Westinghouse

Air-Cooled Synchronous Condensers

GENERAL INFORMATION AND CONSTRUCTION

Installation

Operation

Maintenance

INSTRUCTION BOOK

Westinghouse Electric & Manufacturing Company

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COMMUNICATIONS

When communicating regarding a product covered by this Instruction Book, replies will be greatly facilitated by citing COMPLETE NAME PLATE READINGS of the involved products. Also, should particular information be desired, please be very careful to clearly and fully STATE THE PROBLEMS AND ATTENDANT CONDITIONS.

PURPOSE

The purpose of this instruction book is to give the reader the maximum of useful information and suggestions concerning construction, installation, operation and maintenance of Westinghouse air-cooled synchronous condensers.

The material contained herein has been assembled with a view toward facilitating installation and operation of the equipment and this book is intended to serve as a guide to installation and operating personnel so that the maximum useful life of the apparatus can be obtained.

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Westinghouse

Air-Cooled Synchronous Condensers

GENERAL INFORMATION AND CONSTRUCTION

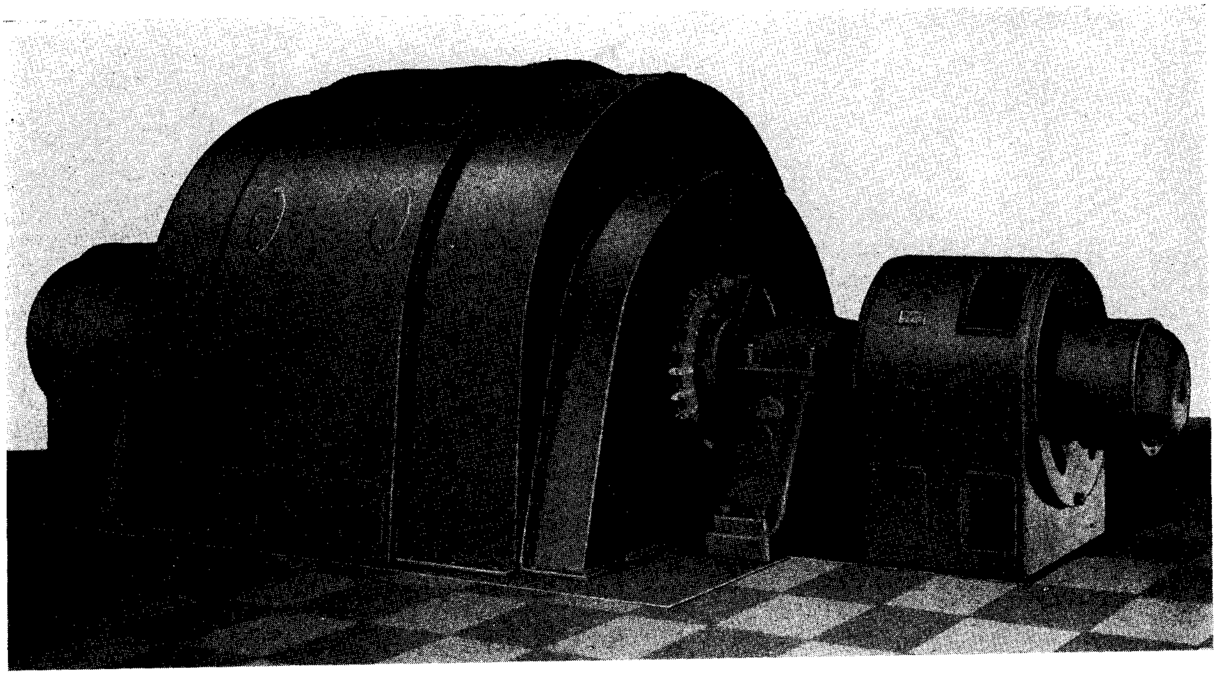


FIG. 1—INSTALLATION VIEW OF A TYPICAL AIR-COOLED SYNCHRONOUS CONDENSER SHOWING MAIN AND PILOT EXCITER, STARTING MOTOR, BRUSH RIGGING, COLLECTOR RINGS AND TOP AIR DISCHARGE OPENING.

PART I

GENERAL INFORMATION

Synchronous condensers differ from other alternating current rotating electrical apparatus, primarily in the functions which they perform. They are not connected to any mechanical load nor do they deliver any energy to the system. They merely "float" on the line.

The standard air-cooled synchronous condenser is designed to operate over a range in capacity from full Kv-a. over-excited to one half of the rated Kv-a. under-excited. By virtue of flexibility in field control, the condenser can be used to automatically correct the system power factor and control the system voltage.

Westinghouse synchronous condensers are designed to comply with the standards of the American Standards Association and the National Electrical Manufacturers Association.

As set forth in these standards, they are guaranteed to operate at their nameplate rating on a single continuous basis without exceeding specified temperature rises above an ambient temperature of not more than 40°C.

Standard air-cooled synchronous condensers are of the horizontal two-bearing totally-enclosed self-ventilated type (except for ratings below 3000 Kv-a. which are of the open type self-ventilated) with a straight steel shaft, two pedestal bearings and with damper windings on the rotor and include a direct-connected exciter all mounted on a bedplate or soleplates. For typical general arrangement note Figs. 1 and 2. Standard or optional equipment, depending upon size and rating, may include a pilot exciter, rheostats, field discharge resistance, embedded armature temperature detectors and oil pressure starting equipment. Accessory apparatus may involve provision of starting autotransformer, starting reactor or starting motor, surface air coolers, housings for outdoor operation and special instruments or measuring equipment.

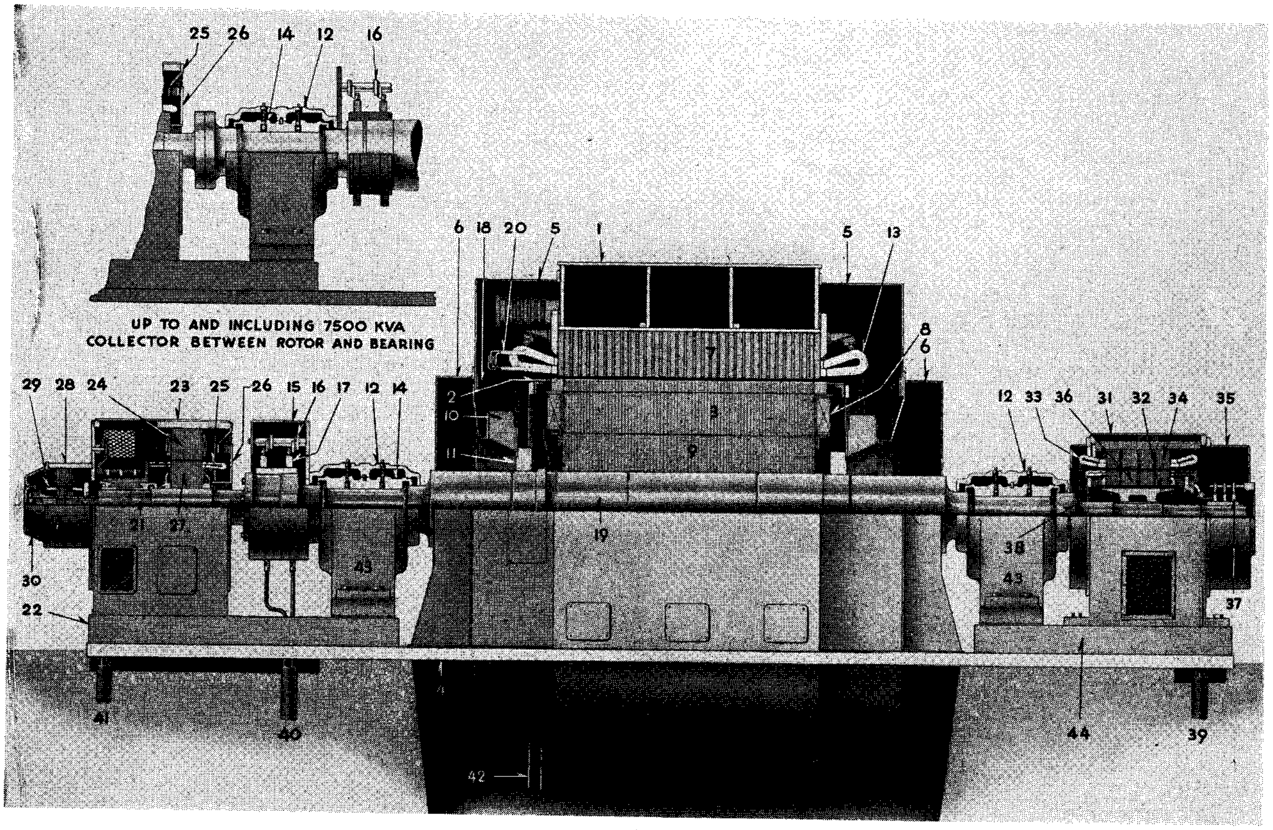


FIG. 2—CROSS SECTION OF A TYPICAL AIR-COOLED SYNCHRONOUS CONDENSER.

PILOT EXCITER

21 Shaft
28 Frame
29 Armature Coils
30 End Bracket
41 Lead Conduit

MAIN EXCITER

21 Shaft
22 Base Plate
23 Frame
24 Field Pole
25 Armature Coils
26 Blower
27 Armature
41 Lead Conduit

CONDENSER

1 Frame
2 Damper Winding
3 Field Pole
4 Base Plate
5-6 End Bells
7 Stator Core
8 Field Coil
9 Rotor Spider
10 Blower Blade
11 Blower Hub
12 Bearing Housing
13 Stator Coils
14 Bearing Shell
15 Collector Cover
16 Brushholders
17 Collector Rings
18 Fire Piping
19 Main Shaft
20 Series Connections
40 Collector Conduit
42 Leads
43 Pedestals

STARTING MOTOR

31 Frame
32 Rotor Spider
33 Stator Coils
34 Stator Core
35 End Bells
36 Rotor Core
37 Collector Rings
38 Shaft
39 Lead Conduit
44 Bedplate

PART II

CONSTRUCTION

GENERAL

A general understanding of the construction of the apparatus is necessary in order that the succeeding chapters on installation, operation and maintenance be the most helpful. Figs. 1 and 2 show respectively an assembled view and cross section view of typical synchronous condensers. It is recommended that the reader study the illustrations in conjunction with the following descriptive matter.

STATOR

Frame

The stator frame is fabricated from electrically welded steel plates to form a rigid box section. The stator core is assembled on bolts which span the length of the frame. Openings are provided in either the top or bottom of the frame wrapper plate for discharge of the ventilating air. If desired, the purchaser can connect duct work to the frame and discharge the air outside the building. Suitable lifting holes are provided in the frame to permit handling during assembly.

Stator Core

The stator core is built up of segmental, high grade, non-aging silicon steel laminations. Both sides of the laminations are treated with a suitable insulating material to prevent short circuiting the laminations. Adequate pressure is applied at intervals during the stacking operation to produce a tight core. The core laminations are kept tight by means of heavy finger plates and end plates which maintain adequate pressure on the core at all times. This insures against loose iron and core vibration.

