INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

Hydrogen-Cooled

SYNCHRONOUS CONDENSERS

10,000 to 100,000 kva
514 rpm to 900 rpm

WESTINGHOUSE ELECTRIC CORPORATION
TRANSPORTATION AND GENERATOR DIVISION
EAST PITTSBURGH WORKS • EAST PITTSBURGH, PA.

NEW INFORMATION

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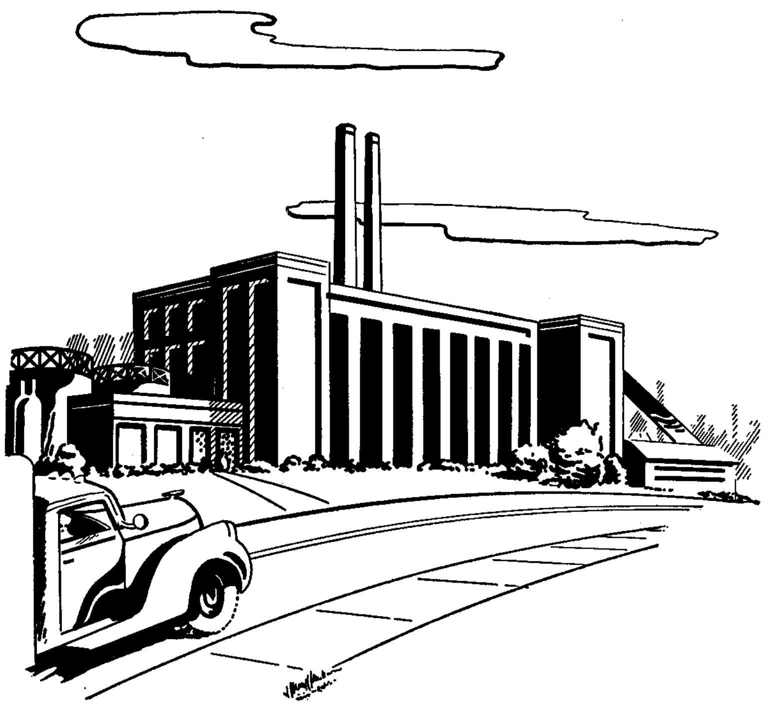

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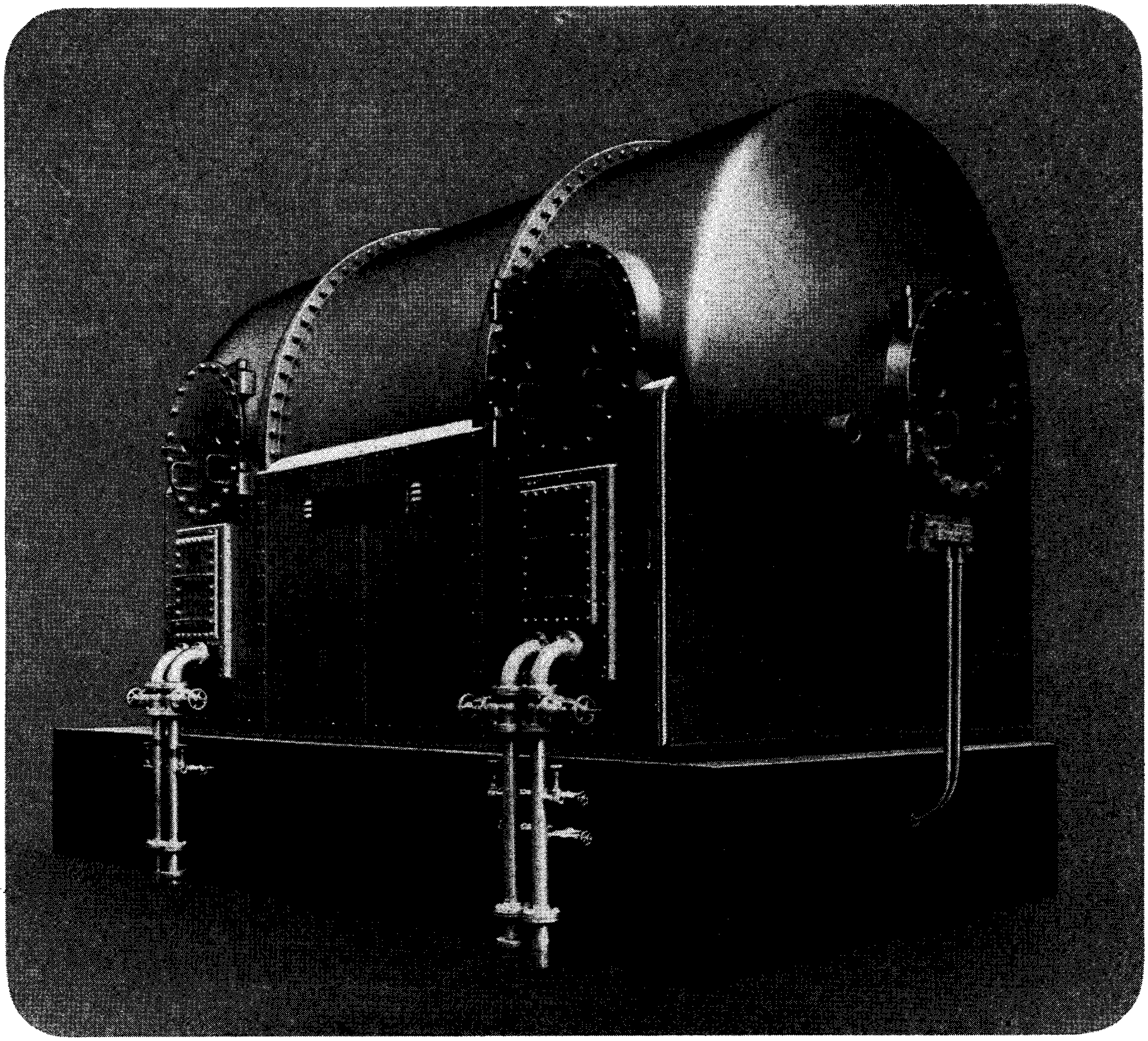


HYDROGEN-COOLED SYNCHRONOUS CONDENSERS

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 hydrogen cooled synchronous condensers differ from the air cooled synchronous condensers primarily in construction. This is due to the fact that the ventilating system is made gas tight and suitable for operation at higher pressures. The hydrogen gas is circulated through the ventilating circuit, consisting of the machine rotor and stator, and the heat exchangers. (See Figures 1 and 2).

Since the synchronous condenser does not drive any mechanical load, the entire assembly, including shaft and bearings, is generally completely enclosed except when direct connected air cooled exciters are used as described elsewhere in this book. With this construction, it is less of a problem to reduce the gas leakage to a minimum because it is not necessary to provide sealing glands around a shaft extension. The standard hydrogen cooled synchronous condenser is designed to operate over a range in capacity from full kva over-excited to forty-one and two thirds ($41\frac{2}{3}$) per cent of the rated kva capacity under-excited. This range is at rated voltage without exceeding the nameplate temperature rise. As in the case of the air cooled condensers, the hydrogen cooled units can be used to automatically correct the system power factor and control the system voltage by means of field control.

All Westinghouse hydrogen cooled 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 gas temperature of not more than 40°C. Heat exchangers within the machine enclosure absorb the heat equivalent of the losses and maintain the ingoing gas temperature at not more than 40°C.

Hydrogen cooled synchronous condensers are standardized over a range of capacities from 10,000 kva to 100,000 kva. The speeds vary from 900 rpm to 514 rpm.

