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NEWNES PRACTICAL ELECTRICAL ENGINEERING

IN THIS PART

SPECIAL TYPES AND COMBINATIONS OF ROTATING ELECTRICAL MACHINERY

HOW CURRENT REACHES THE CONSUMER

TABLE STANDARD LAMPS AND SHADES

TRANSFORMER THEORY AND CONSTRUCTION

1/-

PART 34

A PRACTICAL WORK WRITTEN BY EXPERTS

PRACTICAL ELECTRICAL ENGINEERING

Maintenance of a Static Balancer.

When considering the maintenance of equipment of this type, care should be taken to keep the slip-rings clean and the balancer tank filled to the correct level with good quality transformer oil, when this detail is of the oil immersed type. Note, also, that it is common practice to connect half the interpoles in the positive side, and half in the negative side, when designing a 3-wire generator, and care should be taken to maintain the same method of connection when the machine is reassembled after an overhaul.

The use of a static balancer permits reasonable balance to be maintained between both sides of the system with as much as 20 per cent. out of balance current, but above this amount a balancer machine set is necessary. Moreover, the use of the field rheostat on a balancer machine set gives some control over the degree of balancing, whereas there is no such control when a static balancer is used.

BOOSTERS.

A booster is a special form of D.C. generator which is used to increase, or decrease, the voltage of a circuit. When the voltage is increased, we say that the booster generator is "boosting," but when the circuit voltage is lowered by the opposing booster generator e.m.f., it is said to be "bucking." A booster set usually consists of two machines, the booster generator and its driving motor, and these are commonly direct coupled to each other.

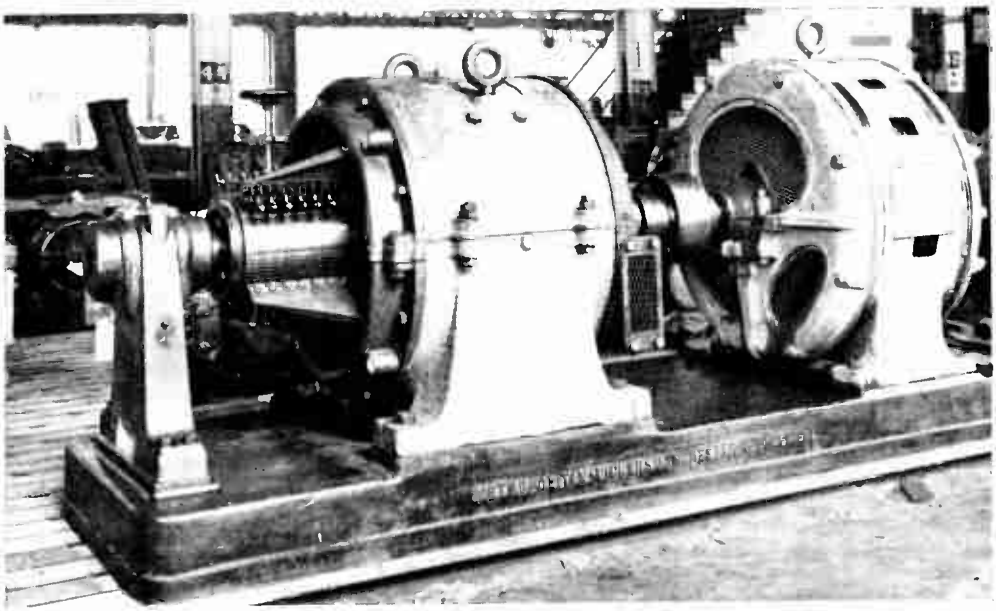

Fig. 5.—HEAVY CURRENT BOOSTER SET.
Observe the large commutator and heavy brushgear. The driving motor is of the A.C. type. This sometimes obtains when the main supply is on the A.C. system while only a comparatively small D.C. load is required; for tramways, for instance. (*Metropolitan-Vickers.*)

Applications of Boosters.

There are three principal applications of boosters; first to assist in the charging and discharging of the batteries used on constant potential D.C. circuits, and in the maintenance of these batteries; secondly, to compensate for the voltage drop in cables supplying outlying areas, and thirdly, to keep the voltage drop in the return rail of traction systems within the limits prescribed by the Board of Trade.

A

Battery Boosters.

There are numerous types of battery booster and many patents have been taken out for these machines; the following brief notes may be of use.

In ordinary practice an accumulator battery is discharged until the voltage per cell has fallen to about 1.8 volts (sometimes less), whereas to give a full charge to the same battery a voltage of at least 2.5 to 2.6 per cell must be applied. When a large battery is used, connected permanently across the terminals of a supply station, it is said to be "floating," and under these conditions it functions somewhat in the manner of a reservoir, i.e., it is charged during periods of light load and it discharges during heavy load peaks. In this manner it improves the "load factor" of the station generators.

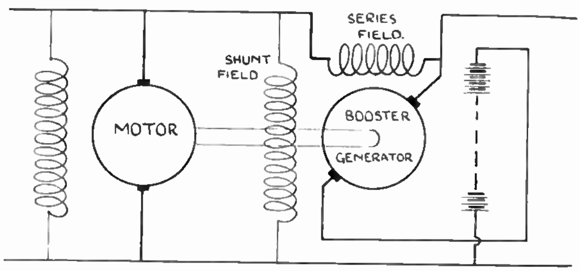

Fig. 6.—DIFFERENTIALLY WOUND REVERSIBLE BATTERY BOOSTER.

In automatic reversible boosters of this type the series and shunt fields oppose each other as described in the text. No field regulation is shown here, but it is usual to connect a field rheostat in the booster generator shunt field circuit so as to provide adjustment of the load at which the battery begins to discharge.

Voltage Across Station Terminals must not Vary.

It will be clear that the voltage across the station terminals must not vary from the declared figure by more than the standard B.O.T. tolerance, and under these circumstances it is necessary to have some form of voltage variation in the battery circuit so that the cells may be fully charged and discharged. The voltage variation is carried out by means of a battery booster.

An Example of Voltage Variation.

Let us take an example. Suppose that we have a 500-volt D.C. system with a battery floating across the busbars for assistance during heavy loads. The number of cells in the battery will be calculated so that the total battery e.m.f. is 500 volts with the lowest voltage per cell at which it is considered advisable to work. If this is 1.8 volts, we have

$$\text{No. of cells} = \frac{500}{1.8} = 278.$$

Now the voltage required to give a full charge to a battery of 278 cells will be approximately

$$278 \times 2.6 = \text{say } 723 \text{ volts},$$

and we therefore require an extra 223 volts to add to the station voltage in order that the battery may receive a full charge.

The battery booster generator will provide this extra 223 volts, and it will usually consist of a shunt wound generator direct coupled to, and driven by, a shunt wound motor which is supplied from the 500-volt system. The connections of the set are shown diagramatically in Fig. 4, and it is clear that, since the voltage of the shunt wound booster generator can be varied by means of the field rheostat, we have a ready means of controlling the amount of boost.

Reversible Battery Booster.

With the connections shown, the booster generated voltage is added to the supply voltage, but, by reversing the booster generator field, its voltage will be applied in the same direction as the battery voltage, i.e., in parallel with the supply e.m.f., and the booster thus helps the battery to discharge, even though the total battery e.m.f. is less than the voltage across the mains. A booster set used in this way is termed a "reversible battery booster," and, since the reversal and control of the booster generator field current necessitates the continual presence of a switchboard attendant, many attempts (successful and otherwise) have been made to devise a combination of machines in which the reversal and control are automatic. Such sets are termed:—

Automatic Reversible Battery Boosters.

This class of apparatus is used when the load fluctuations are sudden and violent, so that the battery is being charged one minute and discharging the next, levelling up the load on the station generators and thus reducing the maximum demand as well as the wear and tear of same. Such conditions as these obtain in D.C. traction systems such as tramways and trains. We will take two typical examples of automatic reversible battery boosters as follows :—

1. The differentially wound booster.
2. The Highfield booster.

The Differentially Wound Booster.

This type of booster set consists of a motor of standard construction, driving a special form of booster generator which is equipped with two independent field windings. One of these fields carries the load current (or a fraction of same), and is so connected as to excite the booster generator so that it tends to help the battery to discharge, i.e., the battery e.m.f. and booster generator voltage are in the same direction ; the other field winding is connected in shunt across the main generator terminals, and is connected so as to oppose the first (or series) winding ; that is to say, it tends to excite the booster generator in such a sense that it will assist in charging the battery. These two windings thus oppose each other and their effects are so adjusted that they balance out on a certain load; regulation is provided to vary the current at which balance is obtained.

It will be clear that at the balance current the booster generator will be unexcited, since the two fields will cancel one another, and it will thus generate no e.m.f. ; at heavier loads, the series field will be stronger and the battery will be helped to discharge and take some of the load off the main generator, while at lighter loads the booster generator will assist in charging the battery ready for the next heavy load period. Thus the control and reversal of the booster generator is entirely automatic, although it will be rather expensive since it has two field windings, entailing twice as much field copper as a normal machine. To overcome this disadvantage, exciter controlled boosters were evolved ; our second example is of this type.

The Highfield Booster.

The connections for this arrangement are shown in Fig. 7. The exciter is a small shunt wound generator which has just sufficient capacity to supply the booster generator field current, and it is wound for a voltage of about the same amount as that of the battery. The connections are so made that the battery and exciter voltages oppose each other, and the set is adjusted so that at a certain load there is no current flowing in the booster generator field windings, because the exciter and battery voltages are equal and opposite. When the load current increases, the main generator voltage drops slightly and the battery begins to discharge, taking some of the load ; as soon as the battery starts discharging, its voltage falls, and since the battery and exciter voltages no longer balance out, current flows in the booster generator field. The connections are so made that this field current excites the booster generator in such a sense that it assists the battery to discharge.

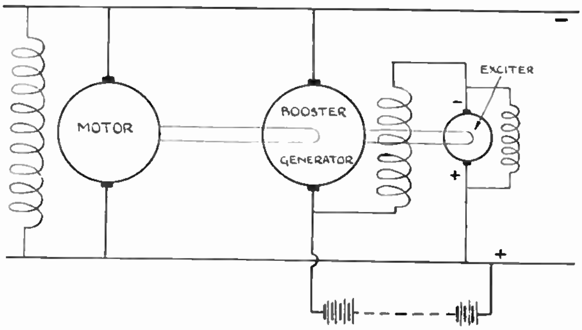

Fig. 7.—The Highfield Battery Booster.
The exciter is usually quite a small machine, either shunt wound as shown or else with some compounding. Its E.M.F. is balanced against that of the battery and by this means the reversal and control of the booster generator is made automatic.

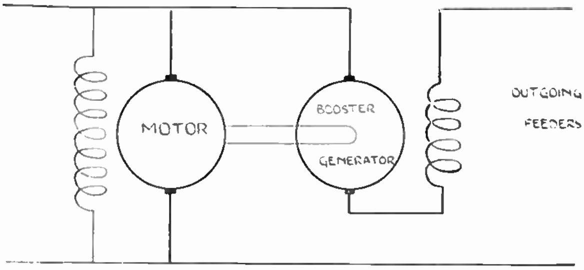

Fig. 8.—A FEEDER BOOSTER.

No regulating means are shown here, but it is usual for a field rheostat to be connected in the motor shunt circuit and for a diverter to control the series wound booster generator field.

On the other hand, when the load current drops, the main voltage increases by a small amount and a charging current starts to flow through the battery. When this occurs the battery terminal P.D. rises, and the balance between battery and exciter is again upset (but in the opposite sense to the previous case), and current flows in the booster generator field in such a direction that the charging is assisted.

Battery Boosters Generally.

On all automatic reversible battery boosters the entire field system is built up of laminations in a similar manner to the armature core; if this is not done, the booster voltage will not be able to follow the load changes quickly enough because of the eddy currents which a rapidly changing magnetic flux would generate in a solid yoke and poles. When cleaning any booster generator, great care should be taken to see that the brush position is not altered, since these machines have to work under rather difficult conditions as regards commutation, and even a small brush movement may upset their operation. If the machines have been dismantled, it must be specially observed that the connections are not altered from their original arrangement when reconnection is undertaken; if this is not done, windings which should oppose each other may be accidentally connected so as to assist, with disastrous results to the booster generator, the battery, or both.

Milking Booster.

On some D.C. systems in which a battery is used across the main busbars, it is the practice to regulate the battery voltage by altering the number of cells in use. During discharge the battery voltage falls and from time to time an extra cell is connected in circuit to raise the total voltage back to its first value. It will be clear that these "end-cells," as they are called, do not get so much use as the main cells composing the battery, and it follows that they cannot receive the same amount of charging as either the main cells or each other without being damaged. It is, therefore, necessary to make some provision for charging these cells separately.

In addition to this, it is sometimes essential in accumulator maintenance to give one cell a prolonged slow charge, the charge being carried on until the cell is "gassing" freely. Both of these operations are carried out by the "milking booster" which gets its name from the milky appearance of the acid in the gassing cell.

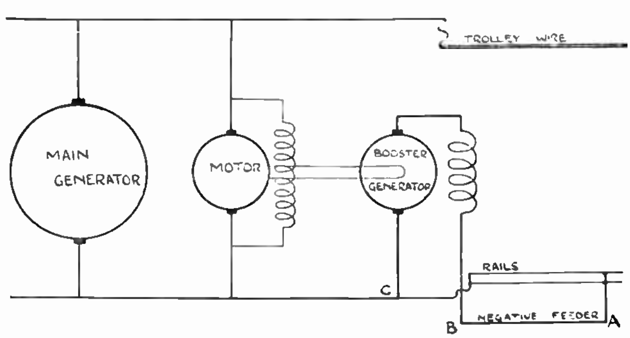

Fig. 9.—CONNECTIONS OF A NEGATIVE BOOSTER.

No main generator field or regulating means are shown. The points A and C are at earth potential, but B is below earth potential due to the resistance drop in the negative feeder. The booster generator is so connected as to provide the necessary E.M.F. to keep B at the correct negative potential.

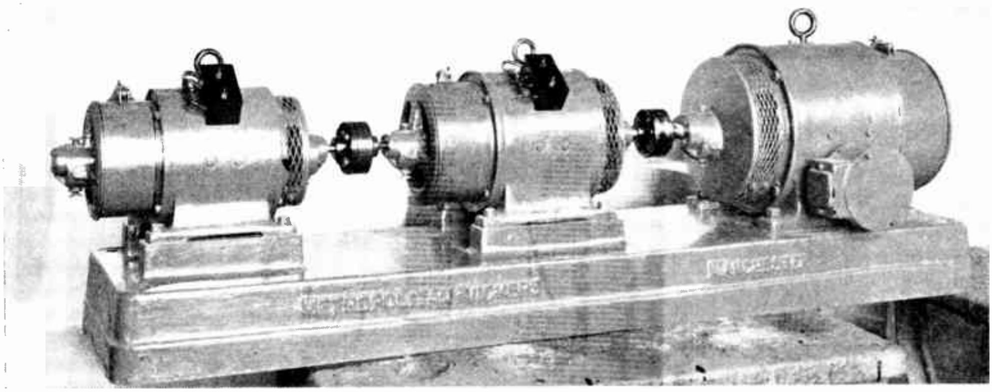

Fig. 10.—A THREE-MACHINE SET.
This small three-machine set shows the general appearance of exciter controlled booster sets. Observe the flexible couplings and the drip-proof commutator covers. (*Metropolitan-Vickers.*)

How the Booster Generator is Excited.

This combination of machines comprises a shunt wound driving motor which is direct coupled to a booster generator wound for a low voltage; about 4 to 6 volts is generally considered sufficient and the booster generator current is chosen with due regard to the normal and maximum charging currents of the accumulator cells. The booster generator is generally separately excited from the high voltage D.C. supply, and a field rheostat is employed to give voltage control during charging.

Maintenance of Milking Boosters.

The only points worthy of note regarding the maintenance of milking boosters are as follows: The booster generator is usually fitted with copper-graphite mixture brushes and the correct pressure for this type of brush material on commutators is about 3 lb. per square inch. Care should be taken that the pressures are as nearly as possible equal on all brushes; otherwise one brush may "grab" most of the load with consequent rapid wear and scoring of the commutator face.

The brushgear should be carefully watched when the machines are first put into service and any tendency to rapid brush wear, "grabbing," or the formation of excessive dust, should receive immediate attention. Milking booster sets are frequently of the portable type and as such are exposed to acid spray and fumes when they are used in the accumulator room; for this reason, the re-enamelling during the annual overhaul should be very thorough, and it should be specified when ordering that the machines must have acid resisting insulation.

Feeder Boosters.

When the load current flows through a feeder cable there is a drop of voltage along the cable due to its resistance, and this results in the voltage at the receiving end (or feeding point) being lower than it is at the generator end. As has already been mentioned, the voltage must be held within certain limits at the consumers' terminals, and it therefore follows that the cable drop must be compensated.

Since the cable resistance may be taken as constant, and as the voltage drop is directly proportional to the product of current and resistance, it is clear that the amount of added voltage must be increased as the load current increases and that it must vary in proportion to the load. For this reason a feeder booster generator is usually of the series wound type, and is so designed as to work on the straight portion of its magnetisation characteristic, i.e., at relatively low magnetic densities. It is thus arranged that the voltage boost, which is generated by the series wound booster generator, is approximately proportional to the current flowing in its field coils, that is, to the main current.

To provide regulation of the ratio of boost to current a field rheostat may be used to vary the speed of the shunt wound driving motor, or a diverter may be employed across the booster generator field.

Negative Boosters.

In a tramway system, the running rails are usually employed as the return, or negative, conductor, and they are usually bonded or welded together for that purpose. It is clear that there will be a drop of voltage along the rails due to the current flowing in them, and it follows that there will be a voltage difference between any two points on the rail system. Now, under these conditions, it is possible for current to leak to earth and flow to the point of lower potential via any path of lower resistance than the rails themselves, and there is a danger that the current may choose to flow along some pipes or other metal work of low resistance; if this happens, the current flow may result in extensive damage due to electrolytic action, and for this reason a Board of Trade regulation limits the potential of rail to earth to not more than about 4.2 volts, and the voltage between any two points on the rail system is not to exceed 7 volts (approx.).

Because of the heavy currents in the rails it is difficult, in systems of any size, to comply with these figures, and for this reason it is usual to install negative feeders. These are insulated cables run to distant points on the rail system and which convey the current from these points back to the power station. To each negative feeder it is usual to connect a negative booster which provides the voltage necessary to drive the current through the negative feeder cable.

Let us take an example. The trolley wire voltage is, say, 500 volts, and the rails are earthed; their potential must, therefore, be taken as zero at the negative feeder connection point. Now the voltage drop along the negative feeder will mean that the station end of it will be at below earth potential, i.e., it will be negative, and the negative booster is so connected as to reduce the station end of the negative feeder to below earth potential. If the drop due to current in the negative feeder in our example is 50 volts, then the booster generator negative terminal will be connected to the feeder and its positive terminal to earth. The current is thus caused to flow through cables of reasonable proportions without the B.O.T. rules being infringed as regards the voltage between rail and earth.

Construction and Maintenance.

In construction, the negative booster is similar to the feeder booster, being usually series wound with a diverter for the field circuit. A shunt wound driving motor is usual. There is very little to say regarding maintenance; brush position is important because of the heavy and rapidly fluctuating currents, and the condition of commutator and brushes must be watched for the same reason. If a diverter resistance is used its contacts should be kept in good condition since the current carried will be of a considerable value.

HOW CURRENT REACHES THE CONSUMER

By JOHN DUMMELOW, B.A. (Cantab.)

BY the end of 1933 nearly all the electricity generated in this country will be sold in bulk to the Central Electricity Board, who will resell it to the local supply authorities. The Board is erecting a network of "extra high tension" transmission lines interconnecting the chief power stations at 132,000 volts three-phase, A.C., which, together with secondary lines working at 66,000 and 33,000 volts, will form the national electricity "grid."

This article deals with apparatus and methods that are typical of modern practice in bringing current from the "grid" to the consumer, but it must be remembered that there are satisfactory alternatives to many of the recommendations given.

Acknowledgments are due to the various manufacturers for supplying much useful data.

