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“Electricity in Factories.”

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OMITTING any comparison of the merits of electricity with those of other forms of power, it is proposed in this Paper to assume that the proprietor of a factory, engine-works or shipyard has decided upon the use of the former, and upon this to proceed to the technical considerations underlying the design and general lay-out of an electrical installation, without dealing with the question of cost. There is, however, one point in connection with the financial aspect which merits consideration. Frequently the cost per unit of power supplied to a motor and the cost of fuel for, say, a gas-engine, are taken as furnishing a proper basis of comparison between the two methods of driving. This is not fair to the electric machine, for although in many cases the cost per horse-power of fuel necessary for the gas-engine is lower than that of electricity supplied to the motor, the real criterion is the total running cost, and it will be found that the first cost generally, and the charges for maintenance, depreciation and attendance invariably, are less for the motor than for the gas-engine. The ease and flexibility of electric driving, with its resultant general economy, are producing a constantly increasing preference for electricity.

Source of Supply : External and Internal.—Having decided to adopt electricity, the first question that arises is whether the power required shall be produced on the premises or bought in bulk. There is a temptation to purchase the electric power, as it puts the factory manager to far less trouble, and power companies are theoretically able to provide power at the cheapest rate possible. The purchase of electricity by the factory or shipyard has the advantage of practically eliminating stand-by charges such as the

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banking of fires to provide steam at short notice to cope with the peaks of a fluctuating load. Moreover, sufficient machinery must be put down in the factory generating-station to deal with the maximum demand of the works, together with spare sets to fall back upon in case of breakdown. On the other hand, a private generating plant is probably more reliable than an outside supply, which may be subjected to influences endangering the supply to the factory; so that it is usual to provide one or more spare sets to run the more important part of the works in the event of a failure of the main supply. The cheapest external power will be in general obtained from a large company, and as it will be probably supplied at high pressure, there is greater possibility of breakdown outside the works. Moreover, transformers, and in many cases rotating machinery, partly on the high-pressure circuit, will have to be employed, and this will not improve the safety-factor of the works station. Spare sets of these transforming devices are as necessary for reliable supply as are the stand-by dynamos of a private generating-plant. A low-pressure system would certainly be adopted for an internal supply, unless the supply area is very large. If the conditions under which external power is supplied are unsuited to the requirements of the factory, elaborate converting arrangements are rendered necessary, thus increasing the first cost both of the machinery and the switch-gear, and adding complications to the plant. For example, a power company's supply of alternating current may have a frequency of 25 cycles, which is suitable for power, but, as is generally conceded, too low for lighting, and therefore an apparatus must be provided for converting either the alternating current to direct current or for changing the frequency to at least 50 cycles per second. A private central station of moderate size can often generate power more cheaply than it can be purchased, for frequently in works the load factor is very good, and many plants work night and day at practically full power. Such conditions give excellent economy, and it is then best, unless exceptional cheapness of the external supply, and possibly other conditions, determine the contrary, for a works requiring 200 HP. and over, to generate its own electricity. The cost of power from an external source is rarely less than 1*d.* per unit, whereas, for example, the total works cost per unit generated in the power plants of two Sheffield works, of 640 kilowatts and 1,325 kilowatts capacity, is 0.72*d.* and 0.68*d.* respectively, and even lower figures are obtained.

Occasionally, leads are brought from an external source as a standby into a works generating its own electricity; but if the two systems be different, complications occur and special machinery is required.

Energy thus obtained will not be bought cheaply, but anything is preferable to a complete stoppage of the works.

Choice of a System.—The factory manager generally finds that he has to decide between the rival merits of a direct-current three-wire system and of three-phase alternating current. He wishes the first cost and maintenance charges to be low, but the system adopted must be as reliable and efficient as possible. It is to be feared that the adoption of electric driving in factories has been frequently retarded by the inability of the manager to decide between the claims of competing systems.