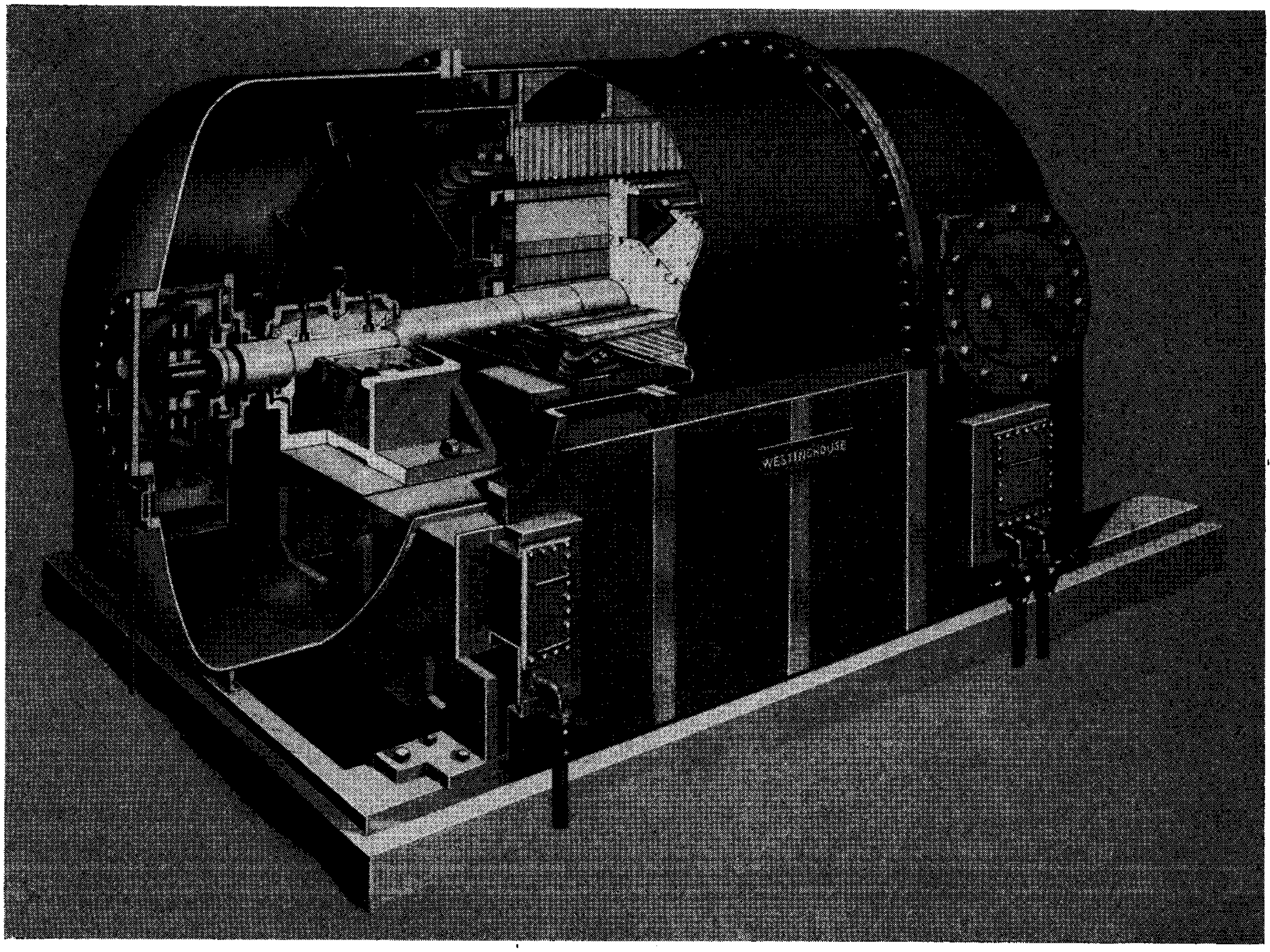


FIG. 1. Cutaway View of Standard Hydrogen-Cooled Synchronous Condenser

DESCRIPTION

A general understanding of the construction of the hydrogen machine, and the functioning of auxiliary equipment, is necessary in order that the succeeding sections on installation, operation and maintenance will be the most helpful. The frontispiece and Figure 17 show typical installation views, and Figures 1, 2 and 3 show cross section views of typical hydrogen cooled synchronous condensers. It is recommended that the reader study these illustrations in conjunction with the following pages of descriptive matter covering the condenser and auxiliary equipment.

The standard condenser is supplied complete with the following equipment:

1. Enclosing housing suitable for outdoor operation.

2. Steel shaft.

3. Sole plates.

4. Two ring oiled, water cooled bearings.

5. Damper windings.

6. Six embedded armature temperature detectors.

7. Six armature terminal bushings.

8. Two field terminal bushings.

9. Oil pressure starting equipment.

10. Surface type gas coolers based on 25°C. cooling water.

11. Indoor type induction motor generator set with pilot exciter to excite the condenser.

12. Two bearing oil level indicators.

13. Condenser field discharge resistance.

14. Motor operated main exciter field rheostat.

15. Hand operated pilot exciter field rheostat.

16. Water detector with alarm contacts.

17. Necessary valves and pipe fittings for the oil and gas piping and control.

18. Hydrogen control panel with accessories as follows:

(a) One hydrogen purity indicator (Inclined draft gage connected to measure fan pressure at normal speed.)

(b) One hydrogen pressure gauge.

(c) Two indicating type bearing thermometers with alarm contacts.

(d) Three indicating type cold gas temperature thermometers with alarm contacts, two for main enclosure and one for collector compartment except when collector rings are outside main enclosure then only two thermometers are supplied.

HOUSING

The sections comprising the housing (usually three), are fabricated from steel plate which is rolled and welded to form the required shapes. Since the housing must be gas-tight, the housing of the first machine of a new design is tested at the factory under water pressure and inspected for leaks at all welds and joints. As a result there is little chance of leaks at these points when the condenser sections are assembled in the field. The middle section contains the stator core and windings; the end sections, the bearings and main gas coolers. The front end section also contains the collector chamber in which are located the collector rings, brush rigging and a small cooler. This cooler maintains the gas temperature in the collector housing at approximately 40°C.

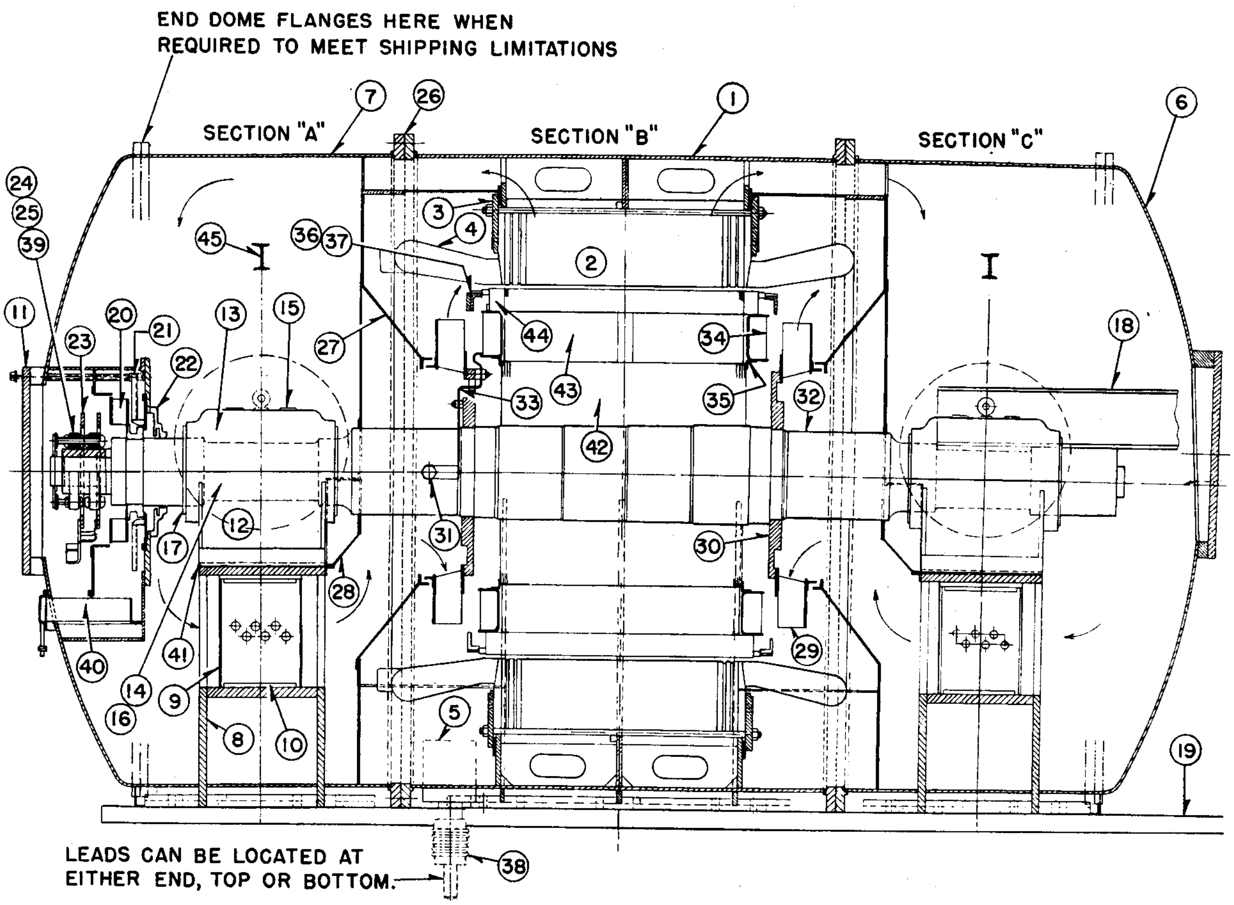
STATOR

Core. The stator core is built up of segmental high grade, non-aging silicon steel laminations. Both sides of the laminations are treated with an insulating material to prevent short circuiting the laminations. Adequate pressure is applied to the core during the stacking operation, to produce a tight core free from objectionable waviness.

