be a side thrust equal to the horizontal component DE, acting in the direction DE, to push the aeroplane sideways.



FIGS. 7,118 to 7,123.—Inclination of wings, lifting and stabilizing effects. Since the lifting power of wings depends on their *projected* area instead of their *actual* area, it follows that when the two wings A and B, are in the same plane, their projected area A',B', will equal their actual area A,B, and the full lifting power will be obtained. Now in the case of inclined wings C,D, the projected areas C',D', are less than their actual areas C,D, and their lifting power is reduced. Here, C'',D'', represent the projected areas lost by the inclination, which also represent the loss in lifting power. ***Stabilizing effect:*** If in flight a sudden gust of wind cause the machine to tip to one side, so that the wings assume the positions E,F, then the projected area E', is less than F', the projected area of F, hence the lifting power of F, is greater than that of E, which tends to bring the machine back to its horizontal position. The solid black area E'', is the projected area lost by wing E, when rotated from the horizontal position A, to the inclined position E, area F, being equal to D'+D''.

Now, if the air pressure become greater on one side than the other, as by a sudden gust, it will raise that side as shown in fig. 7,119. When the machine becomes inclined sidewise as here shown the projected area of the low wing is increased, and that of the high wing decreased, consequently the lifting force on the high side is reduced and that on the low side increased.

These unequal forces will clearly cause the low wing to rise and the high wing to descend, thus bringing the machine back to a horizontal position. The wings are inclined (to the horizontal) only a few degrees, otherwise their lifting power would be unduly reduced.

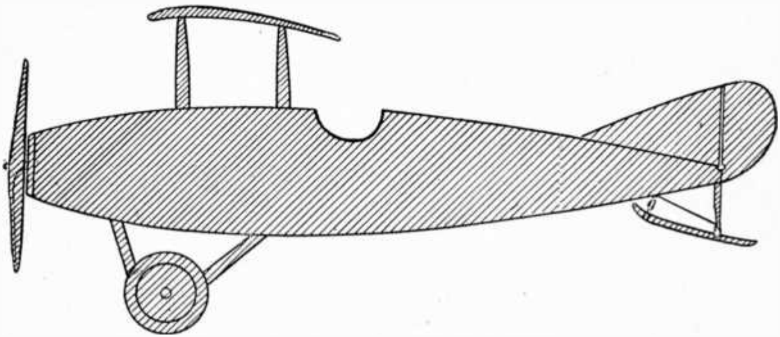


FIG. 7,124.—The side surface of an aeroplane, being *the projected area of everything visible as viewed from the side*, it is the *effective surface upon which the wind may act from the side*. The term *keel surface* is frequently and ill advisedly used for side surface.

Center of Gravity.—The position of the center of gravity has a marked effect on the lateral stability of the machine.

In order to produce a lateral righting effect the center of gravity should be low, just as the ballast in a sail boat is placed low to counteract the side thrust of the sails. However, if the center of gravity be too low, the side oscillations or swings are liable to be increased in amplitude; if too high, the tendency would be to upset the machine.

Side Surface.—It is difficult to understand how the idiotic expression *keel surface* ever came into use to mean the *side surface* of an aeroplane.

Comparing an aeroplane to a boat, any one knows that the keel and side surface of the boat are two entirely distinct things, the surface of the keel being extremely small as compared to the surface of the side.

The term *side surface* means everything to be seen when viewing an aeroplane from the side, that is, by definition *the projected area of everything visible from the side of an aeroplane*.

By properly proportioning and arranging the side surface, the machine is rendered stable against rolling and skidding.

If the side surface be low, the side force, as of a side gust of wind blowing against it, will rotate the aeroplane sideways so that the windward wing will sink; if high, the windward wing will rise, but if on the same level with the center of gravity, there will be no tendency to rotate the machine, and will simply oppose the skidding.

Vertical Stabilizers.—These are the small fins placed above the center of gravity 1, on the tail, and 2, sometimes on top of the upper wings. If, due to a sudden side gust, the machine should move sideways to any extent,

Fig. 7,125.—Forward vertical stabilizer or fin. These are used principally in hydroplanes to balance the abnormally large side surface of the body.

the high fins resist this movement and also, because they are higher than the center of gravity, tend to *bank up*, the machine, that is, revolve it on its longitudinal axis so that the windward wing sinks, thus giving lateral stability.

Evidently, if the vertical stabilizers were placed below the center of gravity the opposite rotary effect would be produced which would tend to upset the machine.

The rear fin placed as an advance continuation of the rudder, evidently prevents over sensitiveness to the movement of the rudder thus avoiding hunting or directional oscillations of the machine in responding to the rudder.

Variable Angle of Incidence.—If the propeller were held so that it couldn't turn, the power of the engine would be spent in turning the aeroplane round its shaft as an axis.

In fact, the air striking the blade of the propeller obliquely presents considerable resistance against its rotary motion, and a corresponding force is exerted on the machine to turn it in an opposite direction. To overcome this tendency to turn the machine, it suffices to give a greater angle of incidence and therefore greater lift to the left wing, assuming the propeller to be turning clockwise from in front. This increased angle of incidence tends to rotate the machine in the same direction in which the propeller is rotating, thus overcoming the opposite rotation which the torque reaction would produce.

Two rather objectionable terms are used to indicate the variable angle of incidence provided for overcoming the propeller torque: ***Wash in***

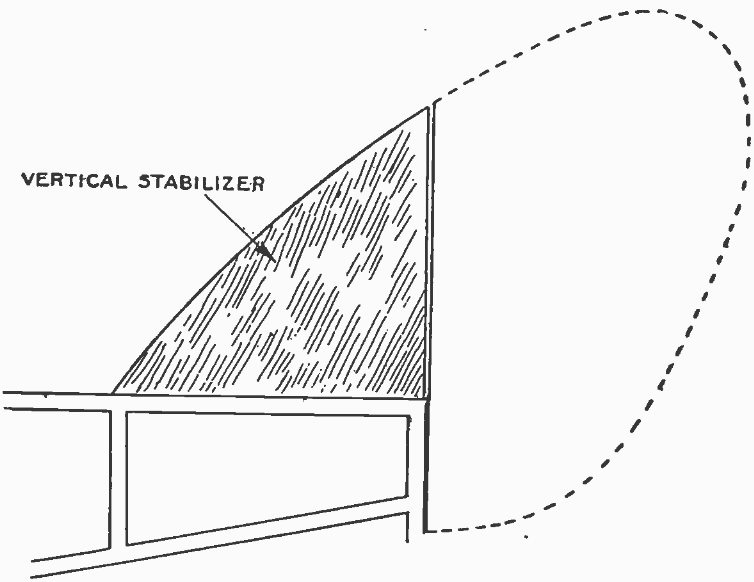
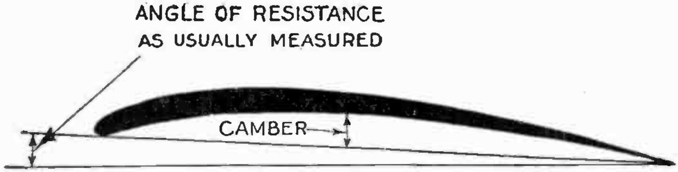
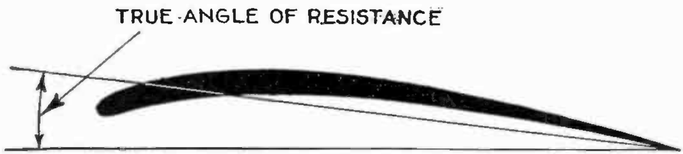


FIG. 7,126.—Rear vertical stabilizer or fin, to secure stability against skidding by resisting the skid, giving a banking effect, also to damp out the directional oscillations due to response to rudder, and to overcome centrifugal force, or tendency of the tail to skid outward in making a turn.

meaning the increase of angle of incidence toward the wing tips, and ***wash out*** meaning the decrease of angle of incidence toward the wing tips, as shown in fig. 7,130. Both lateral and directional stability may be improved by washing out the angle of incidence on both sides.

Wash out renders the ailerons more effective, as, in order to operate them, it is not necessary to give them such a large angle of incidence as would otherwise be required. The effect of *wash in* in opposing the tendency of the propeller torque to turn the machine over is shown in fig. 7,131.





FIGS. 7,127 and 7,128.—Angle of resistance as usually and incorrectly measured, and real angle of resistance. This error has crept in no doubt on account of the difficulty of measuring the angle shown in fig. 7,128.

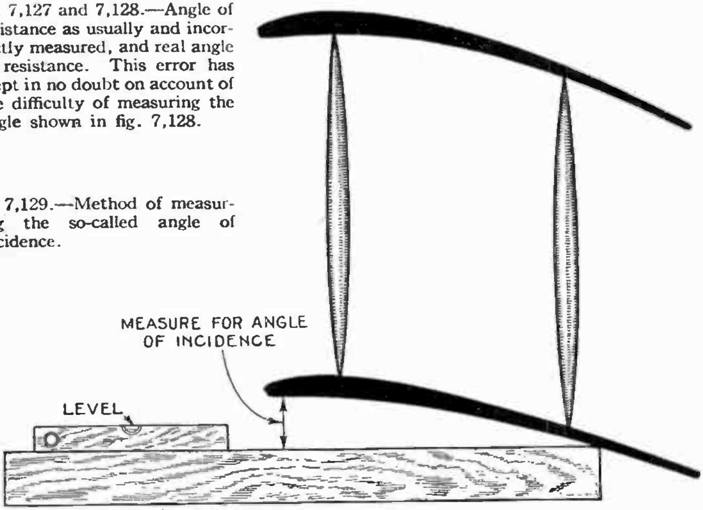


FIG. 7,129.—Method of measuring the so-called angle of incidence.

The advantage of wash in is offset somewhat by loss of lift, as the lift decreases with the decreased angle.

Directional Control.—An aeroplane is steered by a rudder just like a boat. The rudder is pivoted to the rear post and is connected by cables to a foot bar in front of the operator, so that steering (right or left) is done by means of the feet pressing against the foot bar which is pivoted at the center to the cockpit floor as shown in fig. 7,132.

The rudder is sometimes used in connection with the ailerons as a means of checking any swerving tendency. The ailerons at the same time then in restoring lateral balance, tend to change the directional course of the

FIG. 7,130.—Front view of aeroplane illustrating the terms ***wash in*** and ***wash out*** which mean respectively ***the increase and decrease in the angle of incidence of the wings from the center toward the tips.***

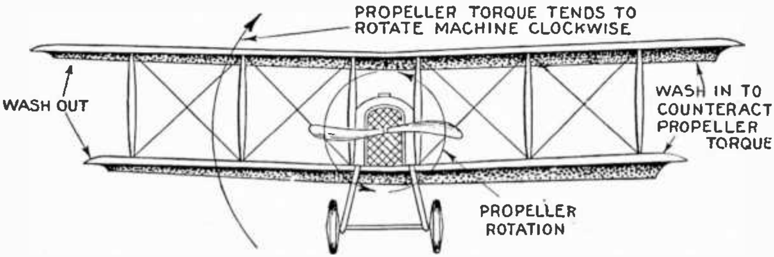


FIG. 7,131.—Front view of aeroplane illustrating how wash in opposes the turning over effect due to the propeller torque.

machine, and the rudder in such case must be used to oppose this tendency. The rudder is also frequently used to preserve a straight course against the disturbing action of side winds.

