Westinghouse Motors and Generators in Industrial Service

Installation, Operation, Care and Repair

Westinghouse Electric & Manufacturing Company

East Pittsburgh Works East Pittsburgh, Pa.

Westinghouse
Motors and Generators
in
Industrial Service

GENERAL INSTRUCTIONS

CAUTION

Keep the motor or generator clean. The finest machines and the most expensive plant may be shut down by accident if they do not have protection and care. The insulation must be kept clean and dry. Oil and dirt in the insulation are as much out of place as grit or sand in a cylinder or bearing. In a direct-connected unit oil may splash from the driving machine, or work along the shaft to the insulation and cause a burn-out unless the attendant provides the necessary protection.

INSTALLATION

All Westinghouse generators and motors of small and medium capacity are shipped completely assembled, ready to set on the foundations. The small machines are boxed and the medium sizes crated. Large sizes, too heavy to handle conveniently as complete machines, are shipped in sections. In the latter case the machines are either assembled at their destination by the Westinghouse Service Department, or complete instructions for assembling accompany them.

Unpacking—When unpacking and handling the machines or parts, they should be carefully guarded from severe shocks or blows. Completely assembled machines, above the very small sizes, are generally provided with eye-bolts; whenever possible these should be used for lifting in preference to slings. Castings at very low temperature are easily broken; it is better to raise their temperature above the freezing point of water before handling them.

Drying Out—All electrical machinery not especially constructed to resist injury by moisture should be kept dry. If a machine has been exposed to moisture, the windings should be thoroughly dried before being put into service. This is true of nearly all machines that have been in storage, especially in unheated warehouses, or machines that have been idle for some time; it is particularly true of new machines that have been long in transit. Small motors can be baked in ovens, and all sizes can be dried by passing a current through the windings large enough to raise the temperature to a point not over 85 degrees Centigrade. The temperature should be raised gradually, several hours being required, depending on the size of the machine, and should be as nearly uniform as possible throughout the windings. It should be maintained constant for a period varying from one day to one week depending on the size and voltage of the machine.

Location—For best results an electrical machine must be set up in a clean, dry, well-ventilated place easily accessible and in plain sight. Ideal conditions are not always possible; nor are all of them absolutely essential to successful operation, but all are desirable. The machines must not be placed under steam or water pipes or otherwise exposed to dripping moisture. They must be kept as free as possible from grease and dirt unless special provision is made in the motor construction to prevent injury from these sources. Cleanliness is very important. Oil, water or dirt has a very deteriorating effect on the insulation. Freedom from acid fumes is essential, and the machine must not be exposed to excessively high surrounding temperature; i. e., where the ultimate temperature of the windings will be over 90 degrees Centigrade. This temperature limit does not apply to specially insulated motors, such as many mill-type motors, which can be operated at a much higher ultimate temperature without injury.

Foundation—The foundation must be solid enough to prevent vibration. Solid masonry or concrete makes the best foundation, but wood framework can be used. Opinions differ as to the wisdom of insulating the motor frame from ground; where this is required, the slide rails or bedplate should be bolted to a timber framework which in turn is bolted to the foundation. The heads of all wood frame holding bolts must in this case be countersunk in the timber and covered with insulating compound. All timber or woodwork used for insulating purposes must be well coated or filled with moisture-repelling wood filler and must be kept clean and dry. Wall or ceiling supports for motors must likewise be rigid. Iron or wood uprights or stringers are generally used.

Erection—The driving and driven shafts must be parallel; pulleys must be in line so that the belt will run true; if geared, the driving pinion and the gear must mesh properly; a pinion should always be placed as near the bearing as possible, to reduce vibration. Outboard bearings are recommended for geared applications of motors above 25 horsepower except on mill-type or crane motors, where they may usually be dispensed with.

Rawhide pinions are recommended for pitch-line speeds of 1200 feet per minute or more, where the noise of metal pinions is objectionable. With any kind of pinion a pitch-line speed of over 2000 feet per minute should not be used without approval of the Company. If the motor is direct connected, the shaft must be in line with that of the driven machine **with slight variation allowable** with a flexible coupling. Full assurance that the pulleys are properly aligned can be obtained by temporarily installing the belt and turning the pulleys by hand where this is possible. When the alignments are accurate, securely bolt the slide rails, bedplate or the machine itself, as the case may be, to the foundation.

Wall and Ceiling Mounting—Westinghouse motors generally have bearing brackets or housings which can be turned through 90 or 180 degrees respectively, for wall, or ceiling mounting, so that the oil reservoirs will be below the shaft; this arrangement, especially on direct-current motors, should be made at the Works and should be specified when ordering. Motors are shipped arranged for floor mounting unless otherwise specified. In most cases the bedplate or slide rails should be attached to the motor, which should then be hoisted and bolted into place. If head room is limited or hoisting facilities poor, it may be better to fasten the rails or bedplate to the supports before hoisting the motor. For some Westinghouse motors the slide rails for wall and ceiling mounting differ from those for floor mounting, and the proper rails should be obtained in each case.

Vertical Motors—All Westinghouse vertical motors must be mounted so that the inclination of the shaft from vertical is not over 10 degrees. Special care must be exercised in aligning the motor shaft with the driven shaft, as all vertical motors will vibrate badly otherwise. Vertical motors are capable of carrying some extra weight on the shafts, as for instance, a pulley, or the rotating part of a pump. For the amount of this weight write the nearest district office giving size, type and rpm of the motor.

