TO BE COMPLETED IN 40 WEEKLY PARTS

NEWNES PRACTICAL ELECTRICAL ENGINEERING

IN THIS PART

ESTIMATING FOR WIRING CONTRACTORS

LAW RELATING TO ELECTRICAL ENGINEERS AND CONTRACTORS

DESIGN OF D.C. MOTORS AND DYNAMOS

APPARATUS FOR THE CORRECTION OF POWER FACTOR

HOW TO START AN ELECTRICAL BUSINESS

1/-

PART 37

A PRACTICAL WORK WRITTEN BY EXPERTS

TABLE I.

Typical Estimate for Labour Costs.

Item of Material.	Quantity.	Size.	Basic Rate.	Total Cost. £	s.	d.
Main switch	1	50-amp.				
Main cables—						
Tube	30 feet	1-inch				
Boxes	2	Angle draw boxes				
Saddles	4	1-inch spacing				
Cable	22 yards	7/.052				
Fuse board (main) ..	5-way	20-amp.				
Fixing bolts	4					
Sub-main cables—						
To ground floor—						
Tube	15 feet	¾-inch				
Boxes, etc. ..						
Cable	12 yards	7/.029				
To first floor .. / To second floor / To third floor	Similarly					
Sub-fuse boards ..	2	3-way 10-amp.				
	2	4-way 10-amp.				
Circuit wiring—						
Tube	As measured					
	Etc.	Etc.				

first ... may be seriously wrong for the second.

Special Conditions.

In almost every contract there are special conditions not under the control of the electrical engineer. The building work may be delayed due to bad weather or non-delivery of material or by the work of some other contractor. Such causes may upset entirely the programme of work laid out when estimating and may involve a very heavy additional cost. The partitions, for example, on a large contract may not be "set out" by the builder at the right moment for the electrician, and this may involve his stopping work on each section of the job and returning later to complete. Even if each such interruption only involves ten minutes of wasted time, this means a loss of 6d. or 8d., and if this is repeated many times it may result in a very heavy addition to the labour bill.

Guessed Estimates.

Just as the old methods of estimating an average rate "per point" are, or should be, a thing of the past in the complete estimate, so the rough and ready estimating of labour costs must be abandoned in favour of more reliable methods. The guesswork basis may suit small jobs which will take two or three men a fortnight or a month, but on larger contracts such figures are of little value except as a rough check on the figures obtained by more systematic methods.

Detailed Estimates Required.

To obtain a reliable estimate, each item of labour cost should be considered and the labour required calculated from past experience—and this obviously involves the recording of labour costs for past jobs. These past results may exist in detailed records kept for reference or may form part of the mental equipment of the estimator, but it is necessary to revise them constantly and to adjust average results to suit the special requirements of each specification.

Cost of Fixing Tube.

The cost of fixing tube may be taken as an example of the way these average or standard costs will vary in different conditions.

The tube has to be fixed to something and this may be timber, brick, stone,

A

TABLE II.

Typical Combined Estimate for Material and Labour.

Item of Material.	Quantity.	Size, etc.	Material Rate.	Labour Rate.	Material Cost.			Labour Cost.		
					£	s.	d.	£	s.	d.
Main switch	1	50-amp.								
Main cables										
Tube	30 feet	1-inch								
Boxes	2	Angle draw boxes								
Saddles	4	1-inch spacing								
Cable	22 yards	7/.052								
Fuse board (main) ..	5-way	20-amp.								
Fixing bolts	4									
Sub-main cables—										
To ground floor—										
Tube	15 feet	¾-inch								
Boxes, etc. ..										
Cable	12 yards	7/.029								
To first floor										
To second floor	Similarly									
To third floor										
Sub-fuse boards ..	2	3-way 10-amp.								
	2	4-way 10-amp.								
Circuit wiring—										
Tube	As measured Etc.									

concrete or steelwork. Timber fixing involves only putting in wood screws. Fixing to brick or stone requires plugging, and this is entirely extra to the cost of timber fixing. Work on concrete may require the use of special dowels cemented in, and if so the setting out must be more accurate than with screwing to timber or even to plugs in brick or stone. Finally, fixing to steel work may be very easy or expensive—easy, if fixings can be obtained by the use of some simple girder clip, or very expensive if it is necessary to drill and tap steel girders.

Difficulties Caused by Position of Tubing.

Further difficulties arise according to the position in which the tubing is fixed. It may be run straight across a floor or on walls or on high ceilings only reached from trestles which need frequent moving—which takes time.

Another factor is whether the runs are simple, as in the case of long runs of mains with no difficulties of junction boxes, or complicated by the need for arranging boxes for switches and fittings at comparatively frequent intervals. For runs for main cables it may be possible to install many score feet of tube without the need for cutting and screwing or bending a single length of tube, whereas on the circuit wiring almost every length of tube fixed may need to be carefully measured off and cut or set with great accuracy.

Surface or Concealed Work.

Whether the work is on the surface or concealed also adds to the complications, as surface tubing needs more careful work than is necessary with concealed—not so much in the workmanship as in the accuracy of the setting, in the spacing of the saddles and so forth. Tubing that is to be buried may be simply held in position with pipe hooks until the plaster or concrete screeding is put over it, but surface tube must be carefully fixed with saddles and run strictly parallel with the walls and ceilings.

All these factors affect the estimate and allowance must be made for every such detail before a decision is made as to the correct rate per unit quantity for fixing.

METHODS OF ESTIMATING.

Probably every estimator has his own ideas as to what is the best method of making these allowances and experience is the only guide as to what they should be in every case. Subject to such allowances there are also many methods of working out the cost.

Basic Rate per 100 ft. Run of Tube and Wire.

One method in common use is to adopt a basic rate per 100 ft. run of tube and wire. The figure used would include the labour cost of setting out the runs; of fixing the tube, including all plugging, etc.; of cutting and screwing the tube; of connecting up all boxes; and of drawing in the wires. The conditions that affect one part of the work, such as fixing tube, also affect the other items to a similar extent, so that the basic rate would vary in the same degree for all the sections of such an all-in rate.

Separate Estimating.

Another method is to price separately at so many pence per foot the cost of fixing tube; to price separately the cost of fixing all the various tube boxes and fittings; and again, separately, the cost of drawing in the wires. This is somewhat more accurate, as the various sections are each estimated and allowance made automatically for variation in costs due to varying quantities of boxes or to the number of wires in a tube.

Such details depend on the experience and method of recording past results, and if used with proper judgment should not greatly affect the final result. In fact, if the allowances for different conditions could be made with complete accuracy, the results should all agree exactly.

Detailed Estimate.

Having prepared a schedule of rates and having decided how the costs are to be divided up among the various parts of the work, the next step is to proceed with the pricing up and here the detailed quantities already prepared for estimating the cost of materials can again be used for estimating the labour cost.

Each item of material can be allotted its own labour charge and the total cost obtained item by item. Such an estimate for labour should be prepared in tabular form on some such system as shown in Table I (page 1737).

Many variations of such a method of scheduling out the details can be used and experience will show which is best suited to the requirements of the estimator and to the method of pricing up that has been adopted. For example, if the "all-in" rate for fixing tube and wire has been adopted, the items above for tube, boxes, saddles and cable would all be charged in one inclusive rate.

Combined Estimates for Labour and Material.

It will be obvious that the details given under "Item of Material," "Quantity" and "Size" must all appear in both the material and labour estimates, and from this it naturally follows that a combined estimate will save much paper and much time. If double columns are provided for the basic rate and the total cost, the whole of the material and labour costs are shown at the same time.

An estimate prepared on such lines would then appear as shown in Table II.

Examples of Labour Costs.

It is extremely difficult to give actual figures for labour costs, and in view of the very wide range of conditions under which work has to be done, any writer must be very diffident in putting figures on paper. The figures given here must be used with considerable care on this account, but they represent average results for work carried out under normal conditions for work of the best class. If conditions suit a rough finish, they could be reduced and also if the conditions suit rapid work. On the other hand, if conditions are difficult they may need to be increased.

Varying Labour Rates.

To avoid the complications due to varying labour rates of pay the figures have been given in hours taken by a pair of men—wireman and mate—to carry out each job.

The actual costs in money can easily be ascertained by taking the wages paid to the men which will vary in different districts and according to whether boys or apprentices are employed; whether trade union rates are paid and so on.

Time required for various jobs :—

Fixing Main Switch and Fuses.
15 amp.—1½ to 2 pair hours each.
60 amp.—2 to 3 pair hours each.
Fixing and Connecting Fuse Boards.
Small (3 to 6 ways)—¾ to 1 pair hours per way.
Large (8 to 15 ways)—½ to ¾ pair hours per way.
(Heavier boards—30 to 50 amps. about 50 per cent. extra.)
Fixing Tube (including setting out runs and plugging in brick).
¾ in.—15 pair hours per 100 ft. run.
1 in.—20 pair hours per 100 ft. run.
1¼ in.—25 pair hours per 100 ft. run.
1½ in.—35 pair hours per 100 ft. run.
2 in.—45 pair hours per 100 ft. run.
Fixing Tube Boxes.
2½ pair hours per dozen.
Drawing in Cables (including measuring off and cutting).
3/.029—2 pr. hrs. per 100 yds. of conductor.
3/.036—3 pr. hrs. per 100 yds. of conductor.
7/.029—4 pr. hrs. per 100 yds. of conductor.
7/.044—5 pr. hrs. per 100 yds. of conductor.
7/.064—8 pr. hrs. per 100 yds. of conductor.
19/.052—10 pr. hrs. per 100 yds. of conductor.
19/.072—12 pr. hrs. per 100 yds. of conductor.
Fixing and Connecting Switches.
Ordinary—4 pr. hrs. per dozen.
Two-way—5 pr. hrs. per dozen.
Fixing and Connecting Combined Switch Plugs.
6 pr. hrs. per dozen.
Fixing and Connecting Power Plugs.
4 to 6 pr. hrs. per dozen.
Twin Lead Conductors (including plugging and measuring off cables).
3/.029—20 pr. hrs. per 100 yds.
3/.036—24 pr. hrs. per 100 yds.
7/.029—30 pr. hrs. per 100 yds.
7/.036—35 pr. hrs. per 100 yds.
7/.044—42 pr. hrs. per 100 yds.
7/.064—50 pr. hrs. per 100 yds.
Fixing Armoured Cables (including plugging and measuring off cables).
¼ to ½ pair hours or more per yard, according to size and conditions.
Jointing Cables.
3 to 5 pair hours, according to kind of joint.
Fixing Fittings.
Plain pendants and brackets—
4 pair hours per dozen.
Special Fittings—
6 to 8 pair hours per dozen, or more, according to kind.

Adjustments of Above Rates.

The above basic rates represent fairly average costs, but they will be subject to very considerable variation and must be used with care. They may be very greatly reduced on large contracts or in circumstances where there is much repetition work or under other favourable conditions. On the other hand, it may be necessary to allow for higher rates on difficult work. The necessary adjustments can only be ascertained by experience with each group of workmen; with conditions prevailing in various districts and with the other items that affect the output.

Overhead Charges.

The figures of estimated cost so far considered cover only the actual outlay for material used and wages paid to the men fixing it, but there are many other items that must be added before the total cost is ascertained. Some of these vary directly with the wages or labour cost and others bear a direct relation to materials, whilst a third group of items are in some respects independent of either total.

Fares and Travelling.

Allowance must be made for the cost of sending men to and from each job and this depends on the distance of the job from the firm's headquarters. The usual practice is to pay the cost of travelling to and from the job each day, without allowance for travelling time, except at the start and end of the contract. This item thus amounts to a fixed sum per man per day for each job, the sum varying with the location of the job. This must be added to the total wages and will amount to 12 fares per man per week—quite a substantial addition to the labour estimate on many contracts.

Country Money.

This is an alternative charge to the daily fare which is paid when jobs are more than an agreed distance from headquarters—in London, 12 miles from Charing Cross. In such cases the country allowance is paid as an addition to wages each week and the fares to and from the job only at the beginning and end of the contract, whilst time occupied in travelling is paid to the men as if at work. Various conditions apply according to the distance of the job, the men being entitled to a return fare at intervals, according to the distance from home.

This charge must be estimated by calculating the number of men-weeks the work will occupy and allowing the country money accordingly with the further sum for the fares and travelling time at the beginning and end of the job.

The figure is often complicated by the possibility of employing local men for part of the work and this possibility depends on the locality of the job; its distance from industrial areas where local men might be available; the state of business in the district and so forth. Every case must be considered on its merits and the necessary addition made to the wages cost. The cost will be about 25 per cent. of the wages paid to the men sent from headquarters to the country job.

Sundry Materials, Use of Plant, etc.

The estimate for materials will or should include everything that can be foreseen, but there will be many small items required that cannot definitely be allotted to particular sections. These will include rubber and sticky tape, solder, various odd screws and so forth. A small sum should be added for these.

Allowance must also be made for use of tools and plant and for the supply of renewable tools. Stocks or other screwing tackle, bending machines, ladders, trestles and steps and so forth must all be used, and although not destroyed on each job, they must be renewed from time to time and the equivalent of their hire must be charged to the job.

Other items, such as dies, draw wires and so on are used up on the job and must be paid for outright.

Finally, certain plant may be hired as, for example, special tower ladders for lofty rooms.

Lost Time.

Some allowance should also be made for "lost time." This is essential if labour costs for each section of the work have been calculated very closely. Some time must be wasted on every job on such work as arranging the runs to meet the requirements of other trades; discussing details of the work with the architect or client; making out reports, wages sheets and orders for material; checking deliveries of goods; returning empty cases or cable drums, and so on. The actual allowance must again depend on the conditions on each job, but it may easily amount to 2 or 3 per cent. of the labour cost.

Supervision.

This may be another heavy item. It can include the foreman's time looking after a big contract or the proportion of a wireman's time not spent in actual work on a small job with only two or three men employed. There will also be the cost of office supervision—i.e., the time spent by the supervisor or travelling foreman who visits the job at regular intervals to ensure that the work is being done properly; that time is not being wasted; that materials are being ordered and delivered when they are wanted and so on.

This again is a very variable item, but it is certainly not likely to be less than 5 per cent. of the wages bill and may be 10 per cent. or more.

This item must include the travelling expenses for the supervisor and this is best allowed for on distant contracts by estimating the number of visits likely to be necessary during the execution of the work—another varying item depending on the complications that need his attention; the possible requirements of the consulting engineer, architect or client, and so forth. Probably one visit every two to three weeks should be allowed on average work.

Office Expenses.

All the items dealt with above are concerned with the actual costs incurred in direct connection with the particular job, but there are, in addition, the overhead expenses for office organisation, etc., for which provision must be made. These will include such items as office rent; salaries to staff; costs for stationery, telephones and the scores of other items that must be met before any profit is earned.

Fixed Expenses.

Certain of these items will represent a fixed expense to be paid out on any job, however small. For example, a call for a man to be sent to renew a fuse, which can be done in five minutes at a cost of a few pence, may involve office expenses amounting to several or many times the cost of the actual work.

Probably on small jobbing work averaging up to 20s. per invoice, they amount to 25 per cent., at least, of the wages and possibly to much more, depending on whether a firm is specially organised, or not, to deal with such small jobs and whether they are all local or scattered over a wide area.

The total of all these costs is, of course, much lower on larger contracts, but is never likely to be much below 10 per cent. of the total cost for wages and material.

A Trap for the Unwary.

All the above charges must be met before the contractor can make any profit on a contract and it is the failure to allow for these charges that accounts for the bankruptcy of so many small firms—and large ones as well in many cases. The small contractor just starting up carries out with his own labour a series of contracts and at first thinks he has no need to meet all these expenses. He makes out his own wages sheets and other records and his accounts in the evening, and he may have no office rent, conducting his work from home. The few jobs thus carried out show him an apparently comfortable surplus above his wages as a journeyman and he decides to tender for larger work or to take on several contracts simultaneously.

It is not long before he finds that the costs on these are very different to those on the jobs he did himself. The men he pays will not do quite as much work in the day as he will himself; they are not quite so careful to avoid wastage of material; much time is lost in going to and from the different jobs to see how they are getting on; the clerical work is more than he can manage in the evening and he has to employ a clerk—which means paying office rent. The costs of the bigger business are found to be entirely different from those of the one-man concern and profits are rapidly converted into losses.

Risks that have to be Allowed for.

Assuming, however, that all the overhead charges have been covered, the final item for profit has to be added, and probably in this will be included an allowance for contingencies—in other words, the risks of not carrying out the work exactly as estimate.

This figure must be left to the contractor to decide, but it may be anything from 15 per cent. upwards on average work.

Summary of Estimate.

Having decided all these various allowances, the final sum to be quoted can be fixed, the ultimate estimate being somewhat as follows:—

	£	s.	d.
Total cost for material			
Total cost for wages—(No. of pair hours at rate paid to men)			
Travelling expenses on jobs near home (12 fares per man per week) .. (or country money on distant jobs—(about 25 per cent. of wages of men sent from headquarters to a country job), plus fares to men and travelling time)			
Sundry materials, use of plant and tools (probably 1 to 2 per cent. of cost of material)			
Lost time (probably 2 or 3 per cent. of wages)			
Supervision (not less than 5 per cent. of wages)			
Total..			
The total of all these items gives the actual total outlay directly incurred in the execution of the contract.			
Office expenses and overhead charges (10 to 50 per cent. of total cost according to size and conditions of contract.)			
Total gross cost of Contract ..			
Add Profit			
Total sum to be quoted for carrying out the work			

It is only by dealing with all these detailed figures item by item that a reliable result can be obtained and inaccurate estimating must sooner or later lead to failure. Prices obtained may be high or low, but unless the contractor knows what each job should cost and can compare accurately the actual costs with the estimates and can adjust future estimates to suit past results, his business is not likely to prosper.

LAW RELATING TO ELECTRICAL ENGINEERS AND CONTRACTORS

By ALDERMAN R. TWEEDY-SMITH, LL.D., F.R.S.A.(Lond.), Hon. Fellow and Solicitor to the Electrical Contractors' Association (Incorp.), Member (Past Chairman) of the Electric Lighting Committee of the Southend-on-Sea Corporation

THIS article contains a summary of the main points regarding the law and its application to those in the electrical industry

1.—Both electrical engineers and contractors should, in their own interests, know a certain amount of law.

2. — Consulting Engineers.

We will consider first the risks and liabilities of consulting engineers. A man who is a consulting electrical engineer is one who has, or professes, skilled knowledge of any particular branch of electrical engineering. Consulting electrical engineers have duties and liabilities of a particular nature to their employers. In the first place, they are expected to have a thorough knowledge of electrical engineering, including the capacity of cables, wires and insulating resistance, and also of all appliances, plant and fittings, dynamos, motors or anything else which they advise their clients to have in any particular matter. Further, they must have a knowledge or make themselves acquainted with all general or local Acts, by-laws or regulations affecting works or installations they are employed to carry out. They must have knowledge of the ordinary rights of adjoining owners and local and other authorities sufficient to put them upon inquiry or to advise the employer of risks which he might run, and if necessary to recommend that legal advice should be obtained in cases where he is in doubt. It necessarily follows that consulting engineers should be fully acquainted

Fig. 1.—ALDERMAN R. TWEEDY-SMITH.

(*a*) in factory work, with the Home Office regulations issued under the Factory and Workshops Acts, 1901, 1907 and to date.

(*b*) In mines, with the general regulations relating to mines.

(*c*) In cinemas, with the Home Office Cinematograph Regulations.