Stator Winding

The stator windings of all standard air-cooled synchronous condensers consist of pulled type, form-wound, interchangeable coils. Standard synchronous condensers up to 10,000 Kv-a. for all voltages, and 10,000 Kv-a. and above for 5000 volts and below, have stator coils insulated with Class A insulation. All standard machines above 10,000 Kv-a. and above 5000 volts have stator coils insulated with Class B insulation.

Class A insulation is identified by A.S.A. and N.E.M.A. Codes ABAV, ABAVX, ABBXV.

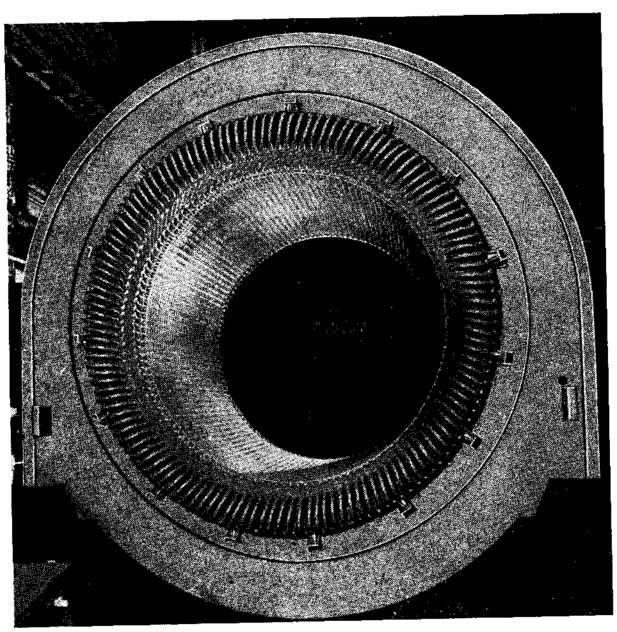


FIG. 3—SHOP VIEW OF A WOUND CONDENSER SHOWING STATOR COILS AND BRACING.

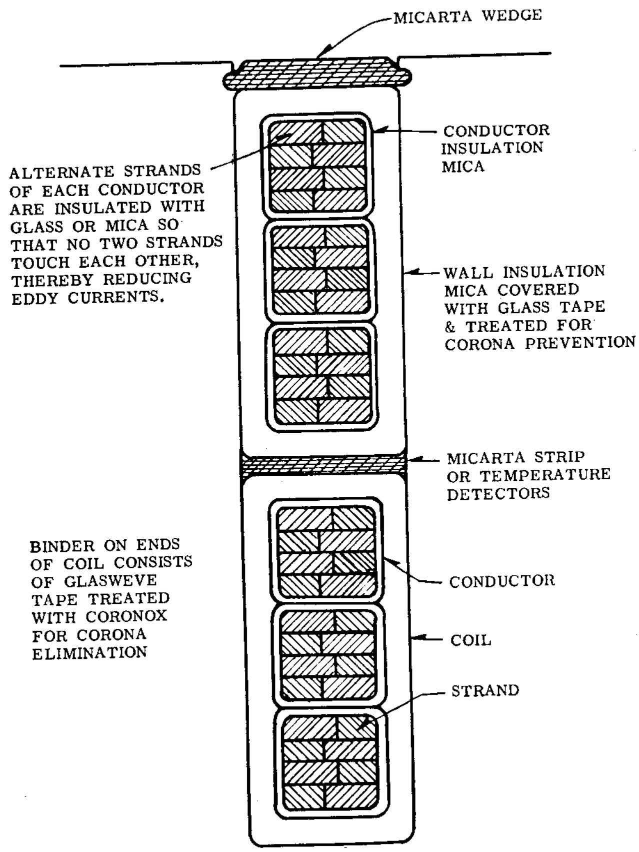


FIG. 4—CROSS SECTION VIEW SHOWING TYPICAL CONSTRUCTION OF ARMATURE COIL WITH CLASS B INSULATION (6900 VOLTS AND ABOVE)

Coils With Class A Insulation are Similar to Above Except Class A Materials are Used, See Page 9.

Class B insulation is identified by A.S.A. and N.E.M.A. Code BBBXV. A cross section view of a typical stator coil is shown in Fig. 4.

Temperature Detectors

Usually six temperature detectors are provided in the stator winding of a standard condenser to obtain a measurement of the operating temperature. The detectors are located at the center of the core and between the top and bottom coil sides in a slot. Note Fig. 4 for location. The detectors consist of a flat copper wire coil having a resistance of 10 ohms at 25°C. The temperature coefficient of resistance of these detectors is .00427 ohms per degree C. The detector leads are brought to a terminal board which is arranged so that one lead of the detectors can be grounded to protect the operator. The terminal board is usually mounted on the condenser frame in an accessible location to permit connection to Purchaser's measuring devices.

ROTOR

Spider and Poles

The rotor spider is built up of the required number of steel laminations or steel plates which are riveted or bolted together to form a compact structure. Dovetail slots are punched in the laminations or machined in the plates of the spider. These dovetail slots in the spider match dovetail projections on the rotor poles. Note Fig. 5 for typical spider construction.

The poles are built up of steel laminations riveted or bolted together under high pressure. Note Fig. 6 for typical pole construction. Dovetail projections on the pole engage the dovetail slots in the spider and the pole is held in position in the spider slot by tapered keys or wedges. In assembly, tapered keys are driven in from each side of the rotor. The taper is so slight (.005 inch per inch) that there is no tendency for the keys to slip after once being set.

The taper key assembly consists of a thick key, a thin key and a liner. The thick key is proportioned to withstand driving without damage.

Field Winding

The field coils are formed of copper strap wound on edge. The copper strap is formed into the shape of the coil and then strips of asbestos, soaked in shellac, are placed between the turns. The partially completed coil is heated and pressed to expel all the solvents.

After finishing, the outer edges of the copper strap are practically bare, being covered only with a coat of insulating varnish. This allows the heat to be dissipated effectively from the exposed edges.

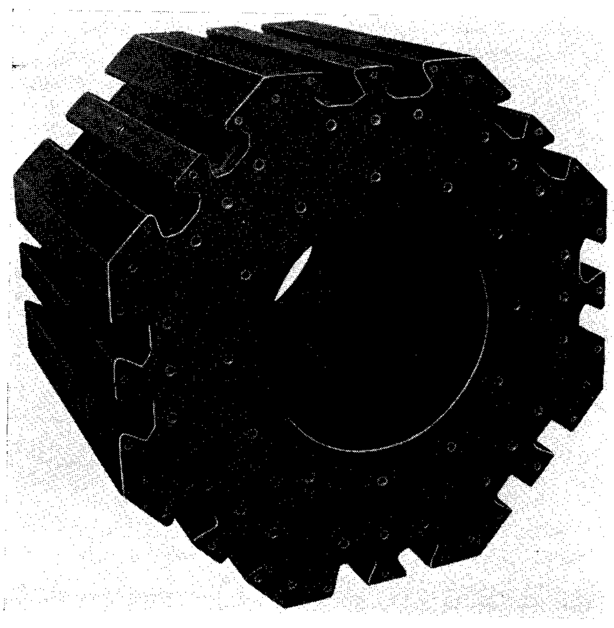


Fig. 5—View of Laminated Spider.

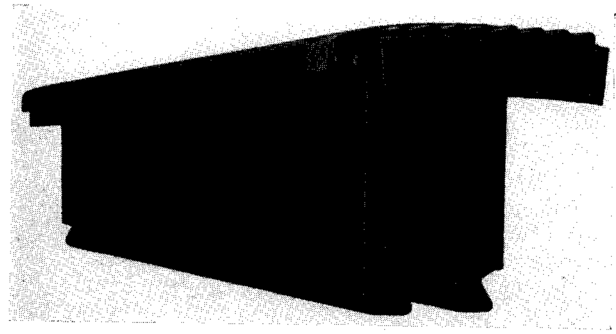


Fig. 6—Shop View of a Typical Condenser Field Pole Showing Laminated Construction and the Rugged Angle Welded Damper Winding.

The field coils are insulated from the pole by a cell of built-up mica and asbestos and by micarta washers at the top and bottom of the coil. For typical construction note Fig. 7.

Damper Winding

Damper windings are provided as part of the field structure of all standard synchronous condensers for the purpose of adapting the machine to A.C. self-starting. The winding consists of heavy high resistance bars, embedded in the surface of the pole face. The resistivity of the bars is selected to produce the maximum starting torque with minimum inrush from the line. Note Fig. 6 for typical construction.

Bedplate

The bedplate for the standard air-cooled condenser is fabricated from standard structural shapes, arranged to obtain the maximum rigidity for the mass of material used. The bedplate is not designed to permit lifting the assembled condenser, hence care should be taken to handle it as an individual part. Failure to observe this limitation will result in distorton of the bedplate and possible damage to other parts.

Ventilation—Fans

The most effective use of the active materials which go into the fabrication of all rotating electrical machinery can be realized only if the machine is adequately ventilated.

Westinghouse air-cooled synchronous condensers are designed and proportioned so that the cooling air is uniformly directed to all sources of heat generation. The fans or blowers, which are mounted on the rotor, are liberally designed; the ventilating ducts in the stator core are liberal in number and so distributed that uniform temperatures exist throughout the entire length of the machine.

CONSTRUCTION (cont'd)

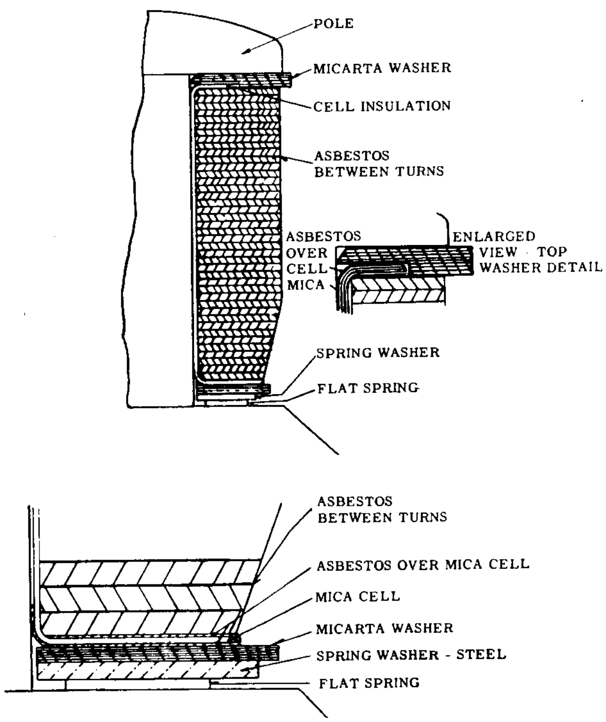


Fig. 7—Cross Section View Showing Typical Construction of Field Coil.

The blowers or fans are of the inclined blade, centrifugal type as illustrated by Fig. 8. When the fans are properly assembled on the rotor, the inner edge of the blades lead the outer edge in the direction of the mechanical rotation. If the fans are incorrectly assembled, they will not deliver the normal amount of air and the machine will operate at higher than normal and possibly at dangerous temperatures.

It is therefore important that the blower assembly be checked before the assembly has progressed too far. If the assembly is found to be incorrectly installed with respect to the mechanical rotation, the fans can be reversed end for end or the direction of rotation reversed by interchanging two of the main leads.

If the direction of rotation is reversed, the connections to the exciters must be changed. Note exciter instruction tag.