In the case of a large establishment or an amalgamation of several factories or shipyards situated some little distance apart, it is best to instal one central station, as nearly as possible at the electrical centre of the system, in which three-phase alternating current would be generated at moderately high pressure, say 3,000 to 4,000 volts, and transmitted by overhead mains to sub-stations arranged at convenient points where the pressure could be stepped down by means of static transformers. In considering whether an ordinary factory should be equipped on the three-phase system or with a direct-current three-wire installation it may be remarked that the cost of copper in the mains is, theoretically, nearly the same for a three-phase star-connected installation, and for a three-wire continuous-current system, but if the three-phase system be mesh-connected the direct current has a decided advantage in this respect. Alternating-current motors are very good for constant-speed work on constant load, as in the case of textile mills, because their speed is determined by that of the main generator. Continuous-current motors may be arranged for constant speed with varying load, but it has been found impossible, so far, to compensate for the variation of speed due to heating. Alternating motors of the type best suited for a factory do not need a commutator, a very vulnerable part of the direct-current machine; while the mechanical design of the squirrel-cage rotor of the induction motor, ensuring freedom from breakdown, gives another advantage to the alternating system. The continuous-current system gives nevertheless much better results and closer regulation with a varying load (an important consideration in view of the lighting portion of the installation) because the electromotive force of an alternating-current system is more variable, although the effect of induction motors in producing a lagging current may be considerably neutralized by the use of over-excited synchronous motors. For good efficiency with induction motors, the air-gap must be very small, and therefore there is but little margin for wear in bearings. Moreover, the frequency for lighting should be at least 50 cycles, whereas that most suitable for

motors is 25 cycles per second or lower. The choice of speeds for alternating-current motors is somewhat restricted, and for variable speeds they compare unfavourably with direct-current machinery. Synchronous motors will not start on load and require separate excitation. Direct-current machines may be readily started and their speed is easily regulated within very wide limits, a facility enhanced by the introduction of the inter-pole design, and the use of a three-wire system which provides two pressures. All motors above 4 brake-HP., installed on the latter system, are placed across the outers, so that the switching on of a machine has no perceptible effect on the lamps. The electromotive force of an alternating-current system may be stepped up or down very easily and efficiently by means of static transformers, but this is seldom necessary in works of ordinary size. For the average factory, where a large number of variable speed motors are required, and in which generally the same system is used for lighting, three-wire direct current with 440 volts across the outers is the best; although it will be evident from the foregoing that the choice of a system is really dependent on the circumstances of the particular case.

Electrical Generating Plant and Auxiliaries.—Although dynamos are now more or less standardized, it is best to have duplicate machines, so that their several parts are interchangeable; it is also well, as an additional safeguard against undue loss of time at a breakdown, to keep in stock a spare armature, in the case of a direct-current machine, or spare armature coils for an alternating-current dynamo, together with one or two field coils and a few spare brushes. A complete standby generating set is also generally installed, for although it adds considerably to the capital cost, it is useful as the works extend, and by supplying the factory in the event of a bad mishap, will probably prove ultimately economical. A careful specification of the machines to be supplied should be drawn up, the conditions of which should be strictly complied with. Nothing should be sacrificed to cheapness, since breakdowns are very costly, and the dynamos must be liberally rated, viz., a 70° F. temperature rise after 6 hours' run at full load, which means, in the case of British machines, that an overload of 25 per cent. for 1 hour, or 50 per cent. for short periods of a few minutes, may be obtained without injury to the plant.

Direct-current machines should be fitted with commutating poles, which will ensure sparkless running even with the heaviest overload. Continuous-current three-wire dynamos may be obtained arranged on the Dobrowolski system with a balancing coil or coils, but their superiority over the ordinary type of machine with a separate

balancing set is doubtful, although, owing to additional lip-rings and brushes, their efficiency is higher. These special three-wire dynamos can be paralleled to each other and with two-wire machines if the voltage is right, provided that suitable equalizing connections are made. Gas-driven dynamos should have special means provided to prevent unevenness of turning moment, which causes the lights to flicker and renders the machines difficult to parallel to each other. Large fly-wheels are of use in this respect. Special attention should be given to the means of synchronizing alternators coupled to gas-engines, and the mechanical synchronizers now coming into use will prove of value in this connection.