Heavy finger plates and end plates maintain sufficient pressure on the core at all times to insure against loose iron and core vibration.

Stator Winding. The stator windings of all standard hydrogen cooled synchronous condensers consist of pulled type, form wound, interchangeable coils, which are insulated with class B insulation. (See Figures 4 and 5).

Class B insulation is identified by A.S.A. and N.E.M.A. Code BBBXV.



1 FRAME
2 ARMATURE PCHG. & VENTS
3 END PLATE
4 ARMATURE COIL
5 WIRING AROUND FRAME
6 END DOME
7 BEARING SUPPORT SECTION
8 BEARING SUPPORT ASSEMBLY
9 BEARING COOLER ASSEMBLY
10 GASKET FOR COOLER
11 HINGED COVERS (END HEAD)
12 PEDESTAL
13 BRG. SHELL (TOP HALF)
14 BRG. SHELL (BOTTOM HALF)
15 BEARING CAP
16 COPPER SLEEVE
17 PEDESTAL SEAL RING
18 ROTOR LIFTING BEAM
19 SOLE PLATE
20 COLLECTOR CHAMBER BLOWER
21 COLLECTOR SEAL ASSEMBLY
22 COLLECTOR HSG. SEAL RING
23 BRUSH HOLDER ASSEMBLY
24 BRUSH HOLDER
25 BRUSHES
26 GASKET FOR HOUSING
27 INNER END BELL
28 OUTER END BELL
29 MAIN BLOWER
30 MAIN BLOWER HUB
31 COLLECTOR LEADS IN SHAFT
32 MAIN SHAFT
33 FIELD LEAD CONNECTION
34 FIELD COIL
35 LOWER COIL SUPPORT
36 DAMPER WINDING
37 DAMPER RING
38 MAIN LEAD BUSHING
39 COLLECTOR
40 COLLECTOR COOLER
41 PEDESTAL INSULATION
42 SPIDER
43 POLE ASSEMBLY
44 UPPER COIL SUPPORT
45 LIFTING BEAM (FOR BEARING AND CAP)

FIG. 2. Cross Section View of a Typical Hydrogen-Cooled Synchronous Condenser

Temperature Detectors. Usually six temperature detectors are provided in the stator winding of a standard hydrogen cooled condenser to obtain a measurement of its operating temperature. The detectors are located at the center of the core and between the top and bottom coil sides in a slot. The detectors consist of copper wire having a resistance of 10 ohms at 25°C. The temperature coefficient of resistance is .00427. The detector leads are brought to a terminal board outside the housing, which is arranged so one lead of the detectors can be grounded to protect the operator.