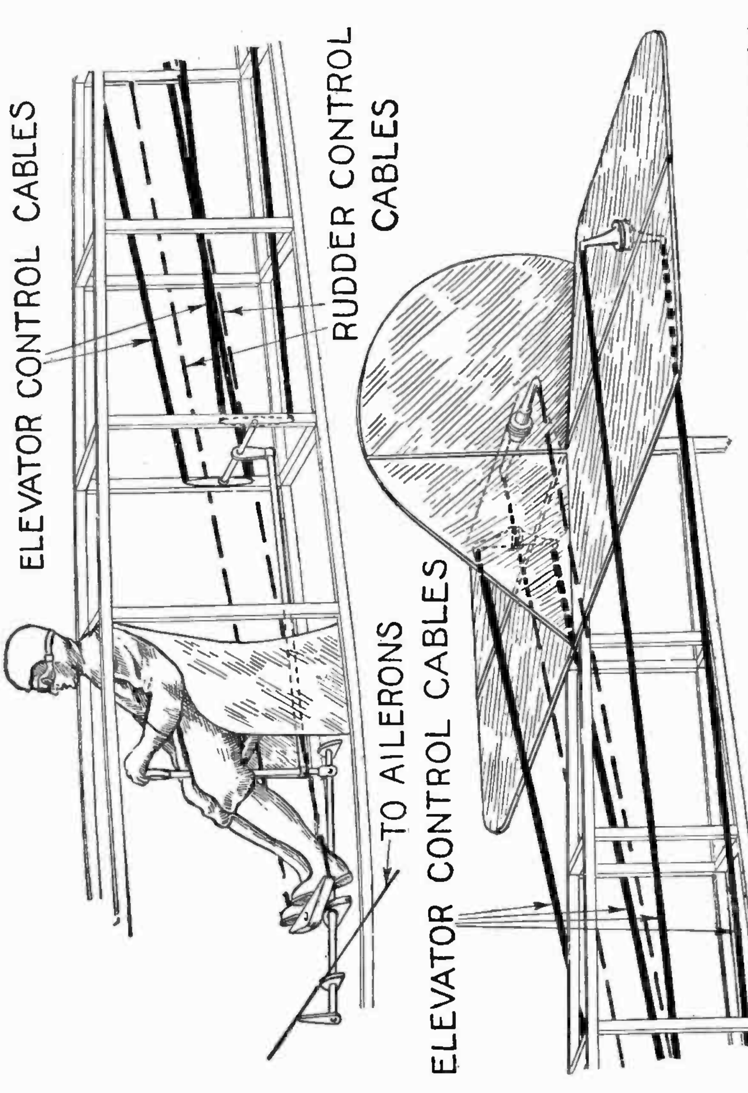


FIG. 7,132.—Rear portion of aeroplane body showing rudder and rudder control as operated by the feet.

TEST QUESTIONS

1. *Of what does an air plane consist?*
2. *Name the 3 motions to which an air plane is subject.*
3. *What mechanical appliances are used to control the three motions?*
4. *Describe the movable controls and the stabilizers?*
5. *Define the terms camber, chord, angle of incidence.*
6. *Draw a sketch showing the up and down control.*
7. *Explain by diagram the effect of drift.*
8. *What happens when the joy stick moves fore or aft?*
9. *Describe the lateral control.*
10. *Make a sketch of horizontal stabilizer.*
11. *Explain the "Dep" (Deperdussin) control.*
12. *Define lateral stability.*
13. *Enumerate the several conditions which tend to turn the machine over sideways.*
14. *What is the method of warp control?*
15. *Why are the wings inclined to the horizontal?*
16. *Draw a diagram illustrating lifting and stabilizing effects due to inclination of wings.*
17. *What are the forward vertical stabilizers?*
18. *Explain the variable angle of incidence.*
19. *What is the function of the rear vertical stabilizer?*
20. *What is the difference between wash in and wash out?*
21. *How is directional control obtained?*
22. *Show by sketch the angle of incidence.*
23. *Draw diagram of rear portion of air plane showing rudder and rudder control as operated by the feet.*

CHAPTER 172

Mechanics of Flight

Lift of the Wings.—When the wings are moving through the air, lift is due to: 1, *pressure* against the under surface of the wings caused by the inertia of the air on being deflected downward by the advancing inclined planes, and 2, partial *vacuum*

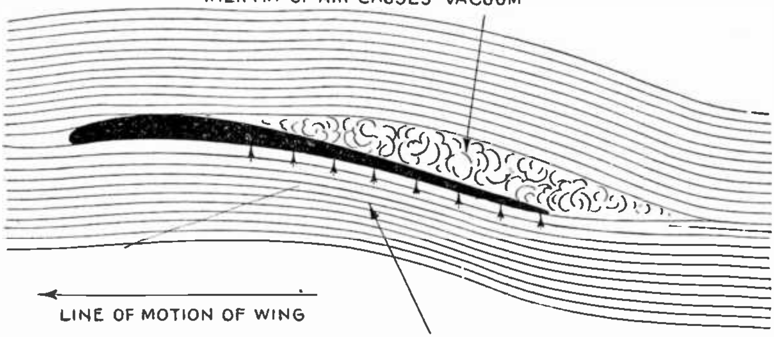


Fig. 7,133.—Section of wing illustrating *lift* as caused by *inertia* of the air in causing upward pressure on the lower surface, and partial vacuum on the upper surface of the wing.

formed over the top of the wing curved surface, also by the inertia of the air by virtue of which it cannot deflect and fill up instantly the space swept through by the advancing inclined wings.

Stagger.—When there are more than one pair of wings as in biplanes, triplanes, etc., if one pair be placed directly over the

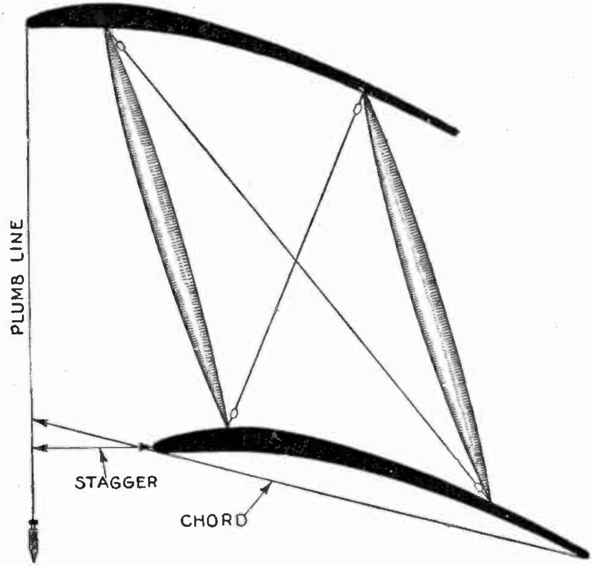
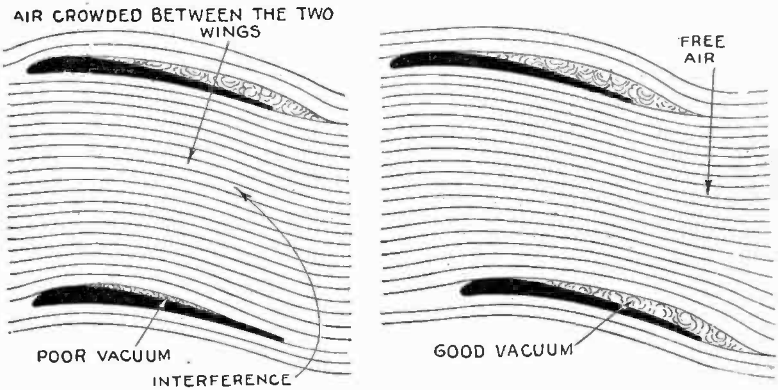


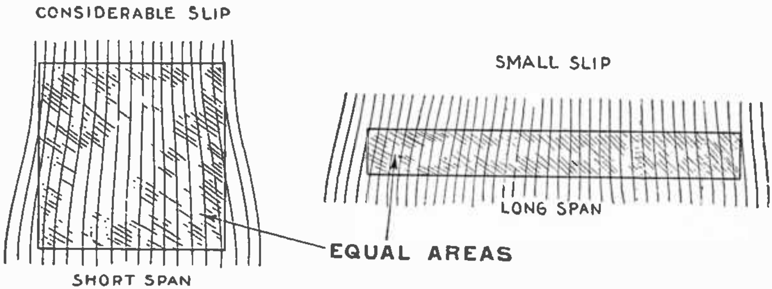
FIG. 7,134.—Method of measuring the *stagger* of the wing. This can be measured either horizontally or along the line of the chord. Some makers measure one way, some another, but the correct way should be shown on the diagram which should accompany every wing. The two measurements may be as much as ¼ inch difference, which is sufficient to make the machine nose, or tail heavy as the case may be.



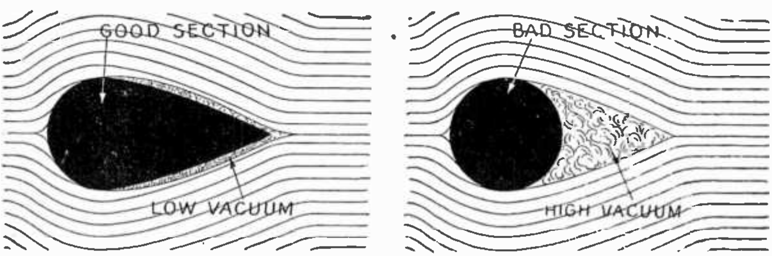
FIGS. 7,135 and 7,136.—Wings with, and without *stagger* showing effect of stagger in increasing the vacuum on the top surface of lower wing.

other pair, the suction region on the top of the under wing, and the compression region below the upper wing both find themselves confined in about the same space, so that the excess pressure under the top wing causes the air to expand downward and reduce the vacuum on top of the under wing as in fig. 7,135, thus decreasing the efficiency of the wing surface.

It has been found that if the top wing be placed a little in advance of



FIGS. 7,137 and 7,138.—Wings of short and long span (low and high aspect ratio) showing why the long wing is the more efficient. Wing tips are inefficient because they "spill," or allow the air to slip sideways past their ends, hence in a long span wing as in fig. 7,138 the end portion or tip is only a small percentage of the total area, and accordingly little air slips by the tips as compared with a short span wing which has a wide tip.