Alternating-current generators should be of the rotary-field type with stationary armatures, because the coils at the higher potential do not revolve, and being more mechanical are less liable to failure. Care should be taken to dry the machines thoroughly before starting, either by means of fires, or electrically by passing a current at low-pressure through the windings, because dynamos, etc., are liable to absorb moisture in transit. There is a difference of opinion on the question of electrically driving station-auxiliaries such as circulating- and air-pumps, mechanical stokers, etc., many considering that steam is more reliable. If, however, the motors are properly rated and cared for, electricity is quite as reliable as steam. It is, moreover, far more economical, as has been proved at the Salford Electricity Supply Works, because considerable losses by condensation occur in the long lengths of steam-piping; and, further, the electrical power taken by the auxiliaries may be measured at the terminals of the motor with the greatest ease, while it is impossible to gauge accurately that absorbed by steam auxiliaries.

In the case of an external supply, the power, on reaching the factory's premises, is transformed to the system already decided upon by means of devices such as those described in the following section.

Regulation: Transformers, Converters, Motor-Generators, Balancers, Boosters, and Batteries. (a) *Three-Phase System.*—The regulation of the electromotive force of alternators is important if a portion of the current is required for lighting, and various more or less satisfactory methods of compounding, to allow for the armature reaction and the drop in the line, have been devised by Mr. Heyland and others. By means of the Tirrill regulator a shunt circuit is rapidly opened and closed across the exciter field rheostat by the action of a differentially-wound relay, and the device may be set so as to provide for the inductive drop in the line. Pressure can be readily and efficiently

changed by means of oil, water, or air-cooled static transformers; and a boosting transformer, the secondary winding of which is in series with the line, may be used to compensate for line drop, although in the average factory the short distances make this unnecessary. It is doubtful whether it is better to use three-phase transformers or combinations of three single-phase transformers. The single-phase transformers are lighter, and two or, at most, three sizes may be standardized for use in groups throughout the works, but with a star-connected three-phase transformer the pressure is beneficially steadied by the action of the single magnetic circuit. The special transformers for electric welding have low-voltage high-current secondaries and present no difficulties, but all the joints on the secondary circuit should be exceptionally well made to avoid loss. Many fly-wheel storage systems have been patented recently for dealing with intermittent load on heavy duty. The fly-wheel levels up the load on the dynamos because the energy given to it by increased speed at light load is returned to the system when the peak occurs, the speed falling at the same time.

(b) *Direct-Current Three-Wire System.*—Unless special three-wire dynamos are employed, a balancing set or sets become necessary in order to keep the pressure constant notwithstanding the variation of load on the two sides of the system. The hand-regulated type of balancer is good, but needs constant attention to obtain close regulation; there is therefore an advantage in using cross-connected shunt or compound balancers, or possibly a combination of the two, which automatically regulate the pressure within close limits. It should be noted that balancers with cross-connected shunts are not satisfactory if used at a place where the line drop is appreciable; and if so used, they should be installed at the feeding point, for the potential on the loaded side must be raised to allow for the drop in the feeders, when the pressure on the motor side falls, thus reversing the condition aimed at in the cross-connection of the shunts.

The direct-current dynamo may be easily compounded level for the drop within itself, or may be over-compounded to compensate for fall of pressure in the lines. A compounding effect may be produced with a plain shunt machine with commutating poles by running with a lead given to the brushes. The Tirrill regulator is also of use in keeping the pressure level, and works on practically the same principle as when applied to alternators, with the advantage that the exciting voltage is the same as that to be regulated. Direct-current feeder-boosters need not be considered here as three-phase medium high-tension current would be used for large schemes

involving appreciable length of mains. It is probable, however, that a hand-regulated, or automatically reversible booster, working in conjunction with a battery, would give satisfaction. Shunt boosters regulated by hand are good, but one of the many automatic types available, whether simple or complicated, is generally preferred. Special mention should be made of (i) the combination of shunt booster and Tilney regulator, the latter being an automatic switch actuated by differentially-wound coils controlling the strength of the booster field in accordance with the load on the line, and (ii) the control of the excitation of a shunt booster by means of a carbon regulator connected with the load current, the resistance of which varies considerably with temperature, and so acts on the fields of a small exciter which supplies current for the shunt of the main booster on the Entz system.