(*d*) In general work, with the Regulations of the Electricity Commissioners and the Electricity Supply Acts, 1882, 1888, 1919, 1922, 1926 and 1928.

(*e*) In preparing estimates he should know something relating to National Standardised Wages Agreement and the working rules and agreement with electrical trades unions in the different districts. (Copies of the above regulations can be obtained from the Home Office, Whitehall, London, or H.M. Stationery Office, Adastral House, Kingsway, W.C.2.) In cases of doubt the Electricity Commissioners, Savoy Court, Strand, W.C.2, are willing to give every assistance. We will, however, proceed to give a summary of the principal points of the Statutes and of the above Regulations which all engineers and contractors should know.

3.—Statutory Provisions and Regulations of the Electric Lighting Acts, 1882, 1899 and 1919.

A contracting engineer and an electrical contractor are, in law, practically in the same category. They are persons, companies or firms who carry out electrical work or supply electrical appliances of any kind. If not acting under a consulting engineer then they are under the *same obligations and liabilities* that a consulting engineer is under, if they hold themselves out as competent to give advice. Contracting engineers acting under the instructions, plans or specifications of a consulting engineer, are protected in law, should it turn out that the consulting engineer is wrong.

4.—Errors in Design.

An electrical engineer or contractor is not liable for errors in design made by a consulting engineer or architect (Adcock's Trustees *v.* Bridge).

5.—Fitness of Appliances.

Contracting engineers, or manufacturers supplying electrical appliances or goods are under legal obligation that the same shall be reasonably fit for the purpose intended. Work done must not only be reasonably fit, but must comply with the regulations herein referred to. (See paras. 2 and 8.)

6.—Undertakers' Regulations.

It must be remembered that Undertakers supplying electricity often issue local regulations which have no legal validity and which they seek to enforce. An agreement is tendered to a consumer which binds him to conform to the local regulations. An engineer or contractor should inquire from a consumer whether he has bound himself to such local regulations. If the regulations are not reasonable, it may be desirable for the engineer to advise his client to terminate the contract as a consumer can only be asked to enter into a contract which

(*a*) specifies the premises;

(*b*) gives the maximum power required;

(*c*) gives the day upon which it is desired the supply should commence.

(*d*) If required by the Undertakers, the Consumer must enter into a written contract for at least two years that the payments for electricity shall be at least 20 per cent. on the amount spent by Undertakers on the electric lines used in making a connection. The cost of transformers cannot be reckoned in the amount so spent.

(*e*) If required by the Undertakers the Consumer must give security for the connection being made and in respect of energy to be supplied (E.L.A., 1899, Sec. 27 of Schedule). See also Husey *v.* London Electric Supply Corporation (1902), 1 Ch. 411.

An engineer to a local authority has no power to enter into a binding contract for the supply of electricity unless he was either in fact authorised or held out by the council as authorised to make such a contract on their behalf (Bourne & Hollingsworth *v.* Marylebone Corporation (1908), 24 T.L.R. 613).

Supply companies and local authorities have no power to specify the use of any special switches, wires or fittings, or the situation of same. On the other hand, they are not compelled to give a supply of energy to any premises unless they are reasonably satisfied that the electric lines, fittings and apparatus therein are in good order and condition and not calculated to affect injuriously the use of energy by the Undertakers or by other persons. Section 27 (5).

The supply authority can also discontinue to supply energy so long as any lamp or other fitting is likely to be dangerous.

If there is any difference of opinion between the electrical engineer or contractor or his client and the supply authority, provision is made for such difference as to alleged defects in any electrical lines, fittings or apparatus to be determined by arbitration. (Section 27 (6).)

7.—Rights of Consumers and Electricity Undertakers.

It is important that engineers and contractors should have a knowledge of the rights of consumers and electricity undertakers. Without this he cannot give adequate advice to his client.

The following gives an epitome of such rights.

(A) *Supply of Electricity.*

Electricity Undertakers are compelled to give and to continue to give a supply of electricity to owners and occupiers of premises situate within fifty yards from any distributing main used as a general supply (Electric Lighting Act, 1882, sec. 19, and E.L.A., 1889, sec. 27).

Undertakers are liable to supply energy, and in default are liable to a penalty unless the court should be of opinion "that such default was caused by inevitable accident or *force majeure*." Reasonable apprehension of a strike does not in itself amount to *force majeure* even if a strike is threatened because a non-unionist had wired a consumer's premises. The undertakers are bound to supply unless a strike is actually proceeding (Hackney Borough Council *v.* Dore, 1922, 1 K.B. 431). It has been held that a draper owning shops and a covered market and stalls let to various traders is entitled to install electric plant for the supply of electrical energy for himself and his tenants (Caerphilly U.D.C. *v.* Griffin, 1928, Ch. 171).

(B) *Conditions of Supply.*

The regulations of Undertakers are of no validity. The only valid regulations are those issued to the Undertakers signed by or on behalf of the Board of Trade (E.L.A., 1882, sec. 6, and E.L.A., 1899, sec. 10). The Electricity Commissioners at present exercise this function.

(i) A copy of such regulations can be obtained from the Undertakers at a price not exceeding 6d. *Penalty* £5 and a daily penalty of £5 for not supplying such regulations (E.L.A., 1899, sec. 70 of Schedule).

(ii) Main fuses or circuit breakers must be placed by Undertakers "as close as possible to the point of entry." Undertakers cannot dictate the position. (Regulation 26.)

(iii) Consumers can be refused a connection if a leakage results of 1-10,000th part of the maximum supply current to the premises. (Regulation 6.)

(iv) Undertakers not making a connection must serve upon consumers a notice stating "their reasons for so declining." (Electricity Commissioners' Regulation 29.) Consumers, if dissatisfied, can apply to a Board of Trade Inspector either to test his lines or those of the Undertakers. (Electricity Commissioners' Regulation 31; E.L.A., 1899, secs. 35 to 48.) *Penalties* on Undertakers for non-compliance £10 plus £10 per day and damages. (Electricity Commissioners' Regulation 35 and E.L.A., 1899, secs. 35 and 36.)

(v) Undertakers are liable to connect prospective consumers to the main notwithstanding threats of a strike on the part of the undertakers' employees. (Hackney Borough Council *v.* Dore, 1922, 1 K.B. 431.)

(C) *Cost of Mains in Compulsory Area.*

(i) When Undertakers obtain Parliamentary sanction they are always placed under obligation within a period of two years to lay down distributing mains in certain streets specified in their special order. *Maximum penalty* in default £5 each day and order may be revoked. (E.L.A., 1899, secs. 21 and 23.)

(ii) In other streets not specified in the Special Order any six owners or occupiers in a street are entitled to demand from the Undertakers free of charge a form of requisition for signature requiring the Undertakers to supply electricity in such street (E.L.A., 1899, sec. 24).

(iii) Undertakers can by notice require persons signing such requisition to take a supply of electricity for two years in London or three years at the least elsewhere. Consumers must agree to take a reasonable amount of electricity and must, within fourteen days of receiving such notice, tender a signed agreement agreeing to take the supply for the above periods. (9 Edw. 7, c. 34, sec. 15; 8 Edw. 7, c. 167, sec. 16,; 62 and 63 Vic., c. 19, clause 25 of Schedule.)

The Board of Trade or Arbitrators will settle what is a "reasonable" amount of electricity; but, in any case, the sum must not exceed 20 per cent. on the actual costs of laying the main (E.L.A., 1899, secs. 24 and 25).

(D) *Cost of Connection.*

(i) The cost of any electric line laid upon private property must be paid by the consumers.

(ii) The cost of electric lines not on private property up to sixty feet must be paid by the Undertakers.

(iii) The cost over sixty feet must be paid by the Consumer (E.L.A., 1899, sec. 27). *Penalty* for non-connection not exceeding £2 per day (E.L.A., 1899, sec. 30).

(E) *Prices and Method of Charge for Electricity.*

THE MAXIMUM PRICES ARE STIPULATED BY THE SPECIAL PROVISIONAL ORDER GRANTED TO EACH UNDERTAKER.

Section 42 of the Electricity (Supply) Act of 1926 endeavours to clear up several ambiguities as to charges. Any method of charge desired by Undertakers must first be duly authorised by the Minister of Transport, or of the Electricity Commissioners to whom he has delegated most of his powers (1919 Act, secs. 2 and 39). Under Section 42 (1) the Minister of Transport or the Electricity Commissioners may authorise "notwithstanding anything in any Act or Order to the contrary" (1) a periodical fixed, or (2) service charge; (3) in addition, a charge for the actual quantity of energy supplied to the consumers, or (4) for the quantity contained in the supply.

These powers, when obtained, enable Undertakers to charge on somewhat similar lines to water companies. For instance, charges may be made (1) on the assessable or rateable value of premises for a given period, or on a fixed kilowatt charge; (2) a service charge on the number of lamps or on the area of the rooms and passages, etc., to be lighted; (3) in addition to the standing charges (1), (2) and (3), a charge may be made for the quantity of electricity supplied; or (4) a charge may be made for the electrical quantity contained in the supply. This is the ordinary flat-rate system of supply.

(F) *Cutting Off Supply.*

Undertakers have power to cut off if any charges for electricity or any other sum are not duly paid (E.L.A., 1882, sec. 21).

Outgoing Tenant.

An incoming tenant who has undertaken to exonerate the outgoing tenant cannot require a supply until he has paid the arrears of the outgoing tenant, but he cannot be sued for such arrears (Cannon Brewery Co. *v.* Gas Light and Coke Co. (1904), A.C. 331).

(G) *No Undue Preference* must be made in charges to one consumer over another under similar circumstances (E.L.A., 1882, sec. 19). The amount of energy consumed and whether day or night loads are factors in considering similar circumstances (Metropolitan Electric Supply Co. *v.* Ginder (1901), 2 Ch. 799).

A reduction by a local authority in the price for electricity in respect of houses electrically lighted throughout constitutes an "undue preference" (Att.-Gen. *v.* Ilford U.D.C. (1915), 84 L.J., Ch. 860).

Undertakers cannot make a lower charge for power supply to users of power who agree to take the whole of their lighting supply from Undertakers, and a higher charge to consumers who take supply for power and partial lighting (Att.-Gen. *v.* Long Eaton U.D.C. (1915), 1 Ch. 124, C.A.).

On the other hand Undertakers can charge at power scale where not exceeding 20 per cent. of total quantity is consumed for lighting a factory or workshop in which motors, etc., are installed, provided the whole supply is taken from same service and meter (Att.-Gen. *v.* Hackney Borough Council (1918), 1 Ch. 372, C.A.).

An agreement by a statutory body for the supply of electricity that their scale of charges to the public shall not exceed those of another statutory body in a neighbouring district is not such a limiting of, or fetter upon, their statutory powers and duties, and is not so incompatible with their exercise and discharge as to be *ultra vires* and void either under the Electric Lighting Acts, 1882 and 1909, or at common law (Birkdale District Electric Supply Co. *v.* Southport Corporation, 95 L.J. Ch. 587; (1926) A.C. 355; 134 L.T. 673; 90 J.P. 77; 24 L.G.R. 157; 42 T.L.R. 303—H.L. (E.)).

(H) ***Consumer's Terminals.***

Where under an Electric Lighting Order and Electric Lighting Acts a company is authorised to supply electricity within a certain area, it is not illegal or *ultra vires* the authorised powers of such company to enter into a contract to supply a firm with electrical energy where the premises of the firm are situated partly in the company's authorised area and the remainder outside such area, and where, for the purpose of such supply, the company have erected the necessary electrical apparatus on the portion of the premises of the firm within the authorised area and the consumer's terminals were also on such part of the premises. "Supply" does not in such a case mean supply for use or consumption, but supply in the sense of delivery at the consumer's terminals (Att.-Gen. *v.* County of London Electric Supply Co., 95 L.J. Ch. 357; (1926) Ch. 542; 135 L.T. 601; 70 S.J. 486; 42 T.L.R. 328, Tomlin J.)

(I) ***Undertakers' Mains.***

By Regulation No. 6, Undertakers must maintain their insulation so that the leakage current shall not, under any conditions, exceed one-thousandth part of the maximum supply current. Contractors should remember that the consumer has the right to have the Undertakers' mains tested as sometimes engineers are unreasonable in their requirements as to consumers' installations, in order to safeguard leakages from the mains. Undertakers are bound under this Regulation to keep weekly records of the tests of each circuit.

(J) ***Meters.***

Types of meters have to be duly certified for general use by electric inspectors. Consumers are entitled to have their meters tested, and if they are more than $2\frac{1}{2}$ per cent. inaccurate, the costs of the test will fall on the Undertakers. No claim for a refund can be legally substantiated until an electric inspector has been appointed by the Ministry of Transport. In case of a dispute as to whether any meter is in proper order, the same is to be determined by an electric inspector, and no cause of action arises against a consumer for electricity claimed to have been supplied, until an electric inspector has been appointed. (See Hendon Electric Supply Co. *v.* Banks, 87 L.J., K.B. 790, and Clauses 35, 49 and 57 of the schedule to the Electric Lighting (Clauses) Act, 1899.)

(K) ***Municipal Powers to Supply Fittings and Installations.***

By the Electricity (Supply) Act, 1926, Section 48, it is provided that:

(1) Subject to the provisions of this section a *joint electricity authority* and *any local authority* authorised by *special Act* or by Order to supply *electricity may sell electric lines, fittings, apparatus and appliances for lighting, heating and motive power, and for all other purposes for which electricity can or may be used* (in this section called "electric fittings"), and may *install, connect,* repair, maintain and remove the *same,* and with respect thereto may demand and take such remuneration or *rents* and *charges,* and may make such

terms and conditions as may be agreed upon.

(2) The exercise of the powers of this section shall be subject to the following restrictions :—

(*a*) The *joint electricity authority* or *local authority shall not manufacture* electric fittings unless expressly authorised to do so by special Act or Order ;

(*b*) The joint electricity authority or local authority *shall not sell electric fittings* except—

(i) to a *consumer* or a person who intends to be a consumer of electricity *supplied by them* ; or

(ii) to a *contractor* who requires such fittings to enable him to supply them to a person who is, or intends to be, a consumer of electricity supplied by the joint electricity authority or local authority ;

(*c*) The *prices* charged by a joint electricity authority or a local authority for the sale of any electric fittings shall not be less than the recognised retail prices, unless the sale is to a contractor, in which case the prices shall not be less than the *recognised trade prices*, and if any question shall arise as to what are the recognised retail or trade prices of any electric fittings, that question shall be determined by the committee appointed as hereinafter provided.

(*d*) Every such joint electricity authority or local authority shall so adjust the charges to be made by them under this section *as to meet any* expenditure incurred by them in the exercise of the powers of this section (including interest upon and sinking fund charges in respect of money borrowed for the purposes of this section).

(*e*) The total sums received and expended by any such joint electricity authority or local authority under this section in each year, including interest upon and sinking fund charges in respect of money borrowed for the purposes of this section, *shall be shown separately in the published accounts of the electricity undertaking* of such joint electricity authority or local authority.

(3) The Electricity Commissioners shall appoint a committee comprising *representatives of associations* representing local authorities who are authorised undertakers, contractors and persons engaged in the business of *making* and persons *engaged* in the business of selling electric fittings, such committee to be appointed after consultation with those associations, and that committee shall determine any question which may be raised under this section as to the *recognised retail* or trade prices of any electric fittings and shall advise and assist the persons concerned as to the method of giving effect to the provisions of this section.

(4) The purposes of this section shall be deemed to be *purposes* for which the joint electricity authority or the local authority may borrow money.

(5) In this section the expression " contractor " means a person engaged in the business of selling and installing electric fittings.

(L) *Unfair Competition.*

Electrical contractors who, in the future, experience unfair competition must note that the last-mentioned section gives three safeguards against the same.

(1) A committee on which electrical contractors will be represented will be appointed to determine *any question* as to recognised retail or trade prices of any electric fittings ;

(2) No local authority can sell or install fittings at a loss. Section 48 (2) (d) provides that the charges shall be adjusted so as to meet *any expenditure*, such as wages, rents, rates, administration, interest on borrowed money, etc. ;

(3) Section 48 (2) (c) makes it obligatory for a local authority, *each year*, to publish separate accounts of the electricity undertaking showing the

total sums received and expended in its fittings department. Ratepayers have the right to be supplied with a copy of such accounts at a price usually not exceeding one shilling. If the local authority does not comply with the above requirements action can be taken against the undertaking.

(M) *Hire or Hire Purchase* of "meters, electric lines, fittings, apparatus and appliances provided by Undertakers on or upon the premises of consumers." Apart from the power given to Undertakers under Section 48 above set forth, to *sell* and *install*, etc., Local Authorities, who are Undertakers, have power by Section 42 to "provide" the above-mentioned things, and to include in the periodical fixed or service charge (*a*) a rent ; (*b*) charge ; or (*c*) remuneration, in respect of same, whether let on hire or hire-purchase terms to the consumers or otherwise. It is clear that a local authority must, under Sec. 42 (2) of the 1926 Act, obtain a "Special Order" or "Approval" for the above "method of charge," and such Special Order or Approval may give an option to *ordinary* consumers to be charged by an *authorised* alternative method. There is no statutory power for Undertakers to disconnect where instalments including fittings are in arrears. (See para. (*e*) of this article.)

(N) *Change-over from D.C. to A.C.*

The Acts or Orders obtained since 1920 authorising the supply of electricity imposes on the body undertaking the supply the obligation to supply according to a system approved by the Electricity Commissioners, and by virtue of regulations made by them under the Electric Lighting Acts, the system and pressure cannot be altered except with the consent of the Commissioners, which is given upon such terms and conditions as they think fit.

Where the supplying body desires to alter the supply from direct current to alternating current it is the practice of the Commissioners in giving their consent to make it a condition that the body shall, at their own expense, carry out any necessary alterations to consumers' apparatus existing at the date when notice of the change-over is given, or to pay to the consumer compensation to be agreed or in default of agreement determined by arbitration.

In order that a consumer may be entitled to have his apparatus altered or to be compensated it is no doubt necessary that the apparatus should be such as he is entitled to use under his contract with the supplying body and within the maximum demand for which that contract provides.

It is further necessary that the apparatus should be existing when the notice of intended change-over is given, and where a consumer resides in an area which is likely to be changed over he should, for his own protection, give information to the supplying body before notice of change-over is received, of apparatus which he has in use or of any new apparatus which he proposes to install, in order that his apparatus may be inspected and recorded.

With regard to companies and municipal undertakers in the County of London the L.C.C. are the consenting authority. With regard to companies in the provinces who obtained their powers before 1920, under the Companies Provisional Orders, it is the local authority who have the power to give the consent to change over.

8.—Regulations.

Reference has been made in para. (2) of this article to certain statutory regulations which engineers and contractors should be acquainted with in carrying out installations. An engineer would be very unwise to rely upon his own judgment, however experienced, as he may find that those who framed the regulations, which are binding, provided for definite methods and conditions in carrying out installations. It is impossible within the limits of this article to embody the same, as altogether they run to some hundreds of pages.

(A) *Electricity Regulations.*

The electricity regulations, copies of which it is advisable for engineers to obtain (see para. 2 hereof), are: Official number *El.C.12B* (in ordering copies this number should be quoted) deals with conditions of supply (*a*) not exceeding

250 volts; (*b*) not exceeding 650 volts; (*c*) not exceeding 3,000 volts; (*d*) exceeding 3,000 volts. The method and provisions as to insulation, precautions against shock or fire, testings of insulations, overhead lines, service lines, prevention of danger are fully set forth in these regulations. The most important of these regulations is No. 3, which provides that the "leakage current shall not exceed one-thousandth part of the maximum current"; and No. 26, which prescribes the minimum permissible size of line conductors. The regulation only applies to a limited number of cases where there are overhead and underground lines to small installations operated without statutory powers.