FIGS. 7,139 and 7,140.—Good and bad cross sectional shapes of struts. In fig. 7,139, the long easy curve permits the air to follow the surface, thus practically no vacuum is formed; while in fig. 7,140, the air cannot follow the abrupt curve resulting in a vacuum which acts as a drag or resistance opposing its advance.

the lower wing (that is, given stagger) there is less interference with the vacuum on top the lower wing, thus the lower wing is rendered more efficient, as shown in fig. 7,136.

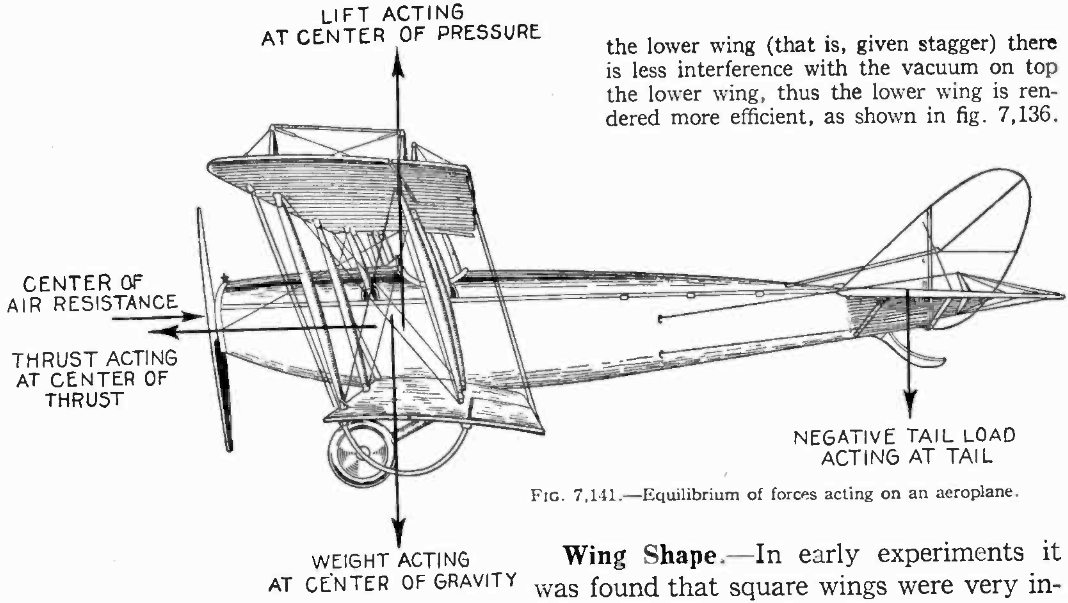


FIG. 7,141.—Equilibrium of forces acting on an aeroplane.

Wing Shape.—In early experiments it was found that square wings were very inefficient, and if they were made long rather than broad the efficiency was improved. The ratio of wing length to breadth is called the *aspect ratio*.

The usual ratio is 6 to 1, that is, the wing is 6 times as long as it is wide. The reason why a long wing is more efficient than a short one is because there is less lateral slip of the air from the tips of the wing as shown in figs. 7,137 and 7,138.

Forces Acting on an Airplane.—When a machine is in flight there are four forces acting on it: 1. Lift (acting upward). 2. Gravity (acting downward). 3. Thrust (acting forward). 4. Air force (acting rearward).

For equilibrium there must be sufficient lift to balance gravity, and sufficient thrust to balance the air force. In other words, there are two pairs of forces, as shown in fig. 7,141, acting respectively vertically and in the lines of flight, and each pair are in balance—that is, the thrust or pull due to the propeller is equal to the force of the air acting on the machine.

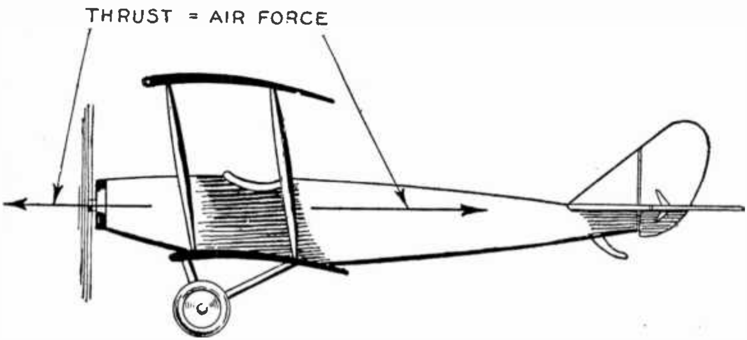


FIG. 7,142.—Relation between the thrust of the propeller and air force or resistance to the forward motion of the machine due to the air.

The ratio of lift to this air force determines largely the value of a wing curve, and in general, that curve which gives the greater amount of lift with the least air force at the speed for which the machine is designed is the most efficient.

The ratio of lift to air force varies approximately from 1 to 1 on a flat plane to 8 or 10 to 1 for wings of special forms. The ratio 8 to 1 is easily obtained. This means that for every pound of forward thrust given by the propeller, 8 pounds of weight can be lifted vertically at the normal speed of the machines.

Center of Gravity.—By definition, the center of gravity of a body is *that point about which, if suspended, all the parts will be in equilibrium*.

The position of the center of gravity of an aeroplane has a marked influence on its behavior in the air; it should, therefore, be known, and accordingly should be measured and marked on the machine.

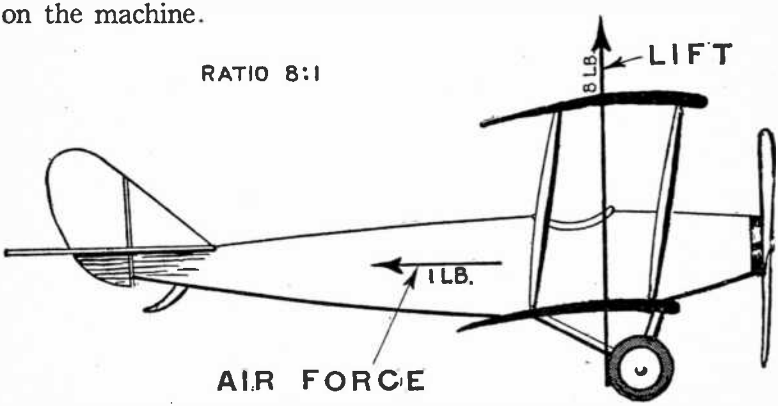


FIG. 7,143.—*The lift, air force ratio*. If for each 1 lb. of resistance (air force) overcome by the forward thrust of the propeller the upward pull or *lift* be, say 8 lbs., then the lift, air force ratio is 8:1.

The conditions would be ideal if all the forces acted at the center of gravity, but in construction the line of thrust and line of resistance do not usually coincide, because the line of thrust coincides with the propeller shaft axis, and this is usually above the line of resistance.

With the line of thrust above the line of resistance there is a tendency for the machine to nose down, and in order to balance this the center of gravity is located a sufficient distance behind the center of lift to give an equal tendency to tip the nose upward.

The position of the center of gravity affects lateral stability; if too low, it causes the machine to roll sidewise; if too high, it tends to upset the machine sidewise. The position of the center of gravity which gives maximum lateral stability is over a little below the center of air force.

Longitudinal Stability.—The angle of flight of an aeroplane with respect to the horizontal is controlled by the elevators. In flight, the center of lift changes its position whenever the angle of incidence or speed is changed.

If an aeroplane be flying at an angle of, say, 2° so that the center of gravity coincides with the center of lift for this angle and a gust of wind cause the angle to increase ¼ degree, the center of lift will move forward and tend to elevate the front

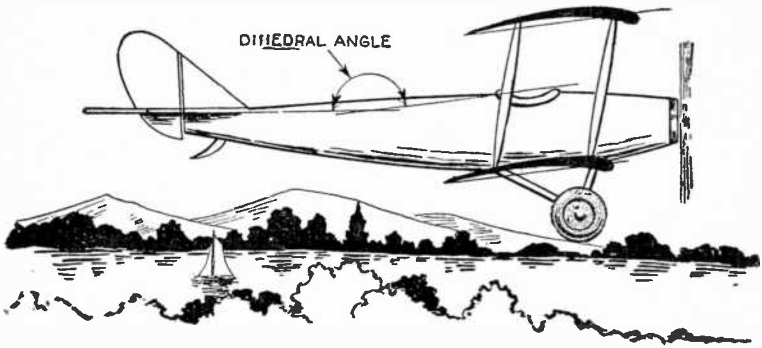
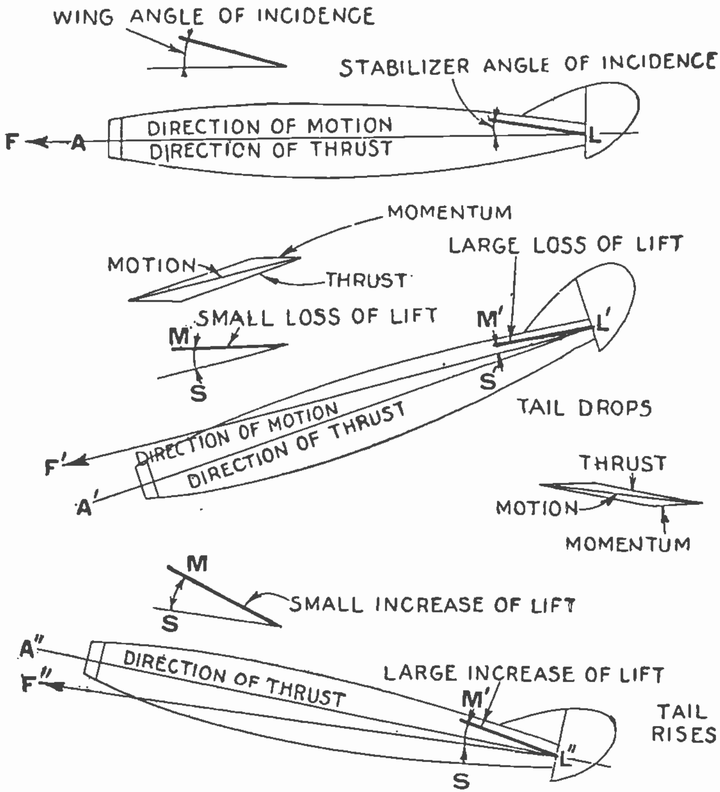


FIG. 7,144.—The dihedral angle. By definition a dihedral angle is *that angle made by the intersection of two planes*, as applied to the aeroplane it means *the difference in angle of inclination of the wing and the stabilizer*, that is the angle formed by the intersection of the wing and stabilizer surfaces projected along the axes.

edge of the wing, thus further increasing the angle. The center of lift will then move further forward to accommodate the increase of angle, and the wing would rear up unless it were firmly attached to the aeroplane body and held in its proper position by the tail. Similarly if the angle be decreased, the tendency would be to depress the wing. It has been found that by giving the stabilizer a smaller angle of incidence than the wings, the disturbing force just described is opposed by a strong righting force.