Most standard condensers have fans designed with adequate capacity to overcome some external pressure drop in the ventilating circuit. In general, it can be stated that any standard Westinghouse air-cooled synchronous condenser will have blower capacity sufficient to overcome $\frac{3}{8}$ inch of water column, external pressure drop. If the external restriction is greater than $\frac{3}{8}$ inch, the manufacturer should be consulted, as the additional restrictions may seriously reduce the air volume circulated through the machine with consequent increase in operating temperatures.

Bearings

The bearings of standard air-cooled synchronous condensers are equipped with oil rings for lubrication. In the larger sizes the rings are supplemented by oil circulation through external heat exchangers. The heat exchanger is usually the oil-to-water type but may be oil-to-air in special cases where water is at a premium. The need for external cooling depends on the loss generated in the bearings.

All bearings have babbitted oil ring guides to reduce the wear of the rings. The bearing surface is provided with a relief at the split to adequately distribute the oil over the entire bearing surface. Fig. 9 shows a cross section of the standard bearing and Fig. 10 shows actual interior construction of a typical bearing.

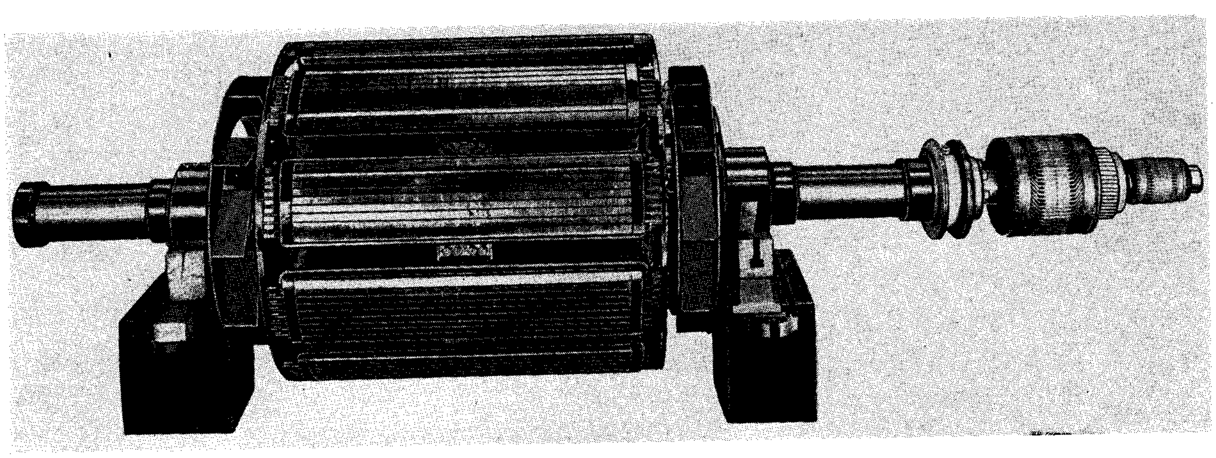


Fig. 8—Shop View of a Complete Condenser Rotor Showing Main and Pilot Exciter Armature, Collector Rings, Centrifugal Blowers, Poles and Coil Braces.

CONSTRUCTION (cont'd)

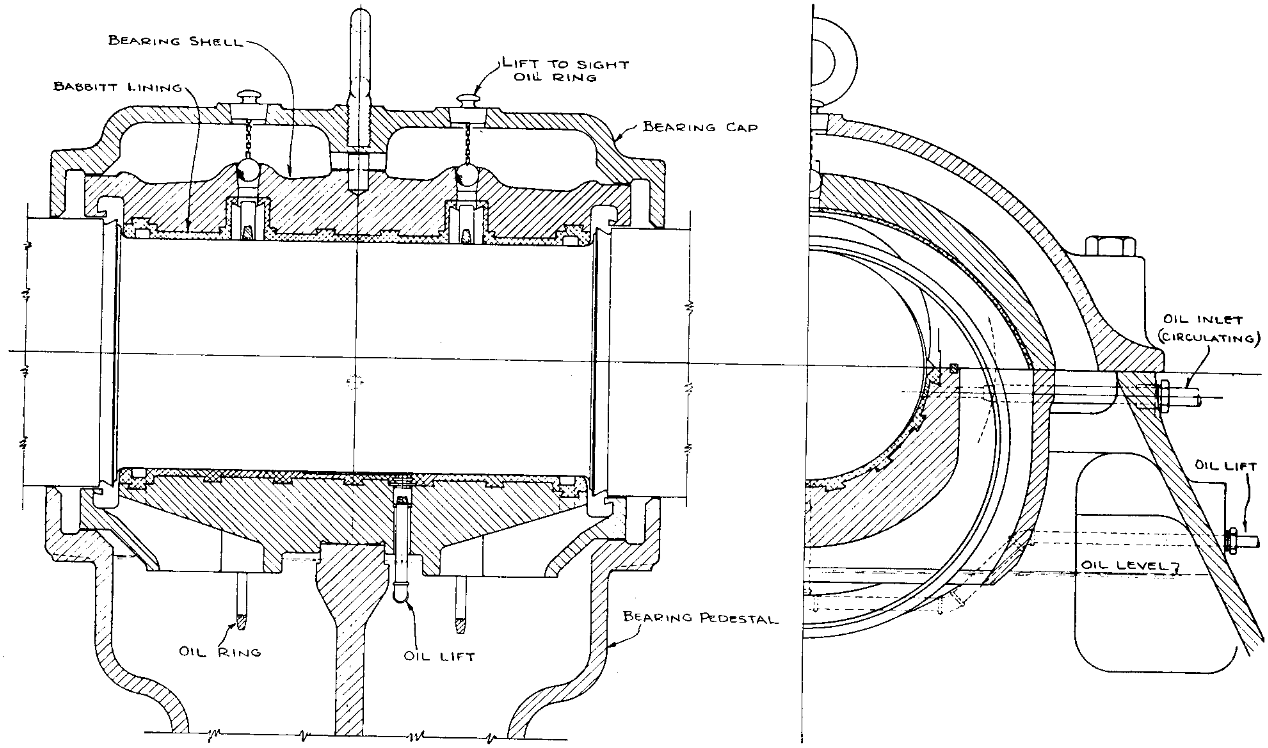


FIG. 9—CROSS SECTION VIEW OF A TYPICAL BEARING ASSEMBLY.

Shaft Currents and Pedestal Insulation

Variations in reluctance in the magnetic circuit of an alternating current machine may cause periodic changes in the amount of flux which links the shaft. This change in flux may generate sufficient voltage to circulate current through the circuit consisting of shaft, bearings and bedplate. If this current is permitted to flow, it soon has a destructive effect upon the shaft journals and bearings. Small pits are usually formed on the surface of the shaft. These pits are sufficiently rough to score the surface of the bearing and in some instances, the bearing babbitt actually shows evidence of having been eaten away by the current.

As it is not practical to provide control of the generation of shaft voltages and currents, it becomes necessary to insulate one or more of the bearing pedestals from ground. This insulation interrupts the path for circulating currents. The insulation consists of a suitable thickness of micarta placed between the bottom of the pedestal and the bedplate. To avoid short circuiting the insulation, the dowels and holding down bolts must be insulated from the pedestal by micarta insulating tubes and washers. Fig. 12 shows the method of insulating the pedestal from the bedplate.

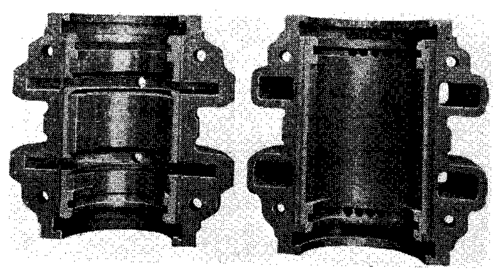


FIG. 10—VIEW OF TOP AND BOTTOM HALVES OF A TYPICAL BEARING, SHOWING BEARING RELIEF AT THE SPLITS AND BABBITTED OIL RING GUIDES.

PART III

INSTALLATION

SHIPMENT AND HANDLING

All synchronous condensers are completely assembled and the parts match marked at the factory. This practice makes it easier to properly reassemble the apparatus in the field.

Except for small units, a synchronous condenser is shipped disassembled. The stator, rotor, bedplate and bearings are crated or wrapped and shipped separately. If the crate or wrapping is damaged during transit, the equipment should be unpacked at once, in the presence of a claim adjuster, and all apparent damage reported to the Transportation Company. When writing to the Westinghouse Electric & Manufacturing Company concerning a synchronous condenser or its auxiliary apparatus such as exciters or starting motor, always give the serial number or stock order number which appears on the nameplate of the apparatus or on the end of the shaft.

Apparatus which cannot be installed as soon as received, should be stored in a room which is dry and clean or should be covered with a tarpaulin and kept dry by use of some source of heat.

FOUNDATIONS

The foundation should consist of solid concrete walls or piers whenever possible and should be carried down far enough to rest on a solid sub-base. A competent consulting engineer who is familiar with foundation design should design and supervise this part of the installation. If it is necessary to support the bedplate on steel girders instead of concrete, the girders should be well braced and supported by adequate columns so as to prevent vibration.

The pit beneath the synchronous condenser should be deep enough to give ample working space for connecting the leads which are normally brought out below the machine and for proper installation of surface air coolers, if provided as part of the apparatus. The pit should also be adequately drained and ventilated.

LOCATION OF MACHINES

It is of the greatest importance in laying out a power house or substation that the following considerations govern the location of the condenser and associated apparatus.

(1) The machine should not be exposed to moisture from leaky pipes, escaping steam or condensation of atmospheric moisture on overhead glass or a metal roof.

(2) It should not be exposed to the corrosive action of acid fumes or other injurious gases.

(3) It should not be exposed to dirt from coal handling or similar operations.

(4) Since the total temperature, and consequently the capacity of the machine, depends upon the temperature of the surrounding air, it is evident that the location should be in a room as cool and well ventilated as is consistent with proper protection from dirt and moisture.

(5) The position of the machine should be such that the exciter commutator and condenser collector rings are readily accessible for inspection and maintenance.

ERECTION

(A) Preliminary Procedure

The following preliminary procedure is recommended before starting to erect the machine:

(1) Check all items available at the site of erection against the manufacturer's shipping report. If all the equipment cannot be accounted for, the shortage should be reported at once to avoid undue delay in erection. Likewise, any damaged equipment should be reported as soon as discovered.

(2) The foundation "bench marks" should be located to permit establishing the centerline of the unit and the elevation of the floor level.

(3) Check the foundation against the outline drawing of the condenser to be sure that the pit below the machine and any cable, bus or ventilating ducts have been provided in their proper locations and of suitable dimensions to permit correct assembly of the unit and its accessory equipment.

(4) Check the size, location, and elevation of top of the foundation bolts against the outline drawing.

(5) Make up the required number of leveling plates and shims on which to rest the condenser bedplate. These plates should be of steel apprixImately ¼ inch x 4 inches and should be sawed or burned in lengths so they will extend about 2 inches beyond each flange of the bedplate. Note Fig. 11 for further details.

(6) Locate the leveling plates where the pedestals and stator frame will rest on the bedplate or soleplates. Use a sufficient number to prevent any distortion of the bedplate.