A battery generally enhances the economy of the system, as it improves the load factor by providing work during the day and by frequently enabling a partial or total stoppage to be effected at night, thus preventing the running of plant at an inefficiently light load. Moreover it assists in keeping the pressure constant, by helping the generators on load peaks. A battery is troublesome to maintain, however, and for economical working needs far more attention than is commonly bestowed upon it. Some fly-wheel storage system will probably replace battery storage in cases where the changes of load are considerable and rapid. A shunt booster can be used connected across the line wires with a fly-wheel on its shaft; it runs as a motor at light load, increasing the speed of the fly-wheel, and as a dynamo at heavy load, the falling speed of the fly-wheel then giving out energy to the line: the necessary field regulation is obtained by means of an automatic-regulator actuated by the changes in the line current. Continuous-current motor-dynamos to reduce the pressure for electro-plating and welding are very simple and need no explanation.

(c) *Conversion of Three-phase to Direct Current.*—This may be readily accomplished by means of rotary converters, motor-generators or Peebles-La Cour motor-converters. In the last case the synchronous motor works half as a motor and half as a transformer, while the converter works half as a direct-current dynamo and half as a rotary converter, resulting in a lighter set than an equivalent motor-generator, although in the latter the continuous-current dynamo is quite independent, and may be compounded or otherwise regulated with ease. Conversion by means of the rotary converter is cheaper and more efficient than the other two methods, but the machine is not at its best with a frequency of 50 cycles. The

mercury-vapour converter is interesting, and not only is it very efficient, but it has no moving parts. It has not yet been widely adopted in practice, owing to the fact that a very considerable potential difference must be applied across its terminals at starting.

Distribution: Mains and Switch-gear, Meters, etc.—The generating-station wiring should be carefully carried out, and whilst all cables must be adequately protected, they should be readily accessible for inspection and overhaul. The dynamo-leads to the switchboard are generally run in concrete ducts, in trenches, or on shelves in fire-proof passages. The lighting circuit, i.e., the local circuit of the station, is best visibly supported on insulators, so that a fault is at once evident. The use of bare overhead mains is likely to be more widely adopted in this country now that the Board of Trade has intimated its willingness to consider each case on its merits, and the use of aluminium in place of copper in this connection is worth consideration, although its advantages are doubtful. With three-phase lines care should be taken to prevent the inductance of the mains affecting telephone circuits. With bare mains above ground great care must be taken to protect the apparatus from lightning. The best systems of underground lines are probably the "draw-in," or alternatively the copper strip system. The first comprises conductors with insulated sheathings drawn into ducts consisting of either bituminous or earthenware conduits or cast-iron pipes, while the second is formed of bare copper conductors laid on insulators in culverts. Cheaper methods, however, may be adopted with safety in ordinary works, as there is little danger from the labourer's pick, and the location of the mains is simply defined. The armoured-cable system, in which conductors with insulated sheathing protected by steel armouring are laid direct in the ground with a stout plank a little way above them, is also suitable. The "solid" design may be also recommended; in this case conductors sheathed with insulating material are laid in troughs of wood, earthenware, or cast iron, which are then filled in with a bitumen compound or pitch.

In an alternating system, care must be taken to diminish inductive effects as far as possible when using metallic armourings or laying cables in iron pipes. Three-core cables should be used, not triple concentric cables, and the algebraic sum of the currents must be zero, as otherwise the inductive effects of the three cores will be unequal and there will be a loss in efficiency. Moreover, in special cases, where direct-current and alternating mains may have to be laid in the same works, great care must be exercised to avoid the mutual

effects of self-induction. With concentric systems of wiring great stress should be laid on sound cable insulation, as otherwise destructive short circuits may occur. Armoured conductors should be adopted for use with portable tools; but it is somewhat difficult to combine proper flexibility with sufficiently strong and reliable armouring. Both metallic conduit and wood sheathing are in use for shop-wiring, but accessibility and visibility are of great importance, and the Author thinks that for the ordinary factory insulated wires supported on insulators are excellent. Great care must be taken when leading cables in and out of junction-boxes to avoid any possibility of surface leakage. As far as practicable, all metallic sheathings, conduits, and boxes should be efficiently connected with earth; and a coil of iron cable buried in permanently wet coke makes a very good earth connection.