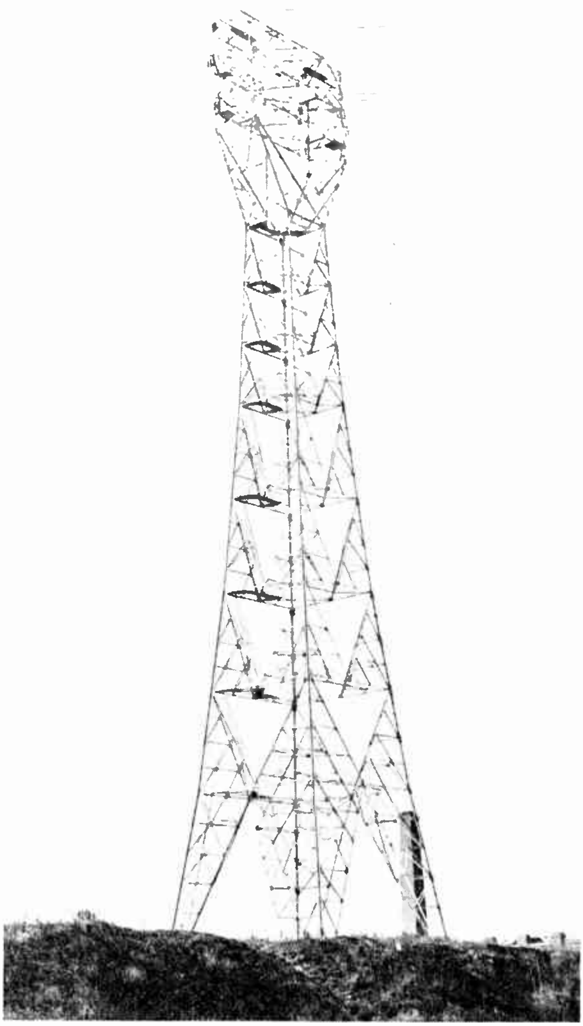

Fig. 1.—"GRID" TRANSMISSION TOWER AT BARKING. This tower is 362 feet high and carries four 66,000-volt 3-phase circuits. (*Pirelli-General Cable Works, Ltd.*)

GENERAL DESCRIPTION

What the "Grid" is for.

In Great Britain there are over six hundred authorised supply undertakings with about five hundred power stations, each selling electricity in its own area, on its own system and at its own price. The purpose of the "grid" is to provide a pool from which all the local undertakings can draw their supplies so as to enable current to be sold on a standard system, at a standard voltage and frequency, and for a standard price in whatever part of England, Scotland or Wales it may be generated.

How the "Grid" System Originated.

The "grid" originated in the Electricity (Supply) Act, 1926, which divided Great Britain into ten areas, seven for England and Wales and three for Scotland. For each area a scheme of interconnection was to be prepared by the Electricity Commissioners, and the Central Electricity Board—a body of eight business men appointed by the Government—was set up to adopt the schemes after consideration (and amendment if necessary) and put them into force.

The Board will form the wholesale side of the electricity supply industry, selling current to the local undertakings at a price fixed to cover the expenses of constructing and operating the "grid" system.

About 130 of the most efficient and best placed of the existing power stations were chosen to supply the "grid," together with eleven new stations, which are being built on the most economical sites; the owners of the selected stations are under statutory obligation to operate their plant as directed by the Central Electricity Board, and to sell to the Board all the electricity so generated.

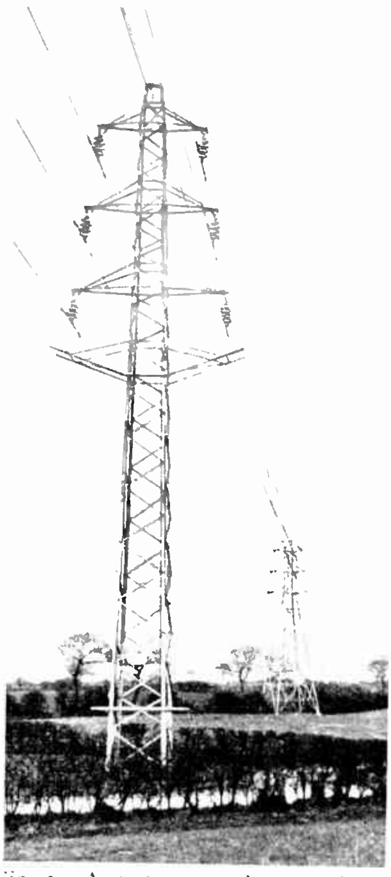

Fig. 2—A 33,000-VOLT LATTICE STEEL TOWER "GRID" TRANSMISSION LINE. (*Pirelli-General Cable Works, Ltd.*)

How the Power Stations are Linked Up.

The selected stations are being linked up by about 3,000 miles of 132,000-volt primary transmission lines. Overhead conductors of steel-cored aluminium are used with 900 ft. spans supported on lattice steel towers 70-80 ft. high. For crossing large navigable rivers the longer spans necessitate the height of the towers being raised, in some cases to 500 feet. Both single and double circuit lines are used. Each conductor has an overall diameter of .77 in. and consists of 30 aluminium strands and 7 steel strands; they are hung about 12 feet apart on chains of porcelain insulators of the cap-and-pin type. Short branches and loops will be provided by about 1,200 miles of secondary lines at 33,000 volts, with conductors and towers similar to those used on the primary lines, but on a smaller scale.

Underground Cables for Crowded Areas.

In crowded urban areas underground cables are used, working chiefly at 66,000 volts. The cables are paper insulated and oil filled; the wires are twisted round a spiral of steel strip forming a hollow tube, which is kept filled with oil at constant pressure; this prevents deterioration due to gas spaces in the insulation. The diameter of the conductors ranges up to .25 in. (on the 132,000-volt lines).

Transforming Stations.

The supply undertakings will take current (usually at 11,000 volts) from the "grid" network at transforming stations situated at convenient points. All transforming stations are of the outdoor type, equipped with switchgear to control the circuits, transformers to reduce the voltage, and meters to give the energy transfer, maximum demand and power factor readings that will be necessary to determine the bulk price of electricity. The transformers are air-cooled and range in capacity from 7,500 to 75,000 kVA.; the switchgear includes isolating switches and oil circuit-breakers, the latter having a breaking capacity of 1,500,000 kVA. at 132,000 volts. Protection against electrical faults such as overloads and leakage is provided by means of relays and other devices.

Central Control Room.

Operations in each area will be directed and supervised from a central control room by an elaborate system of telephones and automatic signalling, and eventually the actual switching operations at the distant stations will be effected from the same point.

How Local Areas are Supplied.

The standard system of transmitting current purchased from the "grid" to rural areas is by high-tension lines at 11,000 volts, usually three-phase but often single-phase for small villages and isolated farms or residences. Distribution to consumers is carried out by low-tension lines on the three-phase four-wire system with 400 volts between phases and 230 volts to an earthed neutral, house services being given at 230 volts single-phase. In large rural areas and in towns where existing apparatus has to be considered, other systems may be necessary, but for new electrifications the standards given above are almost always adopted.

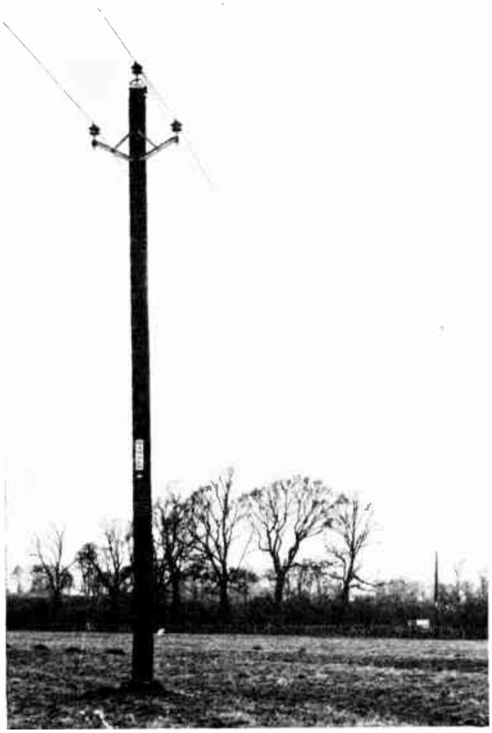

Fig. 3—THREE-PHASE 11,000-VOLT HIGH TENSION TRANSMISSION LINE. (*Johnson & Phillips, Ltd.*)
Note sloping cross-arms to keep off birds.

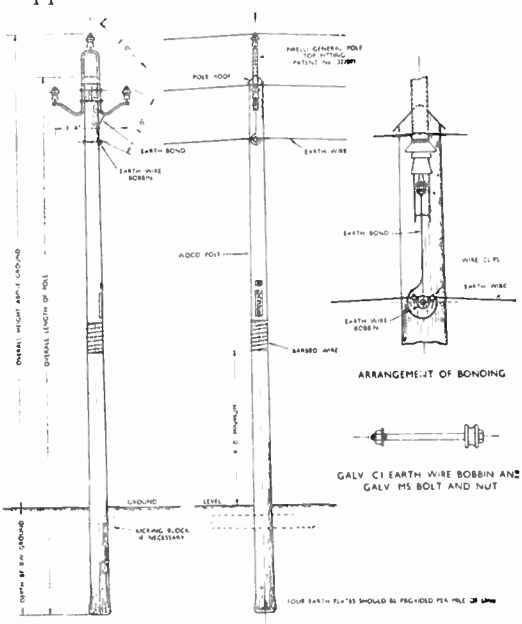

Fig. 4.—DIAGRAM OF STRAIGHT LINE WOOD POLE FOR THREE-PHASE HIGH TENSION TRANSMISSION. (*G.E.C.*)
Showing continuous earth wire.

Transmission and distribution of "grid" current to the consumer may be carried out either overhead or underground. Underground cables are much the more expensive, but they may be necessary for taking H.T. supplies into otherwise inaccessible urban areas and L.T. supplies where there are trees, high banks, or other obstacles to overhead construction.

In addition to the power lines themselves substation apparatus must be provided. At tapping points (i.e., where L.T. lines branch off H.T. lines) transformers are installed to reduce the voltage, and at terminals and junction points switchgear is fitted for controlling purposes. Protective equipment is necessary to prevent apparatus being damaged by electrical faults or by voltage surges due to atmospheric disturbances (on overhead lines).

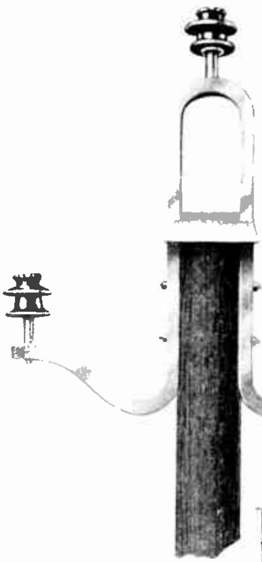

Fig 5.—Cross-Arm and Insulators for H.T. Transmission Line. (*Pirelli-General.*)

SECTION I.—OVERHEAD LINES. HIGH TENSION TRANSMISSION.

Single circuit lines are generally used. Where continuity of supply is very important another route may be selected for the second circuit, and the two connected together to form a ring main, thus extending the area supplied.

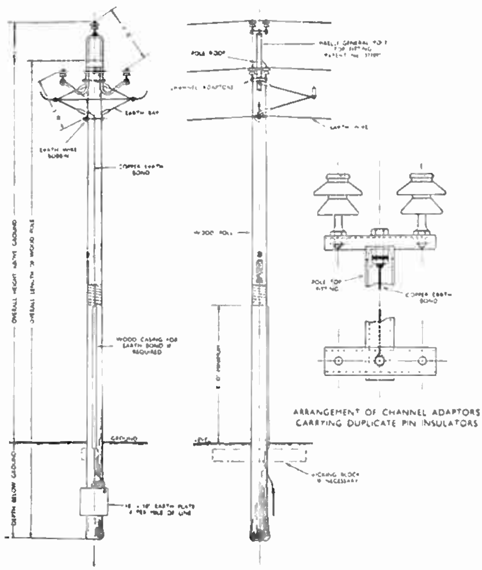

Fig. 6.—Single Pole for H.T. Transmission Line. (*G.E.C.*) Showing details of earth bar for guarding at road-crossings.

Conductors.

The conductor size is generally determined by considerations of voltage drop. Steel-cored aluminium is used for large conductors and long spans without a continuous earth wire such as are common in rural areas. For lighter loads in less populated districts, electrical conductivity becomes secondary to mechanical strength and cadmium copper, copperweld (a steel wire in a copper sheath), composite copper and copperweld, copper-cored steel, or galvanised steel may be used, the last being the cheapest and most suitable for spur lines where the current to be carried is very small.

Particulars of some conductors in common use are given in the table below:—

Conductor.	Overall Diameter. Ins.	Breaking Strength. lb.	Span. Ft.	Sag. Ft.
7/12 S.W.G. Steel ..	.312	5990	534	6.86
7/12 S.W.G. Copper-cored steel	.312	5592	525	8.24
.025 sq. in. Equiv. Cadmium copper	.243	2744	425	9.21
.035 sq. in. Equiv. Composite	.276	4370	500	8.5
.05 sq. in. Equiv. Steel-cored aluminium ..	.396	4106	450	10.04

All steel wires are of 45-ton quality. The composite conductor in the table consists of one strand of extra high-tensile copperweld surrounded by eleven strands of H.D. copper. Conductors are almost always stranded so as to facilitate erection and reduce the risk of crystallisation.

Spans.

Spans between poles should be as long as possible to reduce the initial cost due to fewer poles and wayleaves being required, the wayleave rentals, and the possibility of electrical faults. The spans given in the

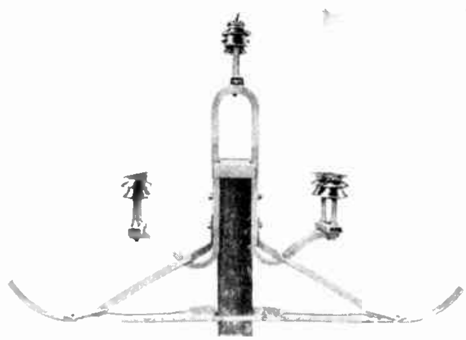

Fig. 7.—Earth Bar and Dup. Insulators. (*Pirelli-General Cable Works, Ltd.*)

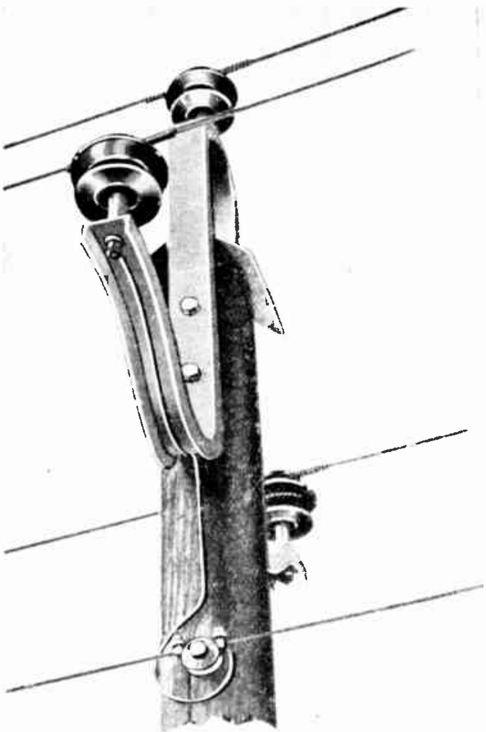

Fig. 8.—METHOD OF BONDING TO EARTH WIRE. (*Pirelli-General Cable Works, Ltd.*)

table are suitable for a three-phase single-circuit single wood pole rural line without continuous earth wire, and the corresponding sags allow a factor of safety of two when complying with the Electricity Commissioners' Regulations.

Poles.

Single-wood poles of winter-felled Norwegian red fir are generally used. The poles are 38-40ft. high and taper slightly from a diameter of about 12 in. at 5 ft. from the butt, to 8-10 in. at the top. At terminals and sharp angles and at section points or sub-stations where switchgear or transformers are mounted on the poles the conductors are tensioned off, and "A" type, "H" type, or four-member poles may be necessary. The wood should be creosoted under pressure to prevent rotting.

A straight line pole in ordinary soil may be planted either 7 ft. deep or 6 ft. deep with a kicking block. Single poles at angles and terminals should be planted 6 ft. deep and fitted with stays, the vertical load of which (except at wide angles) is dealt with by a foot block placed under the butt of the pole. Stays are placed at 45 degrees slope. The stay wire is attached by a bow tightener to a rod 7-9 ft. long, which terminates in a plate on the far side of a stay block of creosoted wood, planted 4-5 ft. deep.

The pole hole is dug somewhat like a stepped trench and should be as narrow as possible laterally so that there is firm earth against the normal direction of load. When filling in, the earth must be well rammed, and layers of broken stone may be placed round the pole at the butt and at about one-third of the depth below the ground; kicking blocks are placed at the latter point.

Insulators.

For straight line and medium angle poles the conductors are nearly always carried on pin-type insulators, consisting of galvanised steel pins screwed into threaded lead thimbles in brown glazed porcelains about $5\frac{1}{8}$-in. diameter. On straight lines the conductor is laid in a groove on the top of the insulator, and at angles in the side groove.

At terminals, section poles, and angles where the deviations are considerable, the conductors must be anchored off by heavy tension-type insulators (Figs. 10 and 11), each consisting of a $7\frac{1}{2}$-in. diameter porcelain with a metal cap cemented on to the apex and a pin screwed into the interior. In industrial districts and near the coast, 10-in. units should be used to reduce the effect of atmospheric deposits. Electrical continuity at straining points is provided by conductor tails or jumpers from one section to another.

Cross-arms.

The three conductors are arranged in triangular formation. All three pin insulators may be mounted on a single length of channel iron (Fig. 5), shaped to give the correct position of the conductors, and clamped to the pole by bolts which lie in the plane of the arms so that the fitting can be mounted without lifting the pole from the ground. Otherwise the two outer insulators may be mounted on a vee-shaped cross-arm of angle iron, and the third insulator on a ridge iron on top of the pole (Fig. 3). In both cases the arms are made sloping so as not to give a foothold for birds.

At straining points, the tension insulator at the top is attached to eye bolts and the two lower insulators to forged eyes in the end of special cross-arms.

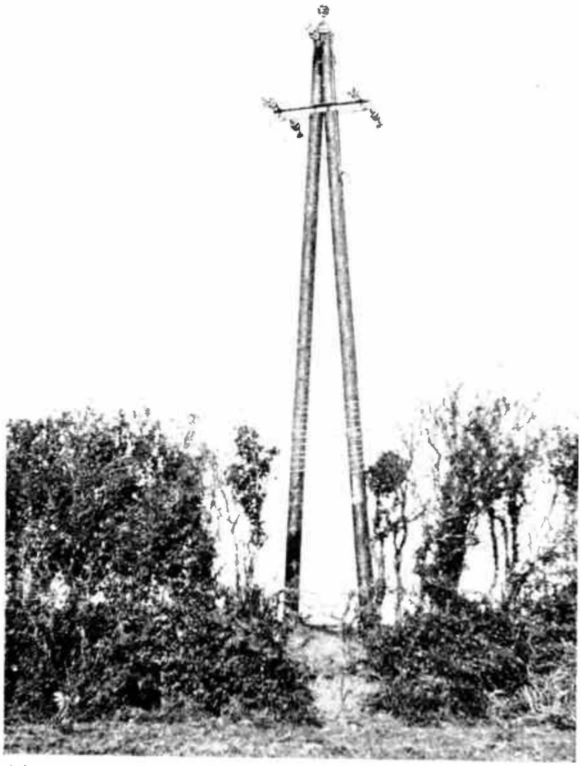

Fig. 9.—"A" POLE AT STRAINING POINT ON HIGH TENSION TRANSMISSION LINE. (*Pirelli-General Cable Works, Ltd.*)

Earthing.

The structural ironwork on each pole must be earthed, either by means of a continuous wire carried on the poles and earthed every ¼-mile, or by individual earthing at each pole. Overhead earth wires are more expensive, except with short spans or where the ground is unsatisfactory for earthing.

A 7/12 S.W.G. galvanised steel wire is used and is carried on iron bobbins mounted either above the conductors on a special bracket or below them direct on the pole.

With an under-running earth wire a bond is clamped at one end to one of the insulator pins and at the other to the earth wire (Fig. 8).

The earthing is effected by means of a bare soft copper wire which is clamped either to one of the insulator pins or to the under-running earth wire, taken down the pole, and connected by a copper bond to a cast-iron earth plate buried near the pole butt; the wire is protected up the pole by an 8 ft. wooden casing.

Guarding.

For crossing public roads the insulators must be duplicated and earthing brackets, carrying a bar about 7 ft. long, fitted (Fig. 6 & 7); bridle lengths of conductor bridging the duplicate insulators are sometimes added. Where the line runs parallel to and within 50 ft. of a public road, earthing brackets are sufficient.

For crossing railway lines the railway companies usually require duplicate insulators and duplicate conductors bonded together every 5 ft.; the additional loading necessitates shorter spans.

For crossing private or farm roads or public footpaths and where the transmission line runs parallel to railways, no guarding is required. Where the line has to cross Post Office wires one or the other must go underground.

Erection.

Conductors are sent to site on a number of identical drums each holding about 1 mile; standard lengths reduce the number of scrap ends and are generally more economical.

The conductors should not be drawn along roads or over stony ground. The drum is mounted on a stand in direct line with the poles and at a distance from the foot of the first pole equal to the height of the pole. It should be provided with a brake to prevent over-running and kinking the conductor.

A light flexible steel running line is spliced to the end of each drum length and, after running out and hauling up to the cross-arms by a hemp line, is then laid in the snatch blocks. At the free end the winch or other pulling-up tackle is attached to the running line, and the conductor length is wound off. When the whole of the conductor has been paid out, the free end must be jointed to the succeeding length or tensioned off at a straining point.