The lubrication system in recent types of vertical motors is entirely automatic. There is no oil connection between the upper and lower bearings; the system for each is similar, except that the lower has no thrust bearing. Centrifugal force forces the oil from a reservoir up along the shaft through grooves in the bearing lining; after reaching the top the oil returns to the reservoir through an outer channel. Attention is seldom needed, and the system is economical of lubricant and oil does not leak.

Bearings—Do not use an inferior quality of oil or grease; it will endanger the safety of the bearings and prove far more expensive than good lubricant. Good lubricant, even at slightly higher first cost, but resulting in reliable motor service, is much more profitable than a cheap, poor quality and overheated and possibly ruined bearings. The best grade of oil to use depends somewhat on the temperature in which the motor operates, the heavier oils being preferable in very warm places.

Bearings of the oil-ring type should be filled slightly below the top of the overflow plugs with a good grade of dynamo oil. If possible turn the shaft by hand and see that the oil rings rotate. Openings are provided in the tops of the bearing housings through which the bearings can be filled and the rings observed. These openings are fitted with lids which should be kept closed under normal operating conditions. Extreme care should be taken to keep all gritty substances, dust, dirt, etc., out of the bearings and oil wells. This caution is especially necessary if the bearings are dismantled for any purpose.

Bearings using oil and waste must be packed with a high-grade wool yarn waste which should fit closely against the shaft; cotton or cheap wool waste soon becomes soggy and settles away from the shaft. The waste must be thoroughly saturated with oil, preferably by immersing it for at least 48 hours and then allowing it to drip on a rack for 10 or 12 hours. Too much free oil in the waste results in overflow and accumulation of oil on the equipment; and there is also the greater possibility of oil getting into the motor.

Bearings using grease should be filled with a good quality of grease which should contain no dirt or gritty substances.

Belting—Pulley faces are proportioned for safe belt stresses with differences between faces and belt widths. With standard pulleys with a face up to 12 inches, the belt width should be at least 1 inch less than the pulley face; for pulleys with a face of more than 12 inches, the belt width should be at least 2 inches less.

The offsetting of pulleys is not recommended because of bearing and shaft stresses; for the same reason an extended shaft longer than standard should not be used except with an outboard bearing.

If possible the lower side of the belt should be the driving side. The distance between pulley centers should be great enough to allow some sag in the upper side of the belt, or an idler pulley should be used to increase the arc of contact. The following general rules from Kent's Mechanical Engineers' Pocket-Book will serve as a guide:

"1. Narrow belts over small pulleys, 15 feet between pulley centers, the loose side of the belt having a sag of 1½ to 2 inches.

2. Medium width belts on larger pulleys, 20 to 25 feet between pulley centers, with a sag of 2½ to 4 inches.

3. Main belts on very large pulleys, 25 to 30 feet between centers, with a sag of 4 to 5 inches."

If the distance is too long the belt will flap unsteadily, resulting in unnecessary wear of both the belt and the bearings; if too short, the severe tension required to prevent slipping will will cause rapid wear of bearings and may cause them to overheat.

The foregoing distances represent good safe practice for long life of belt and bearings. Shorter distances are frequently used but necessitate tighter belts, or the use of wider pulleys and belts, or larger pulleys and higher belt speeds. Very short belts can be made to work satisfactorily by the aid of idler pulleys, which increase the arc of contact.

It is not desirable that the slope of the belt direction be over 45 degrees from horizontal; the belt should never run vertical, if possible to avoid it, since the advantage of sag to increase the arc of contact is then lost.

Belts should be run with the least tension required to prevent slipping or flapping. The slack side should have a gently undulating motion. Lateral movement of the belt on the pulley indicates poor pulley alignment or unequal stretching of the edges of the belt. Belt joints should be as smooth as possible, and a lapped joint should always trail, never lead over the pulley. **Belts should be kept clean and dry;** if any belt dressing is applied let it be very sparingly.

ELECTRICAL CONNECTIONS

A diagram of external connections and full instructions for making them are supplied with each motor and starter. All connections should be made mechanically and electrically secure. The terminal wires must be securely soldered into the connectors supplied with the motors and starters, and the connectors must be firmly bolted or clamped together.

The "National Code" rules require that each motor and its starter be protected by fuses or a circuit-breaker and controlled by a switch on which are plainly indicated the "on" and "off" positions. The switch and cutout (fuses or circuit-breaker) are preferably located near the motor and in plain sight of it. All wiring should be neat and workmanlike and the wires should be run in conduit wherever possible.

All switches should be opened and the starters or controllers in the "off" position when the motor is not running. Circuit-breakers should usually be set to open at a current about 50 per cent greater than the full-load current of the motor, although this setting must be varied to suit special conditions.

OPERATION AND CARE

In general, **keep electric generators and motors clean and dry;** cleanliness and freedom from dripping water, oil, grease, dirt, etc., are very important. Keep all such articles as tools, bolts, oil cans, etc. in their proper places and not lying loosely around the machines or on the frames. Where it is likely that foreign matter will get into the motor, semi-enclosing covers or totally-enclosed motors should be used. (The standard open type motors cannot be enclosed and operated continuously; motors must be specially designed for operating totally enclosed.) Dust-proof attachments can also usually be supplied.