*El.C.*53, revised (22nd May, 1931), gives details of heights of conductors to be used for different voltages from 250 volts to 165,000 volts.

*El.C.*13 contains provisions in regard to the safety of the public where electricity is supplied in bulk or where pressure is over 3,000 volts.

*El.*38 contains the most important regulations for engineers. It gives the provisions for the safety of the public where low pressure is supplied, and sets forth the responsibility of undertakers with lines on consumers' premises. Regulations are given also for ensuring a sufficient supply of electricity and penalties in default.

*El.*38*a* gives additions to the last-mentioned regulations.

(B) ***Factory Act Regulations.***

Risks and obligations arise under the Factory and Workshops Acts, 1901, and the Building Regulations of 1926.

Dangerous Machinery.

The Factory and Workshop Act, 1901, Section 10 (1) (*c*) imposes an absolute obligation on the owner of a factory so to fence all dangerous parts of the machinery as to be equally safe whichever way it is worked.

Machinery which was constructed to be worked downward, was, at the direction of a foreman of the defendants, being worked upwards. The plaintiff on being injured sued the defendants for damages for negligence. It was held that Section 10 (1) (*c*) imposed an unqualified obligation on the defendants to provide proper fencing so as to make the machinery safe to the workmen in whichever direction it was used and that as they had failed to do so they were liable in damages. Pursell *v.* Clement Talbot, Ltd. (1914), 111 L.T. 827 C.A.

The mere provision of proper guards and placing on the workmen the responsibility of using them is insufficient and the mere omission of a statutory duty is neglect to observe as required by the Act.

An accident which is due to a breach of statutory regulations does not arise "out of" the employment and the question of serious and wilful misconduct does not arise until there is misconduct arising within the sphere of employment. Further, no logical distinction can be drawn between statutory regulations and prohibitions imposed by an employer to regulate the employment.

Thomas *v.* Bolton & Sons., Ltd (1928).

Bourton *v.* Beauchamp (1920). A.C. 1001.

By the Building Regulations, 1926, it is provided that:—

> "It shall be the duty of *every* contractor and employer of workmen to observe such of the requirements in Part I of these regulations as affect any workmen employed by him."

Regulation 30 is as follows:—

> "Every opening left in a floor of a building for any purpose shall, until it becomes necessary to remove the fencing in order to complete the permanent enclosure, be provided with a suitable guard rail and toe board, or with other efficient means to prevent the fall of persons or articles into the opening except where and when access is required for workmen or for the movement of material."

By Section 105 of the Factory Act, 1901, it is provided that the word "factory" shall include "any premises on which machinery worked by steam, water or other mechanical power is temporarily used for the purpose of the construction of a building or any structural work in connection with a building."

The direction as to duties is that *every* contractor and employer (whether main contractor or sub-contractor) of workmen shall observe such of the requirements as affect any workman employed by him. It is obvious that the state of the law is very unsatisfactory and intricate, especially in view of the cases that have already come before the Courts.

In Barnett *v.* Caxton Floors, Limited, and Butler *v.* Kleine Patent Fire-resisting Flooring Syndicate, Limited (45 T.L.R. 141), the High Court dealt with the above mentioned Act and regulations. In the first case, the defendants were summoned as "occupiers of a factory" and the point raised on their behalf was that the machinery on the premises was not being actually used at the time of the accident; and accordingly, that the premises were not a "factory" and that the defendants were therefore not "occupiers of a factory" within the meaning of the section. The Court held that the words "temporarily used" in the section are not confined to the actual moment when the machinery is in use, but extend to the whole period during which the machinery is *available* for use in the structural work.

In the second case the defendants were summoned as "employers of workmen," and it was admitted on their behalf that the premises were a factory within the meaning of the regulations and the section, but it was contended that other contractors on the premises and not the defendants were responsible for fencing the opening. In his judgment, the Lord Chief Justice said: "Here it was NOT suggested that the defendants were the persons who had brought the machinery on the premises so as to affect those premises with the character of a factory. But they were working upon those premises as sub-contractors and therefore they came within that part of the regulations which says that 'It shall be the duty of every contractor and employer of workmen to observe such of the requirements in Part I of these regulations as affect any workman engaged by him.'"

Alderman Galliers, of Brighton, an engineer, was carrying out certain electrical work on premises in course of erection. From the 18th January, 1930, until the 11th March, 1930, a crusher and mixer were used on the premises. On the 17th March, 1930, one of Mr. Galliers' workmen fell down an opening intended for a lift-way. Mr. Galliers was summoned as being "the employer of workmen" in a factory and for failing to provide a guard rail and toe board. The prosecution might have summoned Mr. Galliers as "occupier" of the factory, but as there were difficulties in making such an allegation they chose the first alternative. Both the magistrates and the High Court decided in favour of Mr. Galliers on the grounds that, as the machinery had been moved a few days prior to the accident, the premises could not, under the circumstances, be a "factory" within the meaning of the section and regulations.

The case does not decide whether the responsibility of guarding a hole made by some other sub- or main-contractor devolves upon all or one of the contractors engaged upon the job. Meanwhile, it is advisable that engineers and contractors should write a letter when accepting a contract stating that it is understood that the employer or the main contractor will provide that other contractors safeguard any risks caused by them. Engineers should also obtain a copy of Statutory Rules and Orders, 1908, No. 1312 (price 3d.), and study the regulations therein contained in relation to the "Generation, Transformation, Distribution and Use of Electricity."

Statutory Rules and Orders, 1908.

No. 1312 give the regulations made by the Secretary of State for the "Generation, Transformation, Distribution and Use of Electrical Energy under the Factory and Workshop Acts of 1901 and 1907."

Form 928 contains a "Memorandum by the Senior Electrical Inspector of Factories on the Electricity Regulations." (88 pages price, 9d.) All the above should be studied before carrying out work in relation thereto.

(c) ***Cinema Regulations.***

The Statutory Rules and Regulations, No. 983, dated 30 July, 1923, and No. 403, dated 8th April, 1924, and also No. 361 of 6th June, 1930, should be studied for electrical work in cinemas. In any work relating to the manufacture of films and film stripping the Regulations of 1928 S.R. and O. 82 and 84 should be studied.

(D) *Coal and Mines Act,* 1911.

By Section 32 (1) of this Act it is provided that "Subject to the statutory provisions and any regulations thereunder as to the use of electricity in mines electric lamps if enclosed in airtight fittings and having the lamp globes hermetically sealed may be used on main haulage roads or elsewhere within such limits as may be fixed by the regulations of the mine."

Section 60 provides that :—

Electricity may not be used in any part of a mine where on account of the risk of explosion of gas or coal dust its use would be dangerous to life and if the owner of a mine on being required by an inspector of the division not to use or to desist from using electricity in the mine on that ground refuses to do so the question shall be settled by reference to a referee.

Pending the settlement of the question the owner must comply with the requirements of the inspector subject to an appeal to the chief inspector.

The use of electricity in any mine is subject to general regulations.

In all places lighted by electricity where a failure of the electric light would be likely to cause danger one or more safety lamps or other proper lights shall be kept continuously burning.

Where electricity is used for signalling the pressure in any one circuit shall not exceed 25 volts.

Every person appointed to work, supervise, examine or adjust any apparatus shall be competent in the work he is set to do. No person except an electrician or a competent person acting under his supervision shall undertake any work where technical knowledge or experience is required in order adequately to avoid danger.

The "General Regulations as to the Installation and Use of Electricity, with Explanatory Notes," is published in Mines and Quarries, Form No. 11 (83 pages, price 6d.), and Form No. 15B (price 2d.) should be studied in relation to all such work. Copies should also be obtained of the Safety Lamps Orders, S.R. and O. 2264/1920 and 318/1922; Coal Cutting Machinery, M.D. Circular No. 31; Danger from Live Electrical Conductors, M.D. Circular No. 23.

The Mines Department, Dean Stanley Street, Millbank, Westminster, S.W.1, should be consulted on current rules and regulations under the Metalliferous Mines Acts and the Coal Mines Acts, which are now administered by this Department.

9.—Engineers' Liability at Common Law.

Apart from the duty of observing statutory regulations, engineers and contractors are under certain liabilities at common law.

(A) *Estimates.*

They are liable to their clients if the plans or specifications are faulty, or if the estimates are inaccurate. If they do not hold themselves out as being competent to get out quantities or estimates, then it is their duty to advise their client on the necessity or otherwise of employing a specialist in that particular branch. They must consult and advise their client as to obtaining tenders, whether by invitation or advertisement. They must disclose to their client any interest they may have in any firm with whom contracts are likely to be made, and to account for any discounts or commissions. Even if they advised their client to insure the subject of the contract, they must not receive any commission for the insurance without the consent of their client.

(B) *Competency.*

To whatever class the engineer may belong, the engineer must be competent to do what he professes, or take the legal consequences of being sued for negligence and of not recovering fees if they fail in their duty. If he has represented or advised that a motor or dynamo or a switch, etc., will do a certain thing and the capacity of the same proves to be inadequate, then he will be liable for any direct damage which may ensue to his client. In this respect the engineer's liability is similar to that of a doctor or surgeon who may be liable for negligently performing an operation, or a solicitor who renders himself liable in damages to a client to whom he has given bad advice, so the services rendered to their employers by engineers, being undertaken by them for reward they are bound to possess an ordinary and reasonable amount of skill in the art or profession which they profess by undertaking to do the work and to act with reasonable care and diligence in rendering those services and are liable for failure to do so.

(C) *Negligence.*

The question whether a person has exercised reasonable and proper care, skill and judgment is one of fact which appears to rest on this further inquiry, viz., whether other persons exercising the same profession or calling and being men of experience and skill therein would or would not have come to the same conclusion. It is not enough, however, to make a man liable in an action for negligence that some men of far greater experience or ability might have used a greater degree of skill, nor that even he might possibly have used some greater degree of care. The question is whether there had been a want of competent care and skill to such an extent as to lead to the bad result. Also it must be noticed that to show that better methods might have been used is not of necessity to show that the methods employed were so unprofessional or unskilful as to amount to negligence.

Supposing an engineer or a contractor is carrying out some work in a shop window and his man, in bending, negligently knocks over something; then the contractor would be liable for the damage done unless he first warned his employer that he would not take the risk but would do his best. In one case a succession of articles of furniture were knocked over by the first article touched by the workman. The contractor was liable for the first accident, but not for the other damage. A contractor might reasonably be expected to anticipate the first accident, but not a succession of accidents resulting from the employer's own acts.

Take the case of premises being negligently set on fire by a contractor's workman, and we will take it for granted that the employer has insured his premises against fire. Notwithstanding this, the insurance company can refuse to pay until the contractor has been sued for damages. If the contractor is unable to pay, or goes bankrupt, then the insurance company would be liable to indemnify the employer against loss.

The same principle applies where injuries are received by other persons resulting from the negligence of a contractor's workman. The only safe way is to insure against such risks.

(D) *Delegation of Duties.*

As a rule, the duties of architects and engineers are so personal in their nature that they cannot be delegated or transferred entirely to another, but they may make use of the skill and labour of assistants provided only that they retain control of the work and do not cease to exercise their own supervision and judgment. The general rule is that where a man employs an agent, relying upon his peculiar aptitude for the work entrusted to him, it is not competent to that person to delegate that trust to another, but where the act to be done is of such a nature that it is perfectly indifferent whether it is done by A or B and the person originally entrusted remains liable to the principal by whomsoever the thing may be done, the maxim "Delegata potestas non potest delegari" does not apply.

In the case of the Leicester Board of Guardians *v.* Trollope it was the architect's duty under the contract to supervise the work. The clerk of the works permitted the builder to deviate from the design, and the architect, relying upon the clerk of the works, failed to detect the deviation and to have it rectified. As a result of such deviation, dry rot set in. It was held by the Court that the architect was liable in damages.

(E) ***Interference by Employer.***

If the employer insists on superseding the engineer's judgment and asserting his own in matters which relate to the work which the engineer is employed to carry out or gives orders which are ignorant and unskilful, he cannot complain if the engineer follows his orders, subject always to this, that the engineer should, before complying with the orders, be careful to point out the consequences which may result from their adoption and disclaim all responsibility therefor.

An engineer or contractor has also a right to compensation if an employer in other ways interferes with his work or delays the progress of the same, unless the matter is one that might reasonably be anticipated by the contractor.

If an architect or consulting engineer has power by the contract to decide questions of price and extras, etc., and the employer influences or interferes with him in any direction, then the contractor is freed from the decision of such architect or consulting engineer. (Page *v.* Landaff.)

(F) *Loss of Fees.*

If a professional man does not exercise his calling with ordinary skill and care, he breaks his contract express or implied. In such an event he is liable to dismissal and also forfeits wholly or in part his right to be paid under the contract, for a person of skill cannot recover for his services which are useless, or which, in the ordinary exercise of his skill, he ought to have known would be useless towards the object for which he was employed. He also renders himself liable for any damages resulting to his employer from his incompetence or carelessness.

(G) *Liability for Negligence.*

It is important to notice that in order that liability should arise, the damage must have been caused by the negligence. If advice is negligently given, it must be acted upon before any liability of this nature can arise. Where negligence and the omission to use due care and skill have been made out, the amount of damages that can be awarded is to be measured by the consequent loss to the employer, and it is immaterial that such damages may exceed the amount of the commission or fees agreed to be paid to the person employed for the performance of his duties. Sanders *v.* Broadstairs Local Board (1890). The employer can either bring an action for damages for negligence or set up the negligence as an answer to an action for fees, and counterclaim in the action for the damages for negligence.

(H) *Recovery of Fees from Local Authorities.*

Engineers are sometimes employed by corporations, and when this is the case precautions are necessary to render them certain of their fees. It is a general rule of law that corporations can only contract under their common seal. It is well that engineers should have this clearly before them, as in many cases they have failed in recovering their fees after spending a good deal of time and money in the service of a corporation. Thus, for instance, in the case of a municipal corporation, an instruction from a mayor, town clerk or from a committee, or in fact a resolution of the corporation duly passed will not enable the professional man acting under it to recover payment for his services, in case the corporation chose to resist his claim and plead that the agreement was not under seal, for however the rule may have been relaxed in other matters it is still very strictly applied as regards the appointment of officers.

(I) *Effect of Death of Engineer.*

It is important to know what effect death has upon the engineer and the employer as far as the contract is concerned. In considering this effect it is necessary to divide contracts into two classes: (1) personal contracts, and (2) other contracts. Dealing with personal contracts first, these are not rescinded *ab initio* by the death or permanent disablement of the engineer, but are merely dissolved and become null and void as to the future. Any rights of payment which have accrued due under them are enforceable and the remedy is not limited to suing on a *quantum meruit*. This was stated by Martin, B., in the case of Stubbs *v.* Holywell Railway Co., in which he said, "The contract had, it is true, an implied condition that he should live for fifteen months, but his death does not throw back his representative upon the right of recovery on a *quantum meruit* only. He can recover the stipulated price due to the deceased when he died of the work the deceased had actually executed."

The common-law implication excusing non-performance by the act of God adds the implied condition that if death or permanent illness intervenes after partial performance (except in cases where it is clear from the special terms of the contract that payment is only to become due on completion of the services or on acceptance or certified approval or something of that kind) recovery may be had for the value of all work which the deceased has performed.

In the case of all contracts not personal, i.e., where death or illness does not affect the personal element, the burden and the benefit of the contract pass upon the death of either party to his representatives. The case of Davison *v.* Reeves (1892), 8 T.L.R. 391, illustrates this. A engaged B as a civil engineer in connection with certain harbour works. A covenanted for himself and his executors to employ B at a fixed salary for six years. A raised B's salary and subsequently died. A's executors again raised B's salary but dismissed him before the expiration of the term. It was held that the agreement bound the executors of A.

(J) ***Remuneration.***

We must now add a few words as to the remuneration of a person who acts as consulting engineer, or where any engineer or contractor gives advice.

Where the terms of the contract of employment are not specific as to the payment of the engineer, evidence is admissible to rebut the presumed undertaking to pay and to exclude the ordinary business obligation to pay for services rendered. But such evidence must be strong and clear and must not be inconsistent with the terms of the contract. If the employer and engineer agree that the employer shall decide whether the engineer shall receive any remuneration, the engagement in such a case remains a mere engagement of honour until the employer chooses to fix a remuneration and the amount fixed cannot be questioned or increased by the engineer or the Court.

If the agreement is that the employer shall decide the amount of the remuneration the Court may infer an obligation on the part of the employer to pay something, and in such a case the engineer is entitled to a reasonable remuneration and is not bound to accept in satisfaction the amount fixed by the employer or to wait until the employer chooses to fix the amount. It would be for the jury to ascertain how much the employer acting bona fide would or should have awarded.

Where an engineer is suing upon the merits of his work (*quantum meruit*), evidence can be adduced of the nature and extent of his skill to show what the value of his service is.

Where reasonable remuneration has to be given it is clear that the services of a famous or specially skilled man should be valued more highly than those of a newly qualified person and that the employer must be presumed to have had in view the special qualifications of an eminent man when he employed him. It is not relevant in such cases to prove that the employer could have got another man at a cheaper rate, as he, in fact, selected this particular man.

(K) ***Inaccurate Quantities.***

The Courts will not consider the employment of a quantity surveyor to come within the implied authority of the engineer except where a special custom of the profession to that effect can be proved to exist. The practice with regard to bills of quantities is now pretty well settled. The engineer may prepare the quantities and supply them himself to the parties tendering. If an engineer prepares the quantities by agreement with the employer, he is the agent of the latter in preparing them, and in certain circumstances the latter may be held liable for any inaccuracies that they may contain. To make the employer liable to the contractor for inaccuracies two things must be shown. It must, in the first place, be shown that the bills of quantities were so culpably inaccurate as to amount to a fraudulent misrepresentation on the part of the engineer preparing them, and in the second place, it must be shown that the employer himself was aware of that, or that the false representation was made by the engineer, as his agent, and in his interest and that he received the benefit of it.

Further, it is a consulting engineer's duty to inform a contractor when his client dies or becomes insane, or is bankrupt, as it has been expressly decided that where an agent impliedly warrants his employer's authority, it is immaterial whether he justly believed that his authority still existed or not. (Yonge *v.* Tonybee (1910), 1 K.B. 215.)

(L) *Quantities.*

It has been held that there is no implied warranty to a contractor of the correctness of estimates and calculations made by the architect under his employment by the building owner. The architect does no more than state them to be his bona-fide calculations, and it is for the contractor to check them or not at his own risk. (Scrivener *v.* Pask (1865), 18 C.B. (N.S.), 785, and also see Le Livre *v.* Gould (1893), 1 Q.B. 491.)

(M) ***The Different Liabilities of Consulting and Contracting Engineers.***

Where a consulting engineer is employed, a contracting engineer, as previously briefly indicated, is free from most of the risks and liabilities which fall on a consulting engineer. He must, however, carry out the work entrusted to him with reasonable skill. If a consulting engineer is not employed then a contracting engineer who holds himself out as competent to do the work and advise, makes himself liable for all the risks that a consulting engineer is under. An engineer, or indeed any other professional person, must not misrepresent his professional status, for example, by putting after his name letters indicating membership of institutions to which he does not belong, and if he does so, any person so misled will have a remedy in an action for damages. Thus a contracting engineer must not act as a consulting engineer unless he has the qualifications. If he has not the qualifications and he does act, he will be liable for any damage which may result to his employer through his so acting. If the contracting engineer acts as a consulting engineer he is expected to possess an ordinary and reasonable degree of care and skill in the profession of a consulting engineer and is understood to have that degree of care and skill by undertaking to do the work, and to act with reasonable care and diligence in rendering those services and is liable to the employer for failure to do so. A contracting engineer must see that the quality of his work and of the plant, material or appliances are reasonably sufficient for the purposes intended. Of course, a manufacturer is under the same liability also. If damage results from tempest, rain, floods or fire, a contractor is liable to make good unless he covers himself by words in the contract. He must complete the work in reasonable time, and if the contract specifies a date he must comply with the same or he will be liable in damages or a penalty where the contract so provides.