FIGS. 7,145 to 7,152.—Diagram showing righting effect of stabilizer and why stabilizer angle of incidence must be less than wing angle of incidence. *In normal flight* the direction of motion LF, and direction of thrust LA, coincide, as in fig. 7,146. Now, if a gust of wind throw the head down, as in fig. 7,149, then the direction of motion will not coincide with the direction of thrust, but will take the direction of the resultant L'F', of the thrust and motion, as found by the parallelogram fig. 7,147, and in fig. 7,149 it is seen that the stabilizer angle of incidence M'S', is now much smaller in *proportion* than the wing angle of incidence MS, hence *the stabilizer has suffered a greater loss of lift than the wings, and the tail falls*, thus automatically bringing the machine back to its normal position, fig. 7,146. *Again* if a gust of wind cause the head to rise to position L''A'', as in fig. 7,152, there will result a small increase of wing angle of incidence and a relatively large increase of stabilizer angle of incidence, hence the stabilizer receives a greater increase of lift than the wings and the tail rises, thus automatically bringing the machine back to its normal position. Evidently the

A lack of longitudinal stability may be due to:

1. Wrong stagger;
2. Warped body;
3. Wrong angle of incidence.

If there be not enough stagger, the lift will be too far back, tending to make the machine nose heavy.

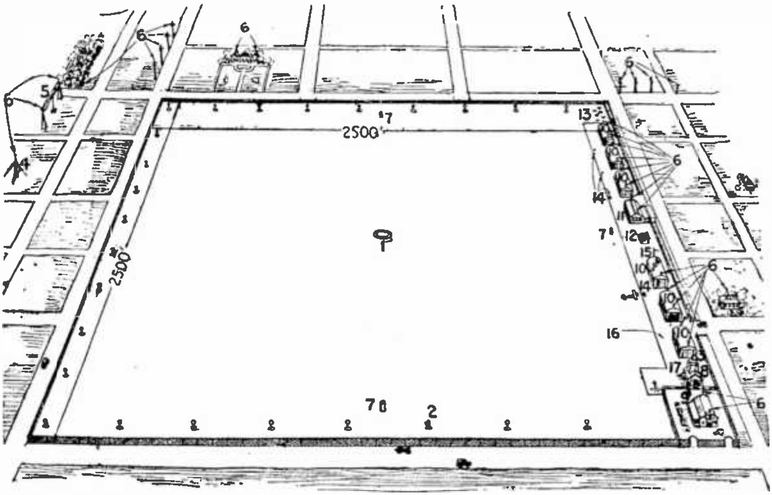


FIG. 7,153—All way airport rated A1A according to airport regulations, Department of Commerce: 1, circle marker; 2, boundary lights; 3, rotating beacon light; 4, radiobeacon with red obstruction light; 5, radio telephone with red obstruction light; 6, red obstruction lights on power and telegraph lines, hangars, houses, etc.; 7, flood lights for landing; 8, administration building; 9, club house; 10, hangars, flood lighted; 11, shop, flood lighted; 12, fire department; 13, underground fuel tanks; 14, fuel outlets; 15, wind indicator (illuminated) 16, concrete apron; 17, ceiling projector.

A warped body may change the angle of incidence, and if the angle of incidence be too great, the machine will be nose heavy; if too little, it will be tail heavy.

FIG. 7,145 to 7,152.—*Text continued.*

stabilizer must be fixed at a *less* angle of incidence than that of the wings, otherwise when the line of motion and line of thrust do not coincide, the two incidences would be altered in the *same* proportion and the righting effect would not be obtained. In the figures the wing and stabilizer are shown straight instead of curved for clearness.

Effect of Altitude.—Air is heavier near the ground than higher up, because the lower layers have to support the weight of the upper layers, hence the lower layers are compressed into smaller space. The heavier each particle of air, the greater is the inertia when the wing drives the particles downward, hence the greater the lift. Accordingly the nearer the aeroplane is to sea level, the greater is its lifting force.

As the machine climbs to high altitudes, the density decreases and the speed increases, but due to the lighter air the engine takes in less charge of fuel mixture, hence the power is reduced, so, taking this into account, the speed is not so great in high altitudes as in low. It follows that aeroplanes to be used for flying in high altitudes must have greater wing area than those for low altitudes.

TEST QUESTIONS

1. *Name two forces which cause the wings to lift an air plane.*
2. *Define the term stagger.*
3. *How is stagger measured?*
4. *Does stagger increase the vacuum on top of the wing?*
5. *Why is a long wing more efficient than a short one?*
6. *What is the disadvantage of a strut of round cross section?*
7. *Name the different forces acting on an air plane.*
8. *How does the ratio of lift to air force vary?*
9. *Define the term center of gravity.*
10. *Explain in detail longitudinal stability.*
11. *What are the causes of lack of longitudinal stability?*
12. *Draw a diagram showing righting effect of stabilizer and why stabilizer angle of incidence must be less than wing angle of incidence.*
13. *What is the effect of altitude?*
14. *Draw a diagram showing deviation of air plane by drift caused by side winds.*

CHAPTER 173

Electric Ship Drive

There are two systems of electric drive for ships which take their names from the type of prime mover used. They are:

1. Turbine-electric drive.
2. Diesel-electric drive.

The object of the electric drive is to overcome the inherent defects or limitations of the turbine and internal combustion engine; that is, its function is similar to the so-called transmission of an automobile in that it gives flexibility of control and permits the turbine or engine to run at its most economical speed.

The turbine is inherently a high speed machine and operates between 2,000 and 6,000 *r.p.m.* depending upon the power rating, when running at its most economical speed; the propeller on the other hand should operate at low speeds, 75 to 300 *r.p.m.* depending upon the type of ship and its power rating, for best efficiency.

In the case of the Diesel engine, multi-cylinder engines are used with high piston speed to reduce *weight* and *vibration*, these two items being inherent defects due to the extraordinary requirements of the Diesel cycle. The result is that the *r.p.m.* of the Diesel engine is too high for the propeller and the interposing of electrical machinery permits each to run at its most economical speed.

In both the turbine electric and Diesel electric forms of drive the prime movers operate in but one direction of rotation, reversal of the propellers being accomplished by switching of the electrical circuits.

In the case of the turbine this eliminates the necessity for a separate turbine for astern operation, which in turn reduces the design to its simplest elements.

With the Diesel engine all reversing elements are discarded and starting air is not required during maneuvering operations.

In twin screw or quadruple screw ships, it is usual practice to install either two or four generating equipments respectively.

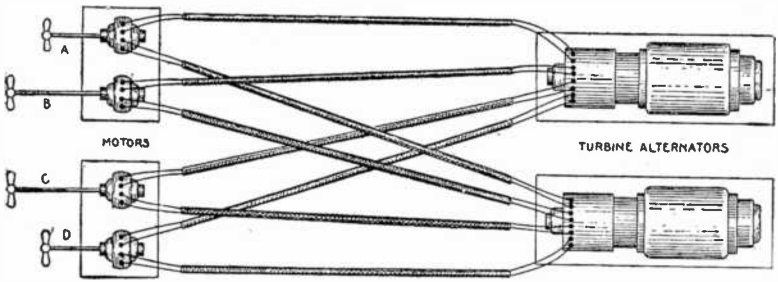


FIG. 7,154—Elementary diagram illustrating the essentials of electric ship propulsion. Two turbine alternator units are shown on the right which are wired for various connections with the motors; the latter operates the propellers A,B,C and D.

At reduced powers it is therefore possible to drive all of the propellers from one or more of the generating units, and close down the plants not in use.

In single screw Diesel electric driven ships it is usual practice to install two or more generating equipments and individual units may in turn be added or taken off the line as the power demands require.

The two systems differ in respect to the type of electrical machinery used.

The turbine electric drive with but few exceptions utilizes alternating current machinery, and the Diesel electric, direct current machinery. These two systems will therefore be described separately.

Turbine Electric Drive.—The type of ship and its service decides largely the kind of electrical equipment selected. Naval vessels which operate over long periods of time at greatly reduced speeds call for one type; ships of special type which engage in unusual duties another and large merchant vessels which operate on schedule still another.

There are three types of *a.c.* motor which find a broad application in ship work.

1. Induction motors in which the field is wound for two different pole connections; these motors are invariably used in large naval vessels.

2. Induction motors of the wound armature type, which permit the insertion of external resistance in the secondary circuit thus allowing the motor to operate at a slow speed without altering the speed or frequency of the main alternator. This type of motor finds a broad field of application on ships of special type and yachts.

3. Synchronous induction motors in which but one electrical gear ratio between the turbine alternator and motor can exist. This type of motor is used on large passenger vessels which operate more or less continuously at or near their rated speed.

NOTE.—*Naval vessel applications.* The large battleships of the U. S. Navy which have been electrified consist of the New Mexico, California, Tennessee, Colorado, Maryland and West Virginia. These vessels are of the quadruple screw type, have one motor attached to each propeller shaft, and have two main turbine generating equipments. The motors are wound so as to give a 24 or 36 pole group of stator windings. When operating with one turbine alternator at reduced speed of ship the 36 pole connection is used thus giving a higher electrical gear ratio between the turbine alternator and motor. This in turn permits the turbine to operate at a higher speed whereby the economy is greatly increased. In the foregoing case the turbine alternator not in use with its attendant condenser and auxiliary equipment, is shut shown, and the motors all operated in parallel from the one turbine alternator in use. At powers above one half power the second turbine alternator is used and the two port propellers operated from one unit, and the two starboard propellers from the other. In this case the 24 pole connections on the motors are used.

NOTE.—*The Saratoga and Lexington* are quadruple screw vessels; they have two motors attached to each propeller shaft which are wound so as to give 22 or 44 pole groups of stator windings. These ships each have four main turbine generating equipments. Any one of these four equipments may be selected to drive the four propeller shafts at reduced power; likewise any two of these equipments may be used to drive the ships at intermediate speeds. Under full power conditions, one equipment is used to drive the two propelling motors on each shaft. The 44 pole motor connection is used at low powers and the 22 pole connection at intermediate and full power conditions.