After the machine is mounted and all mechanical and electrical connections are completed, a final careful inspection should be made before starting. When satisfied that all instructions have been fully complied with, start either without load or with light load except on series motors which should always have enough load to hold the speed of the motor down to a safe value.

Special instructions for starting and stopping are supplied with each motor and starter. Unsatisfactory operation, electrically or mechanically, when first starting shows that some error in assembling, mounting or connecting has been made, and the error should be found and corrected at once.

Bearings—When first starting a machine particular attention must be given the bearings to see that they are well supplied with lubricant. In bearings of the oil-ring type, the rings should revolve freely and carry oil to the tops of the journals. It is well to allow a new motor to run for an hour or two with light load, watching the bearings closely for any indications of undue heating. The bearings of all Westinghouse machines are liberal in size, and with proper care will not give trouble. They may, however, be made to overheat by any of the following causes:

1. Excessive belt tension.
2. Insufficient lubrication which may be owing to
   - (a) Poor lubricant.
   - (b) Insufficient quantity.
   - (c) Failure of oil rings to revolve.
   - (d) Poor grade of waste (in motors having oil-and-waste bearings.)
3. Poor aligning or leveling causing excessive end thrust or binding.
4. Rough bearing surface which may be caused by careless handling, or the presence of dirt or gritty substances in the oil or grease.
5. Bent shaft.

A motor or generator bearing is usually safe if it operates at a constant temperature below the boiling point of water, 212 degrees Fahrenheit (100 degrees Centigrade). The rapid rise of temperature toward this limit, however, is a danger signal calling for prompt attention. In the absence of a thermometer, a dangerously hot bearing can be detected partly by the sense of feeling and partly by the smell of burning oil and the appearance of smoke; a bearing may be safe, however, when hot enough to burn the hand held continuously against the outside a few seconds. It will seldom be necessary to do more than to supply the bearing with an abundance of fresh clean lubricant, making certain that the oil or grease reaches the bearing surface, and to remove any excessive belt tension. If this is not effective, pour a heavy lubricant directly on to the journal if possible. Remove some or all of the load if necessary, but keep the rotating part in motion enough to prevent the bearing from becoming set or "frozen".

In normal service the old oil should be withdrawn from oil-ring bearings occasionally and fresh oil substituted, running enough of the fresh oil through the bearings to wash out all sediment. The old oil as well as that used for rinsing can be run through a filter and used again. A good oil filter is a necessity in every plant where much machinery is in use. The frequency with which the bearings must be refilled depends so much on local conditions, such as the severity and continuity of the service, the room temperature the state of cleanliness, etc., that no definite instructions can be given. Oil-and-waste bearings must also be cleaned and filled with fresh waste occasionally, as the old waste gradually becomes glazed. If such a bearing becomes overheated it should usually be repacked at once. The chief care with grease lubrication is to keep the cups well filled with clean grease and to see that bearings are properly fed.

REPAIRS

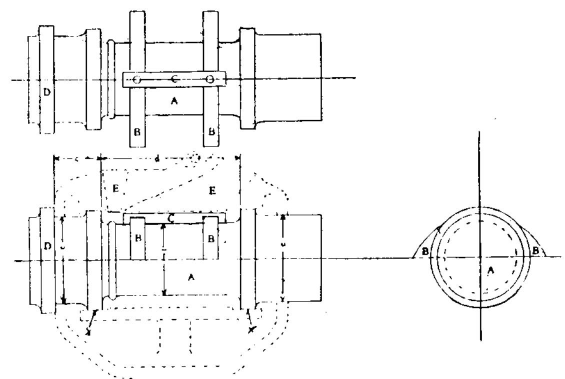
General—For the convenience of its customers, the Westinghouse Company has at some of the larger cities, and well distributed through out the country, shops with the best facilities for making prompt and thorough repairs; the men in these shops are of the same high class as those employed in the manufacturing of the apparatus. An advantage of better work and the saving of time and expense results from having Westinghouse apparatus repaired in Westinghouse shops. Shops are now located at New York, Philadelphia, Pittsburgh, Chicago, Seattle, San Francisco, and Los Angeles. Address communications, however, to the nearest district sales office; see list on page 16.

Request for instruction tags, booklets, repair parts, or communications with regard to Westinghouse apparatus should give **full nameplate readings.** In the case of motors it should give the type letters, horsepower, voltage, etc., and also the serial number which is stamped on the nameplate and on the end of the shaft. When requesting duplicate copies of instruction tags, drawings, etc., give only the number of the tag or other publication.

Save the shipping notices sent when the apparatus is shipped as they give the number of our shop order ("S.O."). This is an excellent means of identification and assists in quickly locating records regarding parts.

Bearings—Solid bearings are furnished with medium and small sized machines. Split bearings with some medium sized and all large ones. Solid bearings, on wearing out, can be repaired, but it is very advisable to have new spare bearings on hand.

Relining Split Bearings—Badly worn split bearings or those accidently injured in service should be relined, using only the best grade of bearing metal, which can be furnished by this Company, a mixture of various heavy metals that happen to be on hand is very undesirable. Unless a considerable number of machines are operated in one plant, necessitating the provision of facilities for renewing bearing linings, such work should be done in a Westinghouse repair shop. It is advisable to keep extra bearings in stock so that a worn bearing can be replaced without shutting down the machinery while the bearing is being repaired.