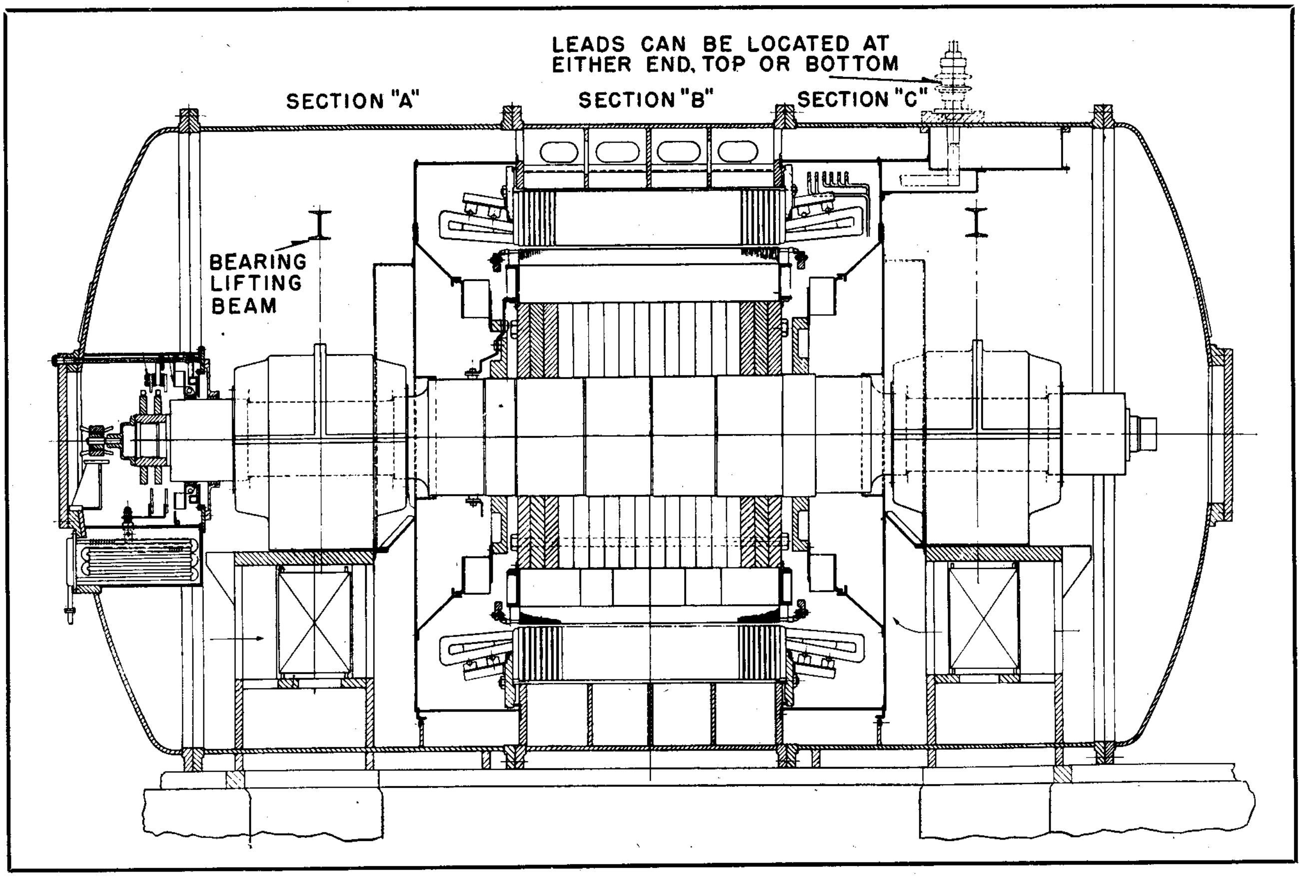


FIG. 3. Cross Section View of a Typical Condenser With Removable End Domes

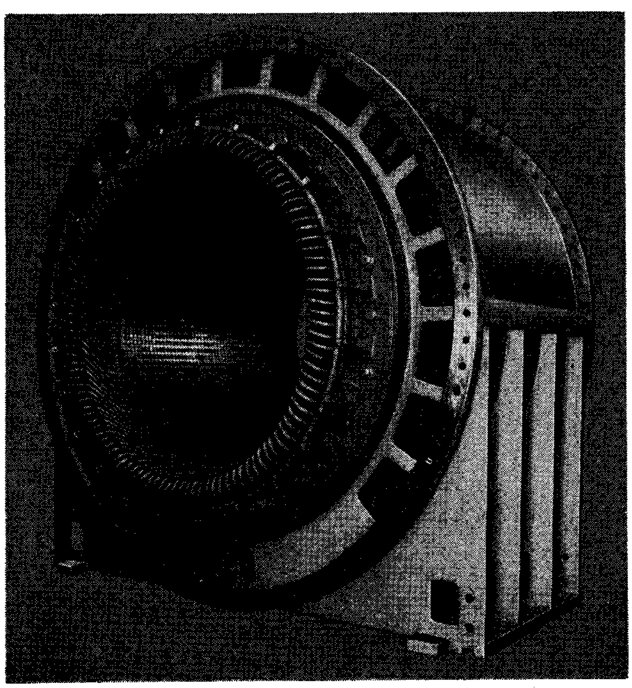


FIG. 4. View of a Wound Stator Showing Stator Coils and Bracing

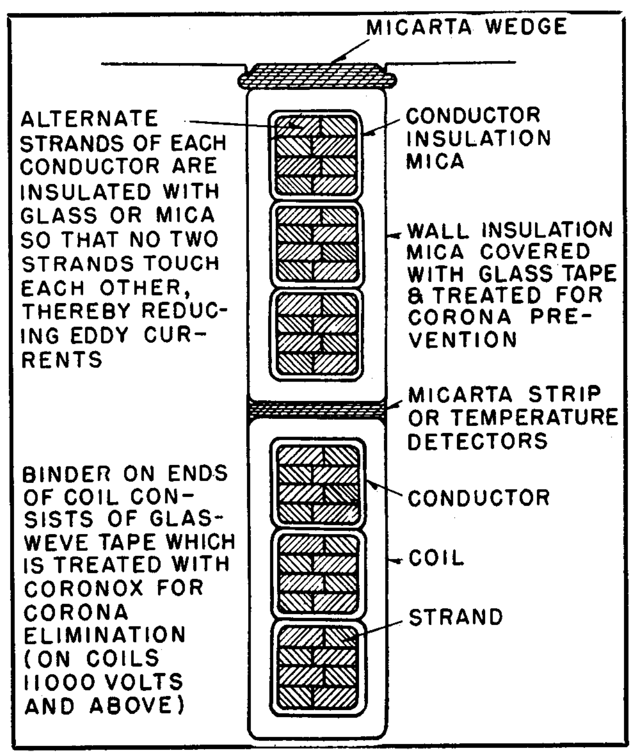


FIG. 5. Construction Details of Stator Coil

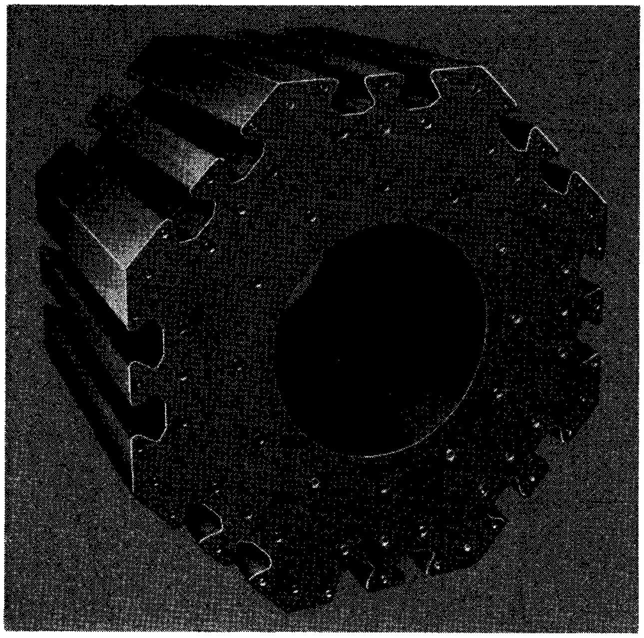


FIG. 6. Laminated Spider

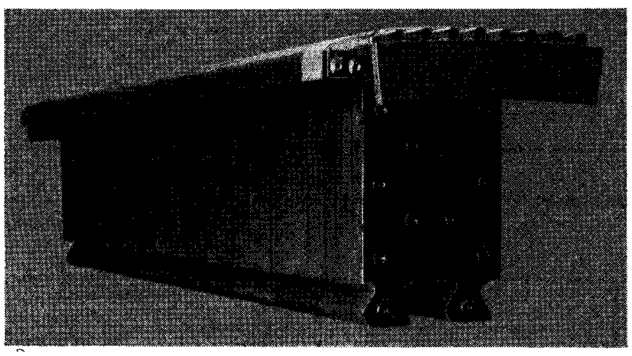


FIG. 7. Laminated Field Pole
Note Welded Damper Winding at Top Face

ROTOR

Spider. 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. In some special cases the spider is machined from a solid forging. Dovetail slots are punched in the laminations, or machined in the plate or forged spiders. These dovetail slots in the spider match dovetail projections on the rotor poles. Note Figs. 6 and 8 for typical spider construction.

Poles. The poles are built up of steel laminations riveted or bolted together under high pressure. Note Fig. 7 for typical pole construction. Dovetail projections on the pole engage with the dovetail slots in the spider, and the pole is held in position by tapered keys or wedges. In assembly, tapered keys are driven in from each side of the rotor. The taper is so slight (.005 in. per in.) 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, brushed with shellac, are placed between the turns. The partially completed coil is heated and pressed to squeeze out all the solvents.

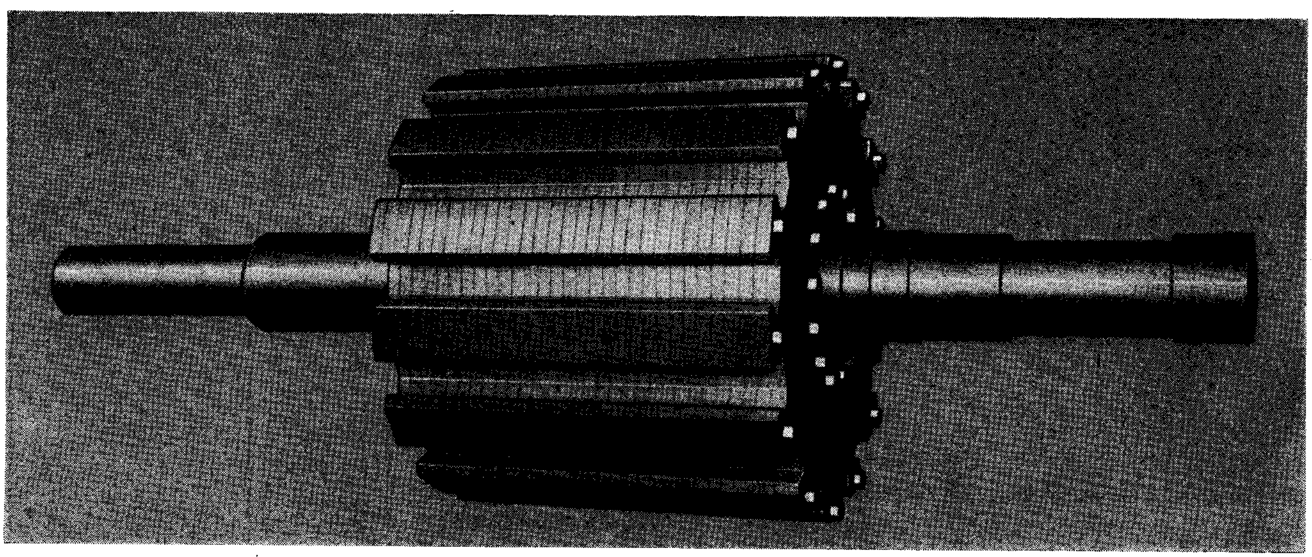


FIG. 8. Laminated Plate Spider Pressed on the Shaft

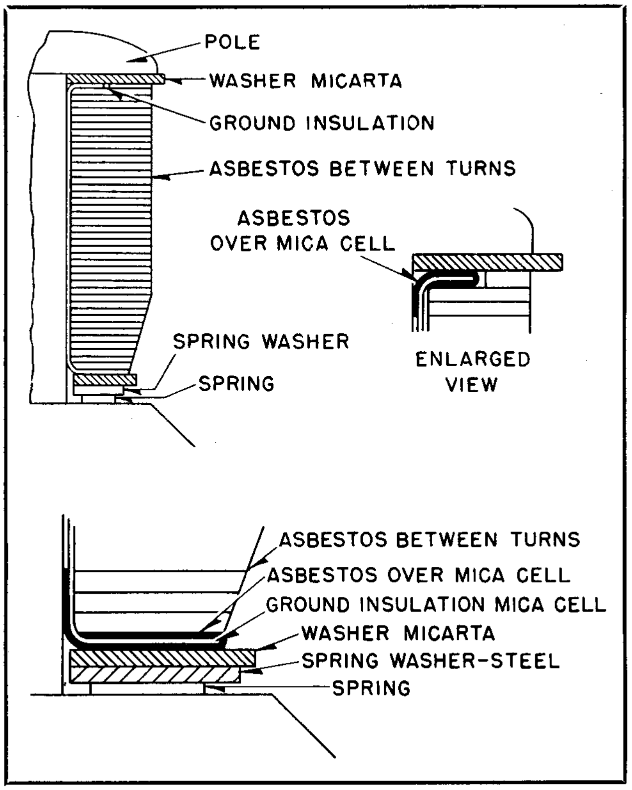


FIG. 9. Typical Field Coil Construction

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

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. (See Fig. 9.)