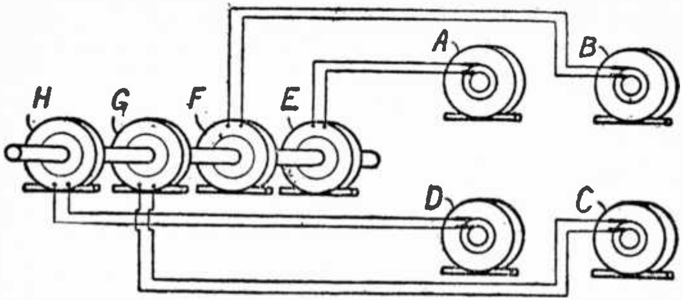


FIG. 7,155—Hobart's alter-cycle control with induction motors for electric ship propulsion. There are four motors E,F,G and H, wound respectively for 24,36,48, and 72 poles. Tbe maximum speed of the propeller shaft is 100 *r.p.m.* with full power of all the motors. To run the motors at 100 *r.p.m.* requires frequencies of 20 cycles for the 24 pole motor, 30, for the 36 pole motor, 40, for the 48 pole motor, and 60 for the 72 pole motor. Thus to obtain equal *r.p.m.* the frequencies of the four alternators A,B,C,D are respectively made 20,30,40 and 60. To obtain these frequencies when the alternatoıs are down say to 600 *r.p.m.* requires respectively 4,6,8, and 12 poles for the alternators A,B,C and D. To drive the ship at two-thirds speed, motors F and H, are connected to alternators A and C, which provide respectively ⅔ of the frequencies of B and D, to which F and H, were connected for full speed running. Since for the lower speed only about .3 as much power is required as for top speed, alternators B and D, and motor E and G, are shut down. For half speed a single motor is sufficient; this can be provided by operating motor H, from alternator B, or G, from A. One-third speed is obtained by operating H, from A.

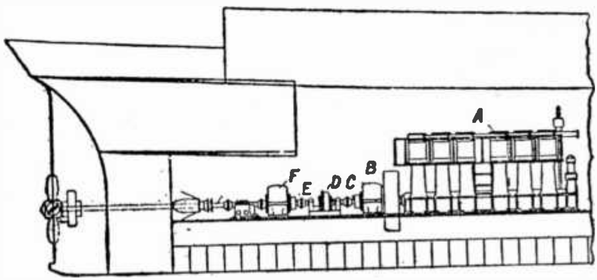


FIG. 7,156—The ***Menlees system*** of propelling ships by gas engines. In the figure, A, is a six cylinder gas engine coupled to a dynamo B. The shaft C, of the dynamo and engine is adapted to be connected by a clutch D, with the shaft E, of the electric motor F, which is connected with the propeller shaft. ***In operation*** at all ahead ship speeds direct driving may be employed, but, for speeds less than half, the electrical transmission may be used, the motor F, receiving electrical energy from the dynamo B. The drive may also be employed for reversing the astern speed by not greater than half the full ahead speed, suitable switches and gear being provided.

Equipments for Passenger and Cargo Vessels.—Large passenger and cargo vessels generally operate at, or near, their full power rating when at sea. For this reason the pole changing feature as described for the naval vessel (see note) and the special uses of the wound rotor induction motor, are of little consequence. Such ships as the passenger liners S.S. California, S.S. Virginia, S.S. Pennsylvania, S.S. Santa Clara, S.S. Morro Castle and S.S. Oriente, make use of the synchronous induction motor.

All of the foregoing vessels are of the twin screw type and have installed two main generating turbine equipments which are used for propulsion only.

The auxiliary power load on these vessels is relatively high because electricity is used throughout the ship wherever it can either add to the comfort of the passengers, or lighten labor on the part of the crew. This high auxiliary power load makes it worth while to install special turbine alternators alone for this purpose.

One of the principal reasons for using the synchronous induction motor is its high efficiency and also the fact that it operates at unity power factor. This in turn reduces the size of the power cables and the size and weight of the alternator.

One turbine alternator can be used to drive the two propellers on all of the vessels referred to in the note on ships of special type, and the ships operated at approximately 75% speed without overloading the alternator in use.

Typical Diagram of Main and Auxiliary Circuits.—A simplified wiring diagram of the main and auxiliary power circuits, for a twin screw vessel using the synchronous induction type of propelling motors and having main turbine alternators is

NOTE.—*Ships of special type.* This includes that large class of vessels such as self-unloading, bulk freight carriers used on the Great Lakes, self propelled dredges, car ferries, or vessels requiring some unusual powering consideration because of their large auxiliary power needs. The main and auxiliary power needs on vessels of the foregoing type must be considered collectively. In cases where it is found advisable to furnish power from the main units for the auxiliaries, the main alternator speed must also be kept within certain very narrow limits because of the effect it would have on the speed of the auxiliaries. When the wound rotor type of induction motor is used, resistance may be inserted in the rotor or secondary circuit of the propelling motor and the speed of the propeller reduced without reducing the frequency below a point which would be troublesome to the auxiliaries.

shown in fig. 7,157 The system shown is for a vessel of 30,000 shaft *h.p.* or 15,000 *h.p.* per shaft in which the main line voltage is 5,000. The system used for ships of smaller power is almost identically the same except that the voltage may be lower.

Fig. 7,158 shows the general arrangement of the propulsion equipment on a turbine electric twin screw yacht using a slip ring induction motor.

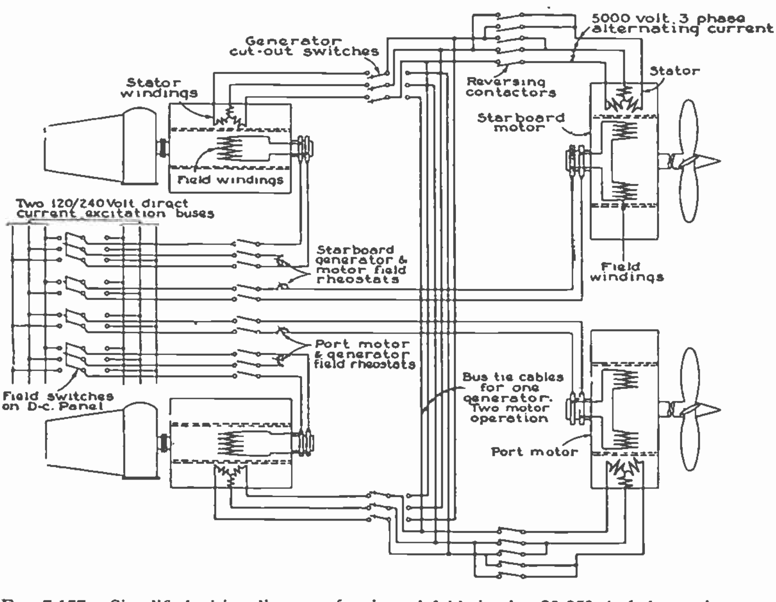


FIG. 7,157.—Simplified wiring diagram of main and field circuits, 30,000 shaft *h.p.* twin screw turbine electric drive. Excitation current for the main alternators and motors is supplied by an auxiliary *d.c.* turbine dynamo. The synchronous motor has a very poor starting torque and for this reason an induction squirrel cage winding is imbedded in the pole faces of the armature for starting. After the motor has come up to its normal slip speed as an induction motor, excitation is applied to the armature windings and the armature speed synchronized with the speed of the rotating field. The system shown is a 3 phase circuit, in order to reverse the direction of rotation of the rotating field it is necessary only to alter the juxtaposition of two of these phases. Reversing contactors which are operated by means of a lever on the operating panel are provided for this purpose. The alternator cut out switches shown in the diagram are for the purpose of cutting out one alternator when it is desired to operate the two motors in parallel from one alternator.

The operating principle of a turbine electric vessel equipped with synchronous induction motors is illustrated in fig. 7,159. In this diagram one propelling unit only is shown, that for the other propeller being a duplicate of the one shown.

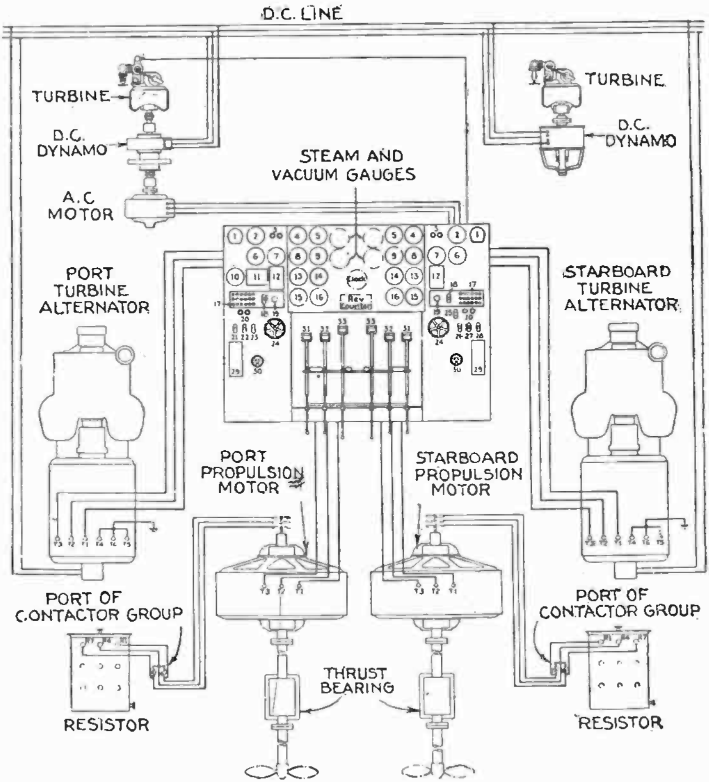


FIG. 7,158.—General Electric turbine electric propulsion equipment for twin screw yachts using slip ring induction motor. The power for the auxiliaries when under way is furnished by the 3 unit motor generator set. This set is driven by the *a.c.* motor when the frequency of the main unit is between 75 and 100 per cent, and the small turbine allowed to idle. At lower frequencies the turbine drives the set and the *a.c.* motor is now used as an alternator furnishing power to the *a.c.* auxiliaries. The small auxiliary turbine generator set is used for a standby at sea, and in port.