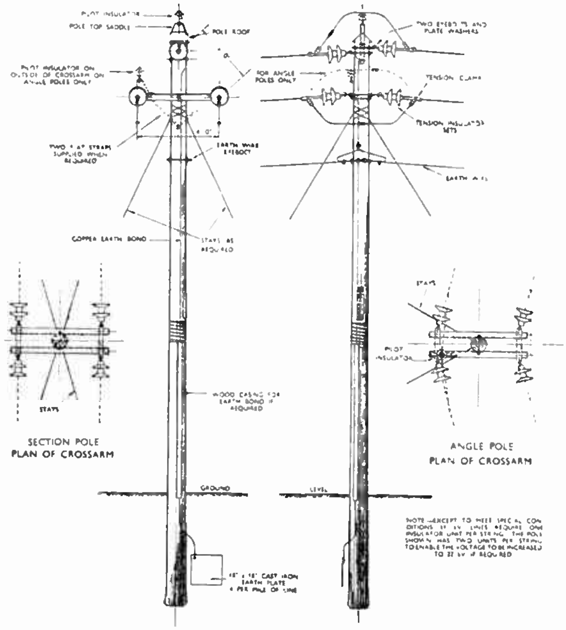

Fig. 10.—Details of Single Pole at Straining Point on H.T. Line. (*G.E.C.*)

Binds.

The conductors are held in place on the insulators by means of binds. About 9-11 ft. of 14/0 S.W.G. soft binding wire of the same metal as the conductor is generally used.

When binding in the top groove, two equal lengths of binding wire may be laid side by side with some inches of single wire projecting at each end. The middle of the double wire is placed opposite the centre of the insulator, and the conductor is bound for rather more than the length of the insulator groove. The two wires at one end are twisted together until each can be passed round the neck of the insulator in opposite directions; they are then twisted together again to reach the conductor. The other end of the bind is treated in the same way. The short wire of each pair is taken round the conductor for five or six turns, and the long wires are crossed over the top of the insulator and finished off with about eight turns round the conductor.

When binding in the side groove, the middle point of the binding wire is placed opposite the centre of the insulator and the conductor bound for a distance equal to the diameter of the insulator neck. Each end in turn is passed once round the neck of the insulator, twice round the conductor, and once round the insulator again; it is then taken round the conductor for about a dozen turns to finish off.

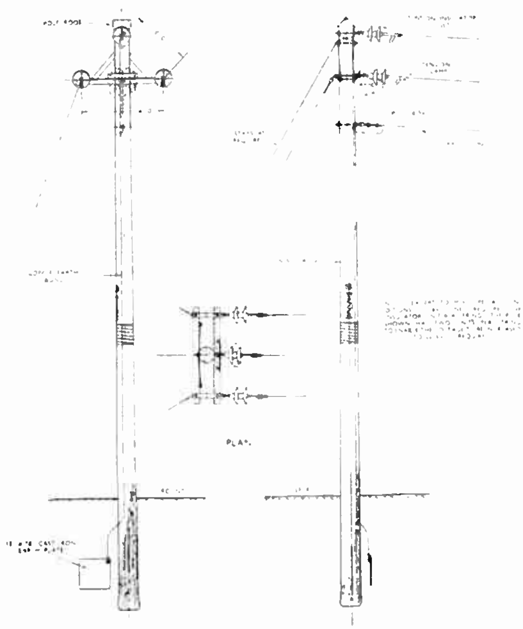

Fig. 11.—Details of an H.T. Terminal Pole Showing Tension Insulators. (*G.E.C.*)

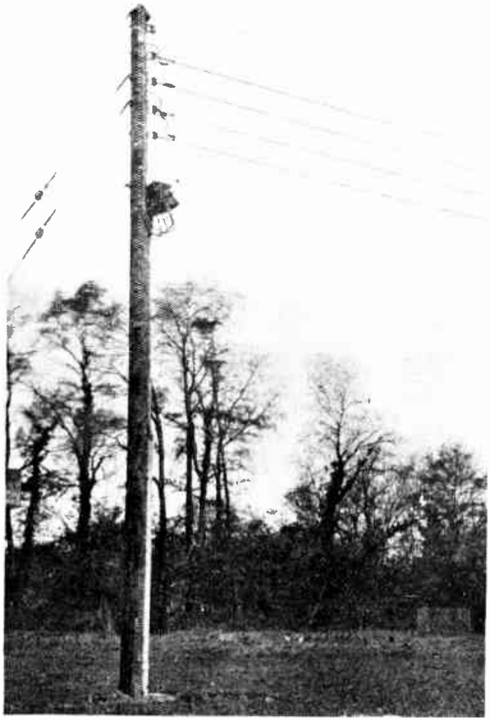

Fig. 12.—TERMINAL POLE FOR LOW TENSION DISTRIBUTION.
This shows the method used for the three-phase, four-wire system. Note the dividing box for connection to underground cable.
(*Pirelli-General Cable Works, Ltd.*)

For the long spans of rural work the conductor, after wrapping with tape, may be bound to the extensions of two stirrups, which fit accurately into the side groove of the insulator and extend along and under the conductor in both directions. The stirrups, tape, and binding wire are made of copper, except for s.c.a. lines, where they are of aluminium.

Joints.

For joints under mechanical load the torsion type designed to withstand 95 per cent. of the ultimate strength of the conductor is recommended. The joints should be approximately opposite one another.

The two ends to be jointed are first vaselined and slipped from opposite ends into a seamless oval tube of copper (or aluminium for s.c.a. lines). The tube is then gripped at each end by a pair of twisting tongs and given $4\frac{1}{2}$-$5\frac{1}{2}$ complete twists, the half-twist being necessary to bring the two parts of the cable into a straight line. For s.c.a. lines a double length tube is used with twice the number of twists. To ensure that the tube twists evenly, one half should be dealt with first, and care should be taken to turn it in the direction of the stranding of the conductor. The completed joint may be filled with a suitable grease such as graphitic paste (except on cadmium copper lines) to keep out moisture.

Joints not under mechanical load can be made by means of parallel groove clamps of galvanised iron, brass, or aluminium, according to the type of conductor.

Parallel groove clamps consist of two parts bolted together to grip the conductors in grooves one on each side of the line of bolts.

To ensure a large contact surface and low resistance at the joint, the clamp should be at least six times the diameter of the conductor, and the bolts should be large and numerous enough to exert heavy pressure when tightened.

Where the current is too heavy for a galvanised clamp, steel or copper tappings may be taken off s.c.a. lines by means of bimetallic connectors with insulating washers.

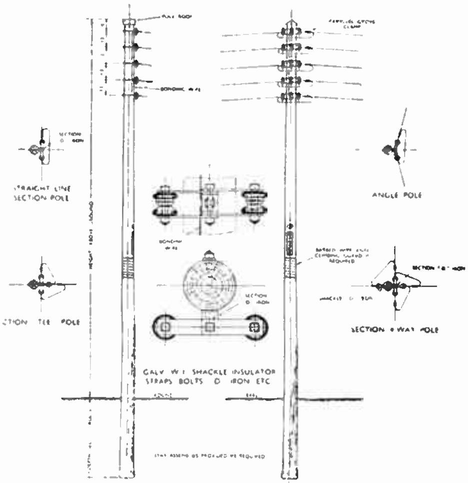

Fig. 13.—DETAILS OF STRAINING POINT POLE FOR LOW TENSION DISTRIBUTION LINES. (*G.E.C.*)

Terminating.

At straining points (Figs. 10 and 11) the conductors are anchored off by means of tension clamps or thimbles (with the smaller conductors and cadmium copper lines), a tail being left for jointing to the next section. Conductors other than steel are protected from damage by binding them with a layer of tape, aluminium for s.c.a. lines and copper for conductors of other materials.

Tension clamps are designed to take most of the load at a radius round which the conductor is bent. The clamp is in two halves, usually of galvanised malleable iron. The conductor is strung up and fastened off temporarily, and the clamp is fitted on with the bolted part in line with the conductor. It is then attached to the tension insulator and the temporary fastening loosened, when the conductor will bend naturally round the radius and the clamp take up its proper position.

Thimbles or eyelets are heart-shaped and made of galvanised iron. The conductor is bent round the thimble, and the two sides of the loop are bolted together by "U"-bolt clamps, the "U" pressing on the side that is not under tension.

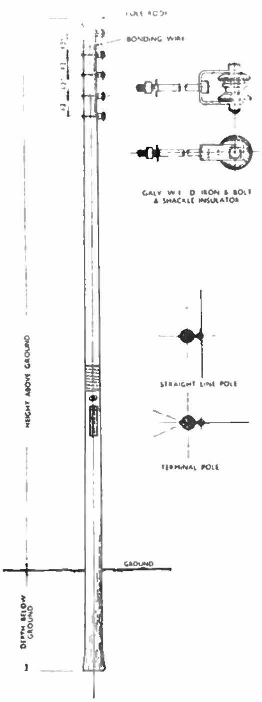

Fig. 14.—Details of Single Wood Pole for Low Tension Distribution Line. (*G.E.C.*)

Single-phase Lines.

The above description applies to three-phase lines.

On single-phase lines the two conductors are usually of 7/12 S.W.G. steel, arranged in the same way as the two lower conductors on three-phase systems. The usual span for rural work is 520 ft. requiring a pole 34 ft. long overall and $10\frac{3}{4}$ in. diameter at 5 ft. from the butt. The poles are planted 6 ft. 6 in. deep or 6 ft. where stays are used; in normal ground kicking blocks are not required.

LOW TENSION DISTRIBUTION.

Conductors.

Conductors are usually of stranded copper, .1 sq. in. for main runs and .05 sq. in. for branches. Where the larger size is not sufficient it is often advisable to develop an alternative route and form a ring main.

Cross-sectional area. Sq. in.	Stranding. No./Ins.	Overall diam. Ins.	Breaking load. lb.
.1	7/.136	.408	5872
.05	3/.147	.317	2914

Spans.

Spans of 150 ft. are most satisfactory; longer spans are inconvenient as they may not provide suitable points for taking off service lines, the routes are seldom straight, and many pole positions are fixed by points where roads branch off.

A sag of at least 2 ft. should be allowed to avoid trouble with the poles bending at angle positions.

Poles.

Single member poles of creosoted red fir or tubular steel (at a higher cost) are used. Wood poles are about 28 ft. long overall, and the diam. measured 5 ft. from the butt may be $7\frac{3}{4}$ in. for .1 sq. in. and $7\frac{1}{2}$ in. for .05 sq. in. conductors. There should be a clearance of 17 ft. between the lowest conductor and the ground, and at road crossings poles 30 ft. overall with slightly increased diameters must be used giving a 19 ft. clearance.

In ordinary soil the poles should be planted 5 ft. deep, no kicking blocks being required. At small angles a larger pole, e.g., 11 in. diameter, can be used with a kicking block. At wide angles it is necessary to use stays or, where this is not possible, struts.

Stays are similar to those used on H.T. lines. The stay wire should be fitted with an insulator of ample dimensions and capable of withstanding the same mechanical load as the stay.

Struts consist of wood poles, 2 ft. shorter and $\frac{1}{4}$ in. less in diameter than the main pole, and placed at 30 degrees to the vertical. The bottom of the strut is

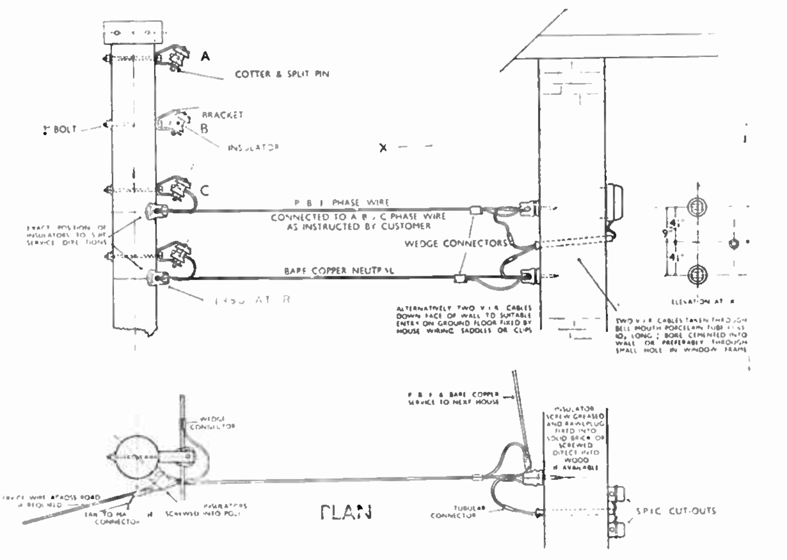

Fig. 15.—How an Overhead Service to a House is Taken from Low Tension Distribution Line. (*Johnson & Phillips, Ltd.*)

fitted with a kicking block and the top bolted to the pole at the centre of the conductor loading. A tie rod surrounded by a distance tube is fitted horizontally between strut and pole about half way up.

Insulators and Brackets.

The conductors are usually arranged vertically at 12-in. centres with the neutral at the bottom.

Shackle-type porcelain insulators carried on "D" brackets of wrought iron are generally used, the porcelains being fixed in the brackets by cotters and split pins or by nuts and bolts. The brackets are fixed to wood poles by bolts and to steel poles by wrought-iron clips.

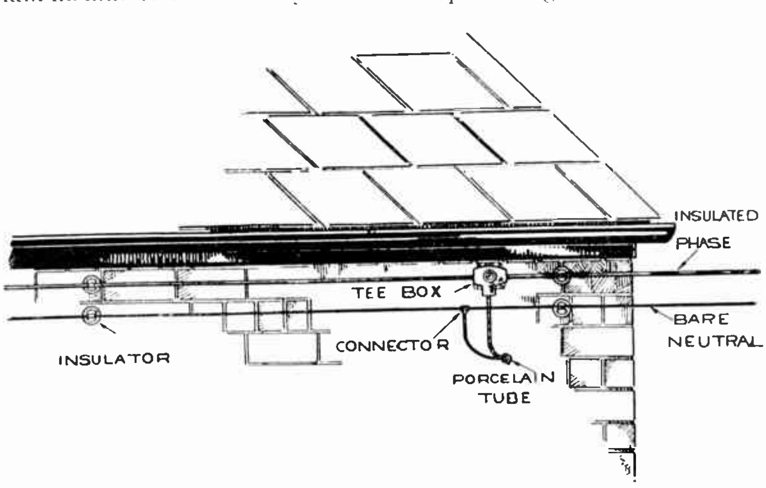

Fig. 16.—Arrangement for House-to-house Services under the Eaves. (*Johnson & Phillips, Ltd.*)

Earthing.

Continuous earth wires are not required with wood poles, but all iron work must be bonded together by means of a galvanised iron wire. Steel poles are provided with a cast-iron earth plate.

Guarding.

Guarding is only necessary for crossing P.O. lines.

Where the power line is underneath, a 7/14 S.W.G. steel-strand guard wire should be erected above the conductors, supported on insulators and bonded to the neutral conductor.

Where the power line is above the P.O. line the conductors should consist of P.B.J. wire of stranded copper insulated with impregnated paper with a cotton covering and a cotton braiding overall, both impregnated with red lead compound. After installation the red lead hardens by oxidisation, providing a reliable covering of high enough resistance to prevent danger to telephone operators if a telephone wire comes into contact with a power wire.

Joints.

Joints under mechanical load may be made with cone type clamps, but where possible they should be arranged to occur at straining points so that the conductors can be terminated on each side of the pole and the tails only jointed.

Joints not under mechanical load may be made by parallel groove clamps or by soldered sleeves. The latter are formed by butting the two ends of the conductors together in a split sleeve of tinned copper and soldering to make a solid joint.

Terminating.

At straining points the conductor is taken round the insulator and fastened off by binding wire or "U" bolt clamps, leaving a tail for connection to the next section of line.

HOUSE SERVICES.

House services can be taken to single houses by means of lightly insulated conductors carried on porcelain insulators and tensioned. Fully insulated cables may also be used, either suspended from a catenary wire (to single houses or from house to house) or carried under the eaves on porcelain insulators or cleats.

The cables leading into the house are fully insulated and are carried through the walls in a porcelain bell-mouthed tube, cemented into the wall or taken through the window frame. They are terminated in two single-pole cut-outs in cast-iron cases.

Conductors.

Services are usually taken off the distribution line by means of a P.B.J. phase wire and a bare copper earthed neutral, a convenient size being .0225 sq. in. section and 7/.064-in. strand. A similar cable insulated with varnished cambric tape instead of paper is also used.

For catenary suspension rubber-insulated cables are used, the sizes varying from .225 sq. in. and 7/.064 in. strand to .1 sq. in. and 19/.083 in. strand; for running under the eaves "Sotonite" compound-insulated cable or twin-core "Anti-pluvius" cable (3/.036, 7/.029 or 7/.044 in.) is recommended.

For leading in to the house two single-core tough rubber sheathed cables are used.

Spans.

Spans may vary from short lengths up to 200 ft. For the longer distances intermediate poles may be necessary, the line becoming practically a single phase distribution line.

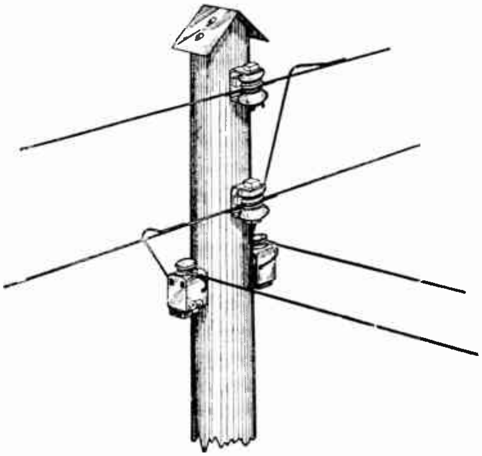

Fig. 17.—Method of Using "Tapoff" Fuse Insulator for Taking Off House Service From Low Tension Distribution Line. (*G.E.C.*)

Insulators and Brackets.

Shackle type insulators may be arranged vertically on the distribution pole or on a "D" iron bolted to an iron bracket on the wall. Another type, which can be used at either end of the service line, consists of a brown glazed porcelain with a screw or a steel stud cemented into it for fixing on wood or steel poles or on the wall. A large hole is provided in the porcelain allowing four or five services to be taken from one insulator.

Cleats consist of two sections of white porcelain provided with grooves to grip the cable; they may be bolted on to eye spikes or screwed direct to the wall.

Alternatively, a "Tapoff" combined insulator and fuse, consisting of a hollow

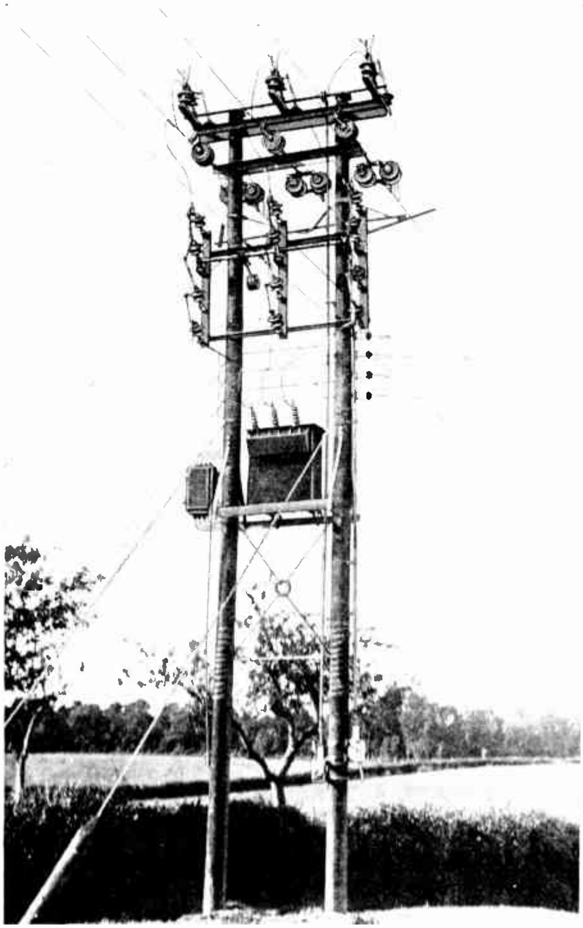

Fig. 18.—" H " POLE OUTDOOR SUBSTATION (WITH H.T. SWITCHGEAR AND TRANSFORMER). Showing H.T. lines above and L.T. below. (*Pirelli-General Cable Works, Ltd.*)

brown porcelain containing a withdrawable fuse, can be used. The distribution wire is taken direct to one fuse contact, and the service wire taken from the other contact round a knob at the top of the porcelain to the house.

Joints.

The service wires are connected to the distribution line by wedge connectors and to the lead-in wires by tubular brass connectors with screws.