Damper Windings. Damper windings are provided as part of the field structure of all standard hydrogen cooled synchronous condensers for the purpose of adapting the machine for 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. (See Figures 7 and 10).

VENTILATION

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

Westinghouse hydrogen cooled synchronous condensers are designed and proportioned so that the cooling hydrogen gas 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 plentiful in number and so distributed that uniform temperatures exist throughout the entire length of the machine.

Fans. The blowers or fans are of the inclined blade, centrifugal type as illustrated by Figure 10. 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 should be rotating in the wrong direction, they will not circulate the normal amount of gas and the machine may operate at higher than normal and possibly at dangerous temperatures.

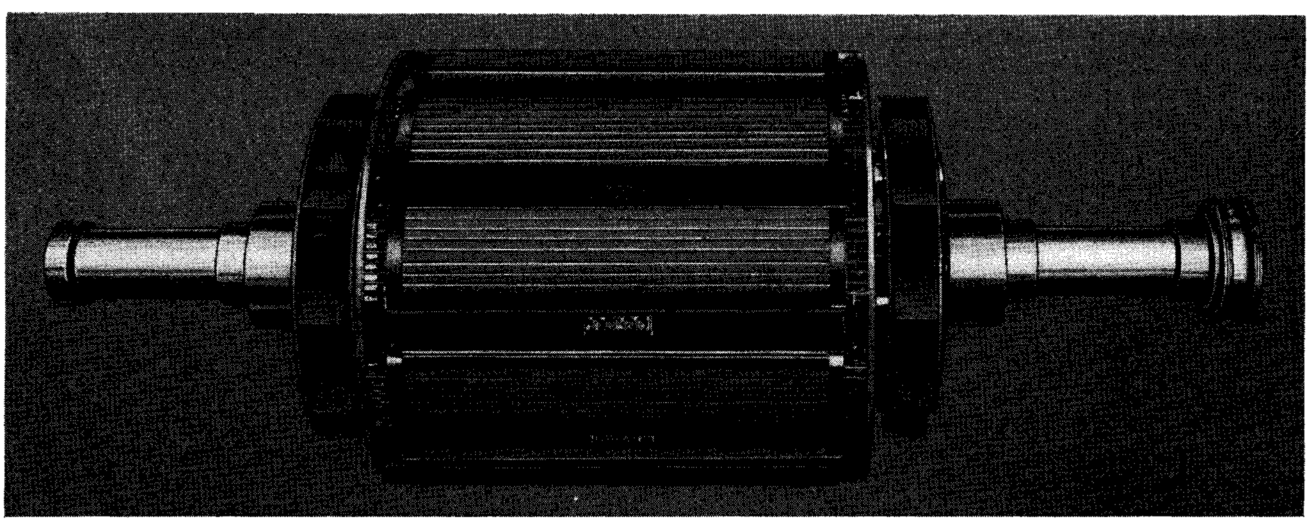


FIG. 10. Complete Condenser Rotor Showing Collector Rings, Centrifugal Blowers, Poles, and Coil Braces

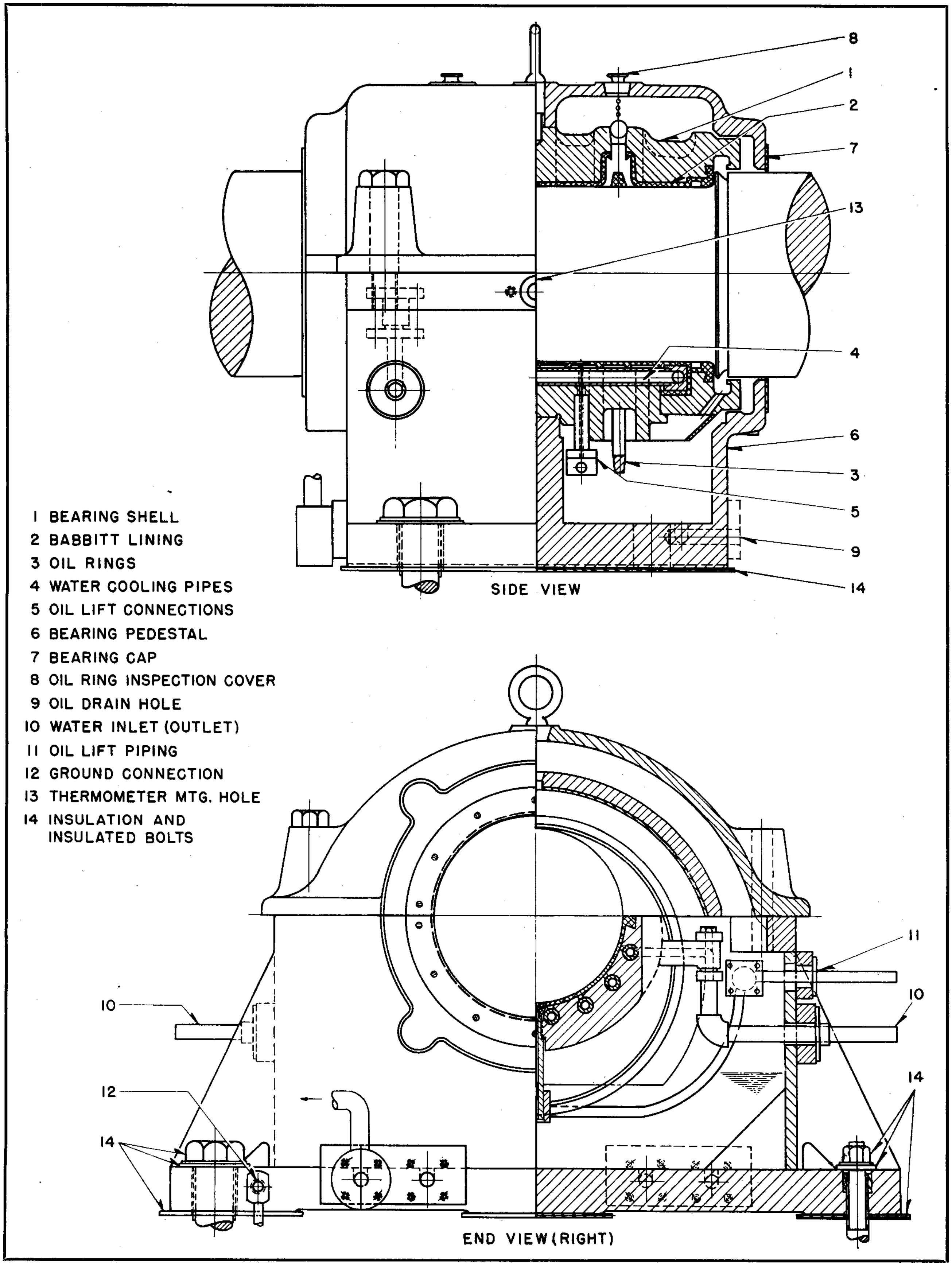


FIG. 11. Cross Section Views of a Typical Water-Cooled Bearing Assembly

It is therefore important that the direction of rotation be checked before the condenser assembly has progressed too far. If the rotation is found to be incorrect, the direction of rotation should be reversed by interchanging two of the main leads.

BEARINGS

Bearings are of the pedestal type. Lubrication is provided by oil rings. Bearing cooling is provided by circulating water through pipes in the bottom bearing shell. Sight oil gauges, connected by piping to each bearing, are mounted outside the housing to permit visual indication of the oil level in the bearing reservoir. See Figure 11.

Shaft Currents. 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 may have a destructive effect upon the shaft journals and the bearings. Small pits are usually formed on the surface of the shaft journals. These pits are sufficently rough to score the surface of the bearings and in some instances, the bearing babbitt actually shows evidence of having been eaten away by the current.

Insulation. 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 bearings from their supporting members. Standard practice is to insulate both pedestals from their supports. This insulation interrupts the patch for circulating currents. The insulation consists of a suitable thickness of micarta placed between each bearing pedestal and its support. To avoid short circuiting the insulation, all water and oil piping and detector bulbs must be insulated. Figure 22A on page 27 shows the general method of insulating the bearings. A grounding strap (see Figure 22B) is provided and brought out of the housing so that either pedestal may be grounded to protect the operator. One pedestal should be grounded normally, to protect the operator. When testing the insulation the ground strap must be disconnected from the housing. See page 27 for method of testing the insulation.