(7) Level all plates to proper elevation, allowing for about 1/8 inch of shims on each plate for subsequent adjustment, then grout to the top surface of the plates.

Fig. 11 illustrates methods of setting structural steel bedplates and anchoring foundation bolts.

(B) Leveling Bedplate

After the grout around the leveling plates is set and has hardened, the bedplate or soleplates should be placed in position on the foundation, inserting about 1/8 inch of shims between the bedplate and the leveling plates. If the bedplate is sectionalized, be sure that the machined surfaces, keyways, and bolt and dowel holes are clean and free from burrs. Paint the surfaces with white lead and oil before bolting the sections together. When the final adjustments are completed, the centerline of the bedplate and the elevation of the bedplate should check with the purchaser's foundation layout.

(C) Placing Stator and Rotor in Position on Bedplate

The method used to assemble the stator and rotor in their correct relative positions on the bedplate will depend upon local conditions and facilities available for doing the work. At some "sites" adequate overhead cranes are available; at others it may be necessary to build an "A" frame and resort to the more tedious task of jacking, blocking and skidding the parts into position.

The method outlined in this instruction book is probably most common and assumes that an overhead crane of adequate capacity is available for handling the parts.

If the erection is done by the Purchaser, it will be necessary that he fabricate or purchase a shaft extension suitable for attachment to the end of the synchronous condenser shaft. This accessory is not supplied as standard equipment on synchronous condensers.

The stator should be placed on the bedplate as close to its final position as possible. It should then be "blocked up," using timber, and sufficiently elevated to allow the rotor to clear the top of the bedplate.

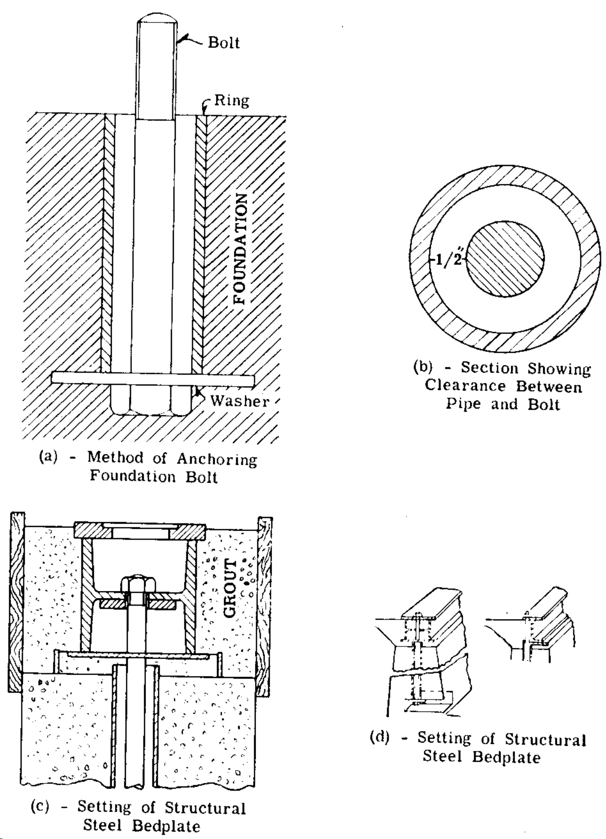
With the shaft extension attached to the synchronous condenser shaft, the rotor should be lifted by slings. The slings should be located on the end opposite the extension and also around the rotor body, so that, when the rotor is lifted and moved into its preliminary position, the shaft extension projects through the condenser stator bore. The rotor should then be blocked and the slings removed from the first position to a new position on both sides of the rotor, so that the rotor can again be lifted by the slings and moved into the stator. Before the rotor is moved into its final position in the stator, suitable protection in the form of fibre or micarta sheets should be placed around the stator bore to shield the end windings and core laminations from possible damage. After the rotor is placed in its correct position in the stator, the rotor can be blocked and the shaft extension removed.

Place the shims, which are furnished with the machine, between the stator frame feet and the bedplate. The number of shims to be used is stamped on the bedplate at the location of the frame feet.

The frame should then be doweled and the holding down bolts tightened.

(D) Assembling Pedestals and Bearings

By means of the crane, lift the rotor as high as the air gap will permit. Move the pedestals into position and place the necessary number of shims between the pedestals and the bedplate. Be sure the pedestal insulation is in place and that the insulating tubes and washers are prop-



(a) - Method of Anchoring Foundation Bolt

(b) - Section Showing Clearance Between Pipe and Bolt

(c) - Setting of Structural Steel Bedplate

(d) - Setting of Structural Steel Bedplate

FIG. 11—TYPICAL ARRANGEMENT OF CONDENSER BEDPLATE, GROUT FORMS AND FOUNDATION BOLTS.

INSTALLATION (cont'd)

erly assembled with the dowels and holding down bolts. The dowels should then be assembled and the holding down bolts tightened.

Before the bearings are rolled into place, the pedestal insulation should be tested. Insulation is provided under each pedestal and around the dowels and holding down bolts to prevent the flow of bearing currents. Note Fig. 12 for typical arrangement.

If water or oil piping is connected to the bearings, insulated couplings or unions must be used. Care should be taken to be sure there is no metallic connection between an insulated pedestal and the bedplate. If this precaution is not observed, the insulation becomes useless and bearing currents will flow.

Such metallic connections may be found in any of the following:

Piping which touches both the pedestal and the bedplate and which has no insulated couplings; guard rail; conduits; BX cables; thermometer tubing; metal ladder set against the pedestal; tools left in contact with both pedestal and bedplate; pump or other device geared to the main shaft.

A break in the insulation may occur during erection due to careless handling and therefore the insulation should be checked before the condenser is started. Both pedestals are insulated but one is grounded during operation of the condenser. When testing the insulation, the ground should be removed from the pedestal which is grounded. This is accomplished by removing the holding down bolt which is painted red. By the use of a test circuit the insulation under each pedestal can be checked. Any test

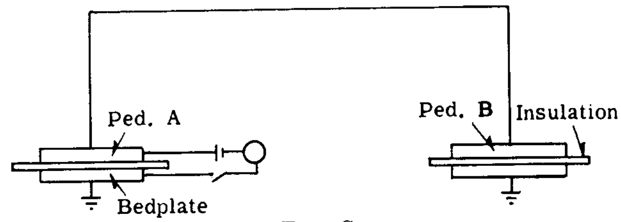


Fig. 13—Test Circuit.

circuit consisting of a source of power, such as a battery, station service supply, bell, lamp or a megger can be used. The procedure is as follows:

Note Fig. 13 for suggested test circuit. If the insulation under both pedestals is satisfactory, then with one side of the test circuit connected to the pedestal and the other to the bedplate, there should be no indication of a "live circuit," as evidenced by a "black lamp," no alarm or an infinite megger reading.

Should there be evidence of a live circuit, the insulation under either or both pedestals is defective or shorted. To isolate the defective insulation, it will be necessary to raise the shaft from the bearing so that there will not be contact between the two members. By the use of the test circuit at both pedestals, the location of the defective insulation can be determined.

Care should be exercised throughout the stages of erection of the condenser to make certain that no dirt, scale or filings get into the pedestals or bearings. The journal should be carefully examined before assembly for damaged spots and should be honed true if necessary.

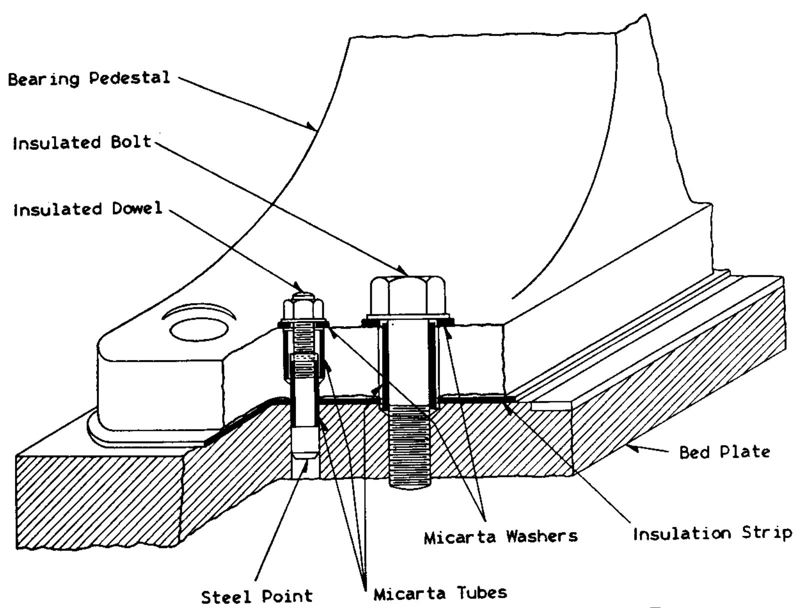


Fig. 12—Method of Insulating Bearing Pedestal from Bedplate.

If the shaft journals are clean and free from rust or scratches, the lower half of the bearing should be rolled into place.

Lower the rotor to its final position in the bearings and check both shaft journals for level.

Due to a slight deflection in the shaft, the journals will not be perfectly level. For correct assembly the outage at each journal should be the same.

Check the oil rings to be sure that they are not bent or damaged and that the joints match smoothly. The oil rings should be handled carefully, especially when making or breaking the joint at the split, to insure that they remain true and smooth. Assemble the rings carefully and place the upper half of the bearing in position.

The oil rings should be checked when placed in the bearing and again immediately after the machine is started to make certain that they are revolving freely.

The oil circulating and oil lift systems (where provided) should then be installed and piping connections completed.

(E) Lubricating Oil

The bearing pedestals should be filled to the normal level, with any good grade of lubricating oil which is free from acid and which has a viscosity of 200 to 250 sec. Saybolt at 100°F.

(F) Oil Circulating Pumps

All air-cooled synchronous condensers have ring oiled bearings. Synchronous condensers below 10,000 Kv-a. in rating have self-cooled bearings.

Synchronous condensers, 10,000 Kv-a. and larger, require external cooling of the lubricating oil. A motor-driven oil circulating pump is provided for each of the main bearings and is mounted in a fabricated enclosure located on the bedplate as close to the bearing as possible. Note Fig. 14 for typical arrangement. The oil is pumped from the base of the bearing pedestals, through a heat exchanger (usually oil to water type) and back into the bearing.

After installation and before placing the synchronous condenser in service, the motors and pumps (where provided) should be checked to be sure that oil is being circulated through the bearings.

Since the external coolers (where provided) are mounted by the customer in a location apart from the machine, the standard machine accessories do not include the piping or any metering devices between the pumps and the cooler. Therefore, to be sure that oil is flowing, it is recommended that the purchaser install a sight-flow gauge in the piping from each bearing. For typical location and piping arrangement note Fig. 14.