Mandrel for Rebabbitting Bearings

The following instructions are suggestive of methods of renewing all split bearings of the oil-ring type. An iron mandrel A, Fig. 1, is prepared having the same diameter *f* as the shaft, and dimensions *c*, *d*, and *e* taken from the bearing to be renewed. Iron pieces *BB* and *C* are attached by screws to the mandrel to form the oil-ring slots and the horizontal inspection opening in the top half of the bearing. The pieces *BB* are tapered so that they will withdraw easily from the cast metal. A shoulder *D*, so placed as to fit against the end of the bearing shell, serves as a guide.

Melt the old bearing out of the shell and warm the mandrel. While both are still warm so as not to cool the metal too rapidly when pouring, place the mandrel in the lower half shell with the shoulder *D* tight against the end of the shell and the straight bottom portions of the pieces *BB* resting on the split plane of the bearing. Close the joints *x* with putty and fill the openings between the shell and the housing leading into the oil well with wet waste. Pour the molten metal, heated just enough to flow readily, into the space between the shell and the mandrel until the metal is flush with the split surface of the housing. The metal will harden very quickly and the mandrel can then be removed.

Fill the openings *E* in the upper half shell with putty and lay the mandrel in the shell (split side up), block the openings leading to the oil well with waste, and pour, as before described for the lower half. Remove the mandrel, smooth all rough edges in the bearing by chipping or filing, and chip the oil grooves in the lining of the upper half. The bearing surface of both halves should be eased off by scraping, and the edges along the split surface should be filed flush with the shell.

Removing Shaft—The laminated rotors or armatures of all Westinghouse motors except the small sizes are assembled on spiders, or riveted between end-plates and pressed onto the shafts and keyed. With either construction the shaft can be removed by applying pressure to the spider hub or armature core and the end of the shaft. Great care must be taken that the blocking behind the hub does not slip and injure the windings. A suitable press can be improvised by placing cross-bars behind the hub and across the end of the shaft, connecting them by iron rods through the spider or core parallel to the shaft, and drawing the bars together by nuts on the ends of the rods.

Insulation—To locate poor insulation or "grounds" in motor windings, connect one terminal of a circuit containing one or more incandescent lamps in series to a good ground and the other to different parts of the motor circuits to be tested while these circuits are subjected to full voltage. If the lamps light, a ground exists, and the point at which least light or no light is obtained is nearest the ground. The combined voltages of the lamps in the testing circuit should be equivalent to the voltage of the motor, i.e., for a 220-volt motor use two 110-volt lamps in series, etc.

If the defective insulation is accessible it can be repaired with mica, adhesive tape, or treated cloth, according to the nature of the defect, and a thorough coating of shellac or insulating varnish should then be applied. A defect of a serious nature may demand the renewal of a portion of the windings.

Dismantling and Reassembling—In dismantling a motor, the most careful attention should be paid to all attachments and adjustments, and notes should be made if necessary. In reassembling, each part should be replaced and adjusted exactly as before. The omission or misplacing of any part or the change of an adjustment may cause serious trouble.

If main or commutating poles are removed, particular care must be taken in replacing them that the spacing is correct and the air-gap the same as it originally was.

The windings, commutators, and bearings must be well guarded from injury. Armatures or rotors must be handled with slings and spreaders to keep all pressure away from the commutator, collector rings, or windings; they must be supported on trusses under the ends of the shaft or laid on a perfectly clean floor or a pad to keep all sharp particles from penetrating the windings. Clean burlap wrapped around the journals and well oiled is a safety precaution against injury and rust if the shaft is to remain long out of bearings. In replacing the shaft, the oil rings must be lifted to avoid bruising them.

Direct-Current Motors—Special instructions for the repair of minor troubles in direct-current motors are given on pages 12 and 13.

ALTERNATING-CURRENT MOTORS

Alternating-current induction motors are made for operation on single-phase and polyphase (two-phase and three-phase) current. Single-phase motors are operated on circuits fed by single-phase generators or on the individual phases of polyphase circuits. Most alternating-current lighting circuits are single-phase. In the latter case the total motor capacity should be evenly distributed among the several phases so as to keep the polyphase circuit balanced. Specific instructions for doing this are given with each Westinghouse single-phase motor.

Two-phase motors are operated on two-phase, four-wire circuits or on two-phase, three-wire circuits, both of which can be fed by two-phase generators or by three-phase generators with phase changing transformers. Transformers can, of course, intervene between the generators and the motors in either case. Two-phase, three-wire circuits are seldom used on account of liability to unbalancing. Three-phase motors are operated on circuits fed by three-phase generators, with or without intervening transformers.

Motors wound for two or more different numbers of poles for giving different operating speeds, which are to operate on two-phase, three-wire circuits, or upon two phases which are inter-connected in the generator or transformers, must be arranged especially. If this condition is not taken up with the Works before the motor is built, trouble may result after installation, due to the combination of connections inside the motor and the line not working properly together.

Methods of Starting—Westinghouse single-phase motors are automatically self-starting. A starting rheostat should be used, however, with motors of the commutator type, where it is desirable to keep the starting current low. Polyphase motors are of two general classes according to the rotor windings; viz., those having squirrel-cage rotors, and those having phase-wound rotors with sl'p rings. Squirrel-cage polyphase motors of 5 horsepower and below can be started by switching directly across the line with a knife switch, provided this is acceptable to the local representative of the Board of Fire Underwriters.