Contracting engineers should cover themselves for accidents to their workmen or against strikes, civil commotion or thefts.

(N) ***The Position of Contracting Engineers under Contracts.***

Decision of Engineer or Architect.—In most contracts for works there is now inserted a condition making the decision of the engineer or architect upon the materials proposed to be used in carrying out the works final, or binding the contractor to use materials of a certain kind or of a superior quality. Even in the absence of such a condition, however, the contractor is bound to use only materials of a reasonably good quality.

If he uses materials of more than reasonably good quality—there being no condition in the contract as to the quality of the materials to be used—or if he uses materials of a much better quality than that required by the conditions of the contract, he cannot in the absence of a new contract with the employer binding the employer to pay for them, recover the extra expense he has thus incurred. The same rules apply to the workmanship employed, which, in the absence of any express condition upon the point, must be reasonably skilful and good.

(O) ***Extras.***

The term "extra works" or more shortly, "extras," when used in connection with contracts for works or buildings, may be taken as meaning those items of workmanship or materials which the contractor may be required, under the terms of his agreement, to execute or supply in addition to the workmanship and materials required.

to complete the work or building in accordance with the drawings and specifications. It is often a matter of great difficulty to determine whether an item of workmanship or materials claimed as an extra by a contractor is fairly so or not. In fact, many of the disputes which arise between employers and contractors turn on this point. The contractor alleges that he has executed certain work not shown upon the drawings and not clearly described in the specification and not covered by the contract sum. The employer refuses to regard the item so claimed as an extra. He asserts that the work was necessary to complete in a proper manner the works of the contract, and then recourse is had to a court of law or to arbitration.

In a court of law, the original contract must be produced and proved in order to show that the alleged extras are not included in it, and in order that the contract may be put in evidence it must be stamped, or if not stamped the penalty for failure to stamp paid upon it. And not only must it be shown that the work done is not within the contract, but evidence must be given that it was the subject of a new contract containing a promise expressed or implied on the part of the employer to pay for it.

A mere acquiescence on the part of the employer in a suggested alteration is not enough in itself to raise an implied promise to pay anything additional unless it can be shown that the employer was aware that the alteration would add to the expense. Where, however, the contract provides that the engineer is to determine the price to be paid for extra works, it would appear that he is entitled to say what are extras and what are not. It is frequently provided in contracts for works or buildings that the employer will not be liable to pay for works alleged to be extra unless such additional work shall have been ordered in writing by the employer or architect. Where this is clearly expressed the written order is a condition precedent to payment. And it would appear that where the engineer is the party appointed by the contract to issue written orders for extra work, the order of the employer for such works verbally given will not entitle the contractor to recover.

If an employer consents to alterations and the engineer or contractor does not inform him that the alterations will increase the expense, then the contractor cannot recover for the increased expense. (Lovelock *v.* King.)

(P) *Waiver of Conditions as to Extras.*

Where extra works have been carried out by the contractor and he is unable to show that they have been ordered in writing in the manner provided in the contract, the Court will endeavour to ascertain whether there has been a waiver of the condition as to the written order. (It would be manifestly unfair that the contractor should be induced to execute extra works on the faith of the verbal promise of the employer that such extra works would be paid for, and that the employer should get the benefit of those works free of cost.) What would amount to a waiver of the condition as to the written order cannot be very closely defined, as there is no express authority on the point. Again, if it can be shown that the extra works claimed for are entirely outside the contract, the want of the written order will not bar the contractor's claim to be paid for such work, as will be seen from the remarks of the Court in the case of Franklin *v.* Darke 6 L.T. (N.S.), 291.

(Q) *Time for Completion.*

A contract for works may expressly state the time within which the works are to be completed or it may be silent on that point. In the latter case the law will imply a condition that the works will be completed in a reasonable time. Sometimes in contracts where no express time is fixed for completion, the contractor undertakes to carry out the works "forthwith," "immediately" or "directly." In all such cases the Court will hold that all that is meant by such indefinite words is that the works shall be carried out as quickly as in the circumstances is reasonably possible.

When the date of completion is expressly stated in the contract, of course that date must be observed. A failure to complete the works before or by it will be a breach of contract and formerly the rule at law was that such a failure entitled the employer to repudiate the contract and to refuse payment. This rule, however, was relaxed in equity. Courts of Equity held that in the absence of express stipulation that the date was to be strictly kept, or if circumstances from which such a condition could be inferred time was not of the "essence of the contract" and a failure to observe it, though a ground for compensation to the employer, was not a sufficient breach to entitle him to repudiate the contract. The equitable rule now having been made the rule in all Courts, we shall consider shortly when equity will regard a time condition as of the essence of the contract. The first and most important instance is when the contract expressly stipulates that time is to be of the essence of the contract. "If the parties choose even arbitrarily (provided both of them intend to do so) to stipulate for a particular thing to be done at a particular time, such a stipulation is effectual in equity as well as in law" (Alderson, B., in Hipwell *v.* Knight).

Again, time may be implied to be the essence of the contract when the nature of the work or the circumstances attending it show that the time of completion is a matter of importance.

(R) *Time for Completion where Additional Work—Penalties.*

Delays in Contracts.—Contracting engineers are often oppressed by terms in a contract to complete the work by a specific date. Very often an employer, or his architect, or consulting engineer, has ordered additional work to be done, not contemplated by the original contract. Such additional work must, of course, be done in a reasonable time; but if it is so mixed up with the work in the original contract, being part and parcel thereof, that it becomes impossible to complete the work in the original contract until the additional work has been completed, then in such circumstances all the work must be done in a reasonable time, and there is good defence against any penalties. (Thornhill *v.* Neats (1860), 8 C.B., N.S. 831.) Even in a contract which provides for additions, deductions, alterations and deviations to and from the contract work and also providing for the architect or engineer to have power to extend the time for completion of the contract and that unless he did so the time should be deemed not extended by reason of such extra works, it was held that the fact of extra works being directed having rendered the contract impossible within the appointed time freed the contractor from the penalties provided by the contract. (Westwood *v.* Secretary of State for India.)

(S) *Delays caused by Architects or Consulting Engineers.*

If a contractor is delayed by failure of an architect or consulting engineer to deliver plans or drawings or other necessary instructions, he is free from penalties under the contract. (Roberts *v.* Bury, etc.)

(T) *Price of Extras.*

If an architect or consulting engineer has given an assurance to the employer that the cost of the work should not exceed a certain specified amount although he refused to guarantee that amount, then it has been decided that the decision of the architect as to the amount to be paid to the contractor for the work was not binding as there was a bias in his mind. (Kemp *v.* Rose.)

(U) *Payments on Account.*

Where A agrees to do work and supply materials upon the premises of B for a specific sum and nothing is said as to payments on account, then A is not entitled to recover anything until the whole work is completed. (Appleby *v.* Myers.) If A covenants to do certain work for B and to finish it in or before a certain day in consideration of a sum of money which B agrees to pay A by instalments as the work proceeds and the instalments are not paid, then the contractor can sue for the whole sum, although the building was not finished at the time appointed. (Terry *v.* Duntze.)

(V) *Floods, etc.*

Where there is a maintenance clause in a contract for the contractor to maintain his work for a certain period, and damage results meanwhile from an extraordinary flood, etc., then the contractor must make good. (Brecknock *v.* Pritchard.) Contractors would be wise to cover themselves by insurance in such cases.

THE DESIGN OF D.C. MOTORS AND DYNAMOS

By H. E. J. Butler

THE method of designing a motor and a dynamo of similar output is essentially the same. A dynamo is designed to give a certain output in watts (volts × amperes), whereas a motor is to give a certain h.p. output. A motor may be treated as a dynamo having an equivalent output in watts. The h.p. output of a motor in watts is given by multiplying the h.p. by 746. Thus, a motor of ½ h.p. has an equivalent output of 373 watts.

The Starting Point.

The main purpose of this article is to determine the size of the armature and field magnet and to show how the winding data is calculated. It will be assumed that the constructor wishes to build a machine of a certain output.

When the output of the proposed dynamo or motor has been determined from requirements, the size of the armature, which is the starting point, may be found from tables 1—4. The armature sizes given are only average values and cannot be taken as definite without further investigation. While the outputs shown are easily developed by the given armature sizes, a higher output can be obtained by careful design. It is not possible to give exact sizes for armatures in relation to output because the working conditions and the particular design of the stampings are variable factors.

The method of determining the design, which is given here, is to consider what output is obtainable from a particular design of standard stampings that are likely to give the required output.

Fig. 1.—An Armature and Field Magnet Stamping of the Typical Design which is Dealt with in the Text.
The armature is $1\frac{23}{32}$-inch diameter with 12 semi-closed slots. The armature spindle hole is $\frac{7}{16}$-inch diameter. The small hole in the armature stampings and the semi-circular nick in the field stampings line up when the stampings are assembled. The field stampings are Sankey's Lohys iron and the armature stampings are Sankey's Stalloy.

Two or Four Poles.

Unless the output of the intended machine is to exceed 500 watts, there is little to gain by constructing a four-pole field magnet. It is possible to obtain a larger output from a four-pole machine than from a two-pole machine of the same size. This is partly because the span of coils of the four-pole armature is approximately half the span of the two-pole windings. This gives shorter end windings, which makes for higher efficiency because

TABLE I.

TWO-POLE DYNAMOS.

Output (watts).	Armature Length and Diam. (inches).	Speed R.P.M.	Field Watts (approx.).
12	$1\frac{1}{4}$	4,000	15
20	$1\frac{1}{2}$	3,750	20
35	$1\frac{3}{4}$	3,500	30
45	2	3,000	35
60	$2\frac{1}{4}$	2,750	35
80	$2\frac{1}{2}$	2,500	40
100	$2\frac{3}{4}$	2,300	40
130	3	2,100	40
200	$3\frac{1}{4}$	2,000	50
275	$3\frac{1}{2}$	2,000	55
350	$3\frac{3}{4}$	1,850	60
450	4	1,800	60
600	$4\frac{1}{4}$	1,750	70
750	$4\frac{1}{2}$	1,700	80
820	$4\frac{3}{4}$	1,650	90
1,000	5	1,600	100
1,100	$5\frac{1}{4}$	1,500	100
1,200	$5\frac{1}{2}$	1,400	100
1,300	$5\frac{3}{4}$	1,300	100
1,400	6	1,200	100

the end windings of the armature are inactive and merely add resistance to the armature. Another reason is that the field excitation is more efficient, because the ampere-turns are obtained with four smaller diameter coils instead of with the two larger coils of the bi-polar dynamo or motor. Hence less power is required for excitation of the field.

Procedure in Design.

The procedure in the design of a dynamo or motor is best understood by considering an actual example. Suppose it is proposed to construct a shunt-wound dynamo with an output of 6 volts 6 amperes, or 36 watts.

The Stampings.

Table I gives an armature diameter of $1\frac{3}{4}$ in. for an output of 35 watts, so that this size is provisionally fixed for the machine. Fig. 1 shows an armature and bi-polar field magnet stamping to suit these requirements. The use of stampings for both field magnet and the armature is advised not only on the score of efficiency but also for simplicity of construction, which is thereby obtained. A laminated field magnet is less than half the weight of a cast iron one designed to carry the same total flux.

The Field Magnet.

Since in a bi-polar machine the length of the armature is made equal to the diameter, the length of the assembled field magnet will be $1\frac{3}{4}$ in. The stampings are .02 in. thick, so that the field magnet will consist of about 90 stampings.

Before the armature can be considered it is necessary to calculate the field strength in the air gap between the armature and the pole faces. With this object in view the total flux in the magnet itself is first estimated.

Calculation of Field Strength.

For laminated field magnets of Lohy's iron, such as are now being considered, it is possible to work economically at a flux density of 95,000 lines per sq. in.

The total flux of the yokes of the magnet is given by area (sq. in.) $\times$95,000.

Area of yokes $= 2\times\frac{1}{4}\times 1\frac{3}{4}$ sq. in.

Since the stampings are paper coated the actual area of iron will be :—

Area $= 2\times\frac{1}{4}\times 1\frac{3}{4}\times .95$ sq. in.

Total flux $= 2\times\frac{1}{4}\times 1\frac{3}{4}\times .95\times 95{,}000$ lines $= 79{,}000$ lines.

The total flux in each air gap is less than this by about 10 per cent. on account of magnetic leakage. That is to say, some 10 per cent. of the magnetic lines developed will not pass through the armature and are therefore ineffective.

TABLE II.

FOUR-POLE DYNAMOS.

Output (watts).	Armature Diam. (ins.).	Armature Length (ins.).	Speed R.P.M.	Field Watts (approx.)
60	$2\frac{1}{2}$	$1\frac{7}{8}$	2,500	35
80	$2\frac{3}{4}$	$2\frac{1}{8}$	2,300	40
100	3	$2\frac{1}{4}$	2,100	40
160	$3\frac{1}{4}$	$2\frac{1}{2}$	2,000	40
250	$3\frac{1}{2}$	$2\frac{5}{8}$	2,000	50
300	$3\frac{3}{4}$	$2\frac{3}{4}$	1,850	60
470	4	3	1,800	70
670	$4\frac{1}{4}$	3	1,750	80
800	$4\frac{1}{2}$	3	1,700	90
1,000	$4\frac{3}{4}$	$3\frac{1}{2}$	1,650	100
1,300	5	$3\frac{3}{4}$	1,600	100
1,500	$5\frac{1}{4}$	4	1,500	100
1,650	$5\frac{1}{2}$	$4\frac{1}{8}$	1,400	100
1,850	$5\frac{3}{4}$	4	1,300	100
2,000	6	$4\frac{1}{2}$	1,200	100

Total flux in air gap $= 79{,}000 \times .9$ line

$= 71{,}100$ lines.

Thus a total flux in the air gap of 71,000 lines forms the basis of the calculations for the armature windings. The odd 100 lines may be neglected.

Estimation of Armature Output.

Now that the total flux in each gap is known, it is possible to calculate the armature windings.

If Z = Total conductors in armature slots,
E = Voltage of armature,
F = Total flux per pole,
P = Number of poles,
N = Speed of armature, r.p.m.,
S = Number of parallel paths in armature, then

$$Z = \frac{E \times 60 \times 10^8 \times S}{F \times P \times N} \text{ conductors}$$

In the present example—
E = 6 volts,
F = 71,000 lines,
P = 2,
N = 3500 r.p.m. (from Table I),
S = 2 for a two-pole machine,

$$\therefore Z = \frac{6 \times 60 \times 10^8 \times 2}{71{,}000 \times 2 \times 3500} \text{ conductors}$$
$$= 145 \text{ conductors.}$$

This does not take into account that the windings cause a drop in volts, which must be allowed for by adding extra turns to the armature. Allow 10 per cent. extra conductors for small machines. For larger machines the actual armature resistance must be worked out. The total armature conductors, therefore,

$$= 145 \times 1.1$$
$$= 160.$$

Since there are 12 slots, 14 wires in each slot are required, which means that there will be 12 coils of 7 turns each. The extra voltage developed by the increase of total conductors from 160 to 168 is negligible.

The accurate determination of the number of armature conductors is possible by using the following :—

$$Z = \frac{10^8 E \times S}{(.0167 \text{ F PN}) - (.0139 \times 10^8 \text{ IlR})}$$

Where E = Terminal volts at full load,
S = Number of parallel armature circuits,
F = Total flux per pole,
P = Number of poles,
N = r.p.m.,
I = Full load current,
l = Length of mean turn of armature coils (inches)
R = Resistance of wire ohms per yd.

Fig. 2.—A PAIR OF SANKEY'S SMALL MOTOR STAMPINGS.

The armature has a key which is made to fit the keyway in the shaft. The armature is $1\frac{9}{16}$-inch diameter, $\frac{1}{2}$ inch hole. The magnet yoke is $\frac{7}{32}$-inch wide and the air gap .01 inch. The armature slots are of a particularly good design.

In the present example—

$$Z = \frac{10^8 \times 6 \times 2}{(.0167 \times 71{,}000 \times 2 \times 3500) - (.0139 \times 10^8 \times 7.5 \times 7.2 \times .01328)}$$
$$= \frac{12 \times 10^8}{.0167 \times 4.95 \times 10^9 - .0102 \times 10^9}$$
$$= \frac{12 \times 10^8}{10^9 (.0832 - .0102)}$$
$$= \frac{12}{.073}$$
$$= 165 \text{ conductors.}$$

Calculation of Field Windings.

The calculation of the magnetising ampere-turns is the same whether a machine is shunt or series wound, although the two types of windings are themselves different. The magnetising power is measured in ampere-turns and is called the magneto-motive force of the magnet. The magneto-motive force of a magnetic circuit gives rise to a "current" of magnetic lines against the opposition of the magnetic resistance of the iron and air gaps, in a similar way to which the electro-motive force or volts of an electric circuit causes an electric current against the opposition of the electrical resistance of the wire.

The estimation of the magnetising force

TABLE III.

TWO-POLE MOTORS.

H.P.	Armature Diam. and Length (inches).	Speed R.P.M.	Equivalent Watts.
$\frac{1}{30}$	$1\frac{1}{4}$	4,000	25
$\frac{1}{20}$	$1\frac{1}{2}$	3,750	37.3
$\frac{1}{12}$	$1\frac{3}{4}$	3,500	62.5
$\frac{1}{10}$	2	3,000	74.6
$\frac{1}{8}$	$2\frac{1}{4}$	2,750	93.5
$\frac{1}{6}$	$2\frac{1}{2}$	2,500	125
$\frac{3}{16}$	$2\frac{3}{4}$	2,300	140
$\frac{1}{4}$	3	2,100	185
$\frac{1}{3}$	$3\frac{1}{4}$	2,000	250
$\frac{1}{2}$	$3\frac{3}{4}$	1,850	373
$\frac{3}{4}$	$4\frac{1}{4}$	1,750	625
1	$4\frac{1}{2}$	1,700	746
$1\frac{1}{4}$	$4\frac{3}{4}$	1,650	935
$1\frac{1}{2}$	5	1,600	1,120
$1\frac{3}{4}$	$5\frac{1}{2}$	1,400	1,310
2	6	1,200	1,500

required to produce a certain flux in a particular magnetic circuit is simplified to measuring the length of the magnetic paths and calculating the flux densities in the different parts of the circuit.

When these two values are known the ampere-turns is estimated from Table V.

Estimation of the Magnetising Force.

The estimation of the magnetising force required for the 36-watt dynamo, which is being considered as an example, is done as follows.

The flux density in the yoke is to be 95,000 lines. Table V gives 33 ampere-turns per inch for the density in Lohy's iron, which is the material from which the field stampings are made.

The average length of magnetic path in the yoke is $4\frac{1}{4}$ in., therefore :—

Yoke ampere-turns $= 4\frac{1}{4} \times 33$
$= 140$ per pole, or
280 total.