The switchgear should be of simple design. The main switchboard is best arranged on the cellular independent panel principle without backs save in the case of high-pressure circuits, where the high-tension gear should be isolated in separate fireproof compartments and controlled from a distance by means of a low-tension current. The high-tension switches, which would be used only in connection with three-phase circuits, should be operated by motors and should break under oil. It is worthy of note that trouble has been experienced with direct-current oil switches, owing to the carbonization of the oil. Dynamo regulators should be made as mechanical as possible; the shunt regulators should consist of bare wire in open spirals, or wound on pots or on micanite or asbestos tubes so as to be as fireproof as practicable; and the series diverters should be of cast-iron grids or of special resistance strip. Main switches of the knife type with carbon breaks, and magnetically operated circuit-breakers, in place of fuses, should be employed for important circuits. Automatic mechanical synchronisers are supplanting the lamp and transformer method, and certainly call for less skill on the part of the attendant. Where bare overhead mains are run, lightning arresters should be provided, of either the Würtz, carbon or horn types. In the two first types the arc is extinguished by breaking across a number of special contacts and the last spreads out the flare to a length at which it cannot be maintained, an action frequently assisted by the use of a magnetic blow-out arrangement. The use of fuses should be confined to minor circuits and motor panels. Many ingenious designs are available such as the Partridge sparklet method, where escaping carbon dioxide extinguishes the arc, while in others, sand or other refractory material is employed for the same purpose. Direct-current motor starters and regulators

should be of mechanical design, the former being fitted with overload and no-volt releases and resistances of the same type as those indicated for the main dynamo regulators. Liquid starters have acquired some popularity in connection with crane motors, but if employed, they should be watched, because towards the end of a shift, after continuous use, the resistance may have dropped so much, owing to increase of temperature and evaporation, that a dangerously high current may be passed through the motor armature when switching on. Magnetically operated automatic controllers are now often used for large direct-current motors; they work through successive identical cycles of operations and are very successful. Automatic-transformers and rheostats for starting alternating-current motors are very simple and need not be described here.

Edge-wise illuminated meters are very easy to read, and the Kelvin sector voltmeter and ammeter is an excellent example of a good cheap meter. It is practically unaffected by external fields, is simple and durable, can be repaired by the ordinary switchboard attendant, and owing to its knife-edge bearing, is remarkably free from friction losses. Moreover its scale is divided into almost equal divisions. The Kelvin electrostatic meters are especially good, owing to their complete immunity from the effects of stray magnetisms.

Lighting and Lamps.—For station-lighting arc lamps would in general be used, assisted by ordinary glow-lamps, or more probably by tantalum lamps, if procurable. Mercury-vapour lamps are convenient for reading meters, especially those placed at some distance above the ground. In lighting yards, dry-docks, etc., flame arcs are suitable, and for closer work protected glow-lamps of the carbon or tantalum types connected to armoured flexible cables will be found serviceable. For lighting drawing offices, or other rooms, mercury-vapour lamps or inverted arcs with ceiling reflection give very good results; while the Nernst type gives a soft light, but has too short a life to render its wide adoption probable. The colour of the light is of considerable importance in some cases, as for instance, when used in textile mills. In shop-work arcs would be used assisted by smaller lamps, and it must be borne in mind that in certain situations enclosed arcs are essential. The slope of the roof and the nature of the ceiling have a great effect on inverted arcs, and frequent cleaning is necessary in dusty shops. Arc lamps used with an alternating current are less efficient than with a direct current, since about 50 per cent. of the light is thrown straight upwards. This objection may be overcome to some extent by employing the ceiling as a reflector. A frequency of 50 cycles per second should be adopted

for alternating-current lighting, an objectionable flicker being perceptible with 25 cycles. The Bastian mercury-vapour lamp, which can be obtained for circuits up to 250 volts, uses only about one-tenth of the energy consumed by the ordinary carbon lamp. The tantalum lamp has an efficiency of 1.7 watts per candle-power; the osmium lamp is said to consume about 56 per cent.; and the osram lamp 70 per cent. less energy than the carbon lamp.