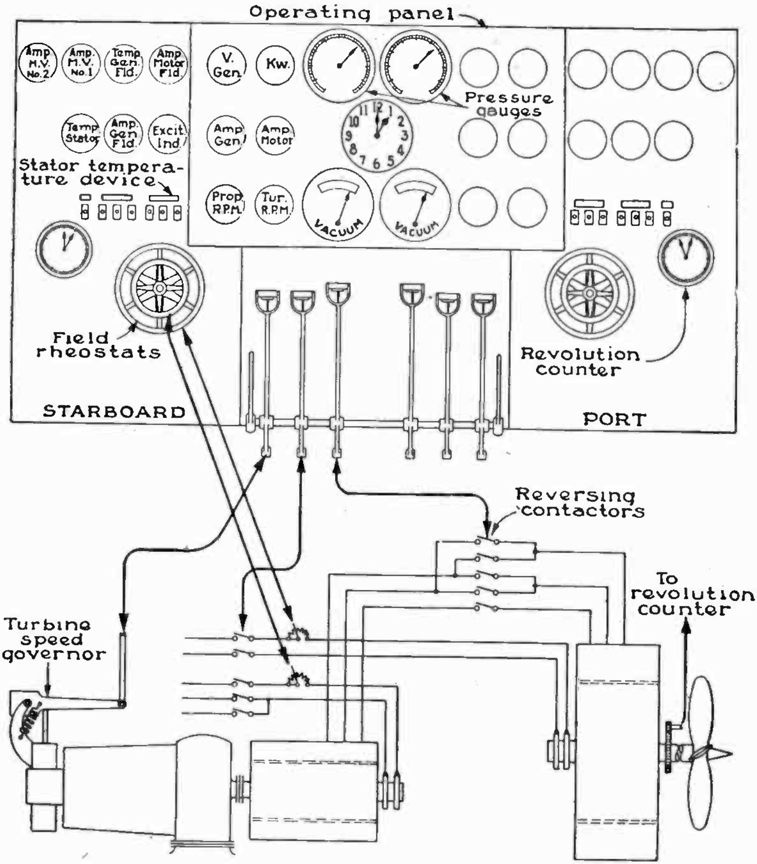


FIG. 7,159.—Diagram showing operating principle of twin screw turbine electric vessel equipped with synchronous induction motors. The operation is briefly as follows: ***Going ahead:*** 1, adjust turbine to ¼ speed lever; 2, move reversing lever to ahead position; 3, move field lever to position 1. When motor has accelerated to a constant speed move field lever through position 2, slowly to run position; 4, adjust turbine speed to give propeller speed desired. ***Stop:*** 1, reduce turbine to ¼ speed; 2, move field lever to off position; 3, move reverse lever to off position; ***Reverse:*** Same sequence as for going ahead except under 2, the reverse lever is moved to reverse position; ***What is happening during maneuvering operations.*** When the field lever is in the off position the alternator field is demagnetized

Points on Operating Electrically Driven Vessels.—There are a few very simple facts for the operating engineer to remember when studying the operation of an electrically driven vessel.

1. The alternator rotor or field is simply a solenoid type of magnet.

2. The turbine and alternator rotor may turn but no voltage is built up in the stator windings until the excitation current is applied to the field or rotor windings.

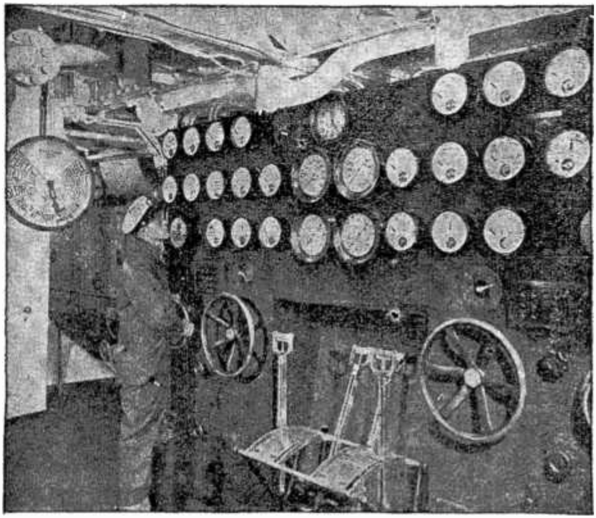


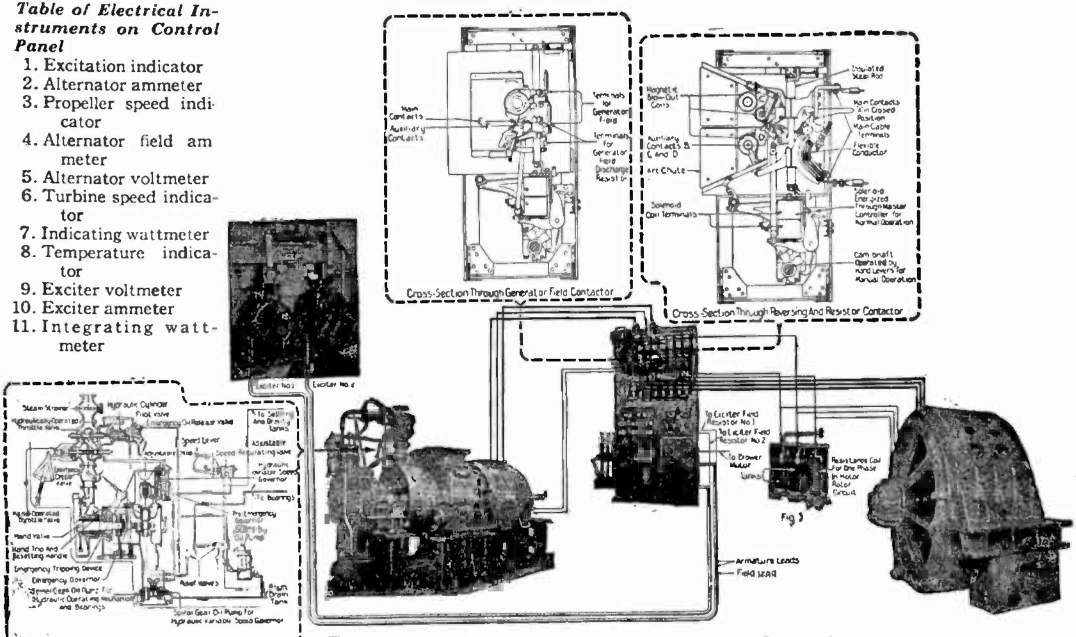
FIG. 7,160—Control room electric drive S.S. Virginia fitted with General Electric equipment.

FIG. 7,159.—*Text Continued*

and therefore no current is being generated. When the foregoing condition exists the main line reversing contactors can be opened or closed. A mechanical interlock exists between the field and reversing levers so that the reversing lever can only be moved when the field lever is in the off position. This is to prevent the burning of the contactor points. After the electrical set up is made for ahead, or reverse operation, the movement of the field lever to the first position allows current to flow through the alternator field only. This starts the motor up as an induction motor. When the field lever passes through the second point normal current flows through the motor field and the motor is synchronized. Movement of the field lever to the run position reduces the excitation to normal value on the alternator. The motor speed is now controlled by varving the turbine speed.

Table of Electrical Instruments on Control Panel

1. Excitation indicator
2. Alternator ammeter
3. Propeller speed indicator
4. Alternator field ammeter
5. Alternator voltmeter
6. Turbine speed indicator
7. Indicating wattmeter
8. Temperature indicator
9. Exciter voltmeter
10. Exciter ammeter
11. Integrating wattmeter



FIGS. 7,161 to 7,164.—Diagrammatic arrangement of General Electric steam governing system and electric connections of ship propulsion machinery. It is easy to control a vessel equipped with a turbine driven alternator and propelled by a three phase induction motor mounted on a single driving shaft. Starting, stopping, and reversing are accomplished by means of an easily operated lever which serves to close, open or reverse the electrical connections between the alternator and the driving motor on the propeller shaft. The speed of the propeller shaft is regulated through a range from one-third to full speed by means of a second lever which changes the speed of the alternator, the efficient driving of the propeller, under varying conditions in a sea voyage is gauged by a set of electrical instruments and governed by a third handle attached to a resistor in the alternator field circuit. This handle adjusts the excitation of the alternator.

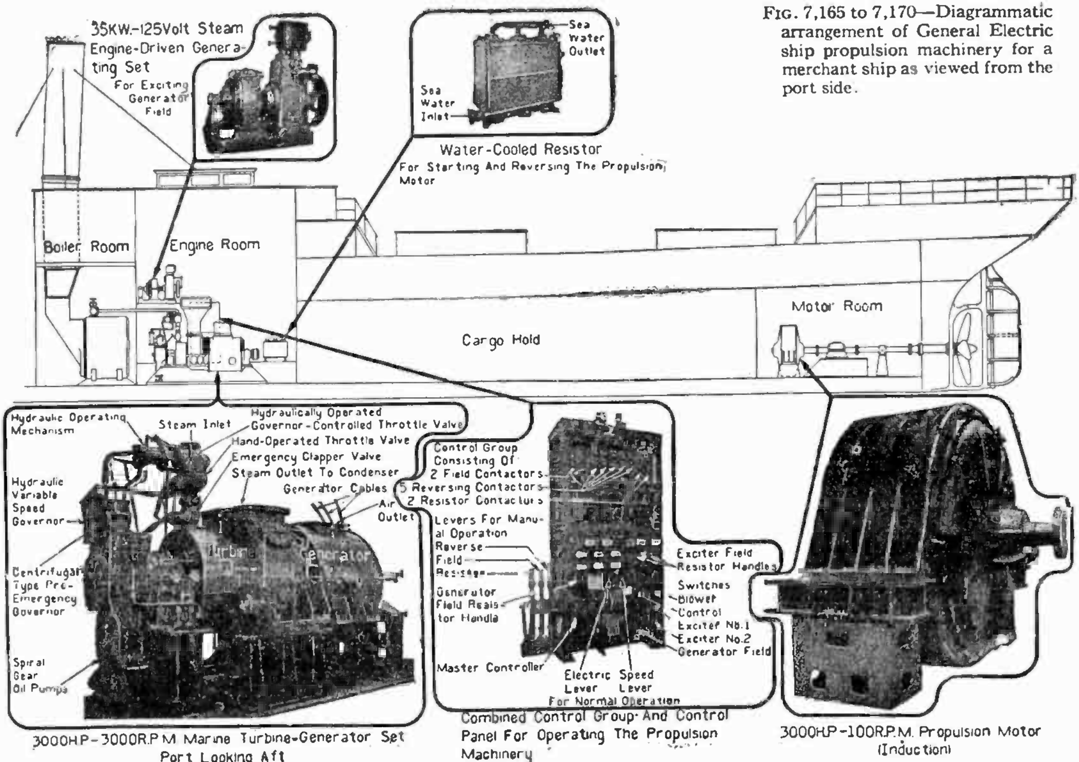


FIG. 7,165 to 7,170—Diagrammatic arrangement of General Electric ship propulsion machinery for a merchant ship as viewed from the port side.

3. In one way the turbine alternator when operating without field excitation may be likened to the operation of an automobile engine with the clutch released.

4. The field current must be switched off before attempting to change the main line contactor set up for reversing the direction of rotation of the motor. This again may be likened to the operation of an automobile; that is, the clutch must be released before attempting to shift gears.