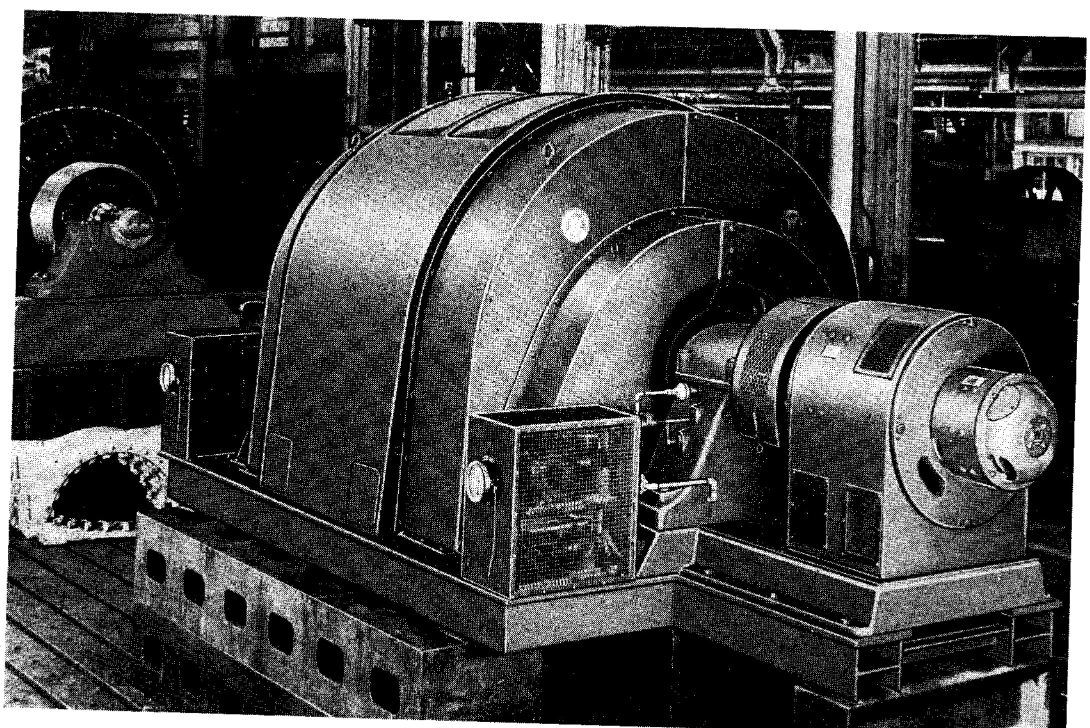


Fig. 14—Shop View of a Synchronous Condenser Showing Main and Pilot Exciters, Collector Covers, Lift and Circulating Pump Housing.

After completion of installation, the circulating system for each bearing should be tested for leaks.

(G) Oil Lift Pumps

Standard air-cooled synchronous condensers, 7500 Kv-a. and above in rating, are provided with oil pressure starting equipment. Each bearing is provided with a separate complete system. The equipment consists of a motor driven high pressure oil pump, necessary piping and gauges. The equipment is mounted in a fabricated enclosure located on the bedplate as close to the bearing as possible. Note Fig. 14 for typical arrangement.

The purpose of this equipment is to force oil in under the shaft journal and thereby reduce the coefficient of friction and the starting torque. By reducing the starting torque the inrush from the line is reduced during the starting period. This is important in cases where the system capacity is relatively small and where excessive starting inrush would cause objectionable voltage disturbances.

Before attempting to start the condenser, the lift pump motor circuit should be checked and energized to be sure that adequate pressure is developed by the pump. Contact making pressure gauges are supplied as standard equipment. These gauges indicate the pressure being developed by the pump and the contacts may be so interlocked with the main starting switch that it cannot be closed until pressure reaches a predetermined value. Depending upon the size of the synchronous condenser, the pressure at the first start will vary from 1000 to 1500 lb. per sq. inch. Subsequent starts will show a pressure in the order of 700-800 lb. per sq. inch. The reduction in pressure after the first start is due to an oil film having been established between the bearings and the shaft. This is normal and to be expected.

To be sure that the oil lift hole in the bottom of the bearing is not clogged, a check should be made to be sure the shaft actually lifts from the bearing. In some cases, this movement can be determined by placing the hand on the shaft, with other machines it may be necessary to use an instrument to detect the movement.

Failure of the pumps to lift the condenser rotor, may result in excessive heating and damage to the damper windings.

In order to avoid starting trouble due to chattering of the pressure gauge contacts, it is the usual practice to connect these contacts to an "SG" auxiliary relay which is adjusted to close when the oil pressure reaches 400 lb. per sq. inch, and to remain closed until the machine is on the line. This "SG" relay operates a "CV" time relay which starts the oil lift pump motors to lift the shaft before the starting circuit breaker is closed.

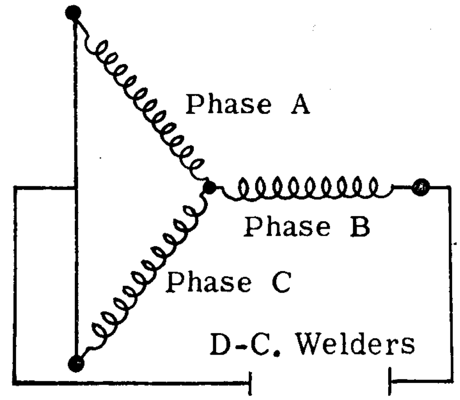


Fig. 15—Connection Diagram Using D-C. Welders.

The pressure gauge is set at 400 lbs. per sq. inch to permit starting when the shaft is rotating, in which case the pressure developed by the pump is lower than when the shaft is stationary.

The oil lift piping system is provided with a pressure damper which depends for its operation upon the compression of oil in a heavy steel reservoir. The purpose of this damper is to damp out all pressure pulsations originating in the oil lift pump which, if not damped out would ultimately ruin the gauge.

This damper is provided with a very small orifice consisting of an .026 inch diameter pin in an .032 inch hole. If any air is trapped in the damper, the rate of flow of oil through the orifice is so small that it takes a very long time for the pressure to build up in the damper. This condition makes it appear as though the lift pumps are not operating satisfactorily.

It is therefore important that the damper and oil pressure gauge connections be completely filled with oil and arranged so that air cannot be trapped in them. The most practical way is to have pipe vent plugs placed at the highest point of the system.

Special attention to these small details will insure that the oil lift system will operate satisfactorily.

(H) Checking Air Gap and Completion of Erection

After the rotor has been lowered into its final position and the bearings have been completely assembled, the air gap should be checked by use of feeler gauges at both ends of the rotor. The gauges should be long enough to reach the center of the machine. If the air gap variance around the periphery of the rotor is not more than 10%, the assembly can be considered satisfactory.

Check the rotor for end play and magnetic center.

INSTALLATION (cont'd)

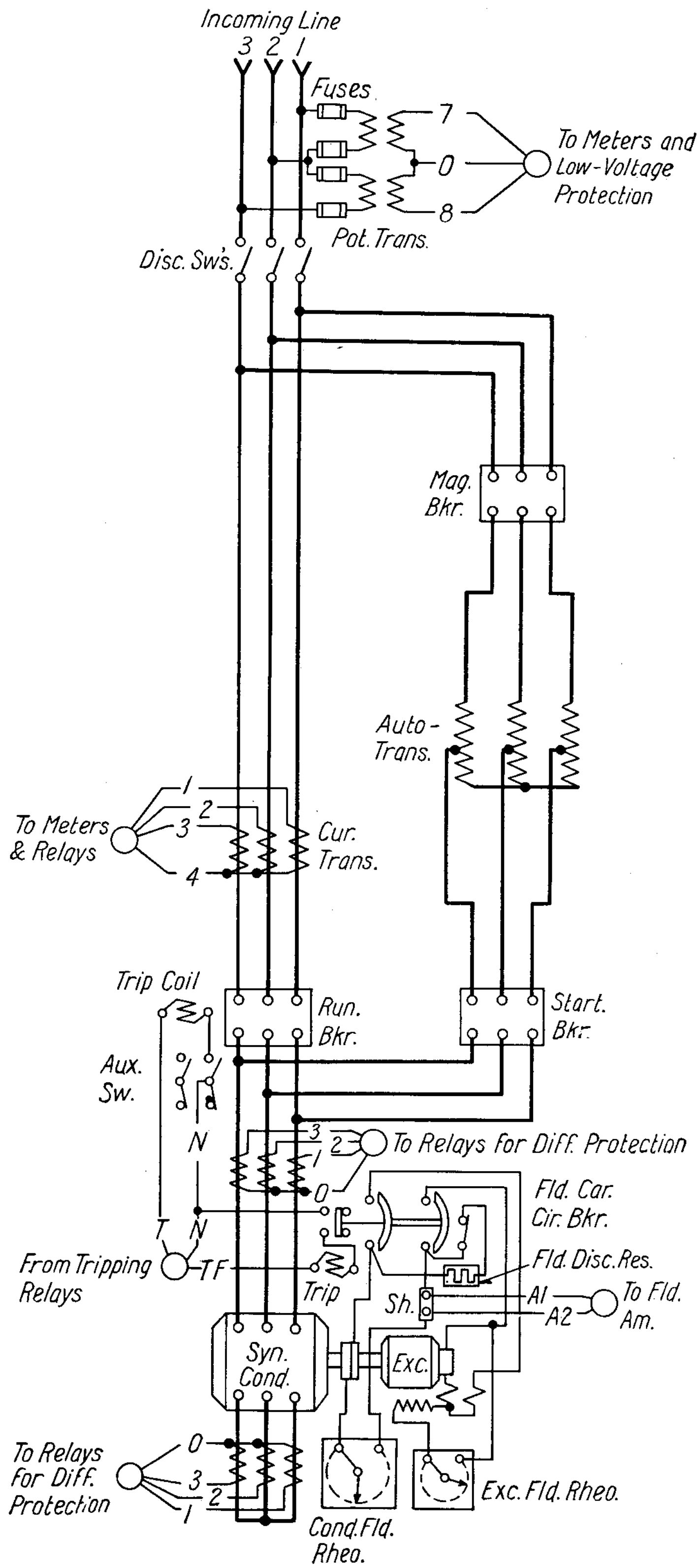


Fig. 16—Typical Diagram of Connections for Manually-Controlled A-C. Self-Starting Synchronous Condenser.

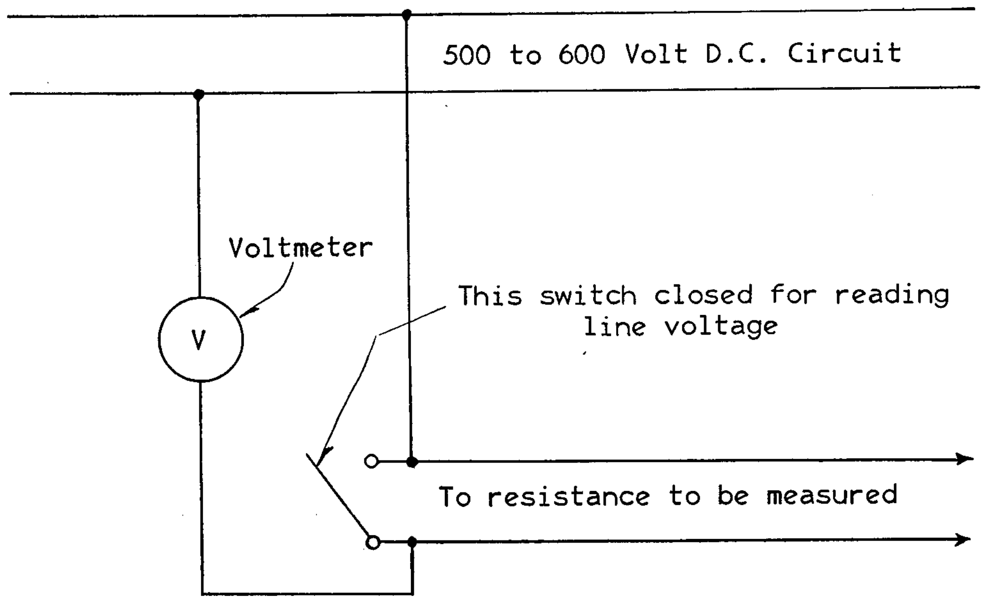


FIG. 17—DIAGRAM OF CONNECTIONS FOR MEASURING INSULATION RESISTANCE.