With house to house systems the lead-in wires are taken off by brass "T" connectors. The phase wire connector is enclosed in a cast-iron box with a removable plug at the top for filling with compound.

SUBSTATIONS.

The substation equipment must be weatherproof and, except when large transformers are necessary, can be mounted on one of the transmission line poles, either on a platform or slung from cross-arms.

Transformers.

The maximum outputs of transformers for mounting on single, " H " type or four-member poles respectively are 25, 75 and 150 kVA. (three-phase) and 35, 100 and 200 kVA. (single-phase).

Transformers are of the oil-immersed natural cooling type. On pole-mounted sizes the terminals may consist of porcelain bushings passing at an angle through the side of the tank and arranged to take cambric-covered or bare copper connections (Fig. 21). On the larger sizes cable boxes may be fitted.

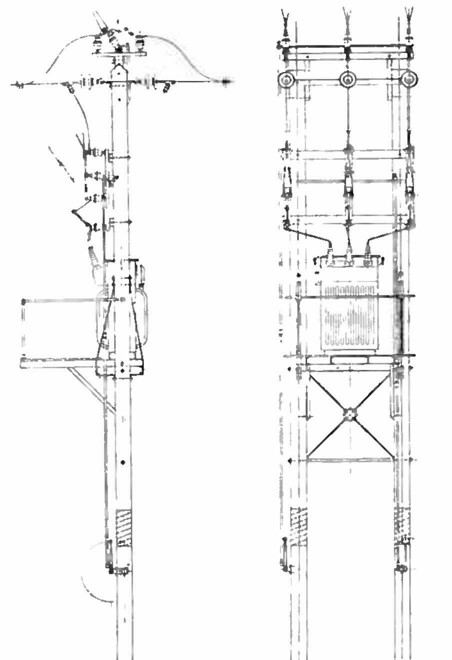

Fig. 19.—" H " POLE SUBSTATION SHOWING H.T. AIR-BREAK SWITCHES AND FUSES AND TRANSFORMER. (*G.E.C.*)

Voltage regulation is given by metallic bridges and tappings on the H.T. windings at 2½ and 5 per cent. above and below the normal voltage.

Switch and Protective Gear.

General switching and protective requirements can be met by hand-operated switches and H.T. fuses, which disconnect the transformers from the H.T. line in the event of faults and short circuits. Air break switches and fuses are cheap and effective. Oil switch-fuses are often used, and automatic circuit-breakers, though more expensive, are sometimes desirable. Air break switch and protective gear is insulated by mounting it on petticoat type porcelain insulators.

L.T. fuses protect the transformers from faults in the distribution system.

Air Break Switches and Fuses.

For isolation purposes single pole knife switches (which are not suitable for breaking load currents) can be used, operated from the ground by an insulated rod. For breaking load currents or magnetising currents of large transformers up to 300 kVA. a triple pole horn break switch is used, mechanically operated from ground level (Fig. 19). The blades are fitted with arcing horns which make contact before and break contact after the main blades, thus drawing out the arc. H.T. fuses are often mounted on the same framework as the switches to form air break switch-fuses (Fig. 22).

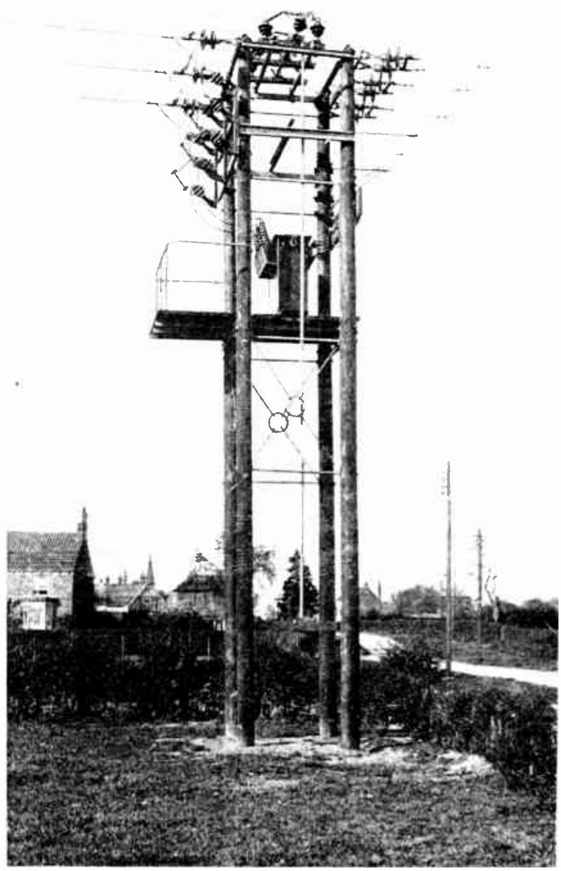

Fig. 20.—ANOTHER TYPICAL OUTDOOR SWITCHGEAR AND TRANSFORMER SUBSTATION FOR TAKING LOW TENSION OFF HIGH TENSION LINE. (*G.E.C.*)

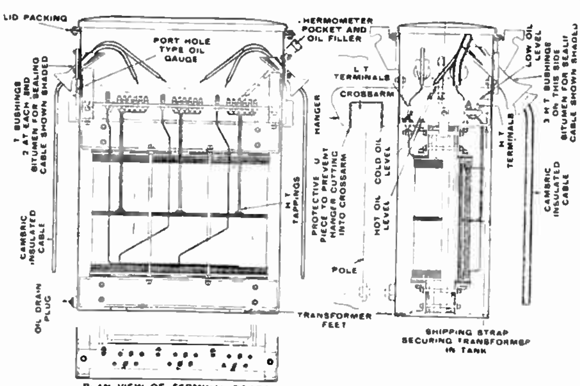

Fig. 21.—DETAILS OF POLE MOUNTING TRANSFORMER. Showing method of connection for cables and mounting for transformer on cross-arm. (*G.E.C.*)

Surge Protection.

To prevent damage from voltage surges, due to switching or faults, and from excessive potential rises, due to atmospheric disturbances, special precautions must be taken. When a surge of high frequency and steep wave front travels along a line and encounters an inductive

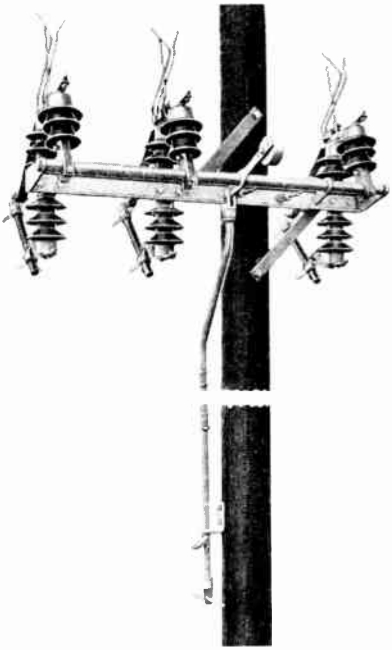

Fig. 22. AIR BREAK SWITCH FUSE FOR SECTIONALISING RURAL DISTRIBUTION LINES. (*G.E.C.*)

winding (e.g., in a transformer), it instantaneously produces a high voltage between the end turns and also to ground. The insulation of the end turns (about 5 per cent. of the total number of turns) is therefore reinforced, and the line is often connected to 50-100 ft. of paper-insulated cable, which acts as a condenser.

Lightning Arresters.

Lightning arresters providing a discharge path to earth can also be used, preferably in conjunction with choke coils. The simple horn type has a narrow gap adjusted so that a potential of 70-100 per cent. above normal will discharge across it to earth, the current being limited by a series resistance connected on the line side of the gap; the arc is forced upwards by electro-magnetic action until it breaks, preventing the line current from following the discharge to earth.

How Choke Coils are Connected.

Choke coils are connected in such a manner that a surge travelling along the line builds up a high E.M.F. across the coil, which tends to hold up the disturbance until the arrester has operated. Choke coils are usually of the air core type, consisting of a continuous length of copper rod. They should always be connected between a line and any transformer or other apparatus, and when transformers tap transmission lines direct or at the end of short branches, arresters are not necessary, the choke coils protecting the transformer and reflecting surges back to be dealt with by the main arresters at terminal points.

SECTION II—UNDERGROUND CABLES.

The routes of all underground cables must be carefully chosen to save cost; it is cheaper and more convenient to lay cable in pathways or grass borders than in roadways.

In rural districts, cables are usually laid direct in the ground. Under railways, tramways or roads carrying very heavy traffic they should be drawn through steel or cast-iron pipes and in certain soils a bitumen-filled trough (or a bitumen-sheathed cable) is necessary. For direct laying the cables are armoured with galvanized iron wire or steel tape; they should never be laid direct in ashes, as these may damage the armouring.

In towns and where a large number of

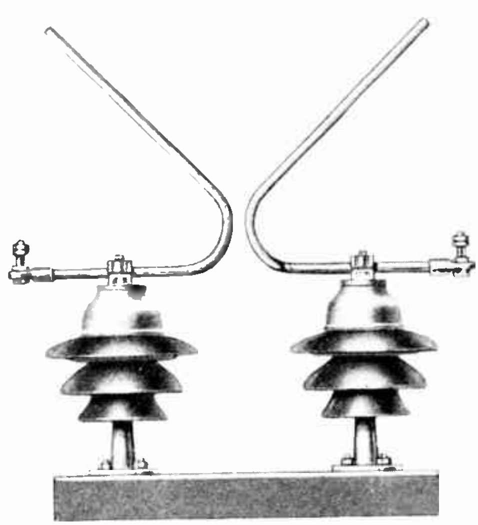

Fig. 23.—HORN LIGHTNING ARRESTER. (*G.E.C.*)

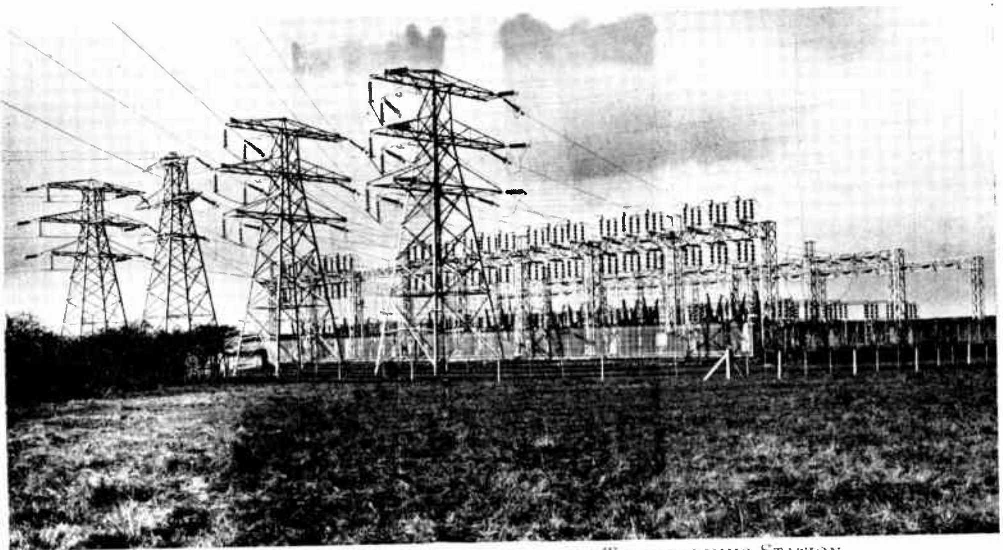

Fig. 24.—THE NORTON-ON-TEES 132,000-VOLT TRANSFORMING STATION.
This is the second largest transforming station on the " grid." (*Photo : W. Parry & Son, Ltd.*)

cables are involved, they should be drawn into stoneware or fibre conduits so that the capacity can be easily increased when required ; concrete troughing may also be used.

High Tension Transmission.

The shortest route should be adopted unless an alternative means fewer obstructions and road crossings, less traffic or easier excavation.

Three-core belted cables are generally used, having stranded copper cores, insulated with impregnated paper, lead sheathed and jute covered. The size of cable is determined by the size of the overhead line to which it is connected ; .0225 sq. in. cable is a size commonly used.

Low Tension Distribution.

The route is usually decided by the possible demands for services.

Three-core paper-insulated cables are used, similar to those for H.T. lines, but with smaller conductors and less thickness of insulation. The conductors may be circular or shaped, and the neutral is sometimes smaller than the line conductors.

House Services.

Twin-core cables, paper-insulated and lead-covered, are generally used.

CABLE LAYING.

Cables, except short lengths which are wound in coils, are usually received from the works in lengths from 250 to 440 yds. on drums. The drums should be taken to site on lorries or special drum carriages, and not rolled. Cables should not be laid in frosty weather, which hardens the impregnating materials.

At junction points a certain amount of slack should be left to save jointing in an extra piece of cable if repairs are necessary.

Direct Laying.

Suitable depths are 30 ins. under roadways or grassland, 12-18 ins. (L.T.) and 24 ins. (H.T.) under pathways and 4 ft. under railways.

The trenches should be made wide enough to allow men to work freely without injuring the cable. The bottom must be smooth and free from stones, and layers of sand are often placed under and over the cables, except in clay soil, where sand would collect water.

Where there are no obstructions the drum carriage is rolled slowly and evenly along the side of the trench while the cable is drawn off. Where pipes, etc., cross the trench above the cable level, the drum carriage must be fixed at one point and the cable drawn off by men spread out along

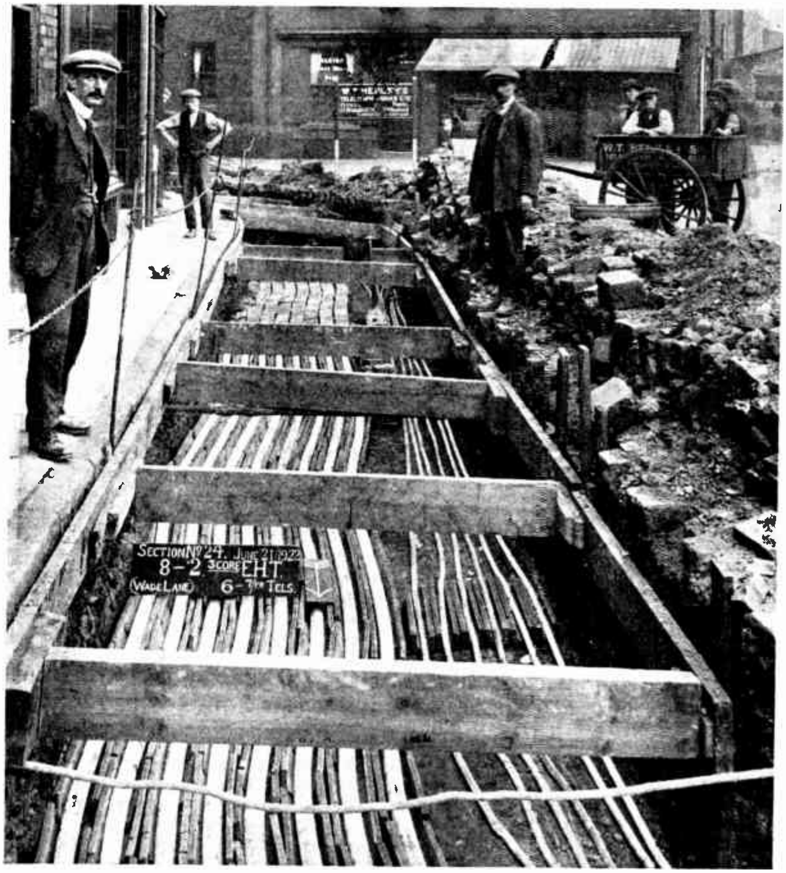

Fig. 25.—A Stage in Laying of H.T. Underground Cables in Conduits.
(*W. T. Henley's Telegraph Works, Co., Ltd.*)

the trench, lifting it well off the ground. The radius at bends should be at least twenty times the overall diameter of the cable. A long enough trench should be opened to allow the whole length of cable to be drawn off in one handling.

When it is necessary to draw off cables in both directions an "8" is formed by drawing off one portion in one direction and laying the remainder on the ground in a loop so that the other end is free for drawing off in the opposite direction. Where space is restricted the cable must be cut and jointed.

In filling in, the cables are covered with some inches of fine soil and a layer of creosoted wood boards, tiles, bricks or concrete slabs to warn anyone reopening the trench. The trench is finally filled in and the earth well pounded.

Drawing-in.

Conduits should be laid deep enough not to be injured by traffic. Where the traffic is heavy, stoneware and fibre conduits should be not less than 3 ft. and iron pipes not less than 2 ft. below the ground surface. They should be laid on a bed of concrete with a slight space between conduits. Concrete is then laid in the space between the conduits and the trench and a thin concrete covering overall to keep out water. Changes of direction should occur at draw-in boxes or manholes, which should be not more than 100 yds. apart, and a drainage fall should be provided from one box to another.

In drawing-in the cable drum is jacked up so that the cable can be taken with a single sweep from the top of the drum into the conduit. A drawing-in rope is attached to the end of the cable, which is drawn in either by hand or by means of a small winch.

Joints and Branches.

Joints must be dry and clean and made in fine weather. Joint boxes and "T" boxes (Fig. 27) are made of cast iron, and for use in damp earth they must be provided with an inside lead sheath.

Straight-through joints are made by means of adjustable clamps or connecting sockets fastened to the conductors and

Fig. 26.—ANOTHER VIEW SHOWING THE LAYING OF H.T. UNDERGROUND CABLES IN CONDUITS. (*W. T. Henley's Telegraph Works, Co., Ltd.*)

soldered with resin, no acid being used. On H.T. cables the conductors are insulated with impregnated paper and surrounded by a lead sleeve; two halves of the joint box are then placed in position and bolted up. For L.T. distribution and service joints the insulation generally consists of oil and cloth.

"T" joints should be of the "married" type or made by means of special claw connectors.

When the joint is complete the box or the lead sleeve is filled with an asphalt compound; care should be taken that air bubbles are not formed and that the compound is not overheated.

Service cables should be taken in pairs out of one "T" joint box so as to save joints and cable trenches. Alternatively a number of buildings can be supplied by connecting a three-core cable to two line wires and neutral, taking it into one house, looping into the service cut-out and out again through the wall to the next cut-out. One cut-out is connected to each line wire and both to neutral.

Terminals.

Where the cable is joined to an overhead line (Fig. 12) it is protected up the pole by an 8 ft. galvanised iron guard pipe and terminated by a dividing box of cast iron filled with insulating compound. The cable enters at the bottom of the box through glands, the conductors being separated inside and brought out through porcelain insulators to bare wire tails.

For indoor use, somewhat similar boxes are employed, the connections being made by rubber insulated tails.

SUBSTATIONS.

Substation equipment is housed in cast iron or sheet steel kiosks or in brick buildings where the supply is important enough. The L T. distribution system is sectionalised for isolating purposes and changing over the conductors by means

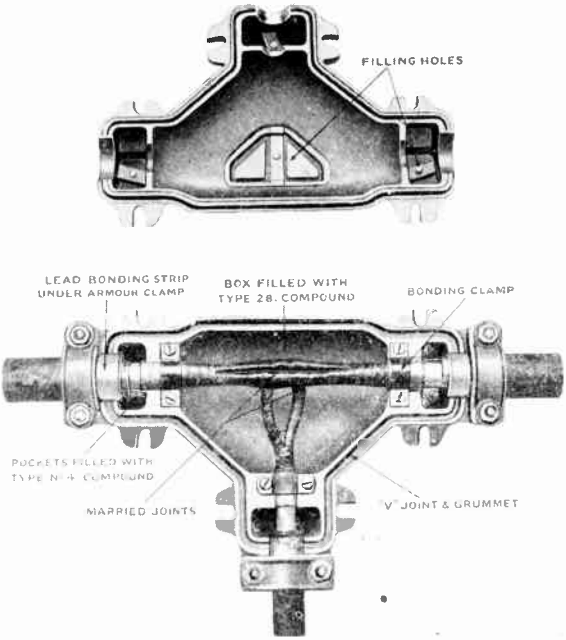

Fig. 27.—INTERIOR OF SERVICE JUNCTION BOX.
(*Pirelli-General Cable Works, Ltd.*)

of feeder pillars or, where space is valuable, by underground disconnecting boxes.

Kiosks.

Kiosks are built up of angle iron framework and sheet steel plates with a roof of welded sheet steel. The foundation is of light concrete or brickwork raised a few inches above ground level. The interior is divided into sections for the transformer and switchgear.

Transformers.

Up to 200 kVA. transformers can be mounted in kiosks, but larger sizes may have to be erected in the open.

In kiosks the ordinary indoor type transformers are used mounted on rollers and fitted with porcelain bushings for connection to the controlling switchgear through vulcanised rubber insulated cables.

Switch and Protective Gear.

On the H.T. side, isolating switches and oil circuit breakers are used, both enclosed by inner doors of sheet steel or expanded metal, but separated from each other for safety.

The L.T. switchgear consists of porcelain handle fuses in the phase circuits and links for the neutral; the fuses are mounted on the unit principle to allow for extensions.

Feeder Pillars.