The total flux in the air gap is 71,000 lines. The area of the air gap is found, approximately, by adding together the area of the five armature pole faces which cover the field pole face.

$\therefore$ Area of gap $= 5 \times \frac{11}{32} \times 1\frac{3}{4}$ sq. in.

Density in gap $= \dfrac{\text{Total flux}}{\text{Area of gap}}$

$= \dfrac{71{,}000 \times 32 \times 4}{5 \times 11 \times 7}$ lines per sq. in.

$= 23{,}600$ lines per sq. in.

Total length of gap $= 2 \times .02$ in.
$= .04$ in.

The ampere-turns per inch for a flux density in air of 23,600 lines per sq. in. is found by multiplying the density by .32.

$\therefore$ Ampere-turns $= .32 \times 23{,}600$
$= 7550$ per inch

Total ampere-turns $= 7550 \times .04$
$= 302$

Finding the Ampere-turns Required to Drive the Flux through the Armature.

It now remains to find the ampere-turns required to drive the flux through the armature. This may be sufficiently accurately estimated by multiplying the sum of the ampere-turns for the yoke and the air gaps by 1.05 to give the total ampere-turns for the whole magnetic-circuit. For larger machines, however, the percentage of ampere turns for the armature is higher and must be calculated. In the present example this is done as follows :—

The area of the armature teeth, neglecting the pole extensions =

$5 \times \frac{3}{32} \times 1\frac{3}{4}$ sq. in.

Density in teeth $= \dfrac{71{,}000 \times 32 \times 4}{5 \times 3 \times 7}$
$= 86{,}500$ lines per sq. in.

Length of teeth $= 2 \times \frac{3}{8}$ in.
$= \frac{3}{4}$ in.

Ampere-turns (Stalloy) $= \frac{3}{4} \times 20$
$= 15$ ampere-turns

Area of armature core $= 2 \times \frac{9}{32} \times 1\frac{3}{4}$ sq. in.

Flux density in core $= \dfrac{71{,}000 \times 32 \times 4}{2 \times 9 \times 7}$
$= 72{,}000$ lines per sq. in.

TABLE IV.

FOUR-POLE MOTORS.

H.P.	Armature Diam. (ins.).	Armature Length (ins.).	Speed R.P.M.	Equivalent Watts.
$\frac{1}{8}$	$2\frac{1}{2}$	$1\frac{7}{8}$	2,500	93.5
$\frac{1}{6}$	$2\frac{3}{4}$	$2\frac{1}{8}$	2,300	125
$\frac{1}{4}$	3	$2\frac{3}{4}$	2,200	185
$\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{3}{4}$	1,850	373
$\frac{3}{4}$	4	$3\frac{1}{2}$	1,800	625
1	$4\frac{1}{4}$	3	1,750	746
$1\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{3}{8}$	1,700	935
$1\frac{1}{2}$	$4\frac{3}{4}$	$3\frac{1}{2}$	1,650	1,120
$1\frac{3}{4}$	5	$3\frac{1}{2}$	1,600	1,310
2	$5\frac{1}{4}$	4	1,500	1,500
$2\frac{1}{4}$	$5\frac{1}{2}$	$4\frac{1}{8}$	1,400	1,680
$2\frac{1}{2}$	$5\frac{3}{4}$	$4\frac{1}{4}$	1,300	1,870

Length of magnetic path in core = 1 in.
∴ Ampere-turns (Stalloy) = 1 × 13

The summary of the above calculations is as follows :—

Ampere-turns for yokes	= 280
,, ,, air gaps	= 302
,, ,, armature teeth	= 15
,, ,, armature core	= 13
Total ampere-turns	= 610

Field Winding.

The diameter of the wire for the wire of the field winding of a shunt machine is found from the formula—

$$D = \sqrt{\frac{.000001 ATl}{E}}$$

Where D = diameter of wire (in.)
AT = ampere-turns
l = length of mean turn of field coil (in.)
E = voltage across coils.

In the present example—

AT = 610
l = 8.3
E = 6

$$\therefore D = \sqrt{\frac{.000001 \times 610 \times 8.3}{6}}$$

$$= .029 \text{ in.}$$

The nearest standard wire gauge to this figure is 22 S.W.G., which has a diameter of .028 in. The current which can safely be passed by this size of wire at 2,500 amperes per sq. in. is 1.5 amperes.

The number of field turns can now be determined.

$$\text{Turns} = \frac{\text{Ampere-turns}}{\text{Amperes}}$$

$$\therefore \text{Turns} = \frac{610}{1.5}$$

$$= 406$$

The field coils will therefore consist of two windings of 203 turns each of 22 S.W.G. enamel covered wire or double silk covered wire. Double cotton covered wire is not to be recommended for small field coils on account of the extra space which it occupies and it will generally be found impossible to accommodate the required number of turns on standard designs of stampings.

Gauge of Armature Wire.

Now that the field current has been determined it is possible to calculate the total current output of the armature.

TABLE V.

MAGNETISING FORCE REQUIRED FOR FIELD MAGNETS.

Lines per Square Inch.	Ampere-Turns per Inch.			
	Air.	Cast Iron.	Lohy's Iron.	Stalloy.
10,000	3,200	11	—	—
15,000	4,800	14.5	—	—
20,000	6,400	19.5	—	—
25,000	8,000	25.5	—	—
30,000	9,600	33.5	3	2.3
35,000	11,200	44.0	3.5	2.8
40,000	12,800	80.0	4.6	3.3
45,000	14,400	—	5.1	4.0
50,000	16,000	—	6.1	4.6
55,000	17,600	—	7.1	5.3
60,000	19,200	—	8.6	6.6
65,000	20,800	—	10.0	8.1
70,000	22,400	—	12.7	11.2
75,000	—	—	15.3	14.7
80,000	—	—	17.8	15.7
85,000	—	—	23.0	20.0
90,000	—	—	25.6	25.4
95,000	—	—	33.0	35.6
100,000	—	—	43.0	55.6
110,000	—	—	127.0	178.0

The total output from the armature is the net output plus the field current. The net output is 6 amperes and the field amperes is 1.5. The total output of the armature is therefore 7.5 amperes. The gauge of wire for the armature depends on two factors : (1) the current in the armature ; (2) the current density at which it is safe to work with the type of armature under consideration. The current density for a naturally ventilated armature may be taken at 2,500 amperes per sq. in. where the machine is to run continuously.

On page 38 is given a table showing the gauges of wire suitable for various armature currents. Now each conductor in a two-pole motor or dynamo carries only half the total current. Thus each conductor carries 3.75 amperes. The suitable S.W.G. is, therefore, No. 18.

Armature Slots.

It now remains to see whether 14 insulated wires of 18 S.W.G. can be accommodated in each slot. The winding space in each slot is .07 sq. in. To find the area which can be usefully occupied by conductors, divide this area by 1.4.

The effective area is, therefore, .05 sq. in.

The maximum number of conductors of 18 S.W.G. double cotton covered wire which can be wound in 1 sq. in. is 295. Therefore, in .05 sq. in. :—

Max. conductors $= .05 \times 295$
$= 15$

Thus with 14 conductors per slot there will be sufficient room to place a stiff wedge between the top of the winding and the top of the slot, which is the usual method of retaining the windings in this type of armature.

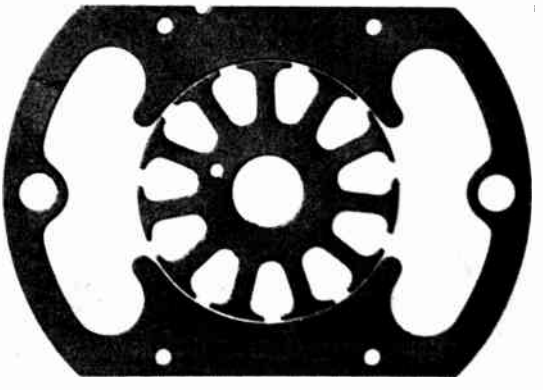


Fig. 3. ANOTHER DESIGN OF SANKEY'S SMALL MOTOR STAMPINGS.

The armature is $1\frac{9}{16}$-inch diameter with $\frac{7}{16}$-inch hole. The air gap is .01 inch. The width of the yoke is $\frac{7}{32}$ inch.

Maximum Output.

It will be seen from the previous paragraph that by winding 14 conductors per slot, the maximum possible output is not realised. If it is sufficient, then no harm is done by not filling the slots to the best advantage. If, however, the maximum possible output is desired, the armature is wound with single silk covered wire. To maintain the output at 6 volts the number of turns is kept the same. A gauge of wire is chosen which will wind so as to fill the slots. Since the slot area is .05 sq. in. the wires per sq. in. will be 280, i.e., $\frac{14}{.05}$. The heaviest gauge of S.S.C. wire which can be put on is therefore 17, which winds 287 conductors per sq. in. This gauge of wire will permit an output of 12 amperes total armature current or an output current of 10.5 amperes. The maximum output is therefore $10.5 \times 6 = 63$ watts.

Cast Iron Field Magnets.

The calculation of the windings for cast iron field magnets is the same as for laminated ones, but different flux densities and magnetising forces have to be observed. Suppose the dynamo, which has just been considered, were to have a cast iron magnet. The magnet would have to be considerably larger than the laminated one to obtain the same total flux in the air gaps. The overall size of the magnet would be increased to 5 in., which would increase the mean flux path to about 6 in.

The most economical flux density for cast iron field magnets, in small sizes, is 35,000 lines per sq. in. The magnetising force required for this is given in Table V as 44 ampere-turns per inch. The total ampere-turns for the magnet is therefore :

$2 \times 6 \times 44 = 528$ ampere turns.

The rest of the circuit is already found to need 330 ampere-turns, so that the total is 858. This means a wire diameter of .036 or 20 S.W.G. The current for this gauge of wire is 2.5 amperes as against 1.5 amperes of the laminated magnet windings.

Motor Design.

The calculation of the shunt field coils of a motor are exactly the same as for a dynamo. The armature design is really the same, although it is treated in a slightly different manner.

The starting point in the design of a motor is the formula :—

$E - V = IR.$

Where E = supply volts
V = armature voltage, or back E.M.F.
I = Total armature current
R = Armature resistance.

It is evident from this formula that it is necessary to find the armature resistance, in order that the speed may be predetermined.

How Armature Resistance is Found.

Suppose, as an example, the stampings previously considered as a dynamo are to be used for a 230 volt motor of $\frac{1}{12}$ h.p. output. The equivalent output of the armature is 62.5 watts. The current in the armature is the watts divided by the back E.M.F. voltage, not the mains voltage. In order to make a trial calculation it is necessary to assume a percentage drop in the armature. If this is taken as 10 per cent. the armature or back E.M.F. voltage is 207 volts. On this assumption the armature resistance is found as follows :—

$$I = \frac{\text{Watts}}{V}$$
$$= \frac{62.5}{210}$$
$$= .3 \text{ ampere.}$$

The resistance of the armature is found by dividing the effective E.M.F. of the armature, which is the difference between the mains voltage and the back E.M.F., by the armature current. The armature resistance is therefore :—

$$R = \frac{230 - 207}{.3}$$
$$= 76.7 \text{ ohms.}$$

Number of Armature Conductors.

The number of armature conductors is calculated from the same formula as for finding the number of dynamo armature conductors. Instead of E the output voltage, is substituted V, the back E.M.F. voltage, thus :—

$$Z = \frac{V \times 60 \times 10^8 \times S}{F \times P \times N}$$

V = 207 volts
F = 71,000 lines
P = 2
N = 3500 r.p.m.
S = 2

$$Z = \frac{207 \times 60 \times 10^8 \times 2}{71{,}000 \times 2 \times 3500}$$

= 5000 conductors, or 418 per slot. As before, with a useful slot area of .05 the wire per sq. in. is $\frac{418}{.05} = 8150$. This corresponds to 35 S.W.G. double silk covered wire. This gauge of wire will carry the current, .15 ampere, at a density of 2700 amperes per sq. in., which is safe.

Calculating Armature Resistance.

It now remains to calculate the armature resistance when wound with 2500 turns of 35 S.W.G. wire, so that the assumed drop in volts in the armature may be checked. The armature resistance in ohms is given by :—

$$R = \frac{Z \times l \times r}{2 \times 36 \times S}$$

Where Z = total conductors
l = mean length of one armature-turn (inches)
r = resistance of wire per yd.
S = number of parallel circuits.

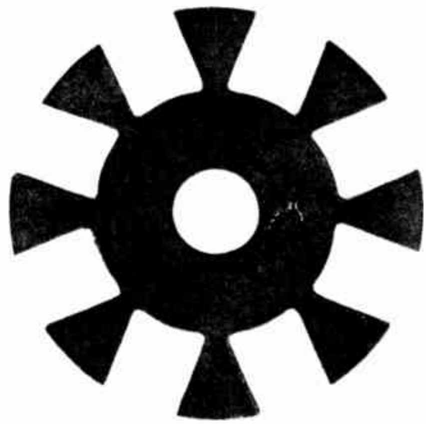


Fig. 4.—A TYPICAL DESIGN OF SLOTTED DRUM ARMATURE.
This open slot type is more suitable for form winding. Binders are used instead of slot wedges to retain the windings.

In the present example :—

Z = 5000
l = 7.25 in.
r = .4338 ohms
S = 2

$$R = \frac{5000 \times 7.25 \times .4338}{2 \times 36 \times 2}$$
$$= 109 \text{ ohms.}$$

The increase in resistance from 76.7 ohms the assumed value, to 109 ohms will result in a lower speed of 3340 r.p.m. This will give a correspondingly lower h.p. output, actually only 4 per cent. less.

For an accurate determination of the number of armature conductors the following expression is used :—

$$Z = \frac{6 \cdot 10^9 S \left(E - \frac{I \times Z \times l \cdot r}{72 \times S}\right)}{F \times p \times N}$$

TABLE VI. WORKING DATA OF MORGANITE AND BATTERSEA CARBON BRUSHES.

Type.	Specific Resistance. Ohms per Inch Cube.	Contact Drop at Normal Current Density Volts.	Maximum Commutator Surface Speed Feet per Min.	Normal Current Density. Amps. per Sq. Inch. Commutators.	Normal Current Density. Amps. per Sq. Inch. Slip Rings.	Mica.	Brush Pressure Lbs. per Square Inch.	Uses.	Remarks.
Link One Morganite	.00083	.95	10,000	60	—	Recessed	2	Stationary machines.	Silent.
Link Five Morganite	.00075	.90	10,000	60	—	Recessed	2	Stationary machines.	Does not expand with heat.
Link HM3 Hard Morganite	.00062	.90	10,000	65	75	Recessed	2	Rotary converters.	A clean lubricating brush.
Link HM5 Hard Morganite	.00065	.90	10,000	65	75	Recessed	2	Turbo-exciters and large D.C. machines.	Low friction.
Link HM6 Hard Morganite	.00075	.85	10,000	65	75	Recessed	2	D.C. machines, turbo alternator slip-rings	A good commutating brush.
Link CM Copper Morganite	.000007	.25	4,000	100	150	Flush	8 for car starters	Bronze slip-rings, 6-volt starter motors and very low voltage machines.	—
Link CM1S Copper Morganite	.000011	.25	5,000	100	150	Flush	2	D.C. machines and slip-rings up to 10 volts.	Specially suitable for oil lubricated slip-rings.
Link CM2 Copper Morganite	.000008	.25	5,000	100	150	Flush	2 2½ for slip-rings	D.C. machines and slip-rings up to 10 volts.	—
Link CM3H Copper Morganite	.000013	.35	6,000	80	100	Flush	3 for slip-rings 8 for car starters	Rotary converter slip-rings, car dynamos and starters.	—
Link CM5H Copper Morganite	.000025	.50	6,000	75	90	Flush	2 3 for slip-rings	Rotary converter slip-rings, induction motor slip rings and car dynamos and starters.	—
Link CM6 Copper Morganite	.000110	.45	5,000	70	90	Flush	2	D.C. machines and induction motor slip-rings up to 50 volts.	—

Link A Battersea Carbon	.0013	1.0	4,000	45	—	Flush	2	Stationary machines.	Good lubricating qualities.
Link A5 Battersea Carbon	.0020	1.1	4,000	40	—	Flush	2	Car dynamos.	—
Link B Battersea Carbon	.0011	.95	4,000	55	70	Flush	2	Machines of all voltages.	Suitable where no special commutating difficulties are present.
Link B6 Battersea Carbon	.0013	1.0	4,000	50	65	Recessed	2	Machines of all voltages.	—
Link C4 Battersea Carbon	.0021	1.1	3,000	40	—	Flush	2	500-volt motors.	Suitable for hard micas.
Link C8 Battersea Carbon	.0027	.7	3,000	40	—	Flush	2 3-6½ for	Traction and other motors.	Suitable where high micas cause blackening.
Link EG0 Electro-Graphitic	.0007	.95	5,000	65	75	Recessed	2	Car dynamos and low-voltage machines.	A comparatively soft brush.
Link EG3 Electro-Graphitic	.0013	1.0	5,000	55	65	Recessed	3-6½ for traction	Traction motors and A.C. commutator motors.	A mechanically strong brush, suitable for contacts subject to violent sparking.
Link EG4 Electro-Graphitic	.0014	.90	4,000	55	65	Flush	3-6½ for traction	Traction motors and A.C. commutator motors.	Similar characteristics to Link EG3.
Link EG10 Electro-Graphitic	.0014	1.2	7,000	60	—	Recessed	2½	A.C. commutator motors, and D.C. machines with widely fluctuating loads.	—
Link EG11 Electro-Graphitic	.0013	1.0	8,000	60	—	Recessed	2½	High speed rotary converters, and traction motors.	—
Link EG12 Electro-Graphitic	.0014	1.2	8,000	60	—	Recessed	2½	High speed converters and dynamos.	Suitable where load and commutating conditions are severe.

This formula is a combination of the three expressions for the armature voltage, the motor formula and the formula for the armature resistance.

In the present example design :—

$$Z = \frac{6 \times 10^9 \times 2 \left(230 - \frac{.3 \times Z \times 7.25 \times .4338}{72 \times 2}\right)}{71{,}000 \times 2 \times 3{,}500}$$

$\therefore Z = 4{,}770$, or 398 per slot.

Series Field Windings.

The examination of series field windings is confined to motors, because the series dynamo has very little practical value. In a series wound motor the total armature current passes through the field coils, therefore the number of turns on the series field coils is simply found by dividing the ampere-turns by the main current. The gauge of wire is proportioned to carry this current at 2500 amperes per sq. in. The resistance of the coils is then found when the volts drop at full load is estimated. This drop subtracted from the mains voltage gives the voltage at which the armature works at full load.

Suppose for the sake of argument the volts drop in the field coils of a 230-volt series motor is 25 volts, the volts applied to the armature would be 205 volts. The calculation of the armature winding is then as for a shunt machine of 205 volts input. It is evident from this that a series motor armature, of the same h.p. output as that of a shunt motor, is wound with fewer turns of thicker wire if the mains voltages are the same.

Sources of Loss.

The overall efficiency of a dynamo or motor is dependent on the following losses :—

(1) Field excitation watts.
(2) Armature copper loss.
(3) Armature iron loss.
(4) Hea ing.
(5) Brush contact drop.
(6) Friction of bearings and brushes.
(7) Windage.

The field excitation and armature copper loss or volts drop have been considered. These are definite and can be calculated without much difficulty. The armature iron loss is practically negligible in small machines. Actually the loss amounts to about 1 watt per pound of armature iron at speed of 3000 revolutions per minute. The loss due to heating is the extra drop in volts in the armature caused by the rise in resistance as the machine warms up on load. This can be determined only by experiment, because the various factors which determine the actual temperature rise cannot be calculated.