With the complete unit now assembled on the bedplate, it should be permanently grouted in. Care should be taken to be sure that all parts of the fabricated bedplate are well filled with grout.

Next assemble the exciter, condenser field brush rigging and the condenser end bells. Then complete the installation by assembling and installing all accessory apparatus such as surface air coolers; starting auto-transformer, reactor, or motor; outdoor housings; enclosures; and measuring and indicating devices (as provided).

CAUTION

Care should be taken to be sure the ventilating ducts in the stator and the interpolar spaces between the field poles are free from foreign material, which will interfere with the ventilation of the unit. It happens occasionally, that workmen may leave waste, rags, paper or other materials in a machine after the work of erection is completed. The time required to exhaust these possibilities is always well spent.

(I) Drying Out Windings

The stator winding, rotor winding, and collector insulation should be kept warm and dry during the erection of the condenser and also after erection until the equipment is operating, particularly if the unit is not placed in service within a short period after delivery or if the equipment has been exposed to wet weather in transit.

Various methods of drying-out can be used depending upon available facilities at the time and place of erection. If the machine parts have been exposed to moisture during shipment, they should be covered with a tarpaulin or enclosed by any other suitable means. If a source of electrical power is available, space heaters can be located within the enclosure and below the windings to dry them out.

Frequently D.C. welder sets are available and can be used to circulate current through the windings. Two large welders will in most cases be sufficient to satisfactorily dry out the windings. The welders can be connected to the stator winding as shown in Fig. 15.

The field winding can be dried out by connecting the welders to copper clamps attached to the collector rings. The copper clamps will prevent burning of the collector rings.

A small fan can be used to provide some circulation of air and thereby accelerate the drying-out process.

In general, the drying should proceed slowly at first, with the heating gradually being increased as the insulation dries. The temperature of the insulation as measured by thermometer should not be allowed to exceed 65°C. If embedded temperature detectors are used to read temperature, the permissible temperature is 80°C.

(J) Insulation Resistance

Insulation resistance measurements should be taken periodically throughout the drying-out period. It will usually be noted that the resistance will decrease at the start of the dry-out but will finally increase until the values are reasonably constant. When the resistance is constant and above the minimum value as recommended below the condenser can be placed in service.

Insulation resistance measurements are made to determine the condition of the insulation on the windings and should be made at regular intervals during the life of the machine.

The resistance may be measured by a megger or by using a 500 volt direct current circuit and a 500 volt direct current voltmeter. Fig. 17 shows a diagram of connections for this method of measuring insulation resistance.

Referring to the diagram, Fig. 17, the insulation resistance can be calculated from the following formula:

$$R' = \frac{R(V - V')}{V' \, 10^6}$$

where:

V = Line voltage.
V' = Voltage reading with the insulation in series with voltmeter.
R = Resistance of voltmeter.
R' = Resistance of the insulation — in megohms.

The insulation resistance of a machine at the operating temperature should not be less than that given by the following formula:

$$R\,(\text{Megohms}) = \frac{\text{Terminal Voltage}}{\frac{\text{Rating in Kv-a}}{100} + 1000}$$

A safe general rule is that the insulation resistance should be approximately 1 megohm for each 1000 volts of operating voltage.

PART IV

OPERATION

STARTING SYNCHRONOUS CONDENSERS

General

Synchronous condensers can be started by one or more of several generally recognized methods. These methods are as follows:

(1) A.C. self-starting by means of autotransformers or from taps on main power supply transformers which impress a reduced voltage (usually 20 to 35% of line voltage) across the terminals of the synchronous condenser.

(2) Starting by means of a direct-connected starting motor (usually a wound-rotor induction motor).

(3) A.C. self-starting by use of reactors to reduce the impressed starting voltage to the desired value.

(4) A.C. self-starting by a special series-parallel connection of the stator winding. The stator winding is designed for starting on the series connection and running on the parallel connection. This is equivalent to starting on a 50% voltage tap. The starting inrush current is greater for this method and can only be used on large systems where the starting demand is not a factor.

The most common method is to use autotransformers (method #1). The starting voltage can be selected to start the synchronous condenser satisfactorily with the minimum starting inrush and hence minimum system disturbance for this method of starting.

However, the very minimum of starting disturbance results when a wound-rotor motor is used (method #2) This method is usually specified only when the inrush for method #1 would cause intolerable system disturbances. The more general use of this method is limited by the fact that it requires auxiliary starting resistors, drum controller, more complicated switching and also occupies additional space in the station.

Only method #1 and #2 will be discussed in this book as they are the most generally used.

(A) Self-Starting—Method #1

After all sequence devices and auxiliary apparatus involved have been checked and found to be satisfactory, the condenser can be started in line with the following typical sequence.

(1) The field winding should be short circuited either through a starting resistor, the exciter armature or "dead shorted" as the case may be, before the starting cycle is begun.

CAUTION: Never start with field circuit open!

(2) Close the starter for the oil circulating pump motors, if such pumps are provided.

(3) Close the starter for the oil lift pump motors, if such pumps are provided. Standard synchronous condensers, rated 7500 Kv-a. and above, are equipped with oil pressure starting equipment to reduce the starting friction and hence the starting voltage and starting inrush. Note Fig. 14. The lift pumps (if provided) are to be operating before the circuit to the starting transformer is energized. Observe the pressure developed by the pumps to be sure it is adequate to lift the rotor, as determined by previous preliminary test.

OPERATION (cont'd)

(4) After the rotor is lifted, the starting breaker should be closed thus impressing reduced voltage across the condenser terminals.

(5) When the machine has begun to turn freely, the oil pressure pump can be shut down. It should not be allowed to run longer than necessary.

(6) When the condenser has reached approximately full speed, as it usually will on the starting tap, the field winding should be excited and the transfer made to line voltage.

If the field is connected directly to the terminals of the direct-connected exciter, the excitation is applied automatically.

The alternative method of first switching to full voltage and then applying the exciting current, is sometimes used. Should the switching arrangement be such that the circuit must be opened for an appreciable interval during the transfer from starting to running, there may be less line disturbance if this method is employed.

The determination of the most optimum excitation can be obtained as outlined in the following section titled "Optimum Transfer Current."

(B) Optimum Field Current Before Transfer To Line Voltage

Fig. 18 shows characteristic curves for an air-cooled synchronous condenser.

Curve "A", Fig. 18, is the "V" curve for a synchronous condenser having no load and full load saturation curves as shown.

The standard air-cooled synchronous condenser is designed for 50% lagging or under-excited capacity at rated voltage, with slightly more than zero field current.

Since the "V" curve is a plot of the variation in armature current with field current for a given voltage, the curve is fixed by the following points: (1) field current for rated stator current and rated voltage 0% P.F. leading (over-excited); (2) field current for no load rated voltage and zero stator current; (3) field current for one half (50%) rated stator current and zero field current. These points determine the "V" curve, "A". Since we are only interested in the leading or over-excited part of the curve, we will ignore the lagging portion or that portion having field current values below no load.

Another no load "V" curve based on the starting tap (in this case 20%) can be plotted, such as curve "B". If the ordinates of this curve are referred to line voltage by multiplying by the per cent starting voltage (in this case 20%), the curve "C" will be obtained.

The intersection of curves "A" and "C" will give the optimum field current I_F to be used before transfer to line voltage.

(C) Induction Motor Starting—Method #2

An air-cooled synchronous condenser, which is provided with a wound-rotor induction motor can be started in accordance with the following outlined general procedure. The starting equipment consisting of starter control, circuit breakers, contactors, timing relays and other switchgear is not necessarily supplied with all synchronous condensers having a starting motor. The equipment involved will vary considerably from that required for manual starting to that required for automatic starting. Fig. 19 shows a simplified diagram for induction motor starting. In the case of automatic starting the auxiliaries such as contactors, relays, interlocks, timing devices etc. are so numerous that it is not feasible to cover them in this instruction book. The purpose of this discussion is to give the operator a brief yet complete, outline of the general starting procedure and the conditions to be satisfied for satisfactory starting.

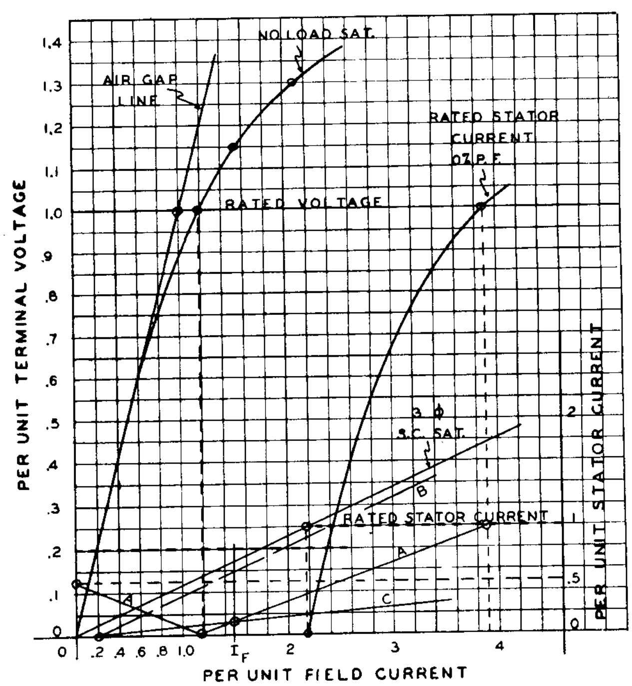


Fig. 18—Characteristic Curves for Air-Cooled Synchronous Condenser.