Selection of Motors and Motor-Control.—In order to obtain a high standard of reliability, motors should be rated on the same scale as that already given for the main dynamos, viz., 70° F. rise after 6 hours' run at full load, with an overload capacity of 25 per cent. for 1 hour and 50 per cent. momentarily. Liberal ratings should not, however, be carried too far. The Author is aware of cases where motors were bought on a 6-hour rating which would have been just as reliable if rated for 1 hour only, owing to the peculiar conditions of their work. "Load-factor," a loose expression, which has nothing to do with the term widely employed in central-station work, has been recently much used in relation to crane-motors. For example, a "load-factor" of 3 means that the machine is running on load for one-third the total time of working. Crane ratings are frequently too liberal: 90° F. rise for 1 hour's run, or for half an hour's run. Frequently 15 minutes would be ample, if the motor is not running during a large portion of the total time with extremely short intervals between each run. Whether a motor is to be enclosed and ventilated, merely protected or totally enclosed, should be decided by carefully considering the working conditions. A temperature rise of 90° F. after 6 hours' run on full load is permissible with a totally enclosed motor. Direct-current shunt machines are good for fairly constant speed work at variable load, although a closer regulation may be obtained by differentially winding with series turns; with a plain shunt machine having auxiliary poles this regulation may be secured by giving a lead to the brushes. Compound motors may be used with advantage where heavy starting torque is required, the series turns sometimes being cut out after starting and the machine continuing to run as a plain shunt. Series-wound motors are excellent for very heavy initial torque and automatically reach high speeds at light loads. Variable speed with direct-current motors on a three-wire system is easy of attainment, as not only are there two pressures available, but modern shunt motors with interpoles may have from 4 or 5 to 1 speed variation on the shunt alone, with good efficiency, so that there is little occasion to employ machines with two commutators to be put in series or in parallel with one another. Series-resistance control

may sometimes be used with advantage where speed reduction is required for very short periods only.

Synchronous alternating-current motors possess the advantage of practically constant speed at all loads and somewhat better efficiency than the asynchronous type. Moreover, they are slightly cheaper than induction motors, and may be used to improve the power-factor of the circuit. They will not start against load, and consequently must be run on a loose pulley in the case of small machines, or if of considerable size, they must be started by an independent motor, necessitating also a special synchronizing device: they need, too, a separate source of excitation. Induction motors have a mechanical construction, and may be started more readily than synchronous machines, but they render the power-factor of the system poor. Efficient speed variation is a very difficult problem with alternating-current machinery, and can only be obtained by pole-changing devices resulting in a few definite speeds, or by means of wasteful resistances inserted in the rotor circuit.

Miscellaneous Applications of Electricity.—The uses to which electricity may be put in factories or shipyards are many and various, and amongst these not the least important is their use for crane work. For this duty, direct-current series motors are desirable, owing to their large initial torque and their capability of automatically attaining high speed with light loads. This last advantage may be carried too far with very light loads, and sometimes a small shunt winding is put on to prevent actual racing. With large cranes, it is best to use a separate motor for each motion. Light goods-hoists are frequently worked by compound motors, i.e., really shunt machines with a few series turns to assist at starting. Motors are becoming more popular for the driving of large rolls, and 1,500-HP. motors have been installed for this purpose with success. They should be heavily compounded to help in starting, and are equipped with heavy fly-wheels to assist at times of maximum demand. Some machines have been connected directly with the rolls, but a rope-drive is frequently preferred, as it lends flexibility to the arrangement. Small machine-tools are most economically driven in groups, a motor driving the corresponding length of shafting, but for large machines, such as boring-mills, large lathes, etc., a separate motor should be used. With the high-speed tool-steels now in favour speed regulation is a matter of considerable importance, and attention is drawn to machines supplied with a motor and regulating switch as an integral part. Motors should be compounded when used with punches, shears or similar tools. Holden magnetic clutches are