The brush contact drop may be estimated from Table VI, showing the characteristics of dynamo and motor brushes. This loss may be compensated by making a suitable allowance before commencing the armature calculations. This loss is negligible in high voltage machines.

Losses due to the friction of brushes and bearings are a source of considerable loss in small machines, and can be determined only by trial. Small machines should invariably have ball bearings and low voltage machines of less than $\frac{1}{4}$ h.p. should have copper gauze brushes.

Windage is another loss which cannot be predetermined. It does not affect the design of dynamos, but lowers the h.p. output of motors.

Overall Efficiency of Small Motors.

The overall efficiency of small motors of good design is given in the following table :—

H.P.	Efficiency	H.P.	Efficiency
$\frac{1}{30}$	.4	$\frac{1}{6}$	.64
$\frac{1}{20}$	.5	$\frac{1}{4}$	.72
$\frac{1}{16}$	.52	$\frac{1}{2}$	.76
$\frac{1}{12}$	.56	1	.81
$\frac{1}{10}$	.6	$1\frac{1}{2}$	.82
$\frac{1}{8}$	.62	2	.83

Calculating Total Motor Current.

In the design of the $\frac{1}{12}$ h.p. motor, which has been considered as an example motor design, the windings are calculated to give an armature output of $_{12}$ h.p. When designing a motor of a certain h.p. output at the pulley, the total motor current is first calculated from :—

$$I = \frac{B.H.P. \times 746}{E \times e}$$

Where I = current in amperes
E = voltage of mains
e = efficiency expressed as a decimal.

Thus a $\frac{1}{12}$ h.p. motor working at full load on a 230 volt supply has a total line current of .48 ampere.

APPARATUS FOR THE CORRECTION OF POWER FACTOR

By Professor MILES WALKER, D.Sc., M.I.E.E., F.R.S.

APPARATUS for the correction of power factor may be conveniently considered under two headings: (1) Apparatus which attacks the evil at its source and prevents the production of wattless current that would otherwise flow in the circuit, and (2) apparatus that neutralises wattless current that has been already produced.

In the first class fall phase advancers and in the second, condensers and over-excited synchronous motors. The term phase advancer should never be used in connection with the second class as it is a specific term intended to be used only for apparatus of first class.

Phase Advancer.

Before the invention of the phase advancer by Le Blanc in 1895, the induction motor always required a lagging current to magnetise it, and the wattless kVA. called for was often as great as one third of the total kVA. input to the motor. At light loads the input to induction motors is often almost entirely wattless, so that a mixed load of lighting and power will often have a power factor lower than 0.8 and the kVA. coming upon the mains and central station is thus very much augmented.

The phase advancer supplies the alternating magnetising current, required by an induction motor, to the rotor and thus relieves the mains which would otherwise have to supply it to the stator. The advantage lies in the fact that the frequency in the rotor circuit is only one or two per cent. of the frequency of the stator. The magnetising current for the rotor can be supplied at a low frequency and low voltage instead of at a high frequency and high voltage. Thus the wattless kVA. required is only a few per cent. of that required by the stator for the same magnetising effect. Here, of course, we are assuming that the stator is the primary and the rotor is the secondary, as is most commonly the case.

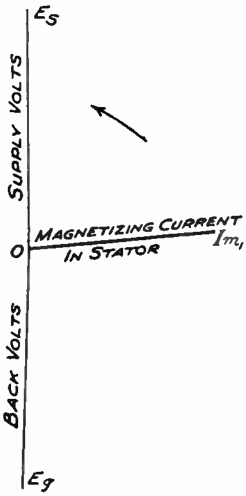


Fig. 1.—SHOWING THE POSITION OF THE VOLTAGE VECTORS AND MAGNETISING CURRENT FOR AN ORDINARY INDUCTION MOTOR.

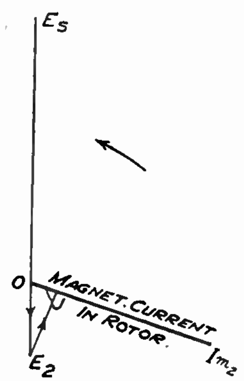


Fig. 2.—SHOWING THE MAGNETISING CURRENT IN THE ROTOR OF AN INDUCTION MOTOR FITTED WITH A PHASE ADVANCER.

Why the Rotor Magnetising Current must Lead.

A magnetising current in a rotor must lead, that is to say, its phase must be ahead of the working current of the rotor. Students sometimes ask why must a magnetising current in a stator be a lagging current while that in the rotor must be a leading current. The answer is obvious from the diagrams Figs. 1 and 2.

The reader is referred to articles by Mr. Dover on the induction motor and on the Calculation of Alternating Current for further explanation of these diagrams. (See pages 809 and 1560.)

If we take the vector OE_s drawn upwards to represent the phase of the supply voltage which tends to force current through the stator, then the

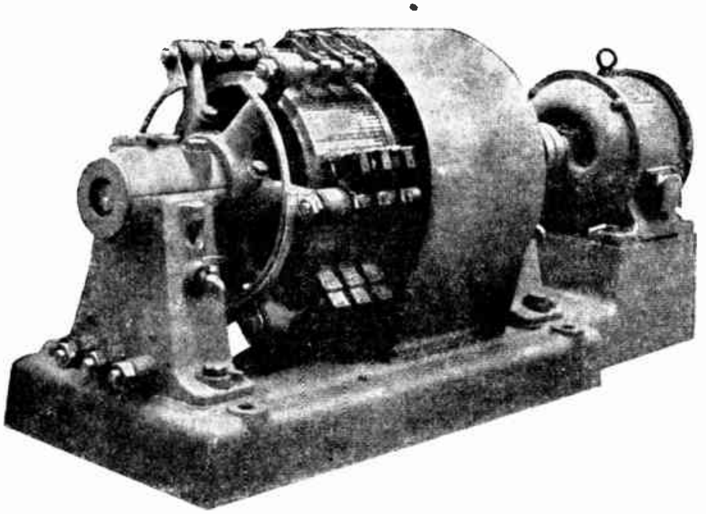


Fig. 3.—Le Blanc Phase Advancer (Scherbius Type) Built By Brown, Boveri & Co.
This has a small driving motor attached.

back E.M.F. set up by the revolving field is nearly equal and opposite to OE_s and may be represented by OE_g drawn downwards. The magnetising current which sets up the revolving flux that generates the back E.M.F. is shown by a line OI_{m1} drawn nearly at right angles to both. This vector lags on OE_s and leads on OE_g.

Fig. 2 shows the supply E.M.F. OE_s as before drawn vertically upwards, and shows the E.M.F. generated in the rotor bars, OE_2, which is in the same direction as OE_g in Fig. 1, but of very much lower value because it is generated at the slip frequency. The resistance of the rotor circuit is very low and its reactance is almost negligible so that only a small E.M.F. is required to drive a very big current.

Suppose now we put a machine in circuit with the rotor which will add an E.M.F. equal to E_2J so that the total E.M.F. in the circuit is OJ, then the current OI_{m2} in the rotor will be almost in phase with OJ. That is to say it will be leading on OE_2, and it will take the place of the magnetising current that would otherwise be required in the stator.

Le Blanc's Exciter.

A phase advancer is a machine for supplying an E.M.F. of this kind. It may be regarded as a sort of alternating current exciter. In the original machine devised by Le Blanc, the E.M.F. injected into the rotor circuit was always 90 degrees ahead of the rotor current. This was quite effective in making the current lead on the OE_2 but it causes a slight increase in the slip, and is not as economical as when the injected E.M.F. is at some other angle, say 30° to the rotor current.

The original Le Blanc advancer is a very simple machine. It consists of a direct current, 2-pole armature provided with three brushes at 120° to one another on the commutator (see Fig. 4) connected to the three slip-rings of the rotor of the induction motor. The low frequency currents from the rotor magnetise the

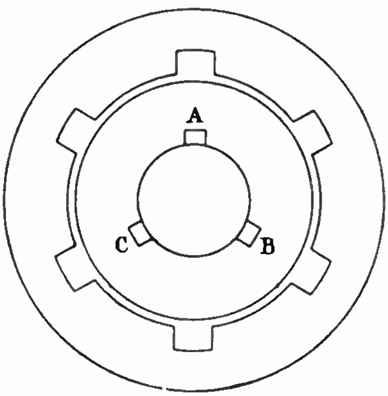


Fig. 4.—Le Blanc's Phase Advancer.

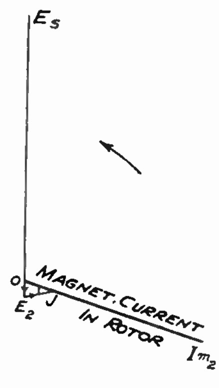


Fig. 5.—Showing the Advantage of Injecting the E.M.F. at an Angle Less Than 90°.

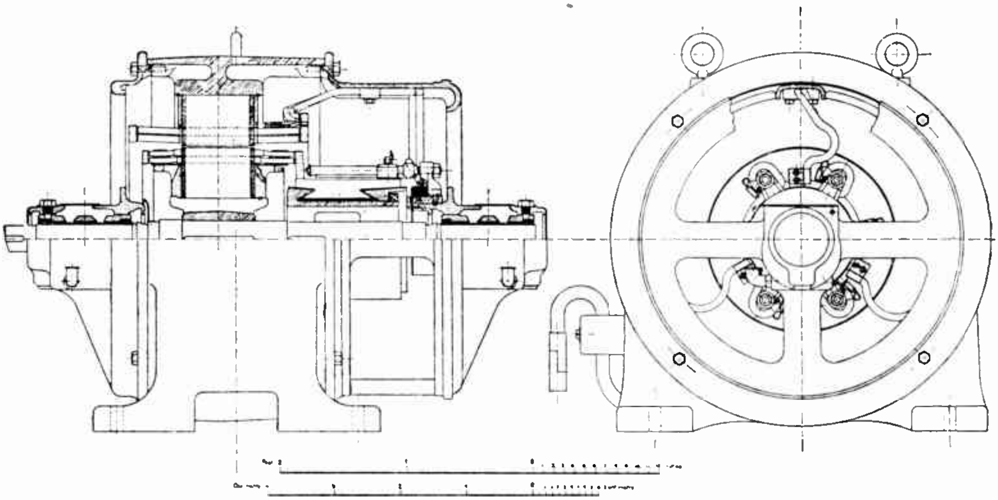


Fig. 6.—Internal Construction of a Phase Advancer.

armature and the field produced revolves slowly with respect to the brushes as the three-phase currents slowly alternate. If the armature is revolved in the same direction as the field and at the same speed the conductors do not cut the field and the armature has therefore no inductance. If now the speed of the armature is increased so that it goes faster than the field, the inductance becomes negative. The phase of the E.M.F. generated in it is 90° ahead of the current. In practice the field may rotate only once or twice a second while the armature is revolved at

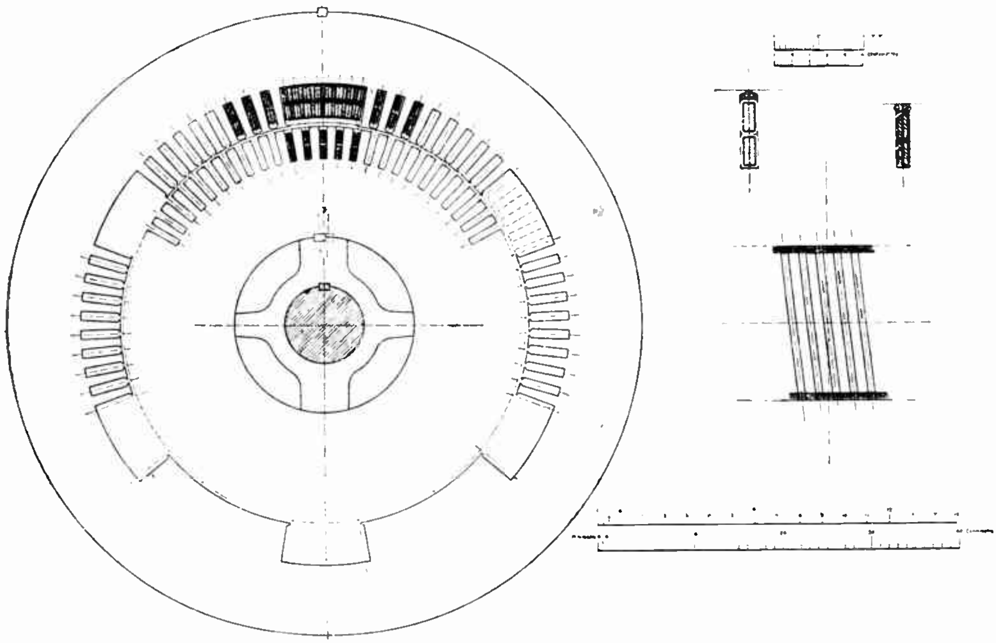


Fig. 7.—Arrangement of Slots in Stator and Rotor and Provision for Compensating Winding and Series Winding on Stator.

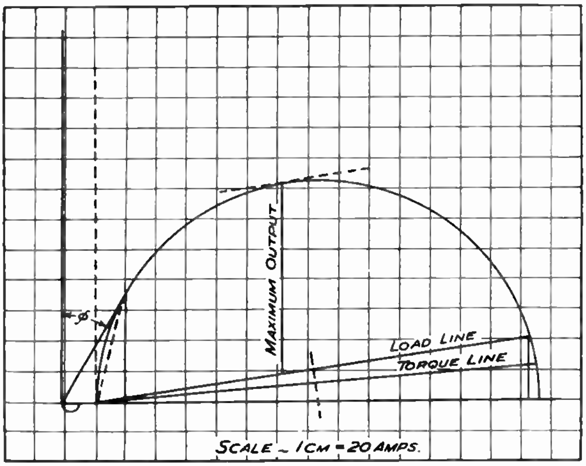


Fig. 8A.—CIRCLE DIAGRAM OF A 475 H.P., 3,000-VOLT, THREE-PHASE MOTOR WHICH WITHOUT A PHASE ADVANCER HAS A MAXIMUM POWER FACTOR OF 0.86 LAGGING.

many hundreds of revolutions per minute so as to generate an E.M.F. as great or greater than the slip E.M.F. The armature will work without any field magnet around it, if provided with closed slots, but it commutates better if built with open slots and is surrounded with an unwound iron stator to complete the magnetic circuit. Fig. 3 shows a machine of this type built by Brown Boveri & Co.

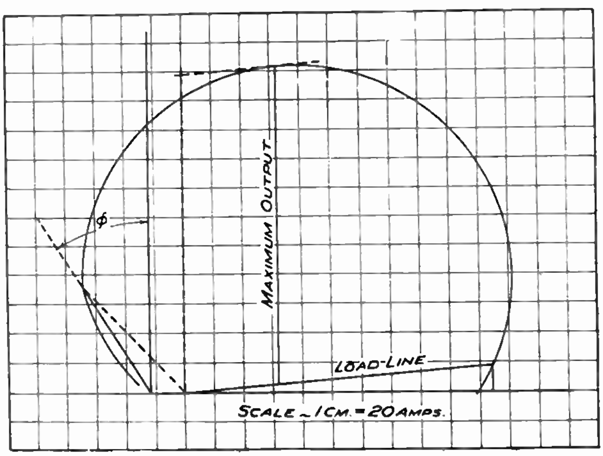


Fig. 8B.—SHOWING HOW BY THE ADDITION OF A PHASE ADVANCER THE LOCUS DIAGRAM IS ALTERED. THE MOTOR NOW HAS A FULL LOAD POWER FACTOR OF 0.84 LEADING.

Advantage of Smaller Angle of Lead.

If it is desired to control the phase angle of the injected E.M.F. (for instance to make it at 30° or some other angle to the current) a winding must be put on the stator of the advancer. By proper connection of the stator coils the E.M.F. can be injected at any angle. Fig. 5 shows the effect of making E_2J at 30° to OI_{m2}. Here OE_2 is reduced.

The advancer may be coupled directly to the shaft of the motor, or it may be driven by a gear or by a separate motor. The amount of power required to drive it is extremely small when the current is out of phase with the volts and the kVA. capacity of the machine is only two or three per cent. of that of the motor.

If an induction motor is designed to be run with an advancer, it can be built more cheaply than a motor possessing inherently a good power factor. The saving in cost of the motor goes to pay for the advancer. The motor can also be made more efficient than a motor running with an uncorrected power factor and the saving in losses on the motor goes to compensate for the losses on the advancer.

Metro-Vickers Advancer.

Fig. 6 shows the internal construction of a phase advancer built by Metropolitan-Vickers Elec. Mfg. Co., Ltd., for connection to a motor of 750 h.p. A cross-section of the machine showing the arrangement of the slots is given in Fig. 7.

The winding lying in the slots of the stator is a compensating winding, which almost wipes out the magnetising effect of the armature. The winding around the six salient poles is selected from the three phases so as to give the desired lead to the injected E.M.F.

Fig. 9 shows an induction motor with a phase advancer, connected to the same shaft, built by the Metropolitan-Vickers Co.

The improvement in the performance of induction motors brought about by the use of an advancer is seen from the two figures on the facing page.

Fig. 8A gives the circle diagram of a 475-h.p., 3,000-volt, three-phase motor running normally (without advancer). It will be seen that the maximum power factor is 0.86 lagging. With an advancer connected to the rotor circuit the locus diagram is altered to that shown in Fig. 8B, which gives a full load power factor of 0.84 leading. If desired, the advancer can be arranged to give less lead to the rotor current so as to obtain a power factor of unity at full load.

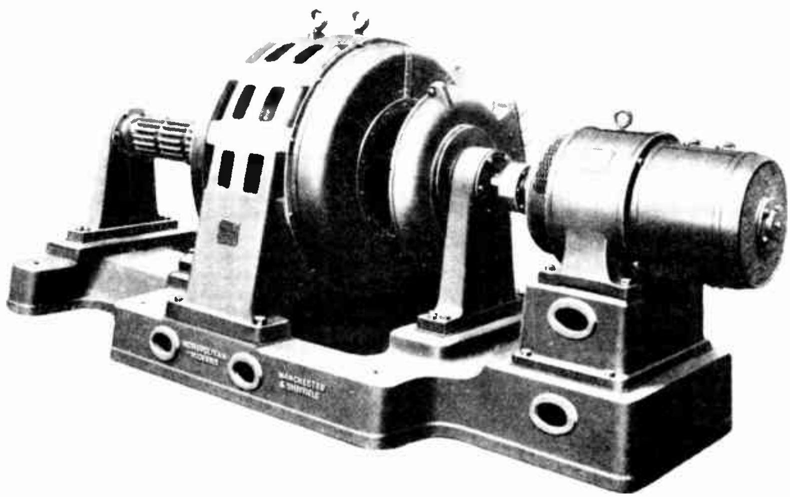


Fig. 9.—INDUCTION MOTOR WITH DIRECT-CONNECTED PHASE ADVANCER. (*Metropolitan-Vickers.*)

With the advancer in circuit the locus of the stator current lies almost on a circle whose centre is far above the centre of the first circle.

The Le Blanc exciter can also be used for changing the value of the slip for a given load. When the injected E.M.F. of the exciter is in phase with the rotor current it augments the E.M.F. generated by the slip, so that the slip will be smaller for a given rotor current. When the injected E.M.F. is opposite in phase to the current it opposes OE_2, and the slip automatically increases until there is sufficient E.M.F. to drive the current against the opposing pressure. By this means the slip can be varied over a wide range, and by arranging the excitation of the advancer so as to have a component of its E.M.F. in advance of the current, the power factor may be improved at the same time as the slip is varied.