Squirrel-cage motors larger than 5 horsepower should have at least one step of reduced voltage for starting. One step is nearly always enough, and it is obtained by auto-starters or auto-starter switches, described in other publications.

The starting voltage applied to a squirrel-cage motor should be high enough for the starting torque but not much in excess. The maximum starting current, taken at the moment the primary circuit is closed, depends only on the voltage and is independent of the torque. If the voltage is greater than is required, the starting current decreases very promptly to a value proportional to the torque and then continues to decrease more slowly as the motor speed accelerates. The standard connections of all Westinghouse auto-starters and auto-starter switches are for starting voltage 65 per cent of full-line voltage, but provision is made for readily changing these connections so as to obtain a starting voltage of either 50 or 85 per cent of full-line voltage.

Slip-ring motors are especially desirable for application where low starting current is desirable. They are, therefore, suitable for driving machinery requiring strong starting effort where close speed regulation under changes in load is imperative. They are started by first closing the primary circuit and then cutting out resistance from the secondary circuit in steps, the process being much the same as in starting direct-current motors. The greater the resistance in the secondary circuit, the greater the slip; hence, the speed of slip-ring motors can be readily controlled by means of variable resistance and gives the same inherent speed regulation as direct-current motors with resistance in the armature circuits; namely, varying speed with varying load. Starters and controllers for slip-ring motors are described in other publications.

Reversing—Instructions for reversing single-phase motors are given with each motor. To reverse the direction of rotation of a two-phase four-wire motor the two leads of either phase are interchanged, and on a two-phase three-wire motor the two outside wires are interchanged. To reverse a three-phase motor interchange any two leads. These changes can be made at the motor terminals, or by a reversing switch.

Voltage and Frequency—For best results induction motors should be operated at their normal voltage and frequency. Some variation from normal voltage and frequency is allowable with all Westinghouse motors, the voltage limits being approximately 10 per cent from normal and the frequency limits somewhat less the exact limits for each is stated in the publications describing each type of motor. The voltage and frequency should never be varied simultaneously in opposite directions, and both should not be varied at the same time to the extreme limits given. With any variation of either the voltage or the frequency from normal conditions the following changes from normal operating characteristics must be expected:

	Power Factor	Torque	Slip	Full Load Eff.
Voltage high	decreased	increased	decreased	Approx. same
Voltage low	increased	decreased	increased	Approx. same
Frequency High	increased	decreased	same	Approx. same
Frequency Low	decreased	increased	same	Approx. same

In general any change from normal frequency should be accompanied by a change of voltage proportional to the square root of the frequency. For example, a 400-volt 60-cycle motor on 66⅔ cycles will give very nearly normal operating characteristics if the voltage is made.

$$\sqrt{\frac{66\frac{2}{3}}{60}} \times 400 = 422$$

For decreased frequency, however, it is not recommended that motors be operated on less than normal voltage on account of increased current and temperature. The application of the foregoing rule for higher than normal frequency gives reduced temperature rise.

Power Factor—The actual power in watts taken from the supply circuit by a motor, if measured by a wattmeter is less than the product of volts and amperes measured independently. The ratio of the wattmeter reading to the volt-amperes measured independently is the power factor. Low power factors are undesirable as they indicate considerable idle, or wattless, current in the generators, lines, and transformers, resulting in increased heating; i.e., in reduced capacity for carrying working current.

Slip—At no load an induction motor runs at practically synchronous speed; with a load the motor speed is below synchronous speed by a percentage known as the slip. That is, if the synchronous speed is 1800 rpm. and the full-load speed 1700 rpm., the slip at full load is 5½ per cent. The slip of any induction motor depends on the voltage drop in the secondary circuit, i.e. on the product of the secondary resistance and current. The greater the secondary resistance, the higher is the starting torque with a given current, the greater the slip, and the greater also are the losses and the lower the efficiency.

Efficiency—The losses in an induction motor are:

1. Primary iron loss, constant at all loads if the frequency and voltage are constant.
2. Primary copper loss consisting of an approximately constant loss due to the wattless magnetizing current and a loss varying with the square of the load.
3. Secondary copper loss which corresponds to the slip in per cent, i.e., if the slip is 5½ per cent the secondary copper loss is the same.
4. Other losses consisting of secondary iron loss, which is usually very small, and friction of bearings and air.

DIRECT-CURRENT MOTORS

Windings—Depending upon the character of field winding employed, a direct-current machine is classified under one of the following three general groups.

1. Shunt wound
2. Series wound
3. Compound wound

Shunt-wound motors—This is by far the most common type of winding, and is generally applied to motors designed for operating at constant speed under constant or varying loads. Nearly all commercial applications, particularly those of large capacity, require this type of motor. When necessary, considerable speed variation can usually be secured by means of a rheostat in the field circuit, increased resistance resulting in an increased speed.

It is the practice on many shunt-wound commutating-pole motors to use a compensating winding for the purpose of insuring stability under all conditions of operation. This is, in effect, a light series winding which, however, does not change the speed-torque characteristics from those of an ordinary shunt-wound motor.

Series-wound motors are variable speed machines particularly adapted to such uses as railway and crane service. The characteristic features of a series-wound motor are its great torque at starting and low running speeds possible.

Compound-wound motors—For some special classes of service, in which it is necessary to start under heavy load and later operate at approximately constant speed, a series winding is added to assist the shunt field at the low speed points. A compound-wound motor combines the characteristics of both shunt and series-wound motors. In most cases, however, the series winding has comparatively little effect except during the starting period.