neat, convenient and durable; their working depends on the attraction of two steel faces for one another, owing to the magnetic effect exercised by a coil embedded in one of them and excited from a low-tension circuit. They are readily controlled by means of a small switch. Many portable tools on this principle are of great interest. Drills, for instance, are sometimes arranged with massive iron feet containing embedded coils energized from the same circuit as the motor, and serving to hold them on the iron surface to be drilled. They are especially useful in shipyards and on structural works. The small hand-drills used in fitting shops should not be too closely rated, as they may be severely tried at the hands of an indifferent workman. Lifting magnets are very useful in steel-works or foundries, where they displace slings and chains. The magnet is suspended from the crane-hook, and is excited by a low-tension current. Special attention should be given to the insulation, etc., as a failure of the excitation generally causes a bad accident. Magnetic swarf-separators generally pay well for their installation and are extremely simple; more may be saved by proper attention to the turnings, chippings and filings of the more expensive metals than is imagined by those who neglect it. The cutting of steel piles by the electric arc is an interesting recent application of electricity. One wire of the circuit terminates in a carbon electrode and the other is connected directly with the steel to be cut; the arc is started by pushing the carbon towards the steel and care is taken that it is not broken again. The operators have to be carefully shielded by means of asbestos gloves and masks. This method has been proved in New York to effect a distinct saving both in time and in cost of cutting as compared with the ordinary practice. Pumping affords a great field for the employment of electricity, and alternating-current motors may be profitably used when the load and speed are approximately constant. If speed regulation is required, as in some classes of pumps for condensing machinery, direct-current interpole shunt motors with field rheostat regulation are suitable. For three-throw pumps driven through heavy gearing the motor should be compounded to assist when starting. Electric radiators for heating purposes are especially useful for large offices, as they need very little attention. Electric furnaces are largely used for many purposes, and are even employed in steel-making, although not as yet to any great extent. Electro-plating is now a familiar process: it is important to arrange the dynamo, switch-gear and vats as near together as possible, and all joints must be soundly made, as instances have occurred in which as much as 50 per cent. of the power developed

by the dynamo was lost between the machine and the vats owing to faulty design. Blue printing by arc light is a great convenience in drawing offices ; it is both efficient and easy to regulate.

Alternating-current machines, especially induction motors, are best suited for driving textile machinery, because the load is practically constant and the speed should be constant. Due care should be taken to see that the motors are properly protected against fluff, etc. Electric locomotives are suitable for moving materials or finished parts from one section of the works to another, and the ordinary direct-current arrangement of an overhead wire with the rails as the return is serviceable enough. In driving fans, such as cupola blowers, alternating-current motors can be used if much variation of speed is not required ; but should change of speed be necessary in order to regulate the quantity or pressure of the blast, direct-current shunt motors should be employed. Dynamos specially arranged as brakes have been found very useful for testing purposes in motor-car works, etc. The armature is arranged to be coupled to the engine to be tested ; while the field-magnet is supported in as nearly as possible frictionless bearings, and carries an arm which can be loaded to counterbalance the drag of the armature on the field, thus giving a measurement of the torque. Eddy-current brakes, depending for their action on the resistance offered by a magnetic field to the rotation of a metal disk, are also used to some extent.

Conclusion : Maintenance, Logkeeping, Inspection, Break-downs and Repairs.—Too much stress cannot be laid on the necessity for keeping an accurate log in the works power-house in precisely the same manner as would be adopted for an ordinary central-station supply scheme ; and further, a record of the condition and history of all motors and other electrical gear in use throughout the works should be carefully maintained. Thus, the actual cost of driving and lighting will be always readily apparent, weak spots will be brought to light, and opportunities of bettering the installation will be given. Economy should be not merely sustained but progressive. Keen foresight will ensure the prevention of many breakdowns, and if a reasonable stock of spare parts be kept, any ordinary repairs will prove a comparatively slight matter, with a capable staff. Great care must be taken to keep all machinery clean and in good condition, especially the commutators and brushes of direct-current machines, while the presence of oil or swarf on the windings of either alternating-current or continuous-current motors tends to destroy the insulation, and should not be allowed. Blown fuses should not be replaced by fuses of unnecessarily large size, which, although they

may render replacement less frequent, threaten the life of the motor. With small machines a hand-bellows, and with large machines a small compressor and hose, form valuable aids to cleanly working. Machines should not be run at a greater over-load than that for which they were designed, since excessive heating causes deterioration of the insulation, which consequently fails sooner or later.

In conclusion, the Author is of opinion that, all things considered, the direct-current three-wire system is the best to adopt for driving and lighting ordinary works.