The Kapp Vibrator.

It has been known for a very long time that when an alternating current is passed along a wire freely suspended at right angles to a steady magnetic field the wire moves in such a manner as to generate a leading E.M.F.; in other words, it has a negative inductance. The reason is fairly obvious. The current produces a force on the conductor which is accordingly accelerated. The phase of the motion must necessarily lag behind the phase of the current. Now the E.M.F. generated by the motor is a back E.M.F., and a lagging back E.M.F. is the same thing as a leading forward E.M.F., because to change the sign of an alternating quantity is to change its phase angle by 180°. Kapp showed that to make a practical advancer on this principle it was best to use an ordinary direct current armature having a very small diameter, so that the moment of inertia is small and the acceleration very rapid. This vibrator consists of three armatures, whose brushes are connected in series with the slip rings of the induction motor and then to a star point. The low-frequency current, from the rotor, sets the armatures

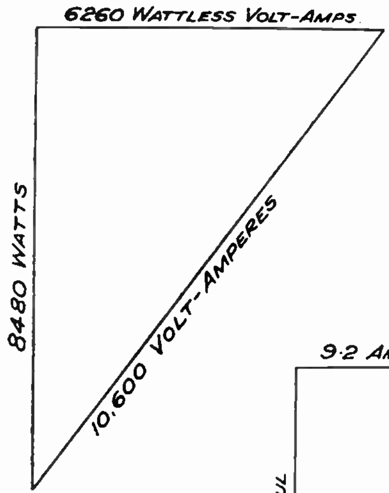


Fig. 10.—THE VOLT-AMPERES OF A 10 H.P. MOTOR.

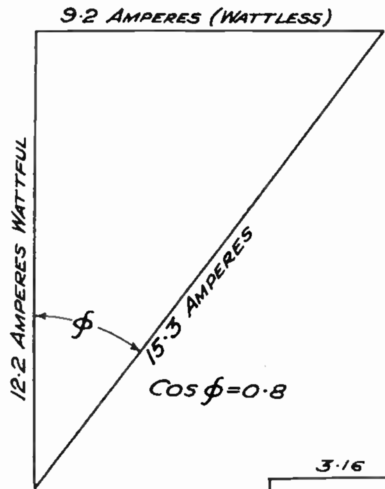


Fig. 11.—THE WATTFUL AND WATTLESS AMPERES OF A 10 H.P. MOTOR AT FULL LOAD.

revolving in a strong magnetic field and the motion sets up a leading E.M.F. When the slip is small, say ½ to 1 per cent. in a 50-cycle motor, the armatures have time to get up a fair speed at each alteration of the current, but at high slips the armatures have not time to attain a high speed and the injected voltage is accordingly lower. For this reason the Le Blanc exciter, which can be run at a high speed all the time, is a smaller machine for a given kVA. rating.

(2) Apparatus for neutralising wattless current that has been already produced.

Condensors.

It is proposed that the electrical condensor shall be spelt with an " o " instead of with an " e," to distinguish it from a steam condenser or any other kind of a condenser. In fact, it would be well if we could have the rule that all words connoting electrical apparatus for carrying out any operation, such as generator, conductor, rotor, etc., should terminate with the letters " or." There are only about a dozen exceptions, and the sooner we do away with them the better. Let gas meter be spelt with " er " and an electric motor with " or." The rule would be helpful to the schoolboy and the technician alike.

A condensor usually consists of a large number of sheets of metal separated by thin sheets of dielectric, such as paraffined paper or mica. Alternate sheets of metal are connected to form one conductor and the other alternate sheets to form the other conductor, separated from the first by the dielectric. Thus, we get a very large surface. The capacity of the condensor is proportional to the sum of the surface of all the sheets and is inversely proportional to the thickness of the dielectric.

How to Calculate the Current Taken.

The thickness and nature of

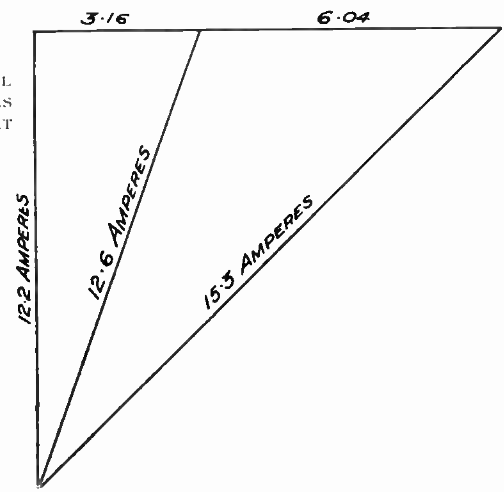


Fig. 12.—VECTOR DIAGRAM SHOWING THE MOST ECONOMICAL METHOD OF COMPENSATING THE CONDITION ILLUSTRATED IN FIG. 11.

Assuming the cost of power is £4 per kVA. per annum, and cost of power factor correction apparatus is £1 per kVA. per annum.

the dieletric will depend upon the voltage to be applied between opposite terminals. Some condensors are designed to take voltages up to 750 and others will withstand 6,600 volts (alternating) for years, and are best made with mica as a dielectric. The current flowing into a condensor is proportional to the voltage, to the frequency and to the capacity. We calculate the current from the formula

$$I = 2\pi f C V,$$

where I is the effective value of the current in amperes, f is the frequency, C is the capacity in farads, and V the effective pressure in volts. The phase of the current is almost exactly 90° ahead of the applied voltage. The amount of current in phase with the voltage is often less than one half of one per cent. of the wattless current.

Suppose that we have a 400-volt, 3-phase, 50-cycle, 10 h.p. motor which ordinarily runs at 0.8 power factor and has an efficiency of 88 per cent. The power taken from the line will be $10 \times 746 \div 0.88 = 8{,}480$ watts. The volt-amperes taken from the line will be $8{,}480 \div 0.8 = 10{,}600$. See Fig. 10.

The wattful current (that is the current in phase with the volt) will be

$$\frac{8{,}480}{400 \times 1.73} = 12.2 \text{ amperes.}$$ See Fig. 11.

The actual current drawn from the line will be $\frac{10{,}600}{400 \times 1.73} = 15.3$ amperes.

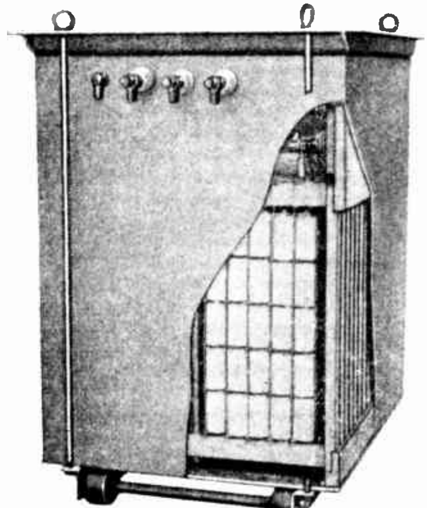


Fig. 13.—Condensor Built by the British Insulated and Helsby Cable Co. with an Input of 312 kVA at 600 Volts, 50 Cycles.

The cosine of the angle of lag ϕ is given by the ratio $\frac{12.2}{15.3} = 0.8$.

The wattless lagging current will be $15.3 \times 0.6 = 9.2$ amperes.

In this case as 0.8 is the cosine of ϕ the sine of ϕ has the value 0.6.

Suppose now that it is required to completely neutralise the 9.2 wattless amperes by means of a condensor. We must have one big enough to take 9.2 amperes at 400 volts, the frequency being 50. The capacity of the condensor will be:

$$C = \frac{I}{2\pi f V} = \frac{9.2}{6.28 \times 50 \times 400}$$
$$= .000073 \text{ farads}$$
$$= 73 \text{ microfarads.}$$

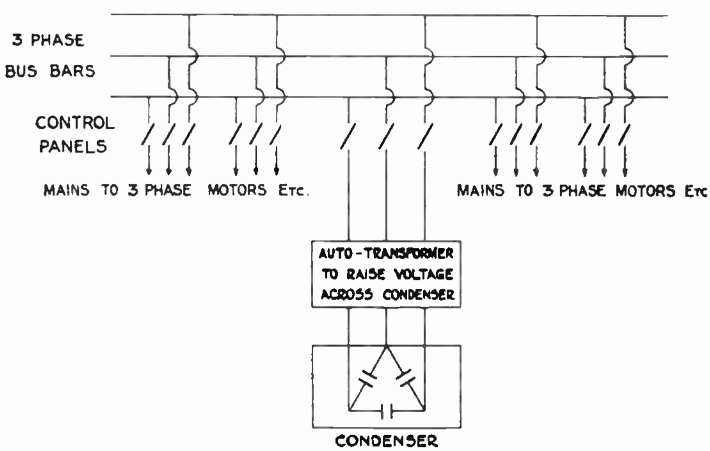


Fig. 14.—Arrangement of Condensor, Auto-Transformer and Switches When the Condensor is on the Low-tension Side.

The Best Capacity to Use.

Electric-supply companies, in order

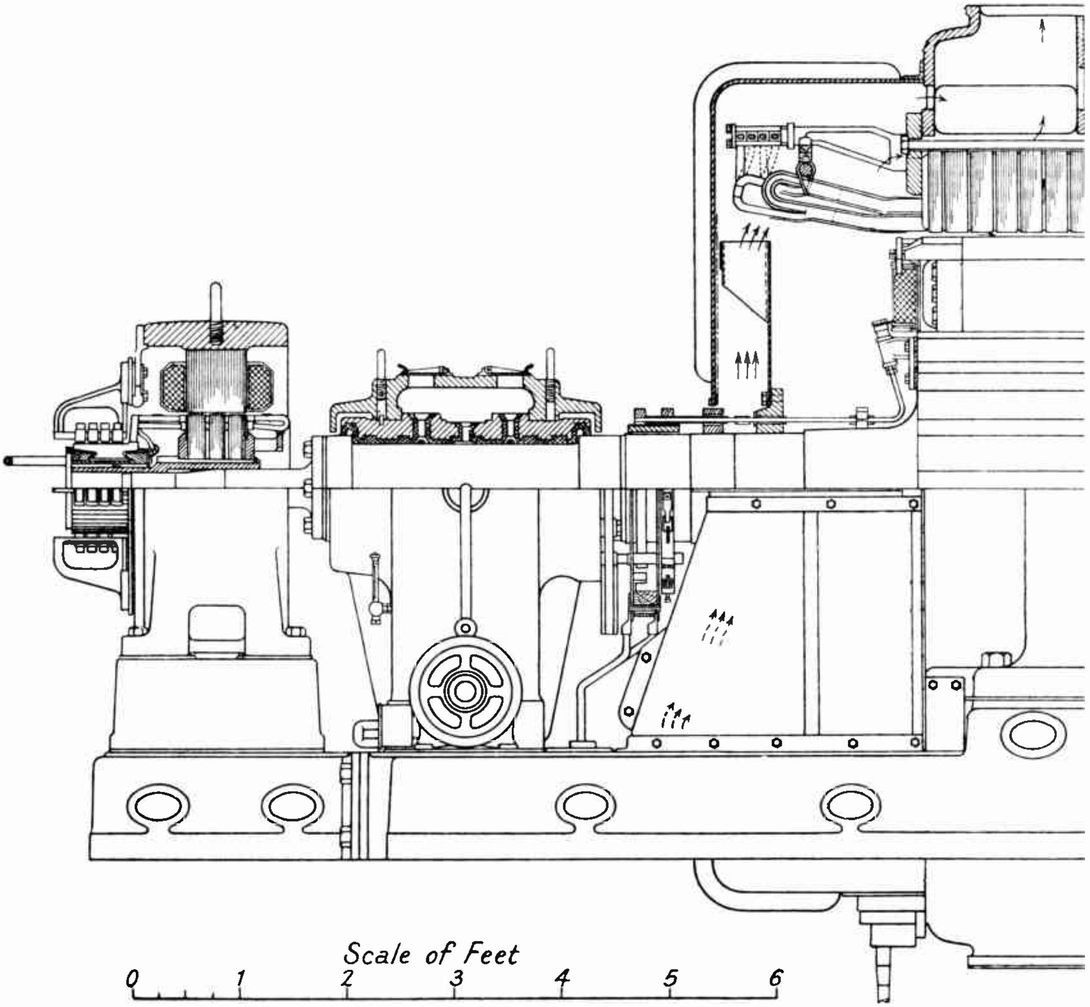
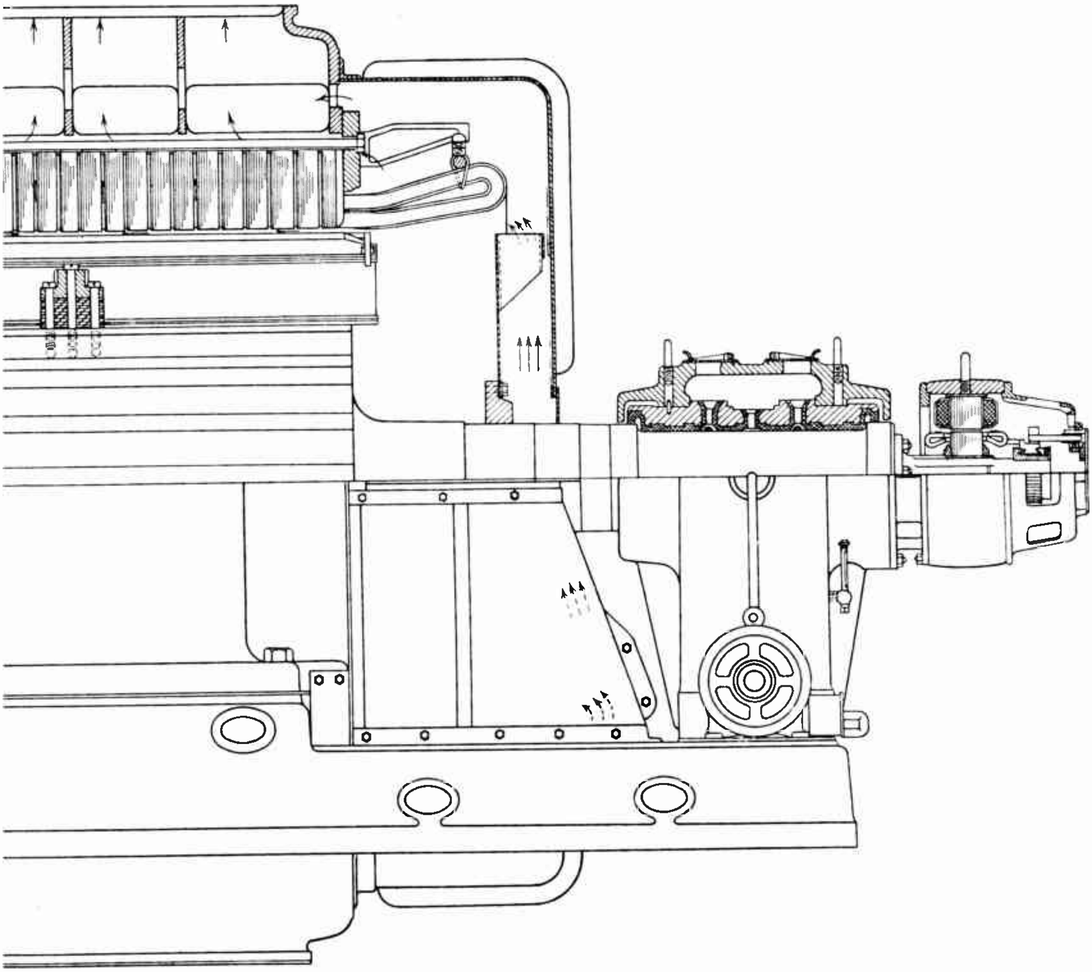


Fig. 15. LONGITUDINAL SECTION OF A 10,000 kVA. SYNCHRONOUS MOTOR BUILT BY THE METROPOLITAN-V
It is designed to run on 11,000 v

to induce their consumers to use apparatus of high-power factor, very commonly make a charge on the basis of maximum kVA. demand. The question then arises: How far is it worth while to improve the power factor, having regard to the cost of the condensors or other apparatus? It can be shown where the annual cost (including interest and depreciation of the power-factor-improving apparatus) per wattless kVA. is denoted by a and the annual cost of the supply is c per kVA. Then it is worth while to improve the power factor, cos ϕ, so that sin ϕ is equal to $a \div c$.

Suppose, for instance, that in the case of the 10 h.p. motor mentioned above the cost of supply is £4 per kVA. per annum, and that the total annual cost of condensors is £1 per annum per wattless kVA. (leading). Then the power factor should be improved until sin $\phi = \frac{1}{4}$. That is, $\phi = 14.5°$.

The state of affairs after the improvement would be as indicated in Fig. 12. Instead of completely wiping out the



ERS ELECTRICAL CO., LTD., FOR THE WAIKAREMOANA HYDRO ELECTRICAL SCHEME IN NEW ZEALAND. , 50 cycles at a speed of 750 r.p.m.

lagging wattless current of 9.2 amperes, it pays better to only compensate for 6.04 amperes leaving 3.16 uncompensated. The power factor will then be improved from 0.8 to 0.968. The line current will be 12.6 and the capacity of the condensor required will be only 48 microfarads instead of the 73 required to make full compensation. If we compensate any further than this, the cost of the condensors and accessories will be more than the saving in the cost of supply. As maximum-demand indicators do not as a rule differentiate between lagging and leading current, care must be taken that the leading current taken by the condensor when the lagging current is small does not increase the maximum demand.

Switching Arrangement for Condensor.

Fig. 13 shows a condensor built by the British Insulated and Helsby Cable Company, designed to work at a pressure of 600 volts. At 50 cycles it has an input of 312 kVA. Where a high-tension transformer is employed to step

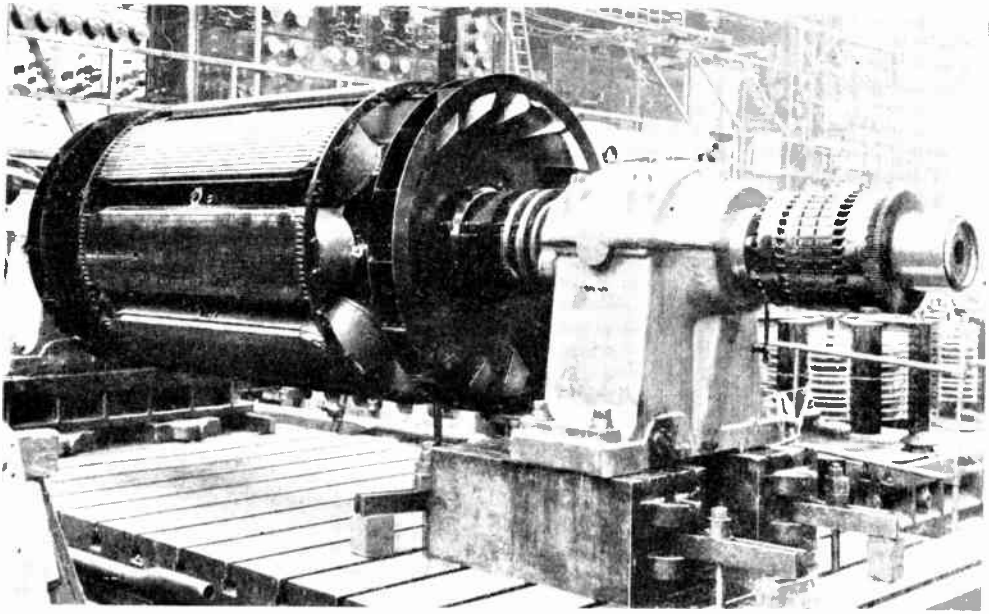


Fig. 16.—SHOWING THE CONSTRUCTION OF THE FIELD MAGNET OF THE 10,000 KVA. SYNCHRONOUS MOTOR FITTED WITH A DAMPER TO PREVENT "HUNTING." (*Metropolitan-Vickers Electrical Co.*)

down the voltage to supply an induction motor or other apparatus, the question arises as to whether it is best to install a condensor of small capacity on the high-tension side or a condensor of larger capacity on the low-tension side. One advantage of putting the condensor on the low-tension side is that it reduces the load supplied by the transformer, so that a smaller transformer can be used and its losses are rather less. Moreover, the switching in and out of the condensor can be carried out at a low pressure. Where the low-tension supply is at 440 volts, it is worth while to use an auto-transformer to raise the pressure to 600 volts for the condensors. The low-tension Helsby condensors are built to withstand this voltage continuously, so that it is cheaper to raise the voltage than to use a larger capacity.