Starting—All direct-current shunt and compound-wound motors larger than the very small sizes are started by first giving the shunt field full excitation and then connecting the armature, with a starting resistance in series, to the circuit. The resistance is then cut out in steps as the motor accelerates, the time required to attain full speed varying from about 15 seconds for small, to one minute for large motors. These limits should be used with discretion, since more time is required to start with heavy load than with light load.

Connection diagrams and operating instructions can be obtained for any Westinghouse starting or controlling device. After all connections are made according to instructions and all mechanical preparations are complete, see that all the field adjusting resistance (if used) is cut out and that the starting resistance is all in circuit. Close the circuit-breaker (if used), then the line switch, and lastly cut out the starting resistance step by step as instructed, allowing enough time for smooth speed acceleration. Too rapid starting results in excessive starting current and possibly flashing at the brushes. Every caution previously given in regard to mechanical operation must be observed in starting. The motor should generally start when the armature circuit is first closed through the starting resistance, and failure to start when the second or third step of resistance is cut out is a signal to open the line switch or circuit-breaker at once and find the cause of the failure.

The shunt and series fields of compound-wound motors are nearly always connected cumulatively, that is, so as to excite the field in the same direction. If the speed of a compound-wound motor increases when the load comes on, the fields are probably connected differentially—usually an undesirable condition. The remedy is to reverse the terminals of the series field.

Stopping—Never move a starter or controller handle to the off position under any circumstances if by doing so the shunt-field circuit of the motor is opened. The high induction of the motor field may generate voltage enough to puncture the insulation. If necessary to open a shunt-field circuit it should be done very slowly, allowing the field current to die out; owing to the resistance of the arc across the switch terminals. If a field circuit must be opened in this manner often, a field switch should be installed, so that a local circuit is closed through the field before the latter is disconnected from the line. Starting rheostats are usually so arranged that the field circuit is always closed through the motor armature. If the starter or controller is provided with a low-voltage release, the line switch or circuit-breaker should always be opened first for stopping; the motor speed will then decrease until the starting resistance is automatically cut into circuit.

Brushholder Adjustments—Westinghouse motors with commutating poles, as well as those designed especially for reversing service, such as crane, hoist, and mill motors have fixed brush position, and no adjustments are required or desired.

The neutral no-load position of the brushes on Westinghouse direct-current machines having adjustable brushes is usually indicated by a chisel mark on the rocker ring and its seat. With the brushes set at this point the motors will run with slight sparking from no load to full load in either direction of rotation, making them suitable for reversing operation in intermittent service. For machines without commutating poles, if only one direction of rotation is required and if the machine is to be overloaded, the brushes should be shifted slowly backward opposite the direction of rotation of a motor and forward with the direction of rotation of a generator to the point where slight sparking begins at no load. Sparking at the brushes when the machine is operating with load can frequently be entirely removed by shifting the brushes slowly from or towards the neutral point. In any case the correct distance of the brushes from the neutral point is very slight, and the movement should be made with great care, for shifting the brushes too much will cause violent sparking.

Care of Commutator and Brushes—Carbon brushes are used on all Westinghouse direct-current machines. The chief considerations in caring for such machines are to keep the commutators clean, the brushes properly adjusted, and the contact surface of the brushes good. The last condition, once fulfilled, will usually take care of itself until the brushes are worn out, provided the other conditions are complied with. At intervals depending on the service and the location, the commutator contact surface and end should be thoroughly wiped with clean canvas that is free from lint. A few drops of oil on the cloth or a piece of paraffine rubbed lightly across the commutator surface will give all the lubrication necessary. Lubricant should be used very sparingly on a commutator, and no grease, oil, or dirt should be allowed to accumulate on the commutator or the brushes.

The ideal appearance of a commutator surface is polished dark brown or chocolate color. Such a commutator needs no attention other than cleaning when necessary. If the surface has a raw copper color with gradual roughening, it should be smoothed with sandpaper or, if very rough, with a piece of sandstone; emery paper or cloth should not be used for this purpose. The sandpaper should be held against the commutator by means of a block having the same curvature as the commutator. The sandstone likewise should be curved to fit the commutator. The brushes should be lifted from the commutator surface when using sandpaper or stone and should not be placed in contact again until the commutator surface is thoroughly cleaned of all gritty particles.

Grinding in the Brushes—When making proper contact with the commutator, the face of the brush is glazed. If the glazed portion does not extend over very nearly all the brush face, the brushes should be ground in by wrappinh a long strip of fine sandpaper closely around the commutator with the rough side toward the brushes and then rotating the commutator and the sandpaper slowly through perhaps one revolution. Shorter pieces of sandpaper held close to the commutator surface and drawn in the direction of rotation under the brushes. (The pressure should be released as the paper is drawn back, to avoid rounding the edges of the brush) will answer the same purpose. The commutator surface should be wiped clean after the brushes are ground in, and lubricated with a few drops of fresh oil on a clean cloth.

Sparking—With the proper installation, operation and care, Westinghouse direct-current machines will not give trouble from sparking at the commutator. If sparking does occur it is probably caused by some one or more of the following conditions, the remedy in each case being either obvious or suggested. The causes are numbered in the order of their probably occurrence. Remedies for causes 6, 7, 8, 9, 11 and 12 follow under "Repairs".