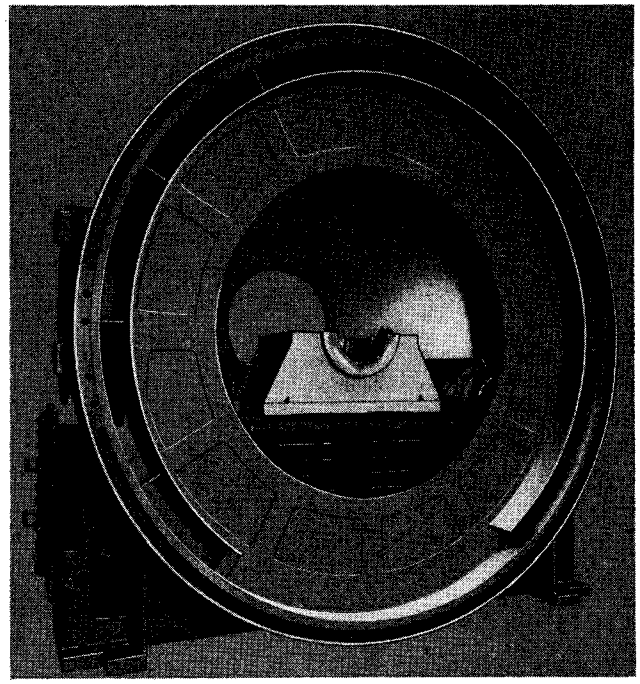


FIG. 12. End Housing Showing Bearing Pedestal, Bearing Cap, and Cooling Section

COLLECTOR CHAMBER

Seal. A special seal is provided between the main housing and the collector chamber so that the collector ring brushes can be replaced or adjusted and the brush rigging cleaned, without removing hydrogen from the main housing. (See Figures 1, 2, 3 and 13). This seal is maintained by spring pressure when the door to the collector chamber is opened. The three large bolts in the entrance door, which compress the springs, should be removed first when opening the door so that the seal will be closed before the door is opened. When closing the collector chamber, first inspect the gasket cemented to the door for serviceability, then, close the door and draw the small bolts up tight. Then the three large bolts should be inserted and tightened with the fingers only. The collector chamber should then be scavenged with CO_2 gas and filled with hydrogen. Finally, the three large bolts should be tightened to make a gas-tight joint with the lead washers. This scavenging and filling operation should be done in as short a time as possible, since there will be a small gas leakage around the three large bolts during the operation.

Collector Compartment Cooler. The collector rings brushes and brush holders are located in a chamber, separated from the main housing by a labyrinth seal which prevents gas and carbon dust

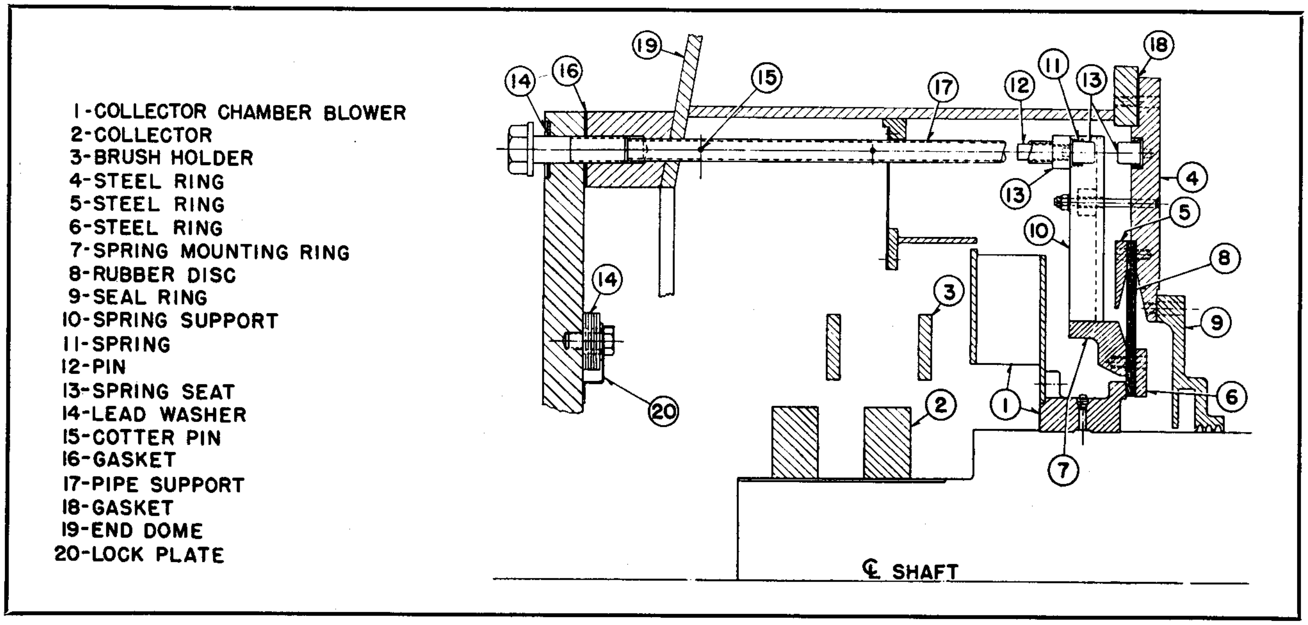


FIG. 13. Cross Section of Collector Seal Assembly

from passing through. The chamber is provided with a fan and a small gas cooler to remove the heat caused by brush friction, collector ring, and brush I^2R losses. Cross Section Drawing, Figures 2 and 3 and Collector Seal Assembly, Figure 13, show details of the seal which is provided to seal the collector chamber when the rotor is at rest, so that the collector chamber can be opened for cleaning without removing the hydrogen from the main housing.

Caution: This seal is not a running seal and therefore the rotor must be at standstill at the time the collector compartment is opened.

The cooler in the collector chamber is fastened at the front end only, leaving the rear end free to move to take care of differential expansion. It is not necessary to remove the cooler from the collector chamber when cleaning tubes.

Collector Rings. The two collector rings are mounted on the end of the shaft and insulated from it by a suitable insulating bushing. They are machined from tool steel or bronze, polished, and generally spirally grooved and adequately ventilated to give maximum service and freedom from accumulation of brush dust. The spiral groove allows trapped gas to escape readily and therefore insures more intimate contact of brush and ring. The groove also prevents small contact areas from carrying high currents. A lead from the field winding is connected to each ring.

The collector leads are carried through an axial hole in the shaft and connected to the collector rings at the end of the shaft. This hole is sealed at the end to avoid gas leakage from main enclosure to the collector compartment.

Gas Coolers. The hydrogen gas is cooled by passing it through a cooler, where the gas gives up its heat to the cooling water in the finned tubes of the cooler. The nozzle end of the cooler is bolted solidly to the housing, while the rear end is permitted to move freely with temperature changes. The rear end is covered with a gas-tight steel cover which must be removed when the cooler tubes are to be cleaned. When the rear outer cover is removed, gas is prevented from escaping by a flexible diaphragm between the cooler and the housing.

With this construction, it is possible to clean the water side of the coolers without removing the hydrogen gas.

Caution. The coolers cannot be cleaned under load.

INDICATING EQUIPMENT

A gauge board is provided upon which are mounted certain gauges and temperature indicators, including:

Gas Purity Gauge of the Inclined Type. This gauge indicates the differential in gas pressures on the two sides of one of the ventilating fans, mounted on the rotor. Since the gas pressure varies directly as the gas density in the condenser when in normal operation, its reading should be used as a check against the density as determined by the Orsat method.

Housing Gas Pressure Gauge. This gauge is graduated to suit operating gas pressure. The pressure gauge is equipped with electric contacts to operate an electric alarm when the gas pressure becomes high or low. For ½ p.s.i. operation the recommended low alarm setting is approximately ¼ p.s.i. and the high approximately 1 p.s.i. For 15 p.s.i. operation the high alarm contacts are usually set for 16 p.s.i.

Cold Gas Temperature Indicators. Three indicators are provided (except when collector rings are located outside the housing), one for the rear end of the machine, one for the front end, and one for the collector chamber. They have a scale ranging from 0 to 55 degrees Centigrade, and are connected by flexible tubing to bulbs located in the respective chambers. Each is equipped with a single high adjustable electric contact for operating an alarm. It is recommended that the contacts be set at 45 degrees Centigrade.

Bearing Temperature Indicators. Two bearing temperature indicators are provided, one for the rear end bearing, and one for the front end bearing. They have a range of 10 to 105 degrees Centigrade, and are connected by flexible tubing to bulbs embedded in the oil reliefs in the bearings. Each thermometer is equipped with a single adjustable high temperature electric contact for sounding an alarm.

Gauges and Detectors Not Mounted On Gauge Board

Pressure Gauges. Located at the hydrogen bottles for indicating bottle pressure and for the feed lines.