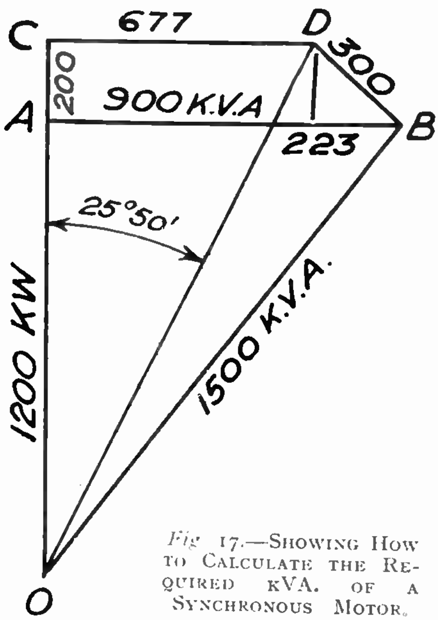


Fig 17.—SHOWING HOW TO CALCULATE THE REQUIRED KVA. OF A SYNCHRONOUS MOTOR.

Fig. 14 shows the switching arrangement applicable to such a case.

Over-excited Synchronous Motor.

In cases where a very large leading kVA. is required it is usual to install a synchronous motor, which can be over excited so as to take a leading current. In some cases a useful load can be found for this motor and then the money spent on it is better worth while. For instance, we may have a coal mine with a large number of motors whose average load makes the power factor rather low. If it is intended to install a large motor to drive a ventilating fan, that motor can with advantage be a synchronous one, and by over-exciting it, we may compensate for the lagging current taken by the small motors.

One very important use of the synchronous motor in controlling power factor is in connection with long distance transmissions. The inductive drop on a very long transmission line would lead to abnormal variations of the voltage with changes of load. If, however, we install a synchronous motor at the load end of the line and control the excitation by means of an automatic regulator, the motor draws leading current whenever the volts tend to fall and lagging current when the volts tend to rise, and thus keep the volts on the load almost steady.

Fig. 15 shows a synchronous motor, built by the Metropolitan-Vickers Electrical Company for the correction of power factor and line regulation on the Waikaremoana Hydro Electric Scheme in New Zealand. The small exciter shown on the right has a steady voltage and supplies the exciting current for the main exciter shown at the left-hand end of the shaft. This current is increased or reduced by an automatic regulator controlled by the voltage on the A.C. mains so as to keep the latter almost constant. The main exciter thus over-excites the field magnet of the synchronous motor when the volts tend to be low, and under-excites it when the volts tend to be high. The motor will take anything up to 10,000 kVA. leading current at 11,000 volts, 50 cycles or anything up to 6,500 kVA. when supplying lagging current. Fig. 16 shows the construction of the field magnet with its amortisseur or damper which prevents phase swinging or "hunting."

How to Find the Rating of a Synchronous Motor.

In order to find the rating of a motor of this kind when it is required to improve the power factor between certain figures, and at the same time yield a definite useful load, we can make use of a diagram like that in Fig. 17. A vertical line represents real power. A horizontal line drawn from the origin o to the right represents wattless lagging kVA. One inch represents 500 kVA.

Suppose that the load in a coal mine is 1,500 kVA. at 0.8 power factor. OA will represent the true load of 1,200 kw. and OB will represent the kVA. of 1,500. The lagging wattless kVA. is 900 kVA. given by AB.

Suppose now that it is desired to install a ventilating motor that will require 200 kw. to drive it, and it is desired at the same time to improve the power factor of the whole load from 0.8 to 0.9. Set off the additional 200 kw. by the line AC giving a total load of 1,400 kw. Now set off the angle COD $= 25° 50'$ which is the angle whose cosine is 0.9. The horizontal line CD then represents the amount of wattless lagging current when the power factor is 0.9. Now join DB and the length of this to scale gives the kVA. rating of the motor required. In this case the leading wattless kVA. required will be $900 - 677 = 223$ kVA. and the true power to drive the motor is 200 kw. So the total kVA. will be $\sqrt{223^2 + 200^2} = 300$ kVA.

HOW TO START AN ELECTRICAL BUSINESS

By D. WINTON THORPE, A.M.I.E.E.

Fig. 1.—INTERIOR OF A TYPICAL ELECTRICAL CONTRACTOR'S OFFICE.
(*Photo by courtesy of Messrs. Troughton and Young, Ltd.*)

ANYONE who is asked to write an article on the subject of starting in any business is faced with an unenviable task. He may, for instance, lead the reader to imagine the life of the electrical contractor to be one which is divided between riding about in a Rolls-Royce and attending board meetings at a mahogany table while smoking a cigar; or he may give the reader a glimpse of a half-starved contractor wearing out his shoe leather in the fruitless search for a customer who will, at least, allow him to change a fuse. Neither necessarily resembles the reality.

Two Facts to Remember.

When a young man decides to start business "on his own" as an electrical contractor he must keep two facts well in mind. The first is, that he is going into business in order to earn a living; not merely for the fun of seeing his own name in gold lettering above his premises; not merely for the privilege of ordering other folk about; not merely because it will afford him an opportunity of gratifying his technical tendencies in congenial circumstances; but for the purpose of making money. And the second fact is, in a sense, contradictory. It is because he has a natural or acquired bent, supported by technical qualifications, for electrical installation work of every description.

These two ingredients are essential to the proper and successful conduct of any electrical contractor's business. A man who can make a success, commercially speaking, out of the sale of pork sausages, might, if he turned his attention to the business of electrical contracting, make a temporary success of that business as well, but his technical shortcomings would assuredly find him out sooner or later; similarly, the brilliant electrical technician may come to grief if he tries to start and run an electrical contractor's business without keeping before his eyes the phrase, "You are doing this for a living."

Be Prepared for all Kinds of Jobs.

It is as well to disabuse oneself of the idea that the electrical contractor is a wiring contractor only. Wiring may, or may not, represent the bulk of his business, but, unless he is prepared to take things as they come—advise on the running cost of an electric heating system in the morning, and install a 3-phase motor in the afternoon—he will find that his limitations will be his downfall. I do not wish to be misunderstood; although it is very desirable that the contractor should himself know all about everything to do with electricity, it is not always possible for him to have this complete knowledge when he starts; but he must be ready to acquire such knowledge through his experience and, while he is acquiring it, to have someone to turn to who can put him right. In order that he shall in time be able to acquire this knowledge, he must have a good deal of fundamental knowledge of the subject of electricity.

Don't be Discouraged by Failure.

He must not, in the early days of his venture, be easily downcast by failures of a technical nature; whatever he may say to his customer he must be prepared to admit to himself that he was in the wrong, or carried out a job in the wrong way, if this was the case. By so doing, his sad experiences — and let me assure my readers, these sad experiences do occur— will be of enormous value to him. In fact, I think I might safely suggest that he will not be able to do a particular job right until he has explored practically every way of doing that job wrong. Again, I must qualify this statement; for, after he has satisfied himself as to the correct way of doing a particular job, he must then open his mind for the reception of new ideas which will improve on the right way of doing it. In short, he will find that first he must do the job wrong, then he must do the job right, and finally he must do the job better.

The First Problem.

We must assume that the would-be electrical contractor has at least some money with which he intends to start his business. The first real problem with which he is faced is the decision as to whether he shall buy a going concern or whether he shall start an entirely new business. Let me take the former case first.

Taking Over an Existing Business.

The existing business will have a certain amount of goodwill waiting there ready for him to pick up; that is to say, there will be a certain number of customers on the books. But it must be remembered that if the goodwill is great, then he will have to pay "through the nose"; and if he has only a little money, and can only contemplate the purchase of a business within his means, then that goodwill is not likely to be very large. He will also find some organisation and some machinery, in the abstract sense, waiting for him. But here, again, if he be a man of ideas, he will probably find himself remodelling that organisation and that machinery. He may find a staff waiting to be taken on by the new proprietor, but unless that staff satisfies him he will not retain it.

Profits may not Vary Much.

The amount of money he will have to pay for the business will be directly proportional to the amount of profit that business was making in the two or three years previous to the sale, and unless the new proprietor does something silly or something brilliant, the chances are that the profits of that business will remain much the same. This means that in buying a going concern, the new proprietor is making an investment which has a certain element of security, and therefore rather less ultimate possibilities. It would be absurd to suggest that in buying a going concern the new proprietor is debarred from turning it into a highly profitable business; but in relation to the alternative of starting a new venture, I think it is fair to say that the going concern represents rather more security and rather less speculation.

Starting a New Business.

In starting a new business, however, the speculative or gambling element is self-evident. The difficulties are greater, but so are the possibilities. I suppose that the majority of young electrical contractors starting in business for the first time adopt this method largely owing to the thrill, which must exist in most human beings, at the prospect of a little "flutter."

The Question of Partnership.

Another problem which arises in the early stages, or before the early stages, is that of partnership. Ignoring for the moment the question as to whether the business is a limited liability company or a firm—for two directors of a limited company are very similar to the partners in a firm—the young contractor has to consider whether he wishes to carry on the business entirely on his own and take all the profits which may accrue, or whether he wishes to share the responsibility and the profits. It is a decision which must be reached, and no one is really competent to advise on such a matter.

A Word of Warning.

Nevertheless, I should like to offer the advice that there is a great deal of difference in the relationship of partners and the relationship of friends. Two friends can make good partners; two partners can remain good friends. But because a man has a very great friend, it does not follow that those two will work satisfactorily in double harness at the same business. There is, I know, a very great tendency to feel that "George and I are such good friends, we are sure to get on magnificently together if we go into partnership." Now a young contractor has met George on the football field; at dances; they go to one another's houses; they discuss the Budget together; in fact, they think that they have something in common in every sphere of activity. Unfortunately, they have not tried sitting opposite to one another in an office and discussing the daily problems which arise in any business; when they do so they may find that they still see eye to eye, but it is probable that they will find a partnership disastrous to friendship and business alike.

Importance of Choosing the Right Partner.

No, the partner must be chosen not because he is a good centre-forward or a good conversationalist round the fire; he must be chosen with an enormous amount of care; preferably so that he does not overlap the contractor in either technical or business knowledge. An ideal partnership, for instance, is that in which one of the partners is the business man, and the other is the technical man. Alternatively, one may be a wiring expert, and the other may be good at power work. Where their qualifications and, therefore, their duties are independent, each problem which arises will automatically fall into the province of one or the other; since no two people can have similar opinions on every subject hour after hour, day after day, week after week, month after month, and year after year, it is very unlikely that two people with precisely similar qualifications will either get on well socially or make a technical or commercial success of their business. If partnership is desirable then perhaps the best method is for the contractor to start in business by himself and not take in his partner until he has run the business by himself for a short while. He will then understand rather more readily what I am driving at here.

STARTING IN BUSINESS.

I have already discussed the relative merits of buying a going concern and starting a new venture. Those problems which arise in the early days of business apply chiefly to the latter procedure, though they do, in lesser degree, arise with the new proprietorship of an established business. What follows, therefore, refers more particularly to the activities of a person who has just taken

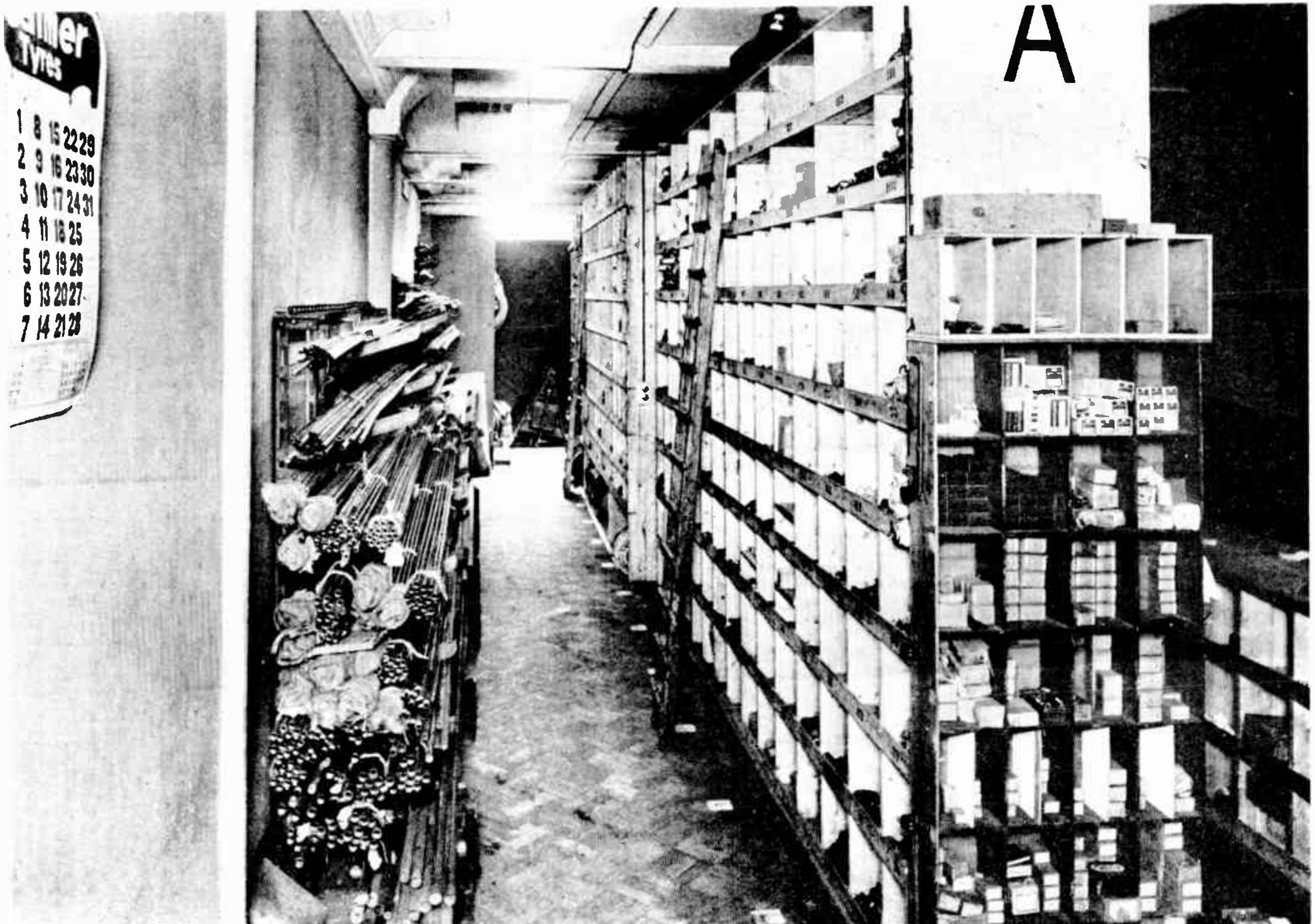


Fig. 2.—A GOOD EXAMPLE OF A STORE ROOM AT A FIRM OF ELECTRICAL ENGINEERS AND CONTRACTORS.
The position and construction of the store room determines to a great extent the degree to which the stock remains in good condition and saleable. (*Photo by courtesy of Messrs. Troughton and Young, Ltd.*).

his place at an empty desk behind a newly painted shop or office door and who is strange to the business.

Advantages of a Showroom.

The showroom, if there be one, will simplify the problem of these early days; for customers will start to drop in automatically, if only to find out what the new shop ("Second turning to the right and opposite the pillar-box, my dear") is like, and will buy his or her lamp. There is no need to emphasize the necessity for promptitude and courtesy with these early customers; for any man starting in business naturally exerts himself to give satisfaction.

Don't Cut Your Prices.

But there is need of a word of warning against that bane of business which is always cropping up—the tendency to cut prices in order to "get in." This is fatal. It will not materially affect the turnover, and it will materially affect the profits; in some cases it will even put the customer off. He will think that there is a catch; that the merchandise is not good; that the method of trading is not quite so straightforward as that of other electrical retailers. I know only too well that paralysing fear which grips the man new to the business, that he will miss the sale unless he wraps it up with some attractive discount; but he must withstand that temptation. It is very unlikely that the offer of a discount will affect the sale; and if it does, why then he is better without that sale.

Why You Should Give Credit for Small Purchases.

On the other hand, I have found that another form of philanthropy does pay; and that is, to be very free with credit for small purchases. If a customer buys a lamp for 1s. 9d. he may pay for it over the counter and leave the shop without any well-formed impression of the name and address of that shop. If, on the other hand, the contractor offers to "put it down" he immediately achieves several very desirable results. In the first place, the spirit of confidence is likely to be returned to his advantage. In the second place, he gets a record of the customer's name and address, a record which may be very useful to him in any circularising or personal canvass he may subsequently wish to undertake. In the third place—and I am inclined to think that this is the most important of the three—he gets an advertisement into that customer's house; for it is undoubtedly a fact that any letter-heading, invoice-heading, or statement of account has a definite advertising value and is, in some cases, as good as a circular. For whereas the latter is usually thrown into a wastepaper basket, the former is more apt to be put into the householder's pocket and taken thence at intervals and looked at with the exclamation—"I really must pay that bill."

A Business Which Has No Showroom.

Now all that I have just said in relation to trading with a showroom applies with equal effect to the case of an electrical contractor's business which has no showroom; but, instead of the casual purchase of a lamp, we must substitute, perhaps, the changing of a fuse at a customer's house. What does not apply, however, is the automatic initiation of business relations with potential customers in the district; for, while the showroom cannot fail to attract a certain number of casual customers, a man who has started in business as an electrical contractor without a showroom may continue to exist for many months before anyone will know of his premises or his telephone number, unless he has taken steps to make these things known to the local residents. How is he to do this?

How Can You Make Yourself Known?

A young electrical contractor can make himself known by one or several of the means at his disposal. (1) He may circularise the district; (2) he may carry out a house-to-house canvass of the district; (3) he may advertise in the local press; or (4) he may place a large signboard outside his premises and sit behind his desk waiting for customers. The last-named procedure condemns itself, except insofar as the signboard is concerned; though even here it is very doubtful whether a business trading without show-

This article on How to Start an Electrical Business is continued in Part 38. Ready July 1st. Order your copy to-day.

Printed in Great Britain for the Proprietors, GEORGE NEWNES, LTD., 8-11, Southampton Street, Strand, W.C. 2. by WILLIAMS, LEA & CO., LTD., Clifton House, Worship Street, E.C. 2. Sole Agents Australasia: GORDON & GOTCH (Australasia), LTD. South Africa: CENTRAL NEWS AGENCY, LTD.