1. Excessive overload.
2. Improper brushholder adjustment. See preceding instructions.
3. Poor brush contact:

(**a**) Accumulations of grease or dirt may hold the brushes from the commutator.

(**b**) Brushes may need grinding to fit the commutator. See preceding instructions.

(**c**) Brushes may stick in the holder. Grind or sandpaper them until the movement is free, but do not make the brushes fit too loosely in the holders.

(**d**) Increased brush pressure may be needed. The method of adjustment will be evident.

4. Rough commutator. See preceding instructions.
5. Poor connection between the brushes and the holders. See that both ends of the shunts are securely fastened in place. Loose shunts are usually indicated by burned connections.
6. Loose connection of armature lead to commutator bar, indicated by the blackening burning of this and the adjacent bars. An open circuit anywhere in the armature will cause sparking that seems to encircle the commutator when running and that will burn the bars to which the open-circuited coil is connected.
7. Short-circuited armature coil, indicated by heavy intermittent sparking, burned commutator bars, and excessive local heating which can be readily found by stopping the armature after running a short time and feeling its surface.
8. Grounded armature coil.
9. Loose commutator bar—indicated by slight jumping of the brushes with intermittent sparking.
10. Unequal spacing of brushes; not likely to occur unless brushholders have been dismantled and reassembled. The spacing can be verified by counting the bars between corresponding edges of the brushes or by marking the distances on a strip of paper wrapped closely around the commutator under the brushes.
11. The mica segments and commutator bars may not wear evenly, that is, the segments may have become pitted below the commutator surface.
12. Flat spot, or a "flat" on the commutator; commutator out of true, caused by rough handling; a bad belt splice; flashing owing to a short-circuit on the line. A "flat" or a commutator out of true can be detected by slight jumping of the brushes or uneven motion of the commutator and brushes. These indications may also point to a bent shaft.
13. Bent shaft; for indication see foregoing paragraph. Test by holding a piece of chalk near the shaft as it rotates in a lathe. Remove the bent shaft from the armature and straighten or replace it by a new one.

REPAIRS FOR DIRECT-CURRENT MOTORS

Field Coils—An open-circuited shunt field coil can be detected by touching the terminals of a voltmeter to the terminals of the individual coils while full voltage is applied to the field circuit. The voltmeter will show no deflection until the defective coil is reached and will then indicate the full voltage.

A short-circuited shunt field can be found by the same test, the voltmeter deflection being least on the defective coil. The short-circuiting of one field coil may easily result in burning out one or more of the others if full voltage is applied to the circuit, unless a resistance equivalent to that of a perfect coil is included in the circuit.

A grounded coil can be found by the process indicated under the subject "Insulation" on page 8.

In replacing a field coil make sure that the polarity of the pole differs from that of either adjacent pole. The polarity can be tested with a small bar magnet or a piece of steel wire suspended from its center by a string. In holding the magnet near the poles successively, it should reverse at each pole; i.e., no two successive poles should attract the same end of the magnet.

Armature—An open-circuited armature coil not revealed by inspection can be located by disconnecting the upper leads from each burned commutator bar (see paragraph 6, page 12) and applying the terminals of magnets or a lamp testing circuit between each free end and all the other bars. A complete circuit will be indicated with all except the end of the open coil.

An open-circuited or short-circuited armature coil can be repaired temporarily by cutting off and taping both commutator leads from the defective coil, fastening them where they cannot injure the other leads, and short-circuiting by means of a jumper the two bars with which the damaged coil was connected. Great care should be used in applying this remedy and it should be for temporary purposes only, permanent repairs being made at the first opportunity. An open circuit in a wave-wound armature will cause burned commutator bars at as many different points as there are pairs of poles. In case of a short-circuited coil the removal of a lead from the commutator bar will not always remove the difficulty, it being necessary to open the coil (or series of coils in a wave, or series winding) elsewhere in order to prevent the short circuit from causing a burn out.

In rewinding an armature great care should be taken to see that the throw of the leads is made the same as on the orignial winding. This is particularly important on machines having fixed brush position.

Commutator—Loose commutator bars (high or low) can sometimes be tightened by screwing up the commutator nut or by tightening the bolts or set screws, if these are used. If this is not sufficient the commutator must be removed from the armature and tightened in a press. This involves the disconnection and reconnection of the armature leads and it is recommended that such work be done in a repair shop.

Pitted mica segments should be repaired as as soon as discovered. Clean the hole thoroughly and fill it with an insulating paste that will quickly harden and that will hold its position when the commutator is warm. Two mixtures which have been used successfully are prepared chalk or plaster paris and shellac; water glass and powdered glass.

Excessive unexplained heating of a badly worn commutator while carrying normal load or less indicates that it is worn out and should be replaced by a new one.

CAUTIONS

Never allow the load to be entirely removed from a series-wound direct-current motor while operating, or to be reduced enough to cause a dangerously high speed. A series motor should not be belted, on account of the possibility of the belt running off, thus permitting the motor to race.

Never open the shunt-field circuit of a motor in operation; otherwise the motor will race, and serious damage will result.

When the shunt-field circuit of a motor or a generator is excited, never open it quickly unless a path for the inductive discharge is provided. The circuit can be opened slowly, if desired, the arc at the opening serving to reduce the field current gradually. **Do not permit any part of the body to bridge this opening,** or a serious shock will be received; better use but one hand, keeping all other parts of the body clear of the circuit.