Pillars consist of cast iron boxes containing units to which the cables can be connected so that fuses or removable disconnecting links can be inserted in the circuit as desired.

Disconnecting Boxes.

A disconnecting box consists of a box and watertight cover, which can be assembled in a built-up pit frame and cover. On rural lines a multi-way ironclad fusebox, which must be weatherproof, is sometimes mounted on the last overhead line pole for disconnecting purposes.

A later section deals fully with the practical methods employed in the erection of high tension transmission lines and the laying of underground cables.

TABLE STANDARD LAMPS AND SHADES

BY GILBERT E. TWINING

THE rapid growth in the use of electricity in the home is leading to a great increase in the demand for table standard lamps and shades. The cheaper class of lamp is well catered for, but there is a growing demand for really high-class articles and the sale of these offers quite a profitable sideline for the electrical dealer. In this article will be found detailed instructions for making four high-class table lamps prepared by a first-class designer.

AN OAK JACOBEAN STANDARD.

In Fig. 1 is given a design for an oak Jacobean standard sixteen inches high, built up of five independent pieces, each turned with a dowel and socket, the whole then being glued together, stained, polished and wired for electric light.

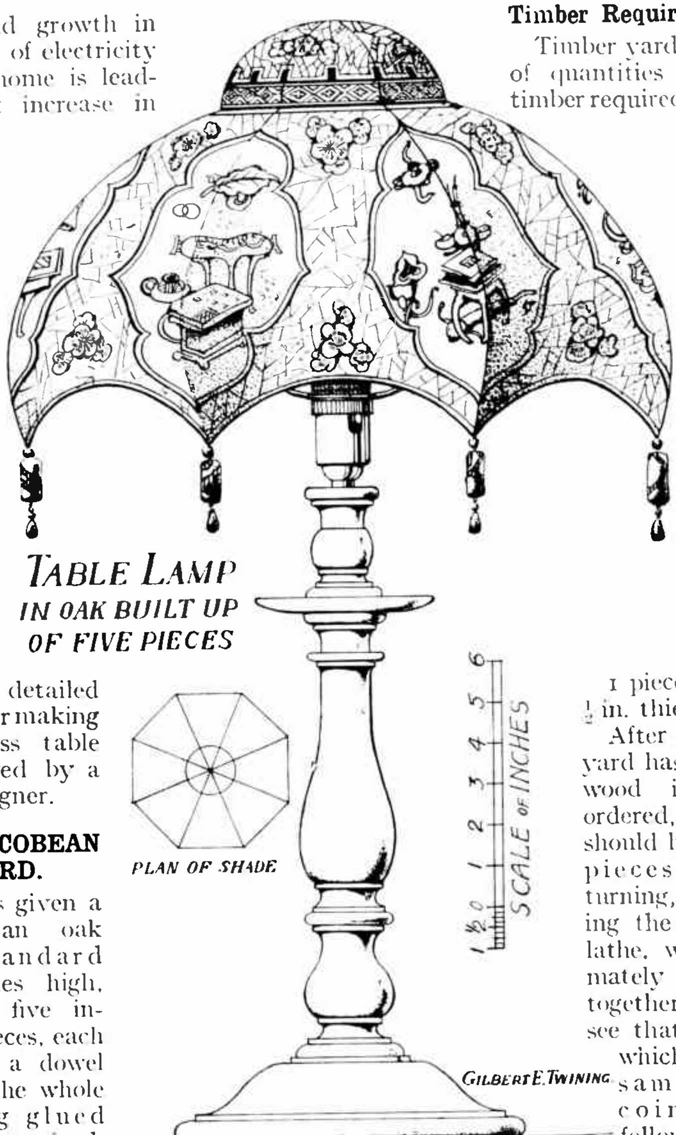

Fig. 1.—DESIGN FOR OAK JACOBEAN STANDARD.
This is 16 in. high and is built up of five independent pieces.

Timber Required.

Timber yards if given lists of quantities and sizes of timber required, will prepare, cut and deliver it.

For the oak standard shown in Fig. 1 the following sizes will be required :—

1 piece 2 ft. by 3 in. sq. A, C and D.

(A is 5 in. long; C, 10 in. long; and D, 9 in. long.)

1 piece 9 in. sq. by 2 in. thick for E.

1 piece $4\frac{3}{4}$ in. sq. by $\frac{1}{2}$ in. thick for B.

After the timber yard has delivered the wood in the sizes ordered, the lengths should be cut into the pieces ready for turning, When selecting the pieces for the lathe, which are ultimately to be glued together in one column, see that all the grain which runs in the same direction coincides or follows through, as nearly as possible ; this will add greatly to the appearance when finished.

Turning Tools, etc.

The operation of turning these pieces should present no great difficulty to anyone who is able to use a lathe, and almost all forms of turning can be done, if necessary, with the gouge and side chisel alone. The sizes obtainable range from ¼ in. to 2 in. wide, but for general use a gouge and side chisel ⅝ in. wide are suitable, although it is advisable to have at least two different sizes in these, large and small, the large one for quick removal of wood and the small one for small work. The gouge should be held at such an angle that its cutting edge is making almost a tangent with the curvature of the work, otherwise it will not cut but scrape. Although scraping is permissible in some cases and with some tools, their edges are far more quickly destroyed than when they are used for cutting cleanly in the correct manner. These tools are shown in Fig. 3.

Drawings.

Set out accurately full size on paper the outline of each piece. The drawing so made may then be laid on the bed of the lathe or hung within easy reach of the calipers and dividers of the turner.

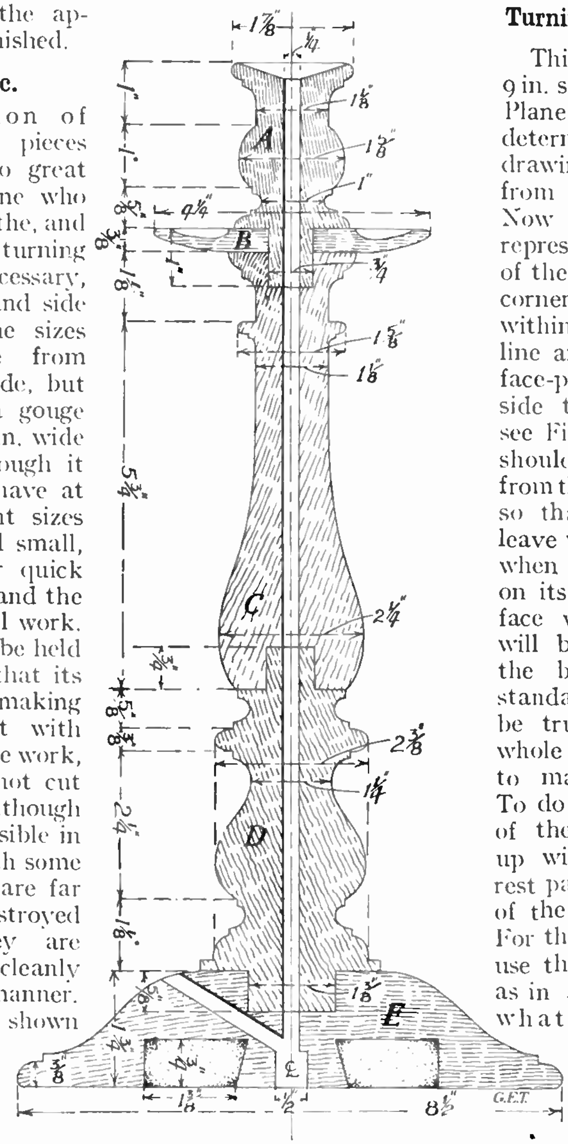

Fig. 2.—Diagram showing Sizes of Wood Required for Standard shown in Fig. 1.

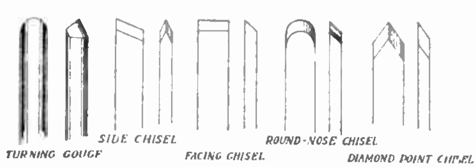

Fig. 3.—Tools Required for Turning.

Turning the Base.

This is a piece of oak 9 in. square by 2 in. thick. Plane one side true and determine the centre by drawing diagonal lines from corner to corner. Now scribe the circle representing the diameter of the base. Cut off the corners of the square to within ¼ in. of this scribed line and screw on to the face-plate with the planed side towards the plate; see Fig. 4. The screws should be placed as far from the centre as possible so that the holes they leave will be turned away when the base is finished on its reverse side. The face which is outwards will be the underside of the base of the lamp standard. It must first be trued up across its whole diameter in order to make it quite flat. To do this the hand-rest of the lathe is brought up with the T of the rest parallel with the face of the work, as in Fig. 5. For the first roughing cut use the gouge, holding it as in Fig. 6, but somewhat more steeply inclined. Begin cutting at the outside and work towards the centre.

If the wood was fairly uniform in thickness, a light cut only will be necessary to render it true. Stop the lathe and test the surface for flatness by laying a straight-edge across it.

Removing the Marks of the Gouge.

To remove the marks of the gouge, finish with the chisel after turning the edge of the work with the gouge in the same way as the face; continue cutting until the wood becomes cylindrical and of the correct diameter, or nearly so. Change to the chisel and finish by taking very light cuts with the heel of the cutting edge. If the edge towards the point is allowed to touch the wood it will probably dig in.

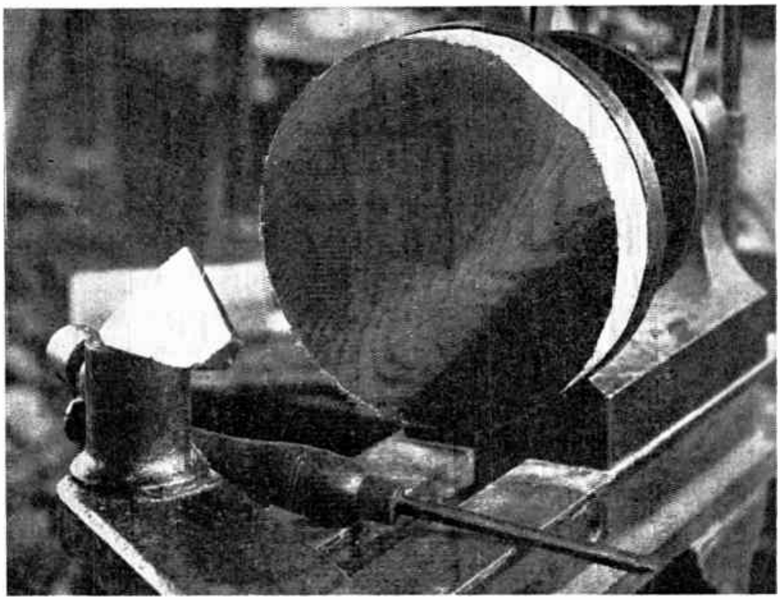

Fig. 4.—TURNING THE BASE (1).
The corners of the square have been cut off and the piece of wood screwed on to the faceplate with the planed side towards the plate.

The sharp angle where the cylindrical part meets the flat must be rounded off, as in Fig. 5, thus forming one-half of the beaded edge of the base. This, as well as the annular groove for the lead weight, had been turned when the photograph (Fig. 5) was taken.

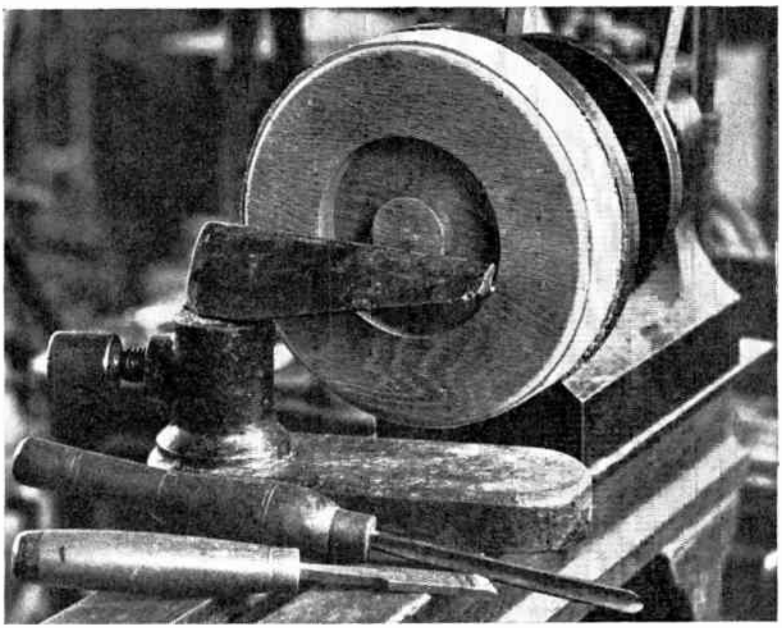

Fig. 5.—TURNING THE BASE (2).
Showing the hand-rest of the lathe brought up with the T of the rest parallel with the face of the work. The sharp angle where the cylindrical part meets the flat must be rounded off.

Turning the Groove.

The turning of the groove must be done with the point of the

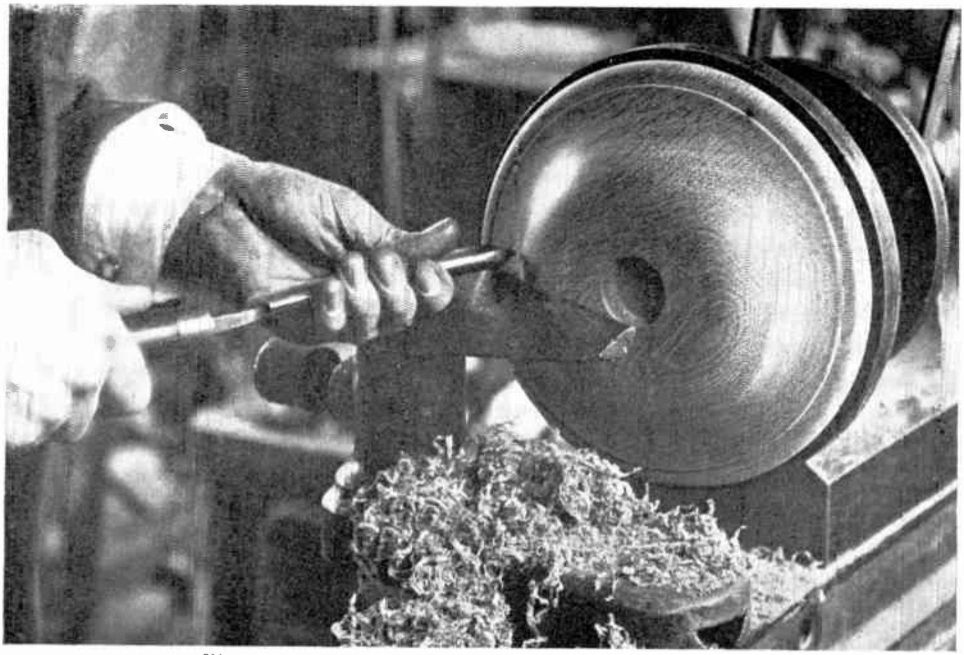

Fig. 6.—How the Base Should Look when Finished.
This shows the upper side of the base being shaped. This is done with a gouge, using the centre of the rounded cutting edge. The convexed portion towards the centre is finished with the chisel.

Fig. 7.—Turning the Lowest Section of the Shaft D.
The photograph shows the wood mounted between centres of the lathe, with the wood-turner holding his tool on the rest, ready to begin cutting. Note not only the upward angle of the gouge, but also the horizontal angle which it makes with the centre line of the work.

chisel. Scraping instead of direct cutting will have to be resorted to, since the angle of the tool on the rest cannot be very steeply inclined. The groove is dovetail shaped in section, so the tool is used with the point towards the periphery of the disc when shaping the larger diameter of the groove, and turned over towards the centre when shaping the smaller diameter. The whole width of the groove should be turned at one time, reversing the tool constantly and working inwards until the full depth is obtained. Glasspaper the outside of the work and then reverse it upon the faceplate, screwing it as before.

Shaping the Upper Side of the Base.

This is done with the gouge, using the centre of the rounded cutting edge. The convexed portion towards the centre should be finished with the chisel, but the hollow will have to be completed with the gouge, taking light cuts and letting the tool travel in a fine spiral direction from where the convex finishes towards the periphery. Scraping will be best at the very last stage, but care must be taken to make the hollow blend nicely.

The little break on the outside of the ogee curve is next cut in with the chisel, using the point side of the cutting edge. Then complete the bead, one-half of which is already formed, and lastly bore the socket to take the dowel or spigot on the shaft, marked D in Fig. 2. Finish all over with glasspaper and the base should then present the appearance given in Fig. 6.

Turning the Lowest Section of the Shaft.

The turning of the lowest section D of the shaft should next be undertaken. This is shown in Fig. 7 mounted between centres of the lathe, with the wood-turner holding his tool on the rest, ready to begin cutting. Note, not only the upward angle of the gouge, but also the horizontal angle which it makes with the centre-line of the work. Whilst making this angle and pointing in the direction shown, the tool *must* be moved to the right, otherwise it would dig in and possibly tear the work from the lathe. To cut from right to left the tool should point in the opposite direction, i.e., towards the headstock. The least carelessness may spoil the job and endanger the operator.

Having turned the wood cylindrical, mark off upon it with pencil, whilst it is still revolving, the principal members of the moulded shape. Then, with a flat,

Fig. 8.—Finishing Off the Round Curves with a Chisel.

Fig. 9.—TURNING THE CUP B.
This shows the wood being glasspapered.

round-nosed tool (not the gouge), proceed to cut into and form the hollows. Finish these and then, with the chisel, complete the round curves, in the manner indicated by Fig. 8. Lastly shoulder down at the ends to form spigots, the lower one to fit the base and the upper to receive the portion of the column C (Fig. 2). This is performed in exactly the same way as D.

Turning the Cup.

The next operation is turning the cup B, shown in the lathe in Fig. 9, and this is executed on a smaller faceplate and held by the central screw of the screwed chuck. Like the base, it has to be turned first on one side, reversed on the faceplate and then on the other.

Before removal from the face plate it should be bored to the diameter of the dowel which will be formed at the top piece A, to within a sixty-fourth of an inch from the other side. It is then glasspapered, unscrewed from the faceplate and the centrepiece left in boring removed on the bench by a circular cut with knife or gouge.

The Top Piece.

Lastly the top piece A is turned; this has a dowel long enough to go through piece B into C, as shown in Fig. 2. It is turned between centres with the dowel portion nearest the prong centre of the lathe; the other end, which will be the extreme top of the standard, can then be recessed; that is to say, made concave in form.

There will be a small projecting piece of wood still left by which the work is carried by the back centre. With either the smallest side chisel or a left-hand pointed chisel this can be reduced to about $\frac{1}{8}$ in. or as small as safety will permit. The top is then removed from the lathe and this central projection is cut away with an ordinary chisel, holding the job in the hands.

Filling the Groove with Lead.

When the base of the standard is turned and drilled, the groove for the stabilising weight may be filled with lead. Pour some molten lead into the turned groove and quickly pass a piece of flat wood across the face of the base to level off any metal which may stand above the surface. Keep the level rather below the surface, otherwise it will need to be filed off afterwards or turned off in the lathe.

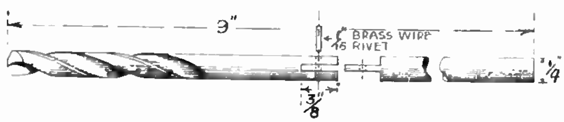

Fig. 10.—METHOD OF LENGTHENING A DRILL.

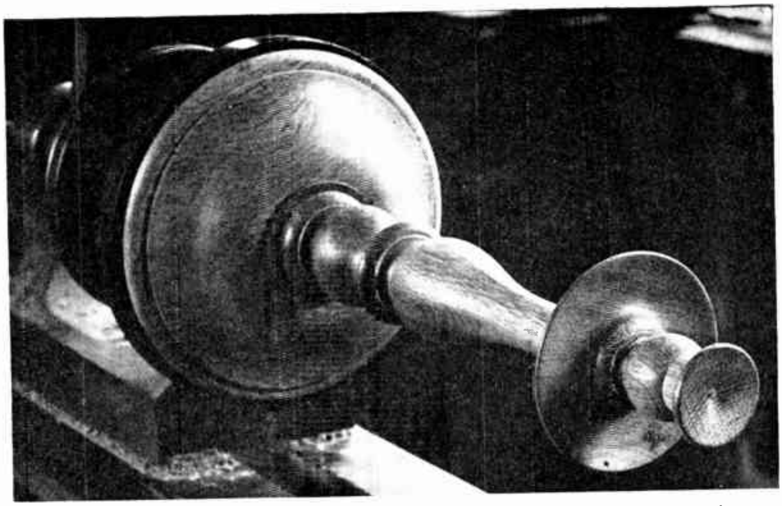

Fig. 11.—THE FINISHED STANDARD IN THE LATHE AFTER BEING GLASS-PAPERED.
It is now ready to be taken out for staining.

Drilling the Separate Pieces.