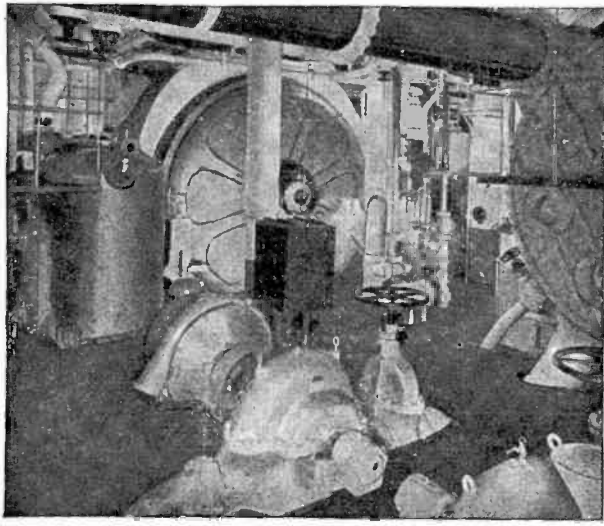


FIG. 7,171—Propelling motor and condenser pumps of S.S. California quadruple screw turbine electric drive; General Electric equipment.

5. There are two levers on the operating panel which perform the foregoing functions. They are known respectively as the field lever and the reversing lever. They are so interlocked on the panel that the reversing lever can be moved only when the field lever is in the off position.

6. A third lever, called the turbine speed lever controls the speed of the turbine.

7. After the reverse lever is placed in either the ahead or astern position as desired, and the field lever moved to the run position, the speed lever is moved until the desired speed is attained.

8. The field rheostats alter the amount of current passing through the fields of the alternator and motor.

9. The alternator field rheostat is adjusted to give the desired voltage and the motor field rheostat adjusted to give unity power factor in the system.

10. The meters and instruments on the control panel consist of ammeters, volt meters and watt meters for the main line circuits, and ammeters for the field circuits. An alternator field temperature indicator will inform the engineer of any overheating.

11. A stator temperature device is mounted on the panel which enables the engineer to take temperature readings of the stator windings of both the alternator and motor whenever desired.

12. Steam pressure gauges, vacuum gauges, clocks, revolution counters, and propeller speed indicators, are mounted on the operating panel.

13. The fundamental operating principle of an electrically driven ship whether it has the induction, or synchronous type of motors is nearly the same.

14. The control panels are generally similar in appearance and have the same number of levers which are operated in the same sequence.

Diesel Electric Drive.—This type of equipment consists of the Diesel engine driven alternators, the propelling motor or motors, and the control panel; in addition to the foregoing there is also usually installed an operating stand in the pilot house from which the captain can reverse and change the speed of the propellers. The system allows of great latitude in its installation and finds ready application in a wide variety of vessels. The Diesel engines used in connection with electric drive are of the relatively high speed type.

The engines operate in one direction only and at constant speed. On account of this latter feature the engines are capable of supplying their full power output throughout a wide range of propeller speeds. The essentials of the Diesel electric drive are shown in the diagram fig. 7,172.

From an operating engineer's viewpoint, the system is very simple. When two or more main generating equipments are installed, and they

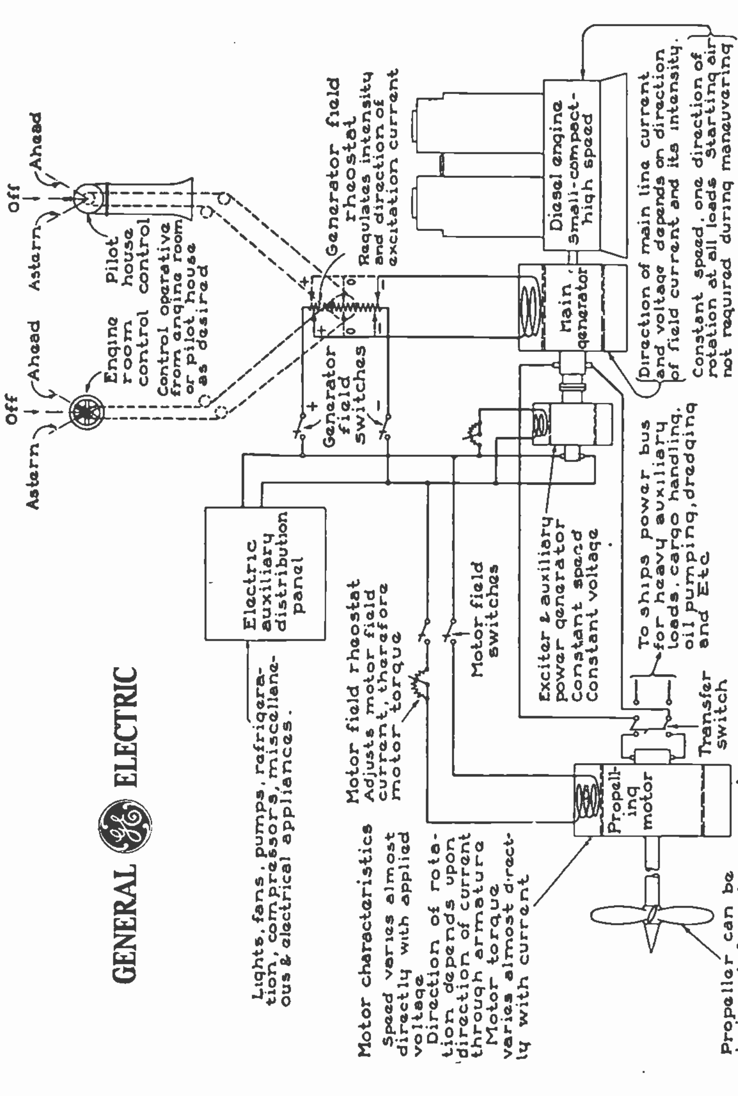


FIG. 7,172.—Simplified diagram showing fundamental characteristics of Diesel electric drive.

are all supplying power to the propelling motor, the armatures are all connected in series. The voltages of the dynamos under this condition of operating are additive. That is, if there be two dynamos of 250 volts each, the main line voltage would be 500 when they are connected in series.

The main dynamos have a small auxiliary dynamo placed on an extension of their shafts for supplying power to the auxiliaries, and for excitation of the dynamos and motors.

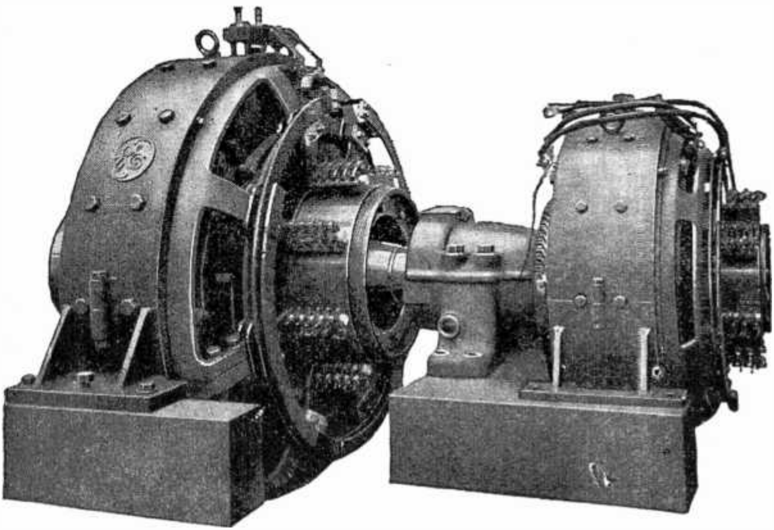


FIG. 7,173.—General Electric main and auxiliary dynamos for Diesel electric drive.

The propelling motor may be of either the single or double type. In the latter case two motors are connected in tandem on one common shaft and coupled directly to the propeller shaft.

Operating Hints on Diesel Electric Drive.—In starting, the engineer first starts the main engine, adjusts the field rheostat on the auxiliary dynamo for constant voltage (usually 125) and starts up the various auxiliaries on the ship. He then closes the main line switch which connects the dynamo to the propelling motor. Next he transfers the control to either the engine room or pilot house as desired and closes the field switches. The system is now in readiness to be operated from the control stand on the bridge or the wheel on the control panel, whichever one has been selected.

If the control be from the pilot house the captain simply pushes the handle in the direction he desires to go and brings the lever back to the central position when he wants to stop. Movement of the control lever operates a potentiometer type of rheostat which either increases or decreases the current flowing through the dynamo field or reverses its direction of flow. This system of control is known as the Ward Leonard system and also as "variable voltage control." When the latter term is used it is also sometimes preceded by the name of the manufacturer who built the equipment.

The propelling motors used are generally of the shunt type. On account of the variable voltage system under which they operate, their fields must be separately excited from a constant voltage source, such as the small auxiliary alternator provides.

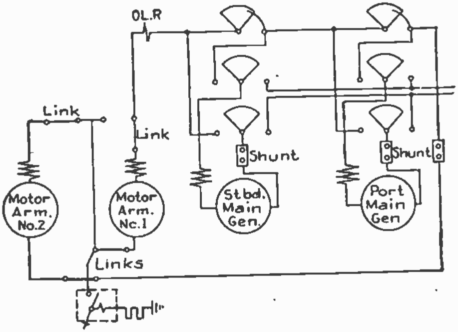
The motor field rheostat is used to alter the field strength of the motor and therefore the reverse voltage of the motor. This in turn alters the armature current hence the motor torque. When less than the total number of dynamos are used the field current of the motor is reduced and the motor allowed to speed up until it draws current from the dynamos in use corresponding to their full load output.

Should all of the dynamos be on the line and a heavy load be imposed on the propeller, which would cause the motor to slow down and therefore draw too much current, the motor field current would be increased to relieve dynamo from any overload.

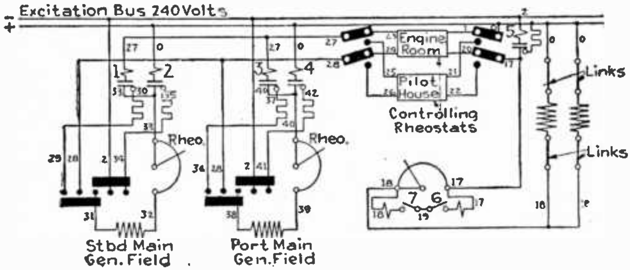
The motor field rheostat is operated by the engineer on watch. It is quite important that he understand its function, especially on a tow boat; because by its proper use he can get the best out of the equipment and also prevent overloads which tend to reduce the life of the equipment.

Variable voltage control is further explained in figs. 7,174 and 7,175.

Rheostatic or Armature Control.—The propulsion control equipment for a vessel fitted with rheostatic or armature control consists of an engine room panel, motor control groups, starting resistors, and master controllers.



Simplified Main Circuits



Simplified Field Circuits

FIGS. 7,174 and 7,175.—Simplified wiring diagrams of variable voltage control. *In operation,* assuming engines and necessary auxiliaries running; 1, selection of the operating station is first made by moving the control transfer switch to either the pilot house or engine room position, as desired; 2, the main switches on the dynamo panels are then turned to the propulsion position; 3, the control switches, which complete the field circuit are then moved to the propulsion position. When the three operations are completed, the ship is ready to start from the station selected. Movement of the lever on the pilot house pedestal from the off to the ahead position gradually increases the strength of the dynamo field, which in turn increases the voltage and causes ahead rotation of the propelling motor in almost direct ratio to the voltage so generated. Movement of the lever from the off to astern position functions in identically the same manner except that the current is reversed in the dynamo fields, which in turn reverses the polarity of the dynamos and thereby causes astern rotation of the propelling motor.