OPERATION (cont'd)

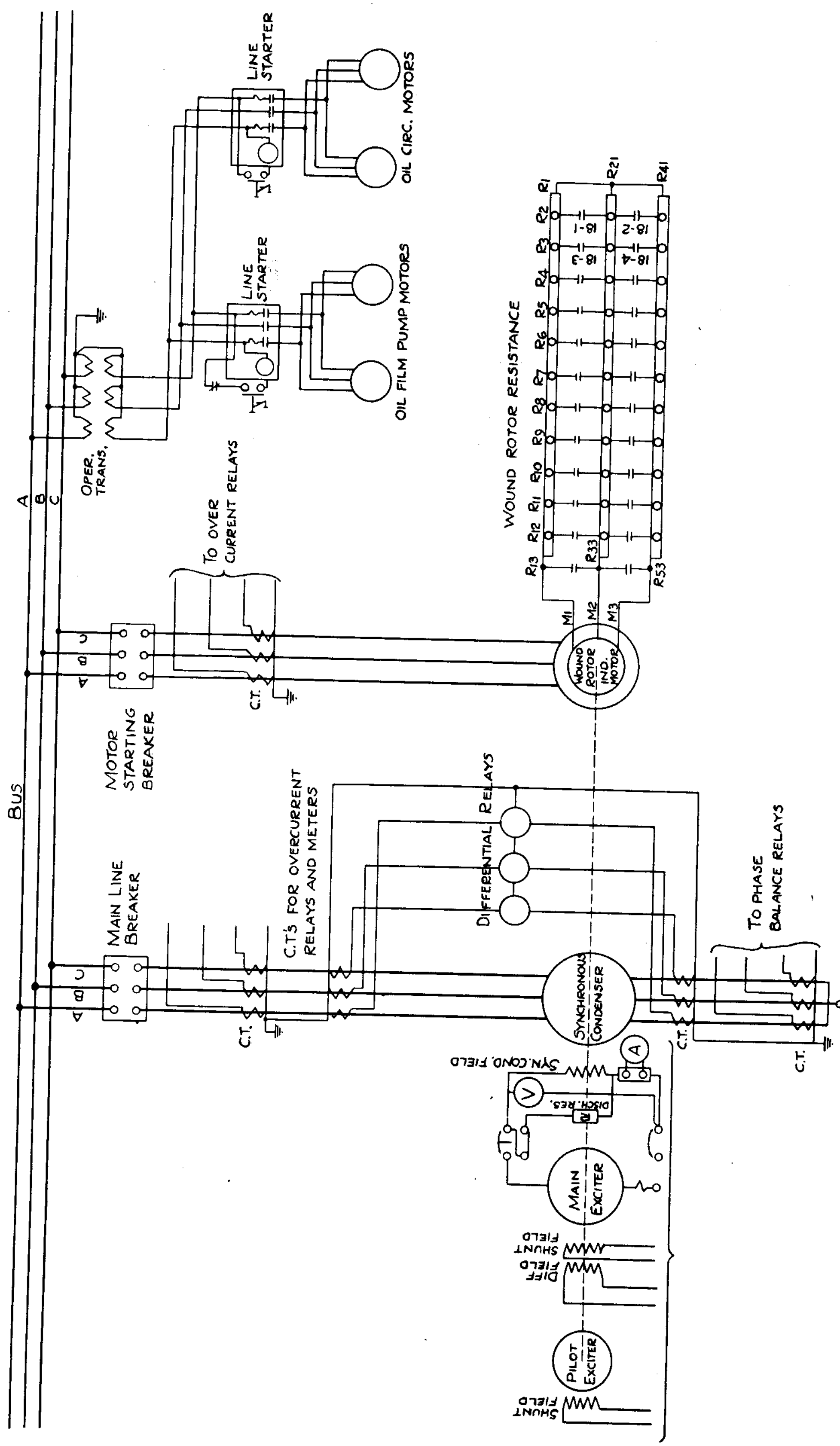


FIG. 19—SIMPLIFIED DIAGRAM OF CONNECTIONS FOR INDUCTION MOTOR STARTING A SYNCHRONOUS CONDENSER

OPERATION (cont'd)

CAUTION !

The following conditions must exist for a normal **start:**

(1) Starting bus must be energized.

(2) Starting and running circuit breakers must be open.

(3) The induction motor starter must be in the "start position."

(4) The line starters for auxiliary motors must be open.

(5) The field switches for the main and pilot exciter fields must be closed.

With the foregoing conditions satisfied, the starting procedure is as follows:

(1) Close the starter for the oil circulating pump motors, if such pumps are provided.

(2) Close the starter for the oil lift pump motors, if such pumps are provided.

(3) Close the condenser field breaker.

(4) Close the induction starting motor oil circuit breaker to start the motor.

In the case of automatic starting, the various breakers and other devices are interlocked so that closing of the sequence breaker can only be accomplished if the main closing circuit breaker is open; oil pressure is built up by both the lift and circulating pumps; and the starting motor resistance starter is in the starting position.

The closing of the induction motor starting breaker energizes the starting motor and also initiates the starting sequence of the motor starter.

The value of resistance which is inserted in the secondary circuit of the induction motor controls the acceleration to rated speed. After the synchronous condenser reaches rated speed, another value of secondary resistance will hold the speed until the condenser is synchronized on the **line.**

After the condenser is synchronized on the line, the starting motor is de-energized and the circuit to the lift pumps is opened.

SYNCHRONIZING

Before the condenser can be synchronized on the line, its field must be excited to generate rated A.C. voltage at the stator terminals.

Any commonly used method can be used to synchronize the condenser. The most general method is to use a synchroscope. If a synchroscope is not available, electric lights can be used and so connected that they will be dark when the voltages are equal and in phase.

When the conditions for synchronizing exist, that is, when the condenser voltage, phase rotation and phase angle is correct, the line breaker can be closed, thereby connecting it to the line.

CONDENSER OPERATION

A synchronous condenser differs in its function from other synchronous machinery in that it does not do any mechanical work or deliver any power. It actually takes some power from the system to overcome its losses. By control of the field current the corrective Kv-a. can be varied from rated capacity leading (over-excited) to rated capacity (usually 50% of leading capacity) lagging (under-excited). It is this characteristic which permits automatic control of system power factor or line voltage even though the load and power factor is a variable. The variation in A.C. amperes with field excitation is shown by the "V" curve "A", Fig. 18.

The standard synchronous condenser is designed to operate safely and continuously over a voltage range of plus or minus five per cent (5%) of its nameplate voltage when delivering its nameplate Kv-a. at zero per cent power factor (over-excited).

It should be noted that operation above the Kv-a. and voltage range for which the machine is designed may result in excessive heating and hence shortens the life of the machine.

Since a synchronous condenser does not deliver any mechanical load, the shaft and bearing dimensions are determined by bearing load and not torque.

CONDENSER SHUT DOWN

When the condenser is to be shut down, the following sequence should be applied.

(1) Unload the condenser by reducing the excitation to the no load value (note saturation curve Fig. 18).

(2) Trip the main circuit breaker.

(3) Trip the field circuit breaker.

(4) After the condenser rotor has come to rest, shut down the oil circulating pump motors. Each of these operations is performed manually.

PART V

MAINTENANCE

CAUTION !

Keep the machine clean! If the ventilating ducts become "clogged" with dirt and foreign material the machine will operate at increased and possibly dangerous temperatures and its life will be materially reduced. The presence of conducting material such as oil and carbon dust, in sufficient quantity, can provide paths for surface discharges which may seriously reduce the life of the coil insulation and the structural material such as spacers and blocking.

Do not permit the machine to operate for extended periods of time without a thorough inspection. Periodic inspections will frequently reveal minor troubles such as movement of stator coils due to loose coil end bracing, presence of dirt or oil on windings, looseness of stator iron, etc., any of which if neglected may result in machine outage and costly repair bills.

CLEANING

Several methods are commonly used to clean the windings of electrical apparatus. The most effective method will depend upon the type and degree of "dirtiness" of the apparatus to be cleaned.

Compressed air is the most convenient method of removing an accumulation of dirt which is not too firmly fixed to be blown out. The only precautions to be observed are that the air line be free from moisture, and that the dirt be blown and not **compacted** or **embedded** into some inner recess within the machine where it will be difficult to remove and where it may close some of the ventilating ducts. The air pressure should be about 50 lb. per sq. inch.

Warm water can be used effectively when the dirt is soluble in water. The washing should be rapid and the parts which are washed should be wiped immediately with a dry cloth and then dried. A jet of hot air, if available, may be used or the apparatus can be covered with a tarpaulin and some source of heat used to dry out the apparatus.

Solvents should be used where the accumulation of dirt contains grease or oil. There are several solvents which can be used to remove grease and oil from machine parts but the one which is generally recommended and generally used is carbon tetrachloride.

Carbon tetrachloride is an active solvent and somewhat corrosive in its action. It should be applied sparingly with sponges or rags. Thorough drying afterwards is essential to avoid damage to the insulation.

CAUTION !

Carbon tetrachloride is a non-inflammable compound—**but it is toxic** and must be used intelligently. The chief danger in its use is that the vapor is heavier than air and will accumulate in pits or confined spaces. It should only be used in locations which are adequately ventilated, as prolonged or concentrated exposure to the fumes is dangerous to life and respiratory membranes.

The Mine Safety Appliance Company make a special nose mask which is recommended as a protection against over exposure to such fumes.

As an additional safety measure it is suggested that any cleaning work be done by more than one workman. With more than one workman it is not likely that all would be affected simultaneously and if one is overcome the others can help him to fresh air.

After the windings have been cleaned, it is recommended that a coat of insulating varnish be applied to protect the insulation.

COLLECTOR RINGS AND BRUSHES

(A) Sparking

If sparking between the brushes and the collector rings should develop, the following **usual causes** should be investigated and the suggested remedy applied.

	Usual Causes	Suggested Remedy
(1)	Insufficient brush pressure.	Adjust to 2 lb. for grooved rings and 3 lb. for smooth rings.
(2)	Brushholder vibration.	Remove source of vibration.
(3)	Brush chatter.	Change to less abrasive brush. Grade L-1 brush should be used with the standard condenser.
(4)	Oil vapor.	Clean ring and brush surfaces and remove source of oil vapor.

MAINTENANCE (cont'd)

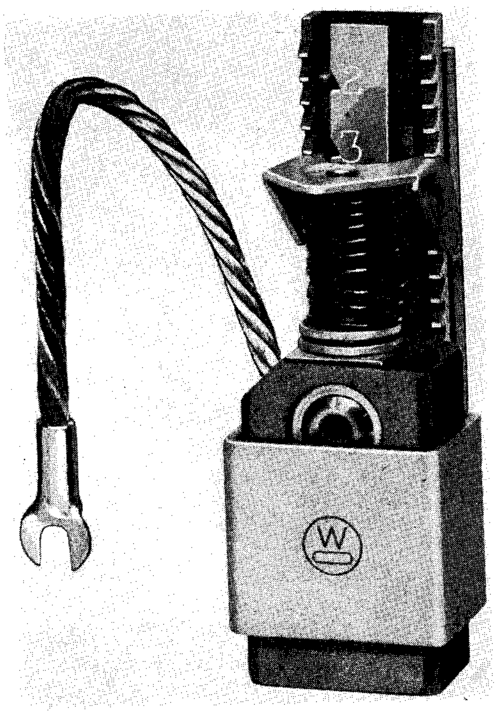


FIG. 20—TYPICAL BRUSHHOLDER AND CARBON BRUSH.

	Usual Causes	Suggested Remedy
(5)	Collector ring truth.	True up by grinding or turning surface of rings — preferably at full speed.
(6)	Spotted rings.	Change to a more abrasive brush.

(B) Selective Action Between Brushes

This condition is generally aggravated by any of the causes of brush sparking and if the same remedies are applied, it will usually be improved.

This action is attributed to the formation of an air film under some of the brushes and has been generally eliminated by the wiping action of helical grooves in the ring surface.

(C) Collector Rings

The collector rings of standard-air cooled synchronous condensers are made of steel. The surface of the rings is grooved to eliminate selective action of the brushes.

In general, collector ring troubles can be attributed to four causes: (1) uneven wear, (2) unclean surface, (3) development of spots, and (4) formation of brush imprints.

(1) Occasionally uneven wear will result if the ring material is not of uniform hardness. The only ultimate cure for this trouble is to replace the rings.