In soldering connections use an acid that will not act on the insulation or the copper, an alcoholic solution of resin is a good soldering flux.

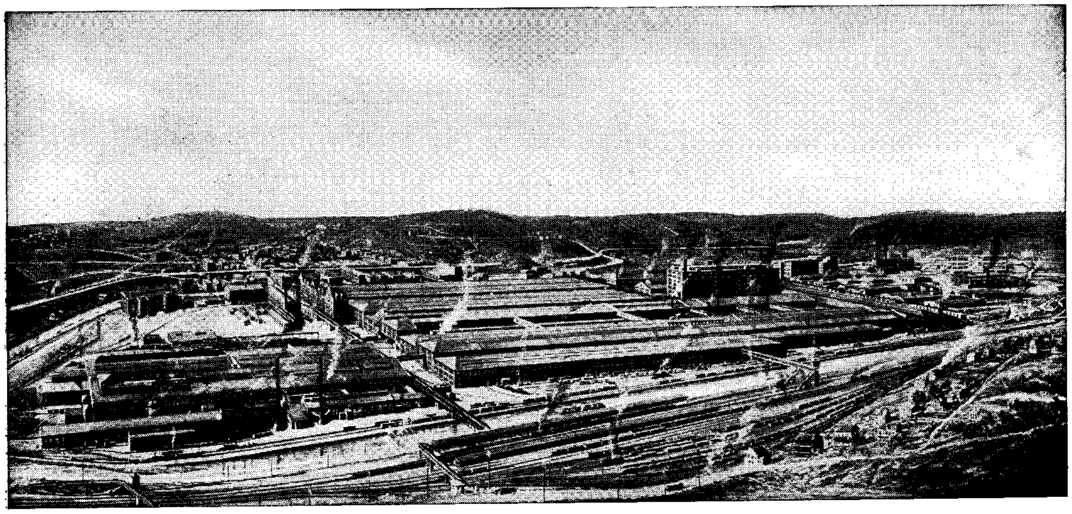
In soldering commutator connections do not allow bits of solder to drop down where they may short-circuit commutator bars.

Keep the commutator and brushes clean.

Never use emery cloth or emery paper on commutator or brushes.

Always follow a fixed regular order in closing and opening switches, unless there are special reasons for departing from this order. A routine method will aid in avoiding mistakes. Keep all switches open when the motors are idle. Close switches carefully, keeping firm hold of the handle until completely closed.

A routine method of making inspections, replenishing lubricants, etc., will also prevent oversights and possible damage.



The Company's Works at East Pittsburgh, Pa.

Westinghouse Products

A few of the Westinghouse Products are listed below and will furnish some idea of the great variety of electrical apparatus manufactured by the Company and the many extensive fields for their use.

For Industrial Use

Instruments

Motors and controllers for every application, the more important of which are: Machine shops, woodworking plants, textile mills, steel mills, flour mills, cement mills, brick and clay plants, printing plants, bakeries, laundries, irrigation, elevators and pumps.

Welding outfits

Gears

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Lighting Systems

Safety switches

For Power Plants and Transmission Lines

Circuit-breakers and switches
Condensers
Controllers
Control switches
Frequency changers
Fuses and fuse blocks
Generators
Insulating material
Instruments
Lamps, incandescent and arc
Lightning arresters
Line material
Locomotives
Meters
Motors
Motor-generators
Portable Power Stands, 110 volts
Rectifiers
Regulators
Relays
Solder and soldering fluids
Stokers
Substations, portable and automatic
Switchboards
Synchronous converters
Transformers
Turbine-generators

For Transportation

Locomotives
Railway equipment
Marine equipment

For Mines

Lamps
Locomotives
Motors for hoists and pumps
Motor-generators
Portable substations
Switchboards
Line material
Ventilating outfits

For Farms

Fans

Household appliances

Motors for driving churns, cream separators, corn shellers, feed grinders, pumps, air compressors, grindstones, fruit cleaning machines and sorting machines.

Generators for light, power and heating apparatus

Portable Power Stands, 32 Volts

Radio Apparatus

Transformers

For Office and Store

Electric radiators

Fans

Arc lamps

Incandescent lamps

Small motors for driving addressing machines, dictaphones, adding machines, cash carriers, moving window displays, signs, flashers, envelope sealers, duplicators, etc.

Ventilating outfits

For Electric and Gasoline Automobiles and the Garage

Battery charging outfits
Charging plugs and receptacles
Lamps
Instruments
Motors and controllers

Small motors for driving lathes, tire pumps, machine tools, polishing and grinding lathes.

Solder and soldering fluids

Starting, lighting and ignition systems, embracing: Starting motor generators, ignition units, lamps, headlights, switches, etc.

Tire vulcanizers

For the Home

Electric ware, including: Table stoves, toasters, irons, warming pads, curling irons, coffee percolators, chafing dishes, disc stoves, radiators and sterilizers.

Automatic electric ranges

Fans

Incandescent lamps

Radio Apparatus

Small motors for driving coffee grinders, ice cream freezers, ironing machines, washing machines, vacuum cleaners, sewing machines, small lathes, polishing and grinding wheels, pumps and piano players

Sew-motors

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

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CANADIAN COMPANY

CANADIAN WESTINGHOUSE COMPANY, LTD., Hamilton, Ontario

WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY

165 BROADWAY, NEW YORK, U. S. A.

Westinghouse Press
Printed in U. S. A.