The engine room control panel carries the rheostats necessary for adjusting the voltage of the main generators; switches and circuit breakers for disconnecting the generators from the main bus; and rheostats for regulating the fields of the propelling motors, motor cut out switches, and the control station selector switch.

The motor control groups contain the contactors for reversing the motor armature circuits and those for cutting in and out the blocks of starting resistors; two levers for operating the contactors manually in emergency;

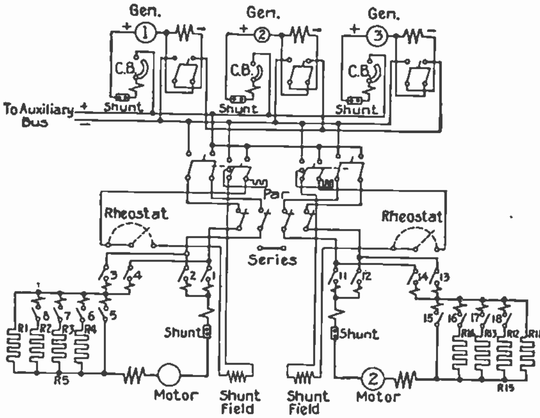


FIG. 7,176.—Typical rheostatic or armature control circuit diagram.

and an overload relay to trip the armature contactors should the armature current become excessive.

The starting resistors which are inserted in the armature circuit are also used to obtain different speed gradations and are designed for continuous operation on any resistor point. The master switches are of the drum type and, as they handle the current necessary to operate only the solenoids, the current values are very small. Any number of master switches may be located in any desired position in the ship.

The operation of the propelling equipment is performed in the following manner, assuming that the main engines and auxiliary equipment are in operation and the switches connecting the propelling motor or motors to the power bus have been closed:

The selector switch which transfers the control to either the pilot house or engine room should be thrown over to the position desired. The operation of the ship is then entirely under the control of the master switch selected.

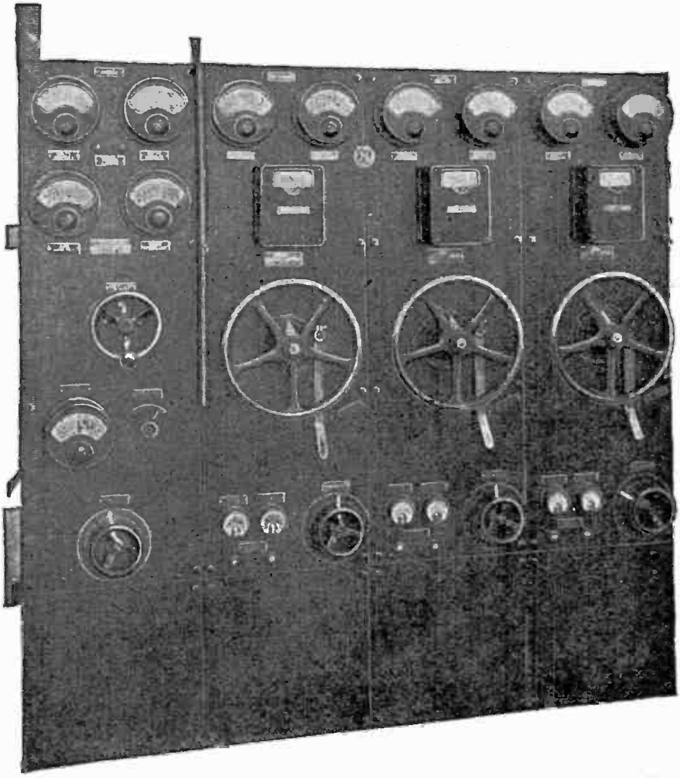


FIG. 7,177—Front view of General Electric control panels for Ward-Leonard or variable voltage control.

By moving the handle of the master switch from the off to the ahead position, the contactors connecting the armature circuit for ahead operation close with maximum resistance in the line. As the handle is moved farther forward, additional blocks of resistance are paralleled with the first. This gradually reduces the effective resistance. On the last point of the controller, a contactor, which short circuits the entire block of resistance, closes and throws the motor directly on the line.

The acceleration is very smooth and may be accomplished as gradually as desired. The operation for astern propulsion is similar to that for

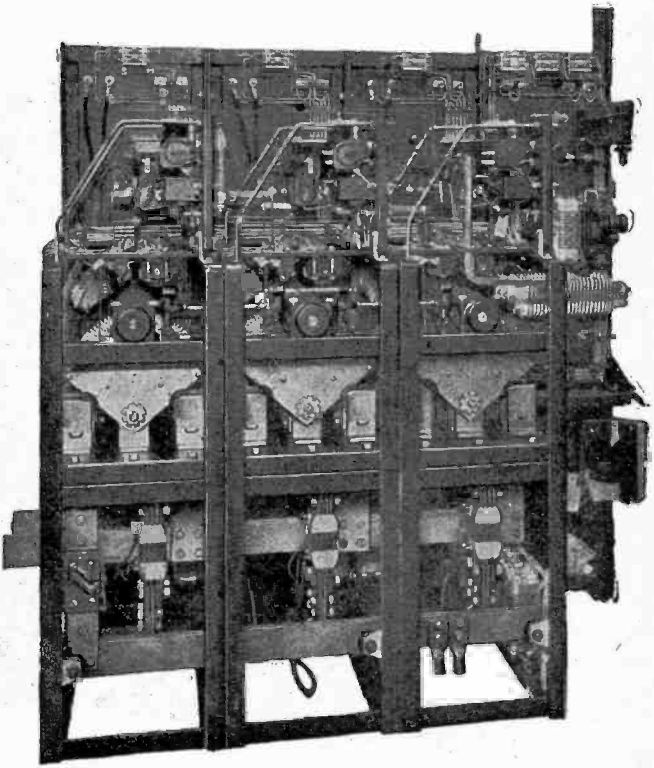


FIG. 7,178—Rear view of General Electric control panels for Ward-Leonard or variable voltage control.

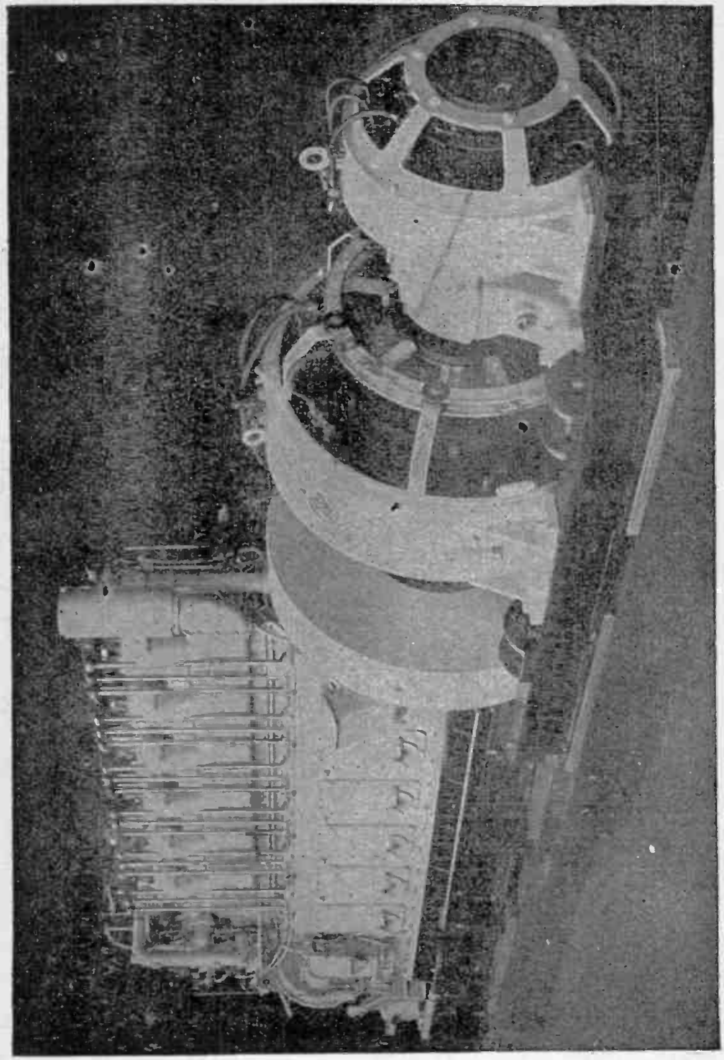
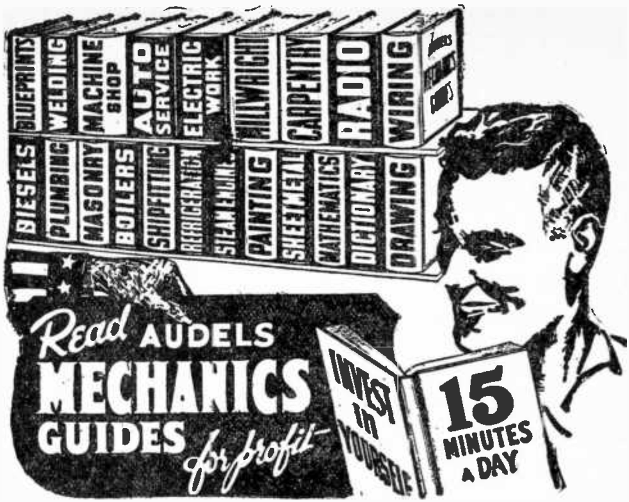


FIG. 7,179.—General Electric Diesel engine with main and auxiliary dynamos for M. S. Farrington.

ahead movement except that in the movement of the lever from the off to astern position, the armature circuit is reversed.

TEST QUESTIONS

1. *How are electric ship drive systems classified with respect to the prime mover?*
2. *What is the object of the electric drive?*
3. *Name some inherent defects of the turbine and internal combustion engine.*
4. *Why are multi-cylinders used on Diesel engines?*
5. *Are reversible prime movers used with electric drive?*
6. *Which system uses* a.c. *and which* d.c. *in most cases?*
7. *Explain in detail the turbine electric drive.*
8. *Name three types of* a.c. *motors used.*
9. *Draw a typical diagram of main and auxiliary circuits, and explain in detail.*
10. *Give* 14 *operating points on electrically driven vessels.*
11. *Explain in detail Diesel electric drive.*
12. *Give numerous operating hints on the Diesel electric drive.*
13. *Explain rheostatic or armature control.*
14. *What other name is given to variable voltage control?*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MACHINE SHOP
AUTO SERVICE
ELECTRIC WORK
MILLWRIGHT
CARPENTRY
RADIO
WIRING
DIESELS
PLUMBING
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