The separate pieces may now be drilled. The best form of drill for the purpose is a $\frac{1}{4}$ in.-diameter engineer's twist fluted drill, having a sufficient length to pass through the longest of the pieces down their centre-line, but no ordinary such drill when purchased is long enough for every piece of the standard, and must be lengthened by adding a piece of $\frac{1}{4}$ in. bright, round steel rod in the manner shown in Fig. 10. Good mechanical fitting is essential where the forked end of the drill butts on to the shoulders of the rod and the same applies to the tongue on the rod in the drill, all such filed ends being dead square. The joint is drilled and riveted together, after which it can quite well be soldered.

The pieces to be drilled can be held either in the lathe or in a vice, but if a lathe is used it will have to be pulled round by hand. Care must be taken when starting the drill for it is then that the greatest strain comes on the joint between the rod and the drill. An excellent precaution against this straining is to place over the joint a piece of brass tubing, two or three inches long, of such diameter as to make a push-on sliding fit over the rod. Keep this in place until the drill has entered the wood up to this point, when it may be removed.

It is better to enter from both ends of the longest pieces of turned work and meet at the centre, as there is less likelihood of the drill running out of truth. The drill should be withdrawn from the wood several times and cleared.

Glueing the Pieces Together.

The pieces may now be glued together, starting from the base. Wipe off all surplus glue from around the joints. When these have set, the standard should be well rubbed down with No. 0 glasspaper. If done in the lathe, the paper should be moved rapidly in a longitudinal direction.

In Fig. 11 the standard is shown in the lathe glasspapered and finished ready to be taken out for staining.

Staining.

Vandyke Brown crystals, not powder, make a very good stain when mixed with ammonia and water, the proportions depending upon the depth of tone required. The crystals can be obtained from any colour shop. If a water stain is to be used for colouring the oak, it is advisable first to raise the grain by means of a rag dipped in water and applied to the wood, and when dry glasspapering down.

Whatever the colour or the stain used it is a good plan to experiment on a few similar pieces of wood until the required result is obtained, always remembering that two weak applications are more effective than one strong one.

Polishing.

After the oak standard is stained to the reader's satisfaction it may be polished.

Several ways of polishing may be resorted to, but waxing is by far the easiest and certainly is a good finish for oak. The ingredients for wax polish are beeswax and turpentine. Thoroughly melt the wax by heat and before it has time to set pour the turpentine into it. Allow to cool before using. It should be about the consistency of ointment and can be applied by means of a brush, afterwards rubbed off and polished with a soft cloth.

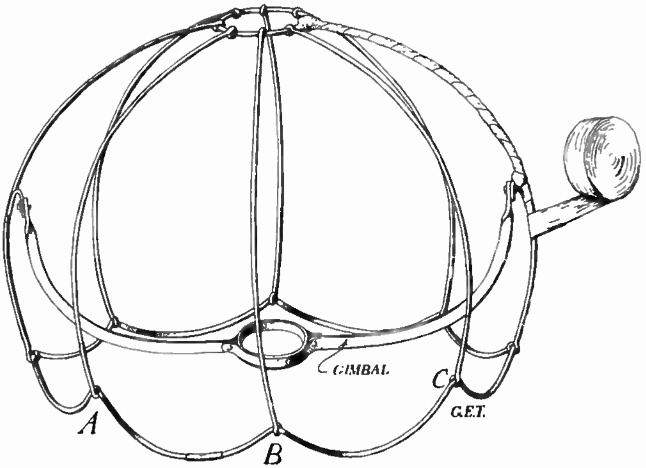

Fig. 12.—DETAILS FOR MAKING THE WIRE FRAME.

The screwed brass collar, one-half of which screws into the bottom part ot the lamp-holder, should then be fitted. A hole is drilled in the top of the standard having a diameter a little less than that of the collar and to a depth a little more than half its length ; the collar will form its own thread as it is screwed into the oak and, with the help of glue, should hold firmly in place. The lamp-holder may then be screwed on to the projecting half of this collar.

Wiring the Standard.

When wiring the standard with flex, a wire should be passed through the hole bored up the centre of the column and the flex attached to the end ; the wire, when pulled through, will then bring the flex with it. The lamp-holder complete with switch is a standard type which will be familiar to all electricians. About 8 ft. of flex is required with a lamp adapter wired to the end.

After the lamp is wired a circular piece of baize, art serge or fine velvet, having a diameter a little less than that of the base, is stuck to the underside to prevent it from scratching polished surfaces.

SHADES.

How to Make Wire Frames.

The making of wire frames for covering with silk or parchment is not a difficult matter ; all that is necessary is the ability to make the simplest of soldered joints, coupled with an eye for correct balance of form and proportion.

Tinned birdcage wire in 3 ft. lengths, about No. 14 gauge, should be used. First set out full-size on paper the curvature of one of the uprights or vertical wires of the frame. This is made to serve as a guide for bending all the curved uprights. Turn over the lower ends of these to form loops to receive the bottom ring, see Fig. 12. This ring is in the form of eight scallops, the wire being continuous with only one butt joint. All rings are jointed with a thin tin or copper ferrule wrapped to cover the joint and secured with solder.

Setting Out the Scallops on Paper.

Draw two straight, parallel lines a distance apart equal to the depth of the scallops : divide the top line into eight equal parts, each division equalling in length the width of the panels A to B in the shade. See Fig. 12. With a compass draw an arc cutting through A and B and touching the bottom line. Do this for each of the eight divisions.

Now lay the wire on the paper and beginning at one end make a sharp bend or kink at the first dividing mark. This kink can be that at B, Fig. 12. From this point bend the wire downwards in a gentle curve, letting it follow the compass-drawn line and touch the lower line on the paper, then continuing the curve upwards make another kink at the next mark, which will be C in Fig. 12. Do this at all the marks until the eighth mark is reached, which will be A in the illustration. The two ends between A and B have now to be bent to curves so that they will meet and produce a scallop like the other seven.

Now make a further bend at each of the kinks but at right-angles to the first, each of these second bends being made to such an angle that when all are made the two ends of the wire meet at the ends where the ferrule is placed. Care must be taken to make all angles equal and see that the scallops then stand vertically or in line with the main ribs of the frame. Now clench the lower eyes in the ribs over the bottom wire at each of the kinks and solder all these joints together with the ferrule.

The middle ring is soldered on to the inner side of the uprights, whilst the top ends of these uprights are not looped but soldered on to a thin disc of tin, as shown in Fig. 13. The gimbal may next be soldered in place; this is a manufactured article and can be purchased, if not already in stock. Its position is determined by the shape and size of the frame. See that the ring which screws on to the lamp holder is approximately level with the bottom edge of the shade.

How to Cover the Frame.

The following materials are required for shade shown in Fig. 1:—

¾ yd. of fine white cambric, such as Dorcas, 36 in. width; a number of glass, wooden or china beads as preferred.

Taping the Frame.

The wire frame must be well bound with white tape of about ½ in. width, wound upon the wires spirally, as shown in Fig. 12, the ends secured in place by stitching. The purpose served by this tape is twofold; it protects the cambric from any destructive action which the metal may have upon it and provides a means of attaching the cambric to the frame by sewing.

Fitting the Cambric.

Three pieces of cambric only will be required, one for every two of the panels of the wire frame, as shown in Fig. 13. Stretch the material as tightly as possible over the space to be covered, on a line drawn from A to B, and secure it with pins as indicated. A gore will have to be cut on the centre line over the wire between the two panels, both at the top and bottom, marked C and D, respectively, in the diagram. Take care not to cut away very much of the material: merely slit it up. Then, dealing with the bottom gore first, turn in one of the edges underneath.

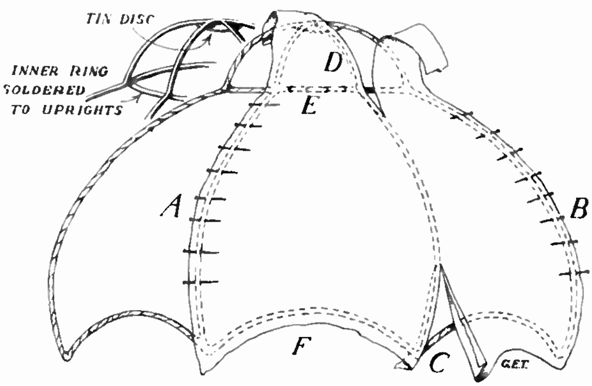

Fig. 13.—Fitting the Cambric on to the Frame.

Having got a distinct crease in the cambric to come exactly on the wire, turn it back and trim off the superfluous material with scissors. Now treat the other side of the gore in exactly the same way. With a fine cotton in the needle, say No. 60, draw these turned-in edges together so that one very slightly overlaps the other.

Top of the Shade.

The same procedure is followed at the top of the shade, finishing off at the centre of the crown. Now turn in the outside edges of the panels on the lines A and B;

C

trim off the unwanted cambric and stitch down to the wires, taking care to pull out all fullness without distorting the frame. Finally, the material will need drawing in to the angle around what has been referred to as the crown. Three or four tiny stitches placed at equal intervals in each panel, as at E, will be sufficient to pull the cambric down to the taped wire ring.

The Bottom Edge.

Lastly, deal with the bottom escalloped edge at F in the same way as the sides of the panels, except for the fact that the hem must be carried round to, and the stitching done on, the inside of the shade so as to avoid showing the taping from the outside. This is necessary because this shade is without fringe or braid. Cover the other two pairs of panels in the same manner.

The Beads.

The beads which form the pendants at all the angles should be added after the painting is completed. These should be threaded on strong double thread, the first bead of each pendant being secured by tying. If wooden beads are used, they may be painted to match the design on the cambric.

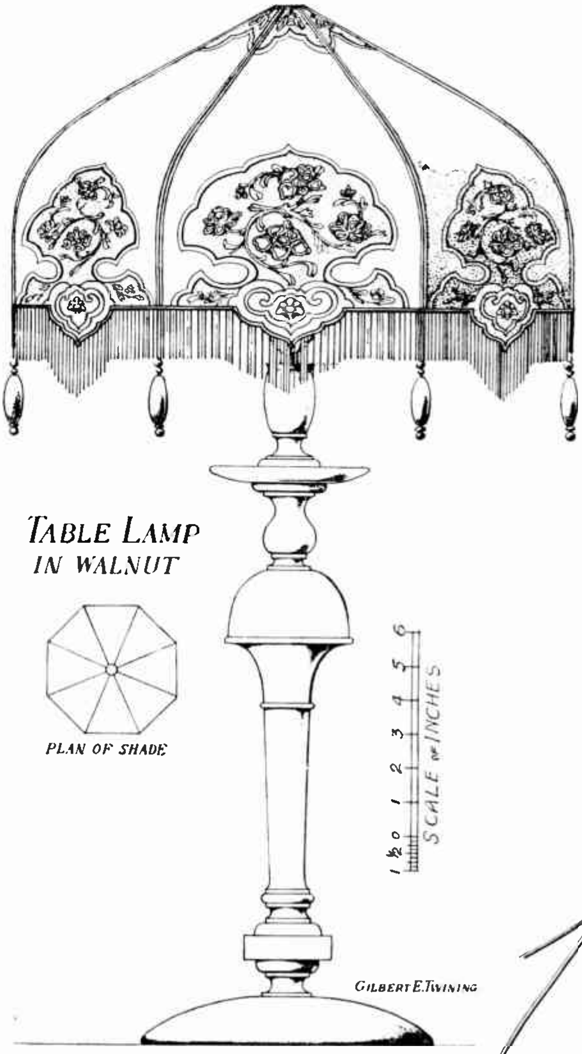

Fig. 14.—DESIGN FOR WALNUT STANDARD OF WILLIAM AND MARY PERIOD.

Preparing the Material ready for Painting.

The material must be treated with a strong solution of starch, made with boiling water in the usual way, the consistency of ordinary running cream. Apply this by means of a flat artist's brush and allow to dry. This enables the cambric to be painted upon with water-colours and also has the effect of shrinking the material and rendering it taut.

Painting.

The colour is used rather drier

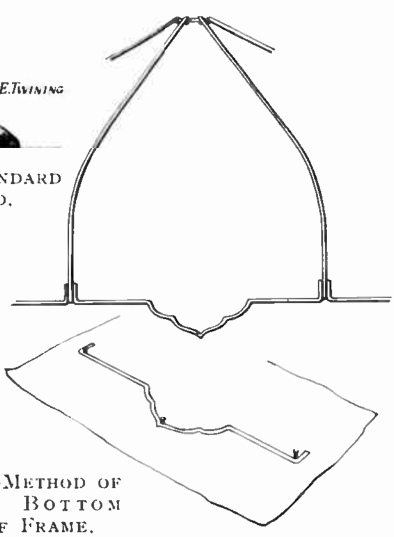

Fig. 15.—METHOD OF FORMING BOTTOM RING OF FRAME.

than is usual when painting on paper. Lightly draw the outline to be painted on the shade with a pencil, afterwards going over with the brush and filling in where necessary, care being taken not to apply too much colour in one place, as it might have a tendency to spread. The shade in Fig. 1 is outlined with Prussian blue, the portions in black in the drawing representing solid blue. Good tube colours and first-class sable brushes should be used.

WALNUT STANDARD OF WILLIAM AND MARY PERIOD.

This standard (Fig. 14) is twenty inches high, built up of eight pieces, and is fashioned after the shape of the leg commonly found in furniture of this period. The square portion, as shown in Fig. 16, is cross-banded with walnut veneer on all its four edges, with burr walnut on top.

List of Sizes.

The following is a list of sizes for ordering:—

1 piece 22 in. by $2\frac{1}{4}$ in. square to cut pieces A, C, G, E.

1 piece $6\frac{1}{2}$ in. by 4 in. square to cut pieces D.

1 piece 9 in. square by $1\frac{3}{4}$ in. thick to cut piece H.

1 piece 5 in. square by $\frac{1}{2}$ in. thick to cut piece B.

1 piece 3 in. square by $\frac{3}{4}$ in. thick to cut piece F.

A is $5\frac{1}{2}$ in. long; C is $4\frac{1}{2}$ in. long; E is $8\frac{1}{2}$ in. long; and G is $3\frac{1}{2}$ in. long.

All the operations of making drawings of the separate pieces, turning, drilling and glueing together, etc. of this standard are similar to those of the preceding oak one.

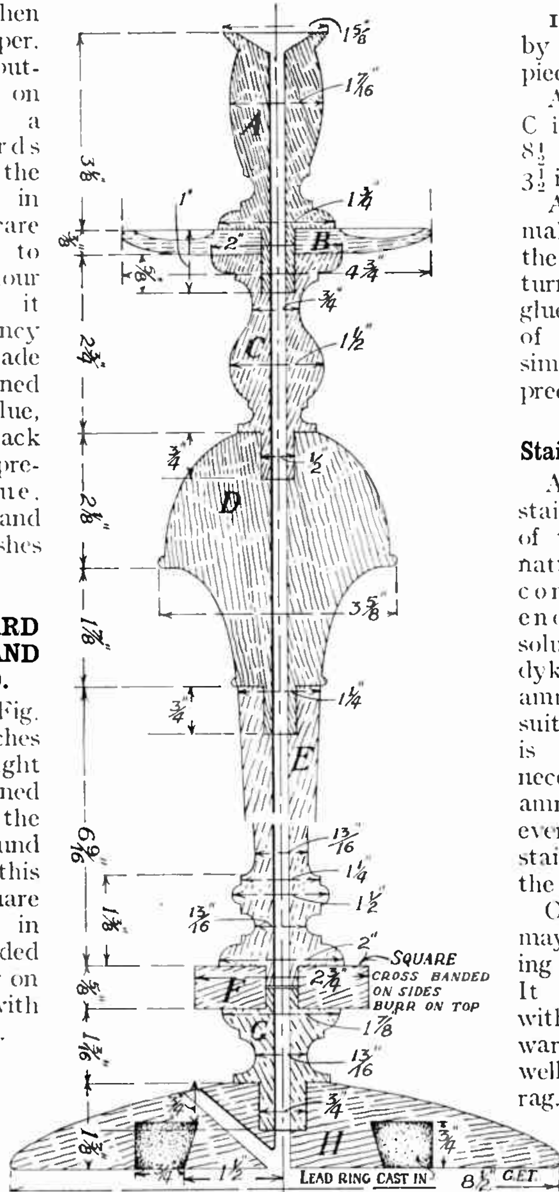

Fig. 16.—Dimensions of Wood for Standard Shown in Fig. 14.

Staining.

As regards the staining and polishing of the walnut, if the natural colour is not considered dark enough, a weaker solution of the Vandyke Brown and ammonia stain is quite suitable, although it is not absolutely necessary to use the ammonia; it will, however, help to carry the stain into the grain of the wood.

One or more coats may be given, according to tone required. It should be applied with a brush, afterwards being rubbed well in with a piece of rag. Very pleasing light and dark effects may be obtained in this way. The standard can then be waxed or French polished. If a fairly light finish is required and the walnut has some nicely marked strong grain in it, all that is necessary is to wax polish without staining, or instead of waxing, polish with white polish.

THE SHADE.

Wire Frame.

Tinned iron wire as described previously, namely, 14 gauge, is used. Fig. 15 shows the method of forming the bottom ring of this frame and shows it set out on paper with brads at the angles to guide the wire when bending. The top ring is made by bending a piece of wire around any circular object of the right diameter, with a copper ferrule wrapped to cover the butt joint and soldered. The vertical wires should be set out on paper as before and bent to the shape; they are then equally spaced around the top ring, the loops clenched over and soldered. The separate pieces of the bottom soldered in place to the uprights and the gimbal attached in place as described.

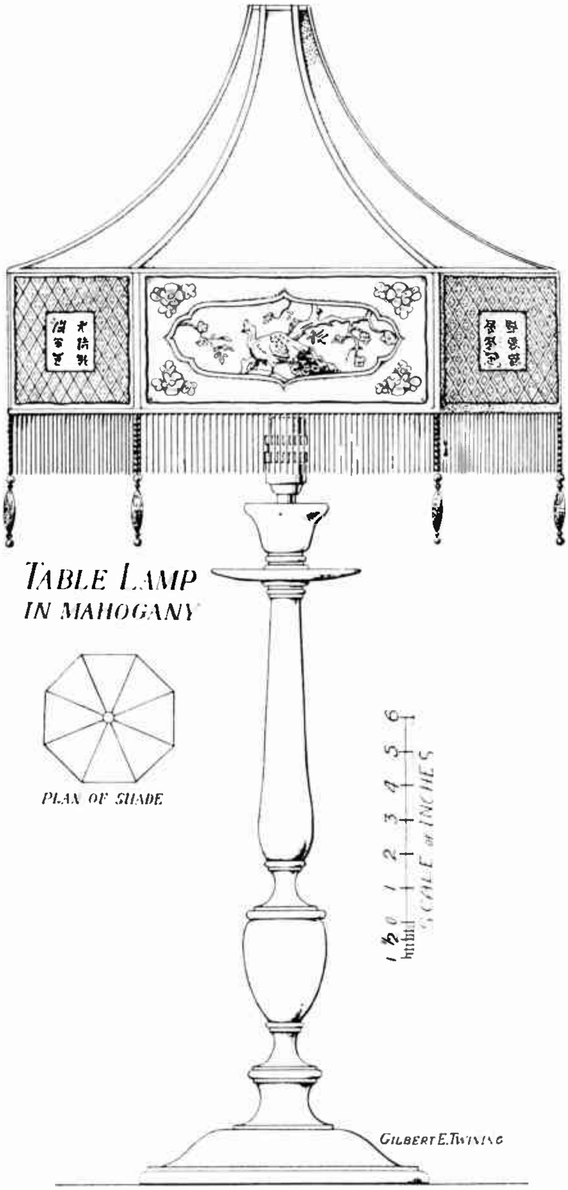

Fig. 17.—Mahogany Standard of Chippendale Design.

How to Cover the Frame.

The materials, etc. required for shade shown in Fig. 14 are :—

1 yd. of 36 in. width white European silk.

1 yd. of 36 in. width white Dorcas Cambric.

5¾ yds. gold braid.

2¾ yds. of tinsel, silk or bead fringe, in either gold or a colour to match the furnishing of the room for which the shade is required.

A number of beads, which can also be the choice of the reader.

The white cambric is used for the lining as a means of reflecting the light downwards.

Taping the Frame.

Tape the wire frame as already described. Next, stretch the cambric as tightly as possible over a portion of the wire frame, securing it with pins, and mark upon it with a pencil the shape of one of the panels. Cut around the pencil line, allowing ¼ in. for turnings. Use this as a pattern from which all the pieces of cambric and silk are cut. Take one of the pieces of cambric and pin it in place on the top side of the frame. The material must be stretched tightly and uniformly, particularly from top to bottom, taking great care not to distort the shape of the frame.

Sew this all round, beginning with the decorative portion at the bottom first; then pin on the next panel. Each piece must be finished off before the adjoining one is begun. Should it be found when all the panels but one are on that there are slight wrinkles or fullness in some of them, the last piece of cambric to be put on should be sewn with sufficient tension to pull these out.