Water Detectors. With pipe connections to the low points of the main housing and the collector housing, the detectors are located in the pit below the condenser (except when collectors are outside the housing). See Figure 26. These detectors are float operated, mercoid switches which sound an alarm signal if water or oil collects in the float chamber.

THE GAS SYSTEM

General. Figure 26 on page 32-A shows the typical gas control and alarm system furnished with standard hydrogen cooled condensers. In some special cases an automatic hydrogen regulator is provided.

In determining the design features and operating procedure of hydrogen-cooled condensers, it is desirable to follow safe and conservative practices. During normal operation, the entire housing is filled with hydrogen gas.

Important. When the condenser is first placed in service, or after any subsequent opening of the housing, safe practice dictates that the air within the housing first be displaced by an inert gas such as carbon dioxide. Likewise, before opening the housing after the condenser has been in normal operation, the hydrogen first must be displaced by an inert gas. This process of displacement is called scavenging and its purpose is to prevent an explosive mixture of hydrogen and air.

The four principal design requirements are therefore determined by the "running", "standstill", "gas filling", and "gas scavenging" conditions. The primary functions of the gas control and alarm system are:

1. To provide for scavenging and filling the housing with gas.

2. To insure that the gas in the housing is within predetermined purity, pressure and temperature limits, and free of moisture during normal operation.

3. To give warning of improper operation of the condenser or of failure of the gas control and (or) alarm system.

ADVANTAGES OF HYDROGEN COOLING

The principal advantages resulting from the use of hydrogen cooling for rotating machines are:

1. Reduced windage, and ventilating losses, because of the low density of the hydrogen gas. The ventilating losses are proportional to the gas density. (Losses approximately 10% of losses with air.)

2. Reduced maintenance expense because of the freedom from dirt and moisture.

3. Increased life of the insulation on the stator windings because of the absence of oxygen and moisture in the presence of corona.

4. Reduced windage noise because of the low density of the gas.

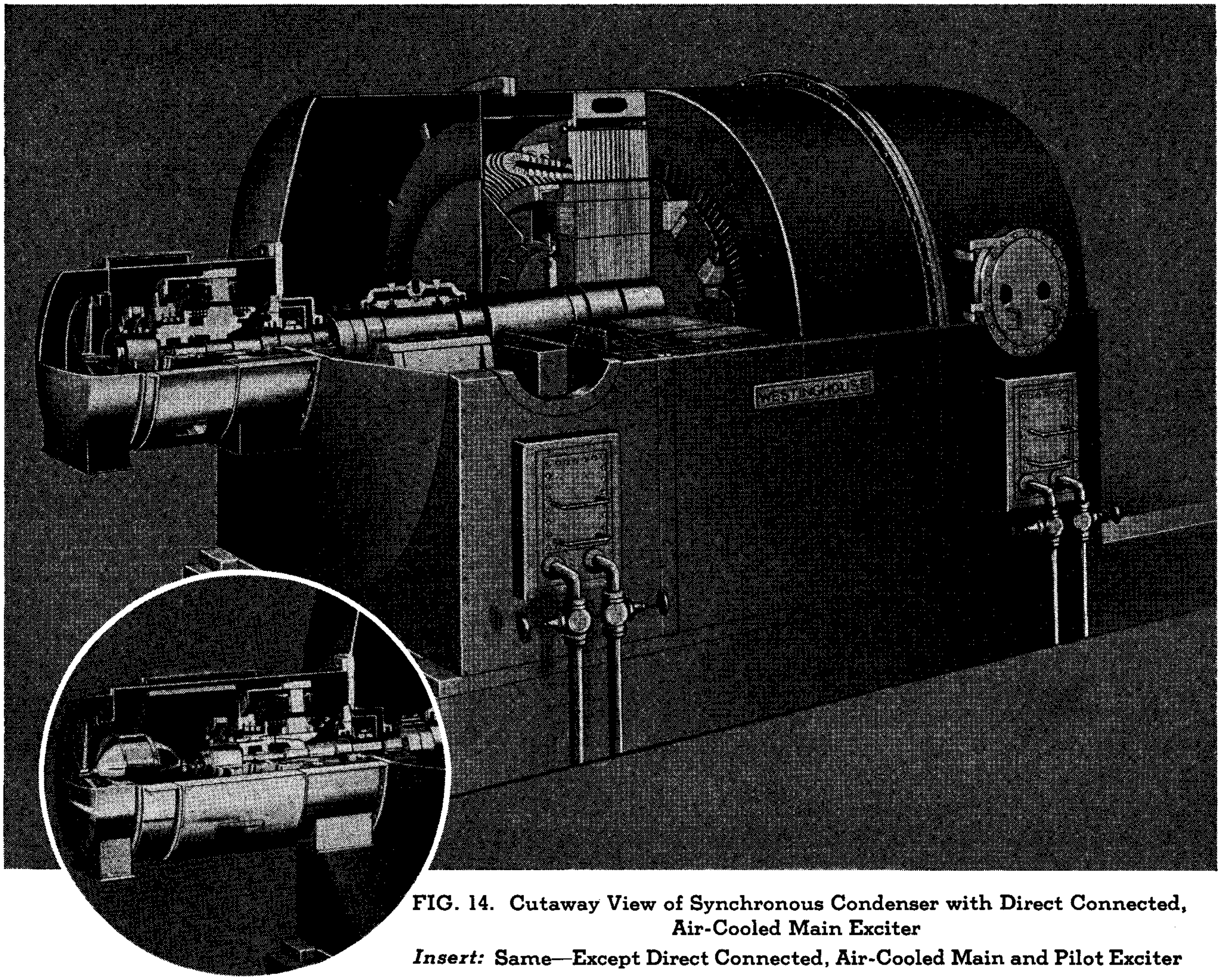


FIG. 14. Cutaway View of Synchronous Condenser with Direct Connected, Air-Cooled Main Exciter

Insert: Same—Except Direct Connected, Air-Cooled Main and Pilot Exciter

Hydrogen-Cooled Synchronous Condensers with Direct-Connected Exciters and Collector Rings Operating in Air.

This design of condenser unit is built by Westinghouse to meet the requirements of certain purchasers, who desire that the exciters be direct connected and driven by the condenser shaft. See Figure 14.

The exciters and condenser collector rings are located outside of the main condenser hydrogen enclosure and they operate in air. This arrangement permits servicing and inspecting the collector rings and exciter commutators and brushes without shutting down the unit and without removing the hydrogen from the collector chamber as is necessary with the conventional design (see Figures 1, 2 and 3).

In general, the condenser proper is the same as the conventional design, and the instructions and descriptions applying to the standard machine will apply to this type of unit.

The direct connected exciters are standard air cooled machines and are covered by Instruction Book 4000.

OIL SEAL

The only special feature of this design is the oil seal around the shaft which drives the direct connected exciter (or exciters). This seal is necessary to prevent excessive leakage of hydrogen from the main condenser enclosure.

Referring to Figure 15, showing the schematic arrangement of the oil seal, it will be noted that the operation of the seal is quite simple.

Operation. The oil seal supply Tank "A" is located in the housing and therefore will be subjected to the gas pressure within the condenser housing. This will insure oil flow to the seal for the

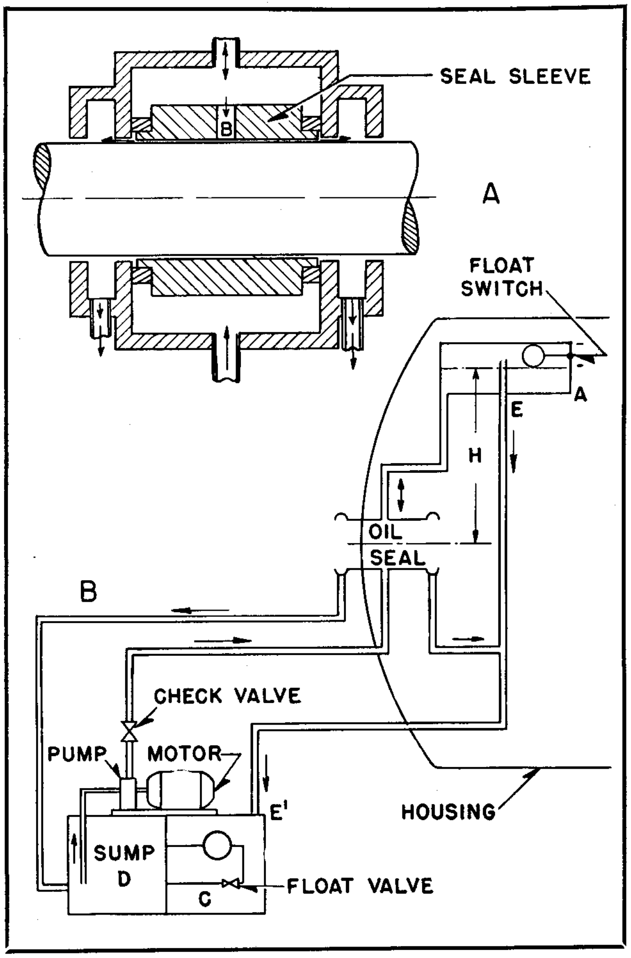


FIG. 15. (A) Sectional View of Oil Seal
(B) Oil Seal Circulating System

time required to repair pump or otherwise reestablish normal pump operation and normal oil flow.