(2) It is important that the collector rings be kept clean at all times. If dirt and dust are permitted to accumulate, sparking and cutting of the ring surface will usually result. Many collector ring troubles are due to lack of proper care and maintenance.

(3) Spotting of the ring surface develops in some cases for reasons which are not well understood. These spots are not serious in themselves, but will lead to pitting of the rings unless removed. If the condition is corrected as soon as it is found, by lightly rubbing with fine sandpaper, no harm will be done to the rings.

(4) Sometimes an imprint of the brushes will be found on the surface of the collector rings. This usually occurs on a machine which is exposed to moisture or acid fumes. When the machine is not operating, the fumes act on the surface of the ring which is not in contact with the brushes. The difference in surface condition caused by this action may cause a slight burning as the ring rotates. Brush imprints due to moisture or fumes will occur at any point where the machine happens to stop, as compared to imprints due to ring inaccuracy, which will always occur at the same place on the ring.

Brush imprints on the rings may also be caused by a slight inaccuracy which may cause a jerk or movement in the brush once every revolution. The brush jumps slightly with a small arc, which in time, burns an imprint of the brush on the ring. Elliptical or egg-shaped rings may also cause this condition.

The remedy for these troubles, of course, is to remove the cause. When "truing-up" a ring be sure to grind or turn the surface at full speed. Hand grinding or turning is not advised because the eccentricity may actually be increased by this method.

BEARINGS

The design of Westinghouse bearings has a background of many years of operating experience and with reasonable maintenance and attention they should give long and trouble-free service. Periodic inspections should be made to be sure the oil level in the bearing pedestal is up to the normal mark on the gauge. The oil should be sampled at intervals to check its viscosity and purity and to be sure it is acid-free. Openings are provided in the bearing cap over the oil rings for the purpose of adding fresh oil and inspection of the oil rings.

The bearings of synchronous condensers may be provided with temperature detectors or indicating thermometers embedded in the bearing shell close to the bearing surface. These are specified as accessory apparatus.

The temperature of the bearing should be observed regularly by the operator so that a sudden change or an unusual rise in temperature can be detected. A normal continuous operating temperature as determined by the embedded detectors is 80 to 85°C. If bearing thermostats are supplied with the condenser, they are usually set to sound an alarm or trip off the machine at a temperature of 96°C.

If external oil coolers are required to cool the bearing oil, such coolers should be inspected regularly to be sure they are clean and operating efficiently.

The cause of overheating of a bearing may be any one of, or a combination, of the following:

(1) Insufficient oil in the reservoir.

(2) Dirty oil or oil of poor quality.

(3) Failure of oil rings to revolve.

(4) Excess end thrust resulting from an installation with the bedplate badly out of level or from the axial magnetic pull resulting from the magnetic centers of rotor and stator being out of line.

(5) Pitting due to bearing currents.

(6) Rough bearing surface due to corrosion.

LUBRICATING OIL

Keep the oil in the bearings clean! The frequency of oil changing depends to such an extent on local conditions, such as severity and continuity of the service, the room temperature, the state of cleanliness, etc., that no definite instructions can be given. A conservative recommendation would be to clean and refill the bearing and pedestal every six months.

Use any good grade of lubricating oil, free from acid and having a viscosity of 200 to 250 sec. Saybolt at 100°F.

ROTOR WINDINGS

Maintenance of the rotor should begin by measurement of the insulation resistance prior to placing the unit in service. Following this, a thorough check-up of all parts of the rotor should be made at the end of a year's operation and annual inspections thereafter should include the following steps:

(1) Check damper winding for loose bars in the iron, connections of each bar to the ring segment, and joints in ring segments between poles.

(2) Check clearance between blowers and coils.

(3) Check for movement or shifting of field coils.

(4) Check the dirt on winding and take cleaning steps necessary.

(5) Inspect strap field coils for condition of turn-to-turn insulation.

(6) Check condition of ground insulation and washers or collars.

(7) Check connections between coils and to the collector.

(8) Measure insulation resistance to ground of field winding, including the collector using a device which applies not more than 500 volts D.C. from the winding to ground.

(9) Refinish with suitable, recommended varnish as required.

STATOR WINDINGS

Maintenance should begin with operation of the unit and therefore, before the unit is started, measurements should be made of the stator insulation resistance. It is desirable to take this reading immediately after the dry-out run at the elevated temperature as this would provide a more nearly correct "bench mark" for future reference. Take these readings in line with rules previously outlined in these instructions.

Annual inspections are recommended unless unusual service conditions require more frequent inspection. The first annual inspection should include a thorough check-up of all parts of the stator windings as listed below, as well as a general clean up of the winding, by blowing with dry air or by wiping with dry rags. If the winding is dirty, take cleaning steps necessary with solvents as described in section titled "CLEANING."

After the first annual inspection, subsequent inspections should include the following steps along with proper cleaning as necessitated by service conditions:

(1) Check for loose wedges.

(2) Check for broken, damaged or missing wedges.

(3) Check end wedges for movement at the end of the core and all other wedges for position.

(4) Check coil ends for distortion.

(5) Check security of all lashing and spacers.

(6) Check tightness of coil support brackets, if any.

MAINTENANCE (cont'd)

(7) Check for loose coils in the slots.

(8) Check coil ends for cracks in the insulation or other mechanical damage.

(9) Check all connections between coils and connections around frame.

(10) Measure insulation resistance of winding to ground, from the machine terminals.

(11) Clean thoroughly where required.

(12) Protect the finish by revarnishing as needed. Use only varnish or compound recommended by manufacturer. Never varnish or paint a dirty or greasy winding.

INSULATION RESISTANCE

Insulation resistance is useful in determining the presence of moisture or dirt upon the winding surface, and a complete record kept of insulation resistance is useful in determining when cleaning or drying of the windings are necessary. It is suggested that insulation resistance readings be taken every six months, preferably summer and winter, and over a period of years. Any sudden trend of the insulation resistance values will indicate that maintenance steps need be taken. The method of taking insulation resistance should be definitely controlled, as described under section titled "Insulation Resistance," and the following routine is suggested:

(1) Adopt a definite time of application for taking readings, preferably after 1 minute of voltage application.

(2) Always use the same voltage instrument.

(3) Keep a complete record of date, temperature of winding and ambient temperature, relative humidity and condition of winding. Insulation resistance factor varies from 1 at 75°C. to about 14 at 25°C.

(4) Take readings at machine terminals, being sure other cable, switches, etc., are isolated.

(5) Whenever motor driven or electronic instruments are used to take readings over a period of time longer than 1 minute, as in the case of dielectric absorption curves, it is essential that, before a repeat reading of the same part is taken, that the winding be discharged to ground for a time at least equal to the total time of voltage application when readings were first taken.

ROTOR

(A) Pole Dovetail Keys

The rotors of all air-cooled synchronous condensers are given a "shake-down" run at the factory. This consists of running the rotor at 25% above the rated speed for a period of time; bringing it to rest and then driving the dovetail keys. It has been found that the keys which were driven in initially, before the rotor was run at the overspeed, can usually be driven in another 1 or 2 inches after the "shake-down" run. This procedure assures that the keys will be tight and remain tight under normal operation, after the unit is placed in service.

During the operation of the condenser it is periodically started and stopped and in so doing may be subjected to "bumps". Also it may be operating single phase during fault conditions and be subjected to vibration. In addition there is some further seasoning which takes place as a result of temperature changes and centrifugal forces. As a result of such operating conditions, the dovetail keys may loosen and require periodic tightening. If sufficient key material is projecting beyond the spider, the keys can be driven tight by use of a sledge. In some extreme cases it may be necessary to drive out the old keys and replace them with new keys. This is quite improbable if the unit is regularly inspected and properly maintained.

(B) Field Coil Braces

Due to the proportions and speed of the larger synchronous condensers, it is necessary to brace the field coils against the action of centrifugal forces by the use of one or more coil braces, which bear against the sides of the coils. These braces are insulated from ground by micarta spacers located between the braces and the coil sides. The braces are kept in position by means of bolts tapped into the rotor spider.

After the condenser has been in service for some time, the insulating spacers may shrink to some extent and may compress slightly due to the forces acting upon them. This action may result in the braces becoming loose. Therefore, the braces should be checked periodically and tightened if necessary. Failure to keep the coil braces tight will result in unbalance and may lead to more serious trouble.

RE-INSULATION OF FIELD COILS

After some period of operation, the condenser rotor may develop short-circuited turns or grounds. **Such developments do not mean that the material or workmanship was inferior at the time of manufacture.** Abnormal operation; failure to keep machine parts clean; failure to keep field coil braces and dovetail keys tight; can all be instrumental in causing such troubles.

When such troubles develop, the repair work should not be undertaken by the Purchaser.

MAINTENANCE (cont'd)

The ground insulation between the field coil and the pole consists of mica and asbestos which is built up on the entire inside surface of the coil. The operation requires tools and baking processes which are not available to the Purchaser. Also the turn insulation is a specific material which is subjected to a variable but pre-determined pressure under large hydraulic presses.

It is therefore recommended that field coils needing re-insulation be returned to the manufacturer's headquarters.

Considerable difficulty may be experienced in some cases in removing the poles and coils from the rotor. This is generally due to the fact that the dovetail keys become rusted and frozen to the spider. In such cases it may be necessary to use special tools, materials and methods which may not be available to the Purchaser. Many purchasers, therefore, return the entire rotor and bearings to the manufacturer, as it is then possible to run the rotor in its own bearings; shake down the rotor; drive in the dovetail keys and balance the reassembled rotor.

The Westinghouse Electric & Manufacturing Company recommends the return of the entire rotor when major field coil repairs are necessary.

REPAIRING

Repair work can be done most satisfactorily at our nearest service shop. However, interchangeable renewal parts can be furnished as listed below, to Purchasers who are equipped to do the work.

ORDERING INSTRUCTIONS

When ordering renewal parts, give the complete nameplate reading of the machine. Always give the name and style number (if known) of the part wanted, also the stock order number of the apparatus on which the part is to be used. Refer to the back of this book for the nearest sales office from which to order parts.

RECOMMENDED STOCK OF RENEWAL PARTS

The following is a list of the Renewal Parts and the quantities of each that we recommend should be stocked by the user of this apparatus to minimize interrupted operation caused by breakdowns. The parts recommended are those most subject to wear in normal operation or those subject to damage or breakage due to possible abnormal conditions.

This list of Renewal Parts is given only as a guide. When continuous operation is a primary consideration, additional insurance against shutdowns is desirable. Under such conditions more renewal parts should be carried, the amount depending upon the severity of the service and the time required to secure replacements.

Synchronous Condensers

Condensers in use up to and including		1	5
Name of Part	No. Per Unit	Recommended For Stock	
Armature Coil—Stationary	1 Set	1/3 Set	1 Set
Cut Winding Insulation	1 Set	1/3 Set	1 Set
Revolving Field Coil—Open	1 Set	1	1
Revolving Field Coil—Crossed	1 Set	1	1
Brush	1 Set	1 Set	2 Sets
Brushholder	1 Set	1/3 Set	1 Set
Bearing Lining—Front	1	1	1
Bearing Lining—Rear	1	1	1
Oil Ring—Front	1 Set	0	1
Oil Ring—Rear	1 Set	0	1