When the frame is completely lined, sew on the silk in exactly the same manner. The silk must then be treated with a starch solution, as previously described.

Painting.

The painting of this shade can be carried out either in transparent artists' oil colours or artists' water-colours, whichever the reader prefers.

The flowers are in deep rose madder, with leaves and stems of green on a background of sepia, surrounded by a band of brilliant yellow.

When the painting is completed, sew on the fringe. After this is done, stitch on the gold braid to cover the centre of each of the downward seams and then over the top edge of the fringe around the bottom and also the small opening at the top. The beads should be threaded on fine strong silk cord to match the colour of the fringe, of sufficient length to allow the tops of the pendants to come level with the bottom edge of the fringe.

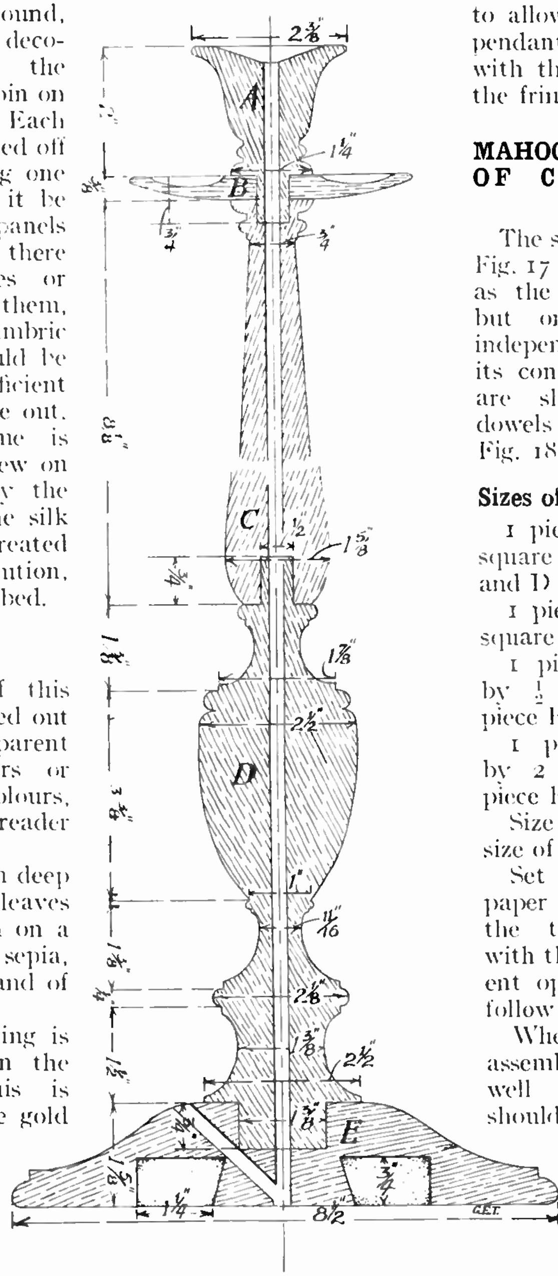

Fig. 18.—Dimensions of Wood for Standard Shown in Fig. 17.

MAHOGANY STANDARD OF CHIPPENDALE DESIGN.

The standard shown in Fig. 17 is the same height as the walnut standard, but only requires five independent pieces for its construction. These are shown with their dowels and sockets in Fig. 18.

Sizes of Timber Required.

1 piece 14 in. by $2\frac{3}{4}$ in. square to cut pieces A and D Fig. 18.

1 piece $9\frac{1}{2}$ in. by 2 in. square to cut piece C.

1 piece $4\frac{3}{4}$ in. square by $\frac{1}{2}$ in. thick to cut piece B.

1 piece 9 in. square by 2 in. thick to cut piece E.

Size of A is $3\frac{1}{2}$ in. long; size of D is $10\frac{1}{2}$ in. long.

Set out the pieces on paper and proceed with the turning, beginning with the base; the different operations will then follow on as before.

When the column is assembled and has been well glasspapered it should be damped down, as previously directed for the oak standard, and then given a coat of stain.

Suitable Stain for Mahogany.

Probably one of the best stains for mahogany is bichromate of potash dissolved in water and applied with a brush or rag wiping off all surplus from the surface. The grain should then be filled with wood filler, or plaster of Paris and water can be used, but it is advisable that any white fillers be tinted to correspond with the colour of the mahogany, therefore a little rose pink must be mixed with it. A damp rag is dipped into the plaster and well rubbed into the grain of the wood; care must be taken only to have the rag just damp and not to apply too much plaster.

When this is dry, the work may be glasspapered down and dusted. Mahogany is usually French polished with shellac dissolved in methylated spirit. Be sure the wood is thoroughly dry before beginning to polish, otherwise the shellac will go milky.

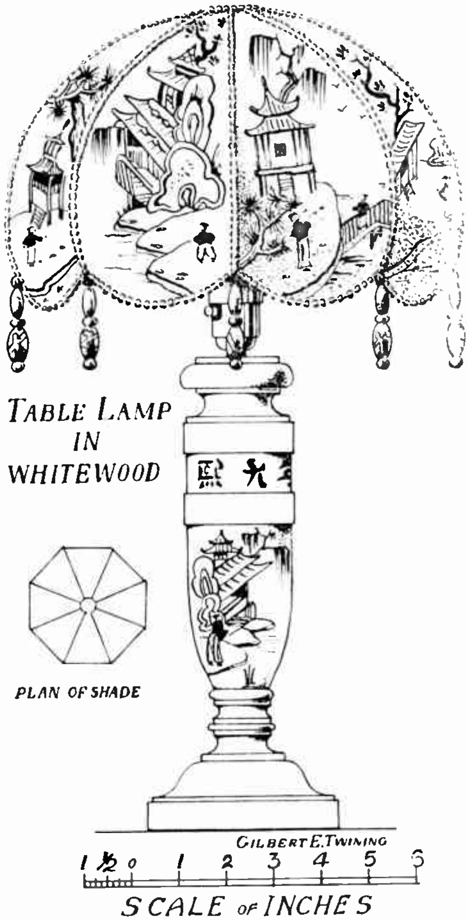

Fig. 19.—Japanese Design for Standard in Whitewood.

THE SHADE.

Making the Wire Frame.

This frame is built up in the same manner as before, tinned iron wire being used. A drawing should be made outlining the curve of one vertical member of the frame as before, a top and bottom ring made and jointed, the intermediate ring being soldered on to the inside of the uprights. When the frame is finished the gimbal may be soldered in place.

How to Cover the Frame.

The materials, etc. required for shade shown in Fig. 17 are :—

$\frac{3}{4}$ yd. of shot blue and green taffeta silk, 36 in. width.

1 yd. of fine white Dorcas Cambric.

$7\frac{1}{2}$ yds. gold braid.

$2\frac{1}{4}$ yds. either gold, tinsel or silk fringe.

A number of beads for pendants.

Tape the wire frame as described for Fig. 1 and when this is done, cover the top part of the frame with both the cambric and silk in exactly the same manner as referred to in connection with Fig. 14, with the exception that in this instance it is advisable to begin stitching the material at the top first. The bottom panels can either be put on separately, in pairs, i.e., one piece of cambric for every two of the panels, or in one long piece only. Whichever method is adopted the material must be stretched tightly over the wire frame, uniformly and evenly, without distorting the shape of the frame. These bottom panels must also be treated with a starch solution as already explained to enable the material to be painted upon.

Painting.

In the case of this shade it would be better to set out the design full size on paper first to act as a guide for lightly drawing in the outline on the cambric. The panel containing the peacock is in natural colours, the bird is green with a yellow breast, blue wing and tail feathers. The tree has a sepia brown trunk. The surround of the panel is painted in crimson lake with the prunus blossom left white. The other alternate panels are in yellow with cross lines of green; the small panel containing the inscriptions is left white with a border of crimson, the Chinese inscription being blue. The border surrounding all the panels is yellow.

All the colouring and designs in these shades have been taken from old Chinese porcelain and may therefore be varied by the reader copying from other pieces of such porcelain.

When the painting is completed, sew on the tinsel or silk fringe around the bottom edge. Next apply the gold braid to cover the centre of each of the vertical seams, from top to bottom of the shade, then crossing these the horizontal braids around the top, around the middle and over the upper edge of the fringe around the bottom.

There remains now only the attaching of bead pendants. Additional length must be given to these by threading on tiny glass beads sufficient in number to make the pendant equal in length to the depth of the fringe as indicated in Fig. 17. Eight such pendants will be required, one for each corner of the octagon.

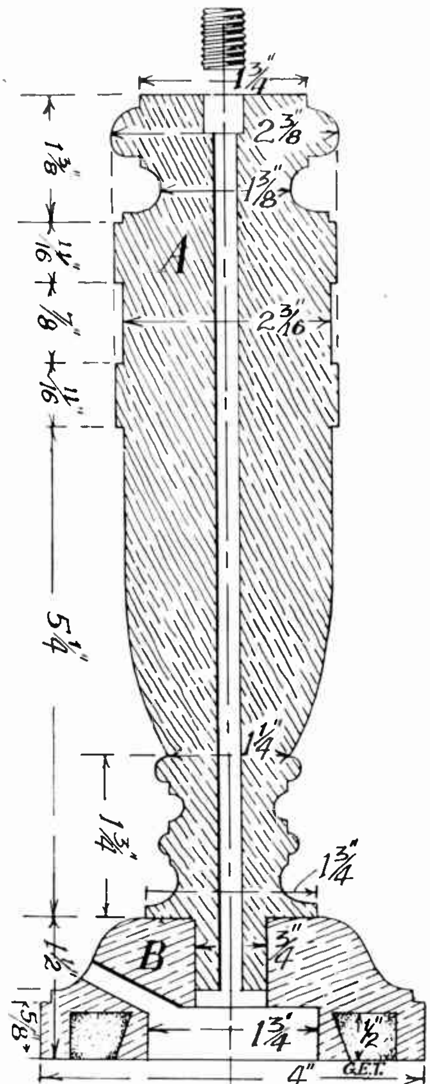

Fig. 20.—DIMENSIONS OF WOOD FOR STANDARD SHOWN IN FIG. 19.

JAPANESE DESIGN IN WHITEWOOD.

This standard (Fig. 19) is turned in two pieces and finished in colour, afterwards being French polished.

Selecting the Timber.

When selecting American whitewood the yellow variety should be chosen, as it is considered the best; it will be less likely to twist or warp and also it cuts much cleaner. If it is of a decided white colour it can be assumed that it is sap wood and it will not work or turn well.

List of Sizes.

1 piece 11 in. by 2¾ in. for A, Fig. 20.

1 piece 4¼ in. by 1¾ in. thick for B.

The next operations are turning, drilling and glueing together, and sandpapering.

Finishing.

The grain must be well filled with size and whitening mixed and applied with a brush. Give two coats, smoothing down with glasspaper between each. Allow to dry.

Any colour, greens, blues and reds, etc., may be made up by using different coloured finely ground pigments; for white use finely crushed flake white.

Mix a quantity of the pigment in bleached shellac; this should be strained off and several coats given with a soft camel-hair brush, allowing each coat to dry before applying another. Build up with coat after coat until a solid body of colour appears, rubbing down with fine glasspaper when necessary.

The last two coats are a mixture of some of the body colour and a varnish made with about equal parts of polish and good transparent spirit varnish, when dry rubbed down and French polished.

When rubbing down great care must be taken not to rub through the colour, especially at the edges.

The colouring of the standard shown is deep vermilion for the ground, picked out with gold, green and black.

To reproduce the raised figure, etc., on lacquer work, the parts should be modelled up on the surface either with plaster of paris and glue or worked with gesso; roughen the surface to be so covered with a knife to ensure the medium adhering and apply with a small camel-hair brush.

The Wire Frame.

This frame (see Fig. 12) is very similar to the first frame described excepting that it has no intermediate ring, but has an opening at the top; the curved vertical uprights should be turned over at each end to form a loop to receive this top, as well as the bottom ring, and when in place they may be soldered. The bottom scalloped ring is made in exactly the same way as described for Fig. 12.

How to Cover the Frame.

The materials required for shade shown in Fig. 19 are :—

1 imperial size sheet of parchment;

3 yards gold braid;

A number of beads, either glass, wooden or china, as preferred.

Tape the wire frame in the usual way before beginning the making of the shade. A pattern of the frame will be required for use as a template in cutting the parchment; this can be made by pinning a piece of strong, smooth brown paper upon the outside of a portion of the frame and marking with a pencil the shape of one of the segments or panels. Cut around the pencil line and this will serve as a pattern from which all the parchment panels can be cut. Take one of the pieces of parchment, pin it in place on the frame and sew this all round by means of tacking stitches; each panel should be finished off before the adjoining one is commenced.

Painting.

The painting of parchment actually takes the form of dyes or stains, either aniline dyes dissolved in spirits or draughtsman's waterproof coloured inks may be used. The main colours in the shade given in Fig. 19 are red, black, gold and green to match the standard, the red predominating. Apply one or two coats, after which certain of the larger masses of colour may be picked out with a thin coat of varnish; this imparts a very nice gloss to the finish.

When the whole of the parchment is painted, make and attach the bead pendants. There then only remains the addition of the gold braid to complete the shade. Sew this on first down over the centre of each join in the parchment and then around the bottom edge and the opening at the top.

TRANSFORMER THEORY AND CONSTRUCTION

FOR LOW AND HIGH FREQUENCIES

By H. W. Johnson

The transmission and distribution of electrical energy on a large scale over large areas is now an accomplished fact. This has been made possible by the aid of the modern transformer.

Electro Magnetic Induction.

In 1831 Michael Faraday discovered that currents can be induced in a closed circuit by moving magnets near it, or by moving the circuit across the magnetic field. He followed up this discovery by finding that a current whose strength is changing may induce a secondary current in a closed circuit near it. Such currents, whether generated by magnets or by other currents, are known as induction currents. The action of the magnet or current in producing such induced currents is termed electro magnetic induction, or simply induction. Upon this discovery is based the principle of the action of the modern transformer.

The Action of a Transformer.

A transformer consists of a laminated core of iron stampings which form a magnetic circuit. Two sets of windings, namely the primary and secondary, are wound over the core. These windings are electrically insulated from the core and from each other; the only exception being the windings of an auto transformer, in which case the primary and secondary windings are connected in series with each other.

When an A.C. supply is switched on to the primary winding, the periodic variations of the current through the winding produces corresponding variations in the magnetic field which is set up. Because the windings are both under the influence of this varying magnetic field an E.M.F. is induced in each of them. The E.M.F. which is induced in the secondary winding is the secondary voltage of the transformer, and the E.M.F. which is induced in the primary winding, this is at any instant in opposition to the supply E.M.F., or primary voltage of the transformer.

In a well designed transformer the value of the induced E.M.F. in the primary winding is nearly equal to the primary voltage when the secondary winding circuit is open. Consequently only a very small current will flow through the primary winding when the secondary circuit is open. This small current is called the magnetising current, and the primary

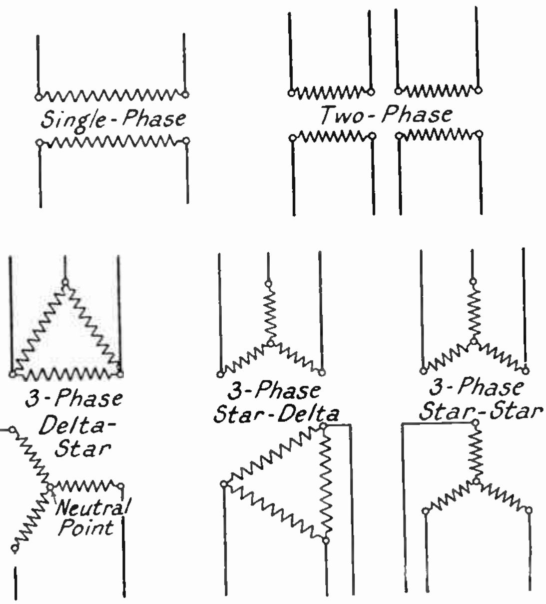

Fig. 1.—Diagrammatic Transformer Connections.
(See also Fig. 2.)

winding is merely acting as a choking coil.

Effect of Closing the Secondary Winding Circuit.

When the secondary circuit is closed a current will now pass the secondary winding, which sets up a magnetic field. This magnetic field will neutralise some of the magnetic field produced by the current flowing through the primary winding, and therefore the induced E.M.F. in the primary winding is reduced. This reduction in the induced E.M.F. in the primary winding will allow more current through the primary winding. It will be seen then that the lower the resistance of the secondary circuit, the greater will be the current passing through the secondary winding and automatically the current taken by the primary winding will be increased.

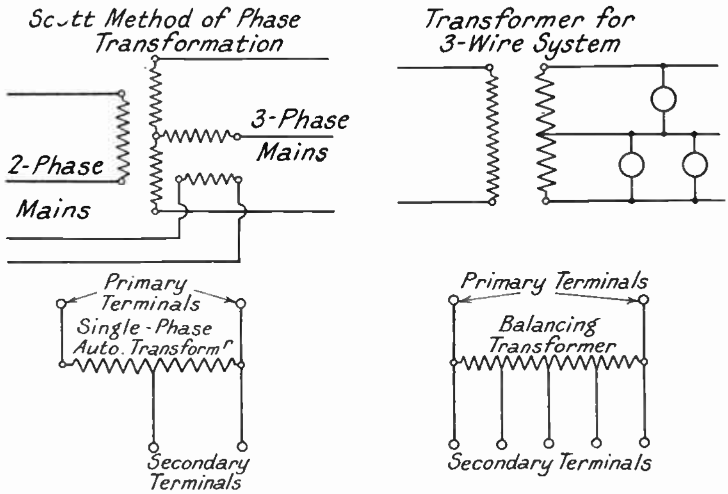

Fig. 2.—More Diagrammatic Transformer Connections.

The Transformation Ratio.

The ratio of the voltage at the terminals of the primary to the voltage at the terminals of the secondary winding is called the transformation ratio and is proportional to the ratio of the number of turns on the primary winding to the number of the turns on the secondary winding. A transformer which is used for increasing the pressure of a circuit is called a step-up transformer and one used for reducing the pressure, a step-down transformer. An alternator whose current is to supply a system of E.H.T. transmission lines would be connected to them through a step-up transformer.

A low voltage appliance which requires a supply of current from the E.H.T. lines would be connected to them through a step-down transformer.

CONSTRUCTION OF A MODERN THREE-PHASE POWER TRANSFORMER

The Core.

The imbricated core is the one most commonly used, this type of core having low flux leakages. The laminations of the core are built up of iron, which will work at the required flux density within the limits of the guaranteed iron loss; the laminations are pressed together with core bolts passing through the centre. The bolts are insulated from the core to prevent excess eddy currents and heating when the transformer is in operation. The core is left unlaced, i.e., the legs open at the top, and taken to the coil winding shop.

The Windings.

The low voltage winding is wound in spiral form to the length of the leg and passed over it, resting on the insulation which has been placed on the bottom yoke. The ends of the winding are uppermost in readiness for connection to the terminal board. A layer of insulation is now placed round the low voltage winding, and the high voltage winding placed in position over it. When the pressure does not exceed 2,000 volts this winding is in one coil. When the pressure exceeds 2,000 volts, the winding is divided into a number of coils which are joined in series, so that the total turns will give the correct voltage ratio with the turns on the low voltage winding.

Suitable insulation is now placed over the high voltage winding and the building of the core is completed. End plates are placed on each side, top and bottom of the core and the whole clamped up. A downward pressure is exerted on the high voltage winding with stay bolts passing between the top and bottom end plates. If the low voltage winding current is heavy, stay bolts made of manganese bronze are used instead of steel. Steel bolts would be heated up. The terminal boards are now fitted and all connections made. High voltage connections to one side of the board and low voltage to the other.

THE TESTS.

Ratio of the turns checked, tolerance allowed 0.5 per cent.

Iron Loss.

Apply normal voltage to low voltage winding and measure input watts with the high voltage winding on open circuit, 10 per cent. tolerance allowed, magnetising current should not exceed 10 per cent. of the full load current to the low voltage winding.

Copper Loss.

Short the low voltage winding and pass full load current through the high voltage winding, measure input watts and impedance voltage across the winding. Tolerance of 10 per cent. allowed for copper loss in watts and voltage amperes above guarantees at 75° Centigrade.

Over Potential Test.

Apply twice normal voltage to low voltage winding at twice the rated frequency for one minute, with the high voltage winding on open circuit.

FLASH TESTS.

(1) Apply twice the normal voltage plus 1000 between the high voltage winding and the low voltage winding and earth.

(2) Apply twice the normal voltage plus 1000 between the low voltage winding and earth.

Special Switching-in Test.

Apply normal voltage to low voltage winding with high voltage winding on open circuit, and note the maximum surge current when switched in and out 12 times.