The oil surrounding the seal will be subjected to this gas pressure plus the head "h" due to the elevation of tank "A" above the seal. Accordingly, the effective differential pressure between the oil around the seal and the hydrogen will be equal to this head "h" while the differential pressure between oil and air will be equal to the machine gas pressure plus the head "h". The differential pressure will force the oil through a series of holes "B" distributed circumferentially around the seal and then axially along the shaft in both directions.

Oil along the shaft effectively separates the air outside from the hydrogen inside. The oil also lubricates and centers the seal on the shaft. The flow is so small that there is no necessity of an elaborate defoaming or vacuum system such as required on a hydrogen cooled turbine generator.

As indicated by the diagram the oil on the air side will drain directly to the sump "D". On the

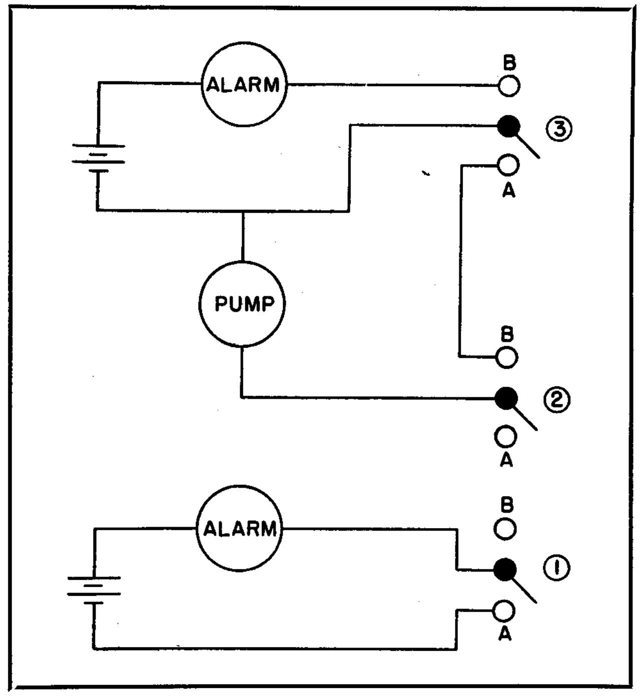


FIG. 16. Schematic Diagram of Oil Seal Control

hydrogen side, however, the oil will flow first to tank "C" outside the condenser housing where the oil is maintained at a minimum level by a float valve thus preventing contact between the hydrogen and outside air through the drain line. When the maximum level is exceeded the float valve will allow the oil to flow from the tank "C" to the sump "D".

When the level of the oil in Tank "A" falls below a predetermined height a float switch is set to start the pump motor which raises the oil from the sump "D" to tank "A". The cycle of oil flow is thus continuous. The tank "A" is of adequate size to provide an emergency supply of oil thus insuring continuity of the seal performance in event of power failure and also permitting servicing of the pump, motor or other parts without affecting efficiency of the seal. Note that an overflow pipe (E—E') is provided to limit the oil level height.

Figure 15 also shows the oil piping arrangement.

Oil Flow Control. Figure 16 illustrates in a general way the oil flow control scheme used. For a specific design refer to the drawings applying to that unit.

Switches 1, 2 and 3 are activated by a float control. Switch 1 serves as a low level alarm switch. Switch 2 starts and stops the pump motor. Switch 3 is the high level alarm switch. Note that both switches 2 and 3 must be in the "a" position when the pump operates. This serves as a double insurance that the pump will shut down before an abnormally high level is attained in tank "A". In addition an overflow pipe (E—E') is provided.

It can be seen that under normal operating conditions, the oil supply system is continuous and automatic.

Design Features. The following design features in the seal should be noted. Referring to Figure 15, the seal sleeve is self-centering upon the shaft due to hydrodynamic action. Water cooling of the seal is usually not required, but when necessary the water supply lines are constructed so that they cause minimum restraint to the radial motion of the seal sleeve. The seal sleeve is electrically insulated from the remainder of the machine.

The assembly of the seal entails no particular difficulties. Proper performance of the seal during shut-down in cold weather, if this is an operating requirement, is obtained by the use of space heaters and pipe heaters.

Maintenance of Seal Equipment. The fundamental operation of the seal as described is quite simple and the associated equipment is rugged and dependable. However, it is recommended that the following periodic procedure be followed to insure trouble free performance.

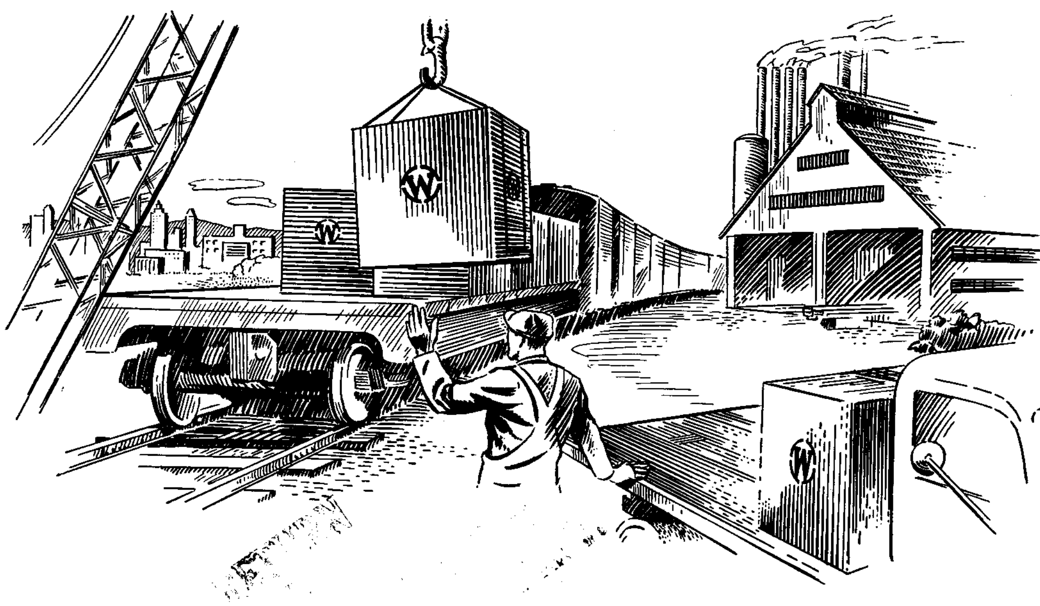
1. Check level of oil in sump tank "D". Any leakage in the piping might reduce volume below normal.

2. Check quality of oil for viscosity, and acid content. If viscosity is much below specified value or if oil is acid, it should be replaced with clean, fresh oil of specified viscosity.

3. Check float switches to be sure they are operating freely.

4. If seal water cooling coils are used, check water flow to be sure that there is no restriction.

5. Check oil level in tank "A". This oil level should not vary more than approximately 3/4" as determined by the float switches.



RECEIVING, HANDLING AND STORING

All hydrogen cooled synchronous condensers are completely assembled and the parts match-marked at the factory. This procedure makes it possible to properly reassemble the condenser in the field with minimum supervision and fewer experienced workmen.

RECEIVING

Due to shipping limitations it is necessary to ship all hydrogen-cooled condensers disassembled. The three or more stationary members, the sole plates, the rotor with shaft, the bearings, and the coolers are crated or wrapped and shipped separately. When necessary to meet shipping limitations, removable end domes are supplied. (See Figure 17).

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.

Important. **When writing to the Westinghouse Electric Corporation concerning a condenser or its auxiliary apparatus, always give the serial number or shop order number which appears on the nameplate or on some part of the apparatus. This is important!**

STORING

Parts of machines which cannot be installed as soon as received, should be covered with a tarpaulin and kept dry by use of some source of heat. It is usually sufficient to maintain the temperature of the machine parts 5 or 10°C above the surrounding temperature.