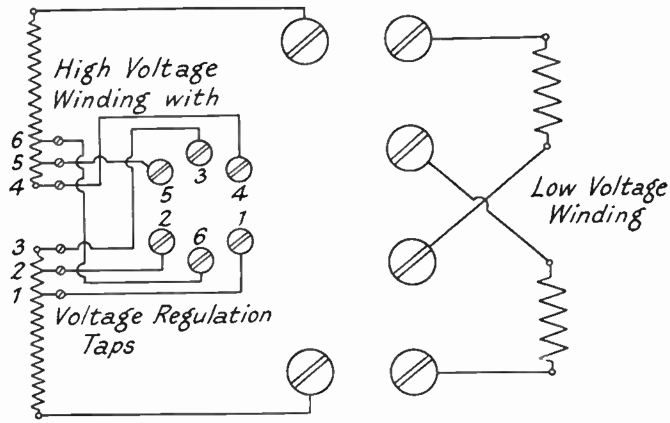

Fig. 3.—CONNECTIONS OF A SINGLE-PHASE TRANSFORMER.
The low voltage winding is in two equal coils, which may be connected in series or in parallel to give double the voltage and half the output current of the parallel connection. The high voltage winding is provided with tappings to obtain a reduction of voltage in steps of 2½ per cent. Links are used to join the numbered leads together to obtain the desired voltage.

If all the tests are satisfactory the transformer is dried out in a heater until the insulation resistance between the windings and earth is not less than 1000 megohms.

Transformers whose ratings are 5000 KVA. and upwards are placed in a heated vacuum tank and oil forced into the tank whilst the vacuum is maintained, thus impregnating the windings with oil.

High voltage transformers are placed in a tank of oil for iron loss, over-potential and flash tests.

Cores for Single-phase Transformers.

The cores of single-phase transformers are generally of the shell type. The windings are subdivided, and between each winding is placed a sheet of insulation

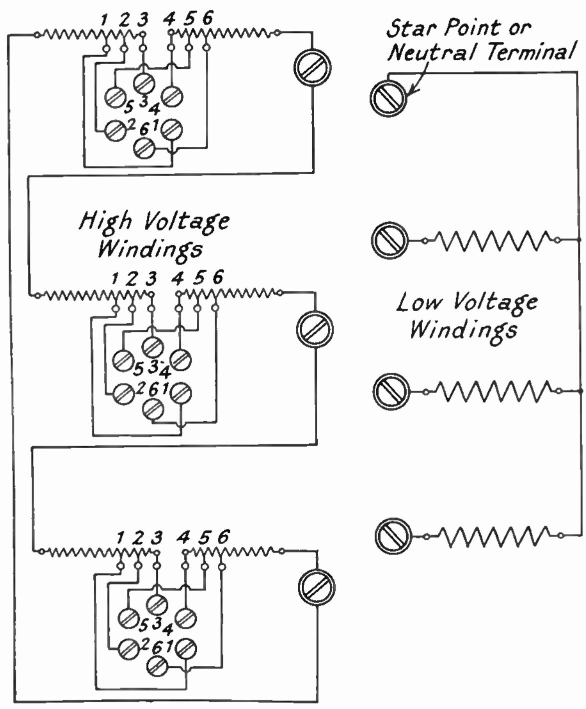

Fig. 4.—CONNECTIONS OF A THREE-PHASE DELTA STAR TRANSFORMER WITH VOLTAGE REGULATION TAPS ON THE HIGH VOLTAGE WINDING.

Tappings 3 and 4 connected on each of the H.V. windings give the full voltage on the H.V. windings. The voltage is reduced as required by cutting out the turns on the H.V. windings between the tappings, with a rotary switch or with plugs.

which is corrugated to allow of free oil circulation between the windings. The whole of the windings are built up in the form of a box with a hole through the centre. The core is then built up through the hole and all round the box. The tests applied are similar to those for the three-phase transformers.

Current Density of Transformer Windings.

A current density of about 1,600 amperes per square inch is adopted as a working standard, and a rise in temperature of 50° Centigrade, when measured by thermometer, and 55° Centigrade when measured by the electrical resistance method.

Allowance should be made for increase of the volume of the oil in the tank due to the temperature rise. This allowance should be about 7 per cent. of the cold oil volume for the maximum temperature rise of 50° Centigrade.

COOLING ARRANGEMENTS.

Several methods are adopted for cooling.

Small transformers may be air cooled, oil cooled without radiator tubes or oil cooled with radiator tubes having a flat surface to give a greater cooling surface.

Large transformers are always oil cooled. The oil is pumped out of the tank through a water cooled chamber and back to the tank. The latest practice is to cool the oil in the radiator tubes by an air draught created by a fan. The air is forced through small holes in the air circulating tubes on to the fins of the oil radiator tubes.

Conservators are sometimes fitted above the oil tank. The tank is filled completely with oil, the conservator is fixed above the tank and connected to it with a tube. When the conservator is partly filled with oil a head of oil is assured and no air can enter the tank.

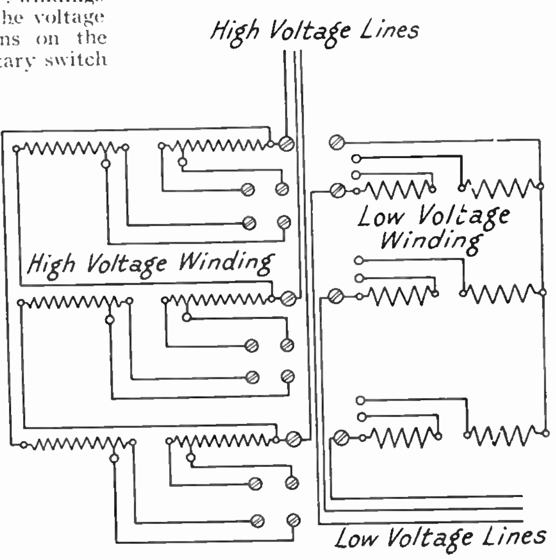

Fig. 5.—CONNECTIONS OF A THREE-PHASE DELTA TO STAR TRANSFORMER WITH LOW VOLTAGE WINDING.
Arranged for series and parallel connection, and voltage regulation taps on the high voltage winding.

Extra Precautions Taken to Prevent Damp Air Entering the Oil Tank.

An attachment called a " breather " is attached to the side of the tank and connected to the top of the conservator with a pipe.

The " breather " is a metal box fitted with a number of trays on which is placed calcium chloride. Any air which passes into the conservator must pass over the calcium chloride and consequently any moisture in it is absorbed by the calcium chloride. The calcium chloride should be renewed every year.

Insulation of the End Turns on the High Voltage Winding of Transformers.

The end turns of the high voltage winding are insulated to a greater extent than the rest of the winding, in order to resist the disruptive effect of a surge on the line circuit of the transformer. Paper covered wire is used for the insulation of the high voltage coils, and the coils, when wound, are oil impregnated and dipped in insulating varnish.

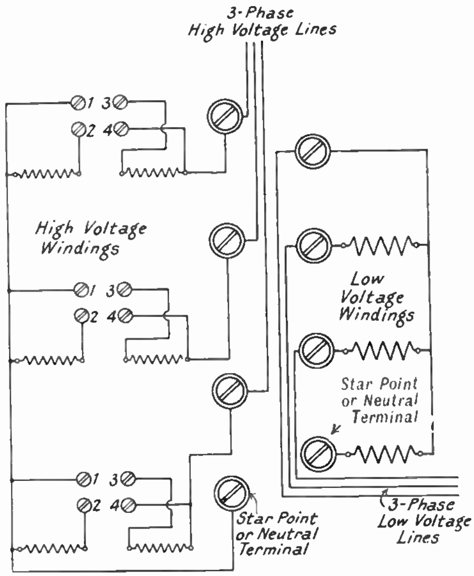

Fig. 6.—CONNECTIONS OF A THREE-PHASE STAR TO STAR TRANSFORMER.

This has an arrangement to connect each of the two halves of the high voltage windings in series or in parallel with links or a rotating switch. Leads 2 and 3 connected in each of the H.V. windings will give the series connections. Leads 2 and 4 and 1 and 3 connected in each of the H.V. windings will give the parallel connection. Series connection will give double the voltage and half the output current of the parallel connection.

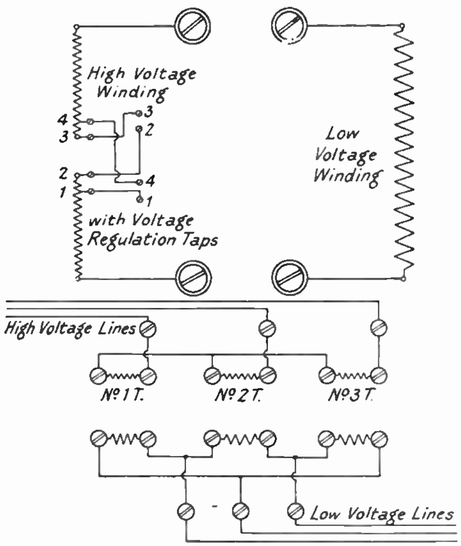

Fig. 7.—CONNECTIONS OF BANK OF THREE SINGLE-PHASE TRANSFORMERS CONNECTED IN STAR DELTA.

High voltage winding provided with taps to give ± 2½ per cent. voltage regulation. The impedance voltage of each unit is approximately the same.

Voltage Variation on Transformers.

Most transformers are required to give a voltage variation of ± 2½ to 5 per cent. This is effected by adding or cutting out some of the turns on the high voltage winding. Tappings are taken from the turns of the winding which are to be added or cut out, to suitable radial contacts operated by a rotating switch blade, or to suitable terminal blocks which may be connected by links or plugs.

TYPES OF TRANSFORMERS.

Instrument Transformers.

Electrical measuring instruments for E.H.T. circuits are generally connected to the circuit through an instrument transformer. The use of this transformer insulates the instrument from the high pressure circuit and allows a less costly instrument to be used.

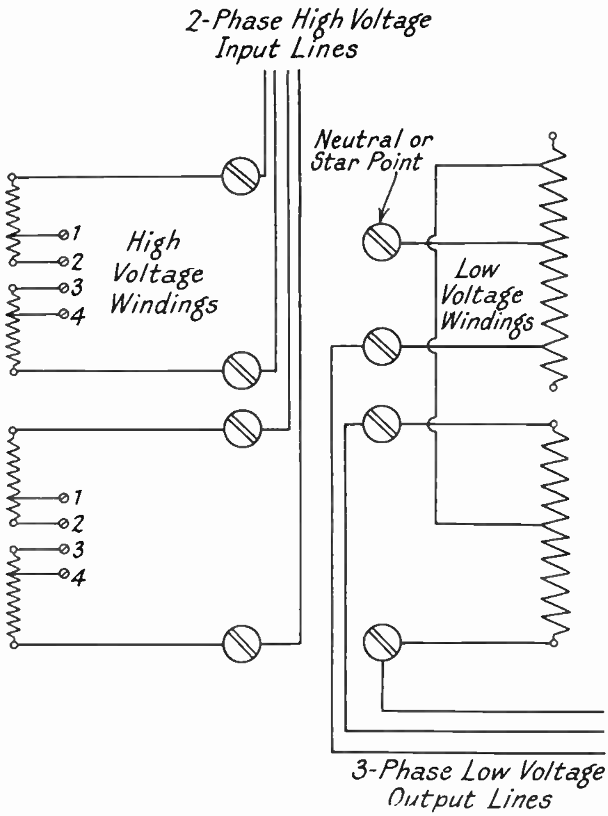

Fig. 8.—Connections of Two Three-phase Scott Transformer.

Two identical transformers are connected together. The H.V. supply to them is two-phase and the output is three-phase low voltage current. The pressure of the low voltage three-phase supply is altered by varying the turns on the H.V. winding at the tapping lead connections.

Each pair of transformers so made are balanced and are tested together to ensure this.

A pair are placed over a heavy copper bar and connected together in opposition, a milliammeter being connected in the circuit. A.C. current is passed through the copper bar and the out-of-balance current measured on the milliammeter. Turns are taken off from one or the other until there is no current registered on the milliammeter.

Each pair, which comprises a unit, is then taped up and flash tested with a pressure of 2000 volts for one minute.

Auto Transformers.

These are used for starting polyphase induction motors and in cases where it is desired to reduce the pressure of a low-tension circuit to that suitable for the appliances which require a supply of current. The primary and secondary windings are connected in series and may in some cases consist of one single winding having suitable tappings taken off for connection to the circuit.

Auto transformer starting switches are equipped with a switch which, on the starting position, will give a certain fraction of the supply circuit pressure to the motor, by connecting the secondary tappings to the motor circuit. When the switch is changed over into the running position, the motor is connected directly across the supply mains and the auto transformer is cut out of circuit.

Current Instrument Transformers.

The primary winding consists of few turns connected in series with the line and carrying the line current. Inside the primary is placed the secondary winding, consisting of many turns. The ratio of the turns on the two windings is almost equal to the current ratio required, a small compensation allowance of 0.5 per cent. being made. Iron of a special quality and suitable for low flux density is used for the core.

Merz Price Balanced Current Transformers.

A heavy core is made up of circular slotted core plates, and a coil of few turns is wound on each protuberance of the core. The coils are connected in series.

Booster Transformers.

Booster transformers are used to regulate the alternating current pressure supplied to a rotary converter. In a rotary converter the ratio between the A.C. pressure supplied to and D.C. pressure obtained from the armature is constant whatever may be the excitation. The only means of regulating this D.C. pressure is to vary the pressure of the A.C. current supplied.

The booster is a transformer with a movable secondary winding. In construction it resembles an induction motor, the primary winding being wound on the stator and supplied by the A.C. curent, so as to produce a rotating field. The secondary winding is wound on the rotor and connected to the slip rings of the converter. The rotor, however, is not allowed to rotate, but the phase relationship of the primary to the secondary is determined by the relative positions of the stator and rotor. The position of the rotor is capable of adjustment with a worm and wheel gearing.

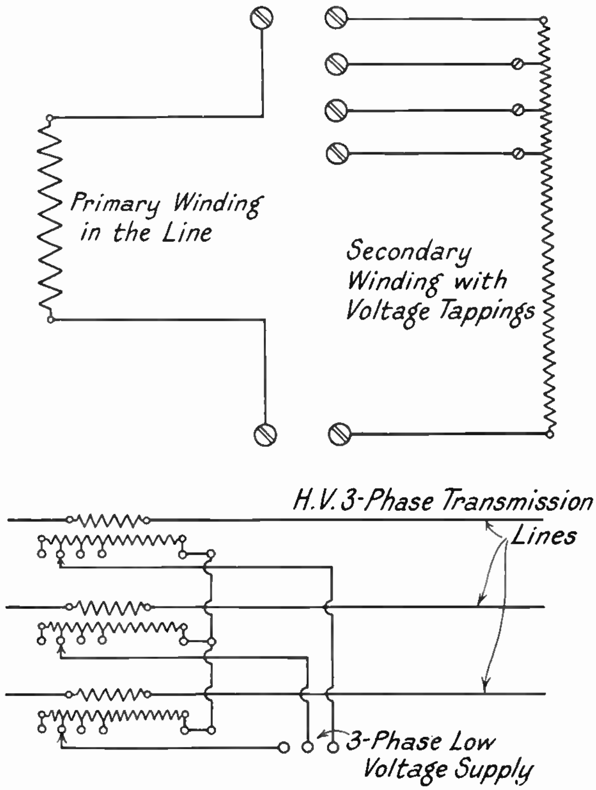

Fig. 9.—Connections of Three Single-phase Series Transformers.

The primary winding of each transformer consists of a few turns, and is connected in series with one of the lines. The secondary windings of the transformers have voltage taps, so that the low voltage three-phase supply given from them may be adjusted to a constant value when the primary currents supplied from the H.V. transmission lines vary.

Scott Transformer.

An interesting application of transformers is the conversion of a two-phase into a three-phase system, and vice versa, and was invented by Mr. C. F. Scott.

The two-phase supply gives current to the primaries of two transformers. The end of one of the secondary windings is connected to the mid point of the secondary of the other transformer. The three phase output is then obtained from the free end of the first secondary and two ends of the other secondary winding.

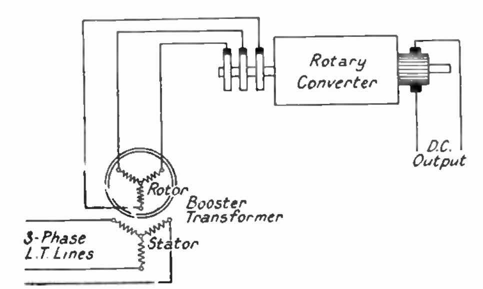

Fig. 10.—Booster Transformer Connected to Rotary Converter.

The rotor winding is given an angular displacement relative to the stator winding for adjustment of D.C. output voltage.

Balancing Transformers.

These are used to maintain the balance on a three-wire system of distribution, either A.C. or D.C.

In a D.C. system fed from a rotary converter the ends of the winding are connected to the slip rings on the A.C. side, and the centre tap to the middle wire of the system.

They may also be used for subdividing a supply pressure between a number of circuits.

SAFETY DEVICES.

It is an essential condition that the

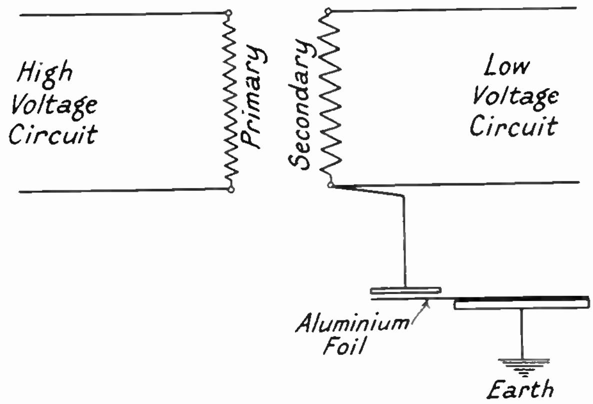

Fig. 11.—CARDEW'S SAFETY DEVICE.

When the potential between the plate connected to the secondary winding and the aluminium foil is increased beyond the safety limit, the foil is brought into contact with the plate by electrostatic attraction and the secondary circuit is earthed.

insulation between the primary and the secondary windings be perfect. If this condition be not satisfied the use of transformers becomes dangerous as a transfer of pressure from a high voltage transmission line to a low voltage circuit through defective insulation would probably be attended with serious results.

Safety devices are therefore fitted to transformers to prevent such an occurrence.

Metal Dividing Sheet.

The simplest safety device is that of a metal dividing sheet, which is earthed and placed between the primary and secondary windings of the transformer. This device ensures safety only in so far as a leak from one winding to the other, but it is useless against a leak in any other part of the transformer, e.g., the lead-in wires or between the terminals of the two circuits.

Another Safety Device.

A safety device was invented by Major Cardew which is reliable and gives adequate protection against the introduction of high pressure in the low voltage circuit. In this device the action depends on the electrostatic attraction between a metal plate connected to the secondary winding of the transformer and an aluminium foil lying on a plate which is connected to earth. Provision is made to adjust the distance between the plate and the aluminium foil. The foil is permanently at zero potential, while the plate has, under ordinary conditions, a potential not exceeding the secondary voltage. The electrostatic attraction corresponding to this potential difference between the plate and the foil is insufficient to raise the foil. When the potential of the plate, however, is raised, due to a fault which will introduce the pressure of the high voltage primary circuit to the secondary circuit, the potential difference between the

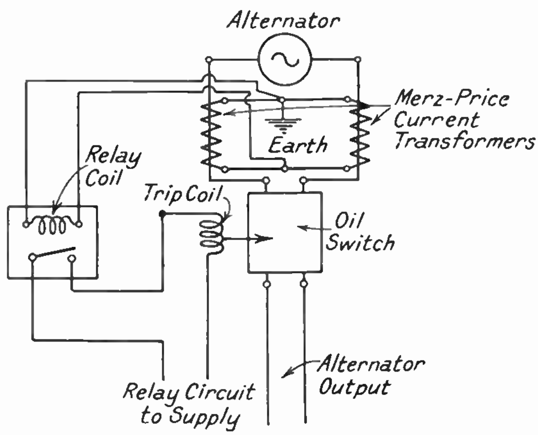

Fig. 12.—ALTERNATOR WINDING PROTECTION AGAINST INSULATION FAULTS WITH MERZ-PRICE BALANCED CURRENT TRANSFORMERS.

The mid-points of a pair of Merz-Price balanced current transformers are connected to a relay coil. Under normal working conditions when no fault exists in the insulation of the windings, the same current flows through the primaries of the current transformers and therefore the secondary windings contribute equally towards the current which flows towards the mid-points. The mid-points will therefore be at equal potential and no current will flow through the relay coil. When a fault occurs in the insulation of the alternator windings which allows current to pass to earth, the current in the primaries of the transformers will no longer be equal and the mid-points will not be at the same potential, a current now flows through the relay coil, which will cause the relay circuit to close and the trip coil will be energised, causing the oil switch in the alternator circuit to be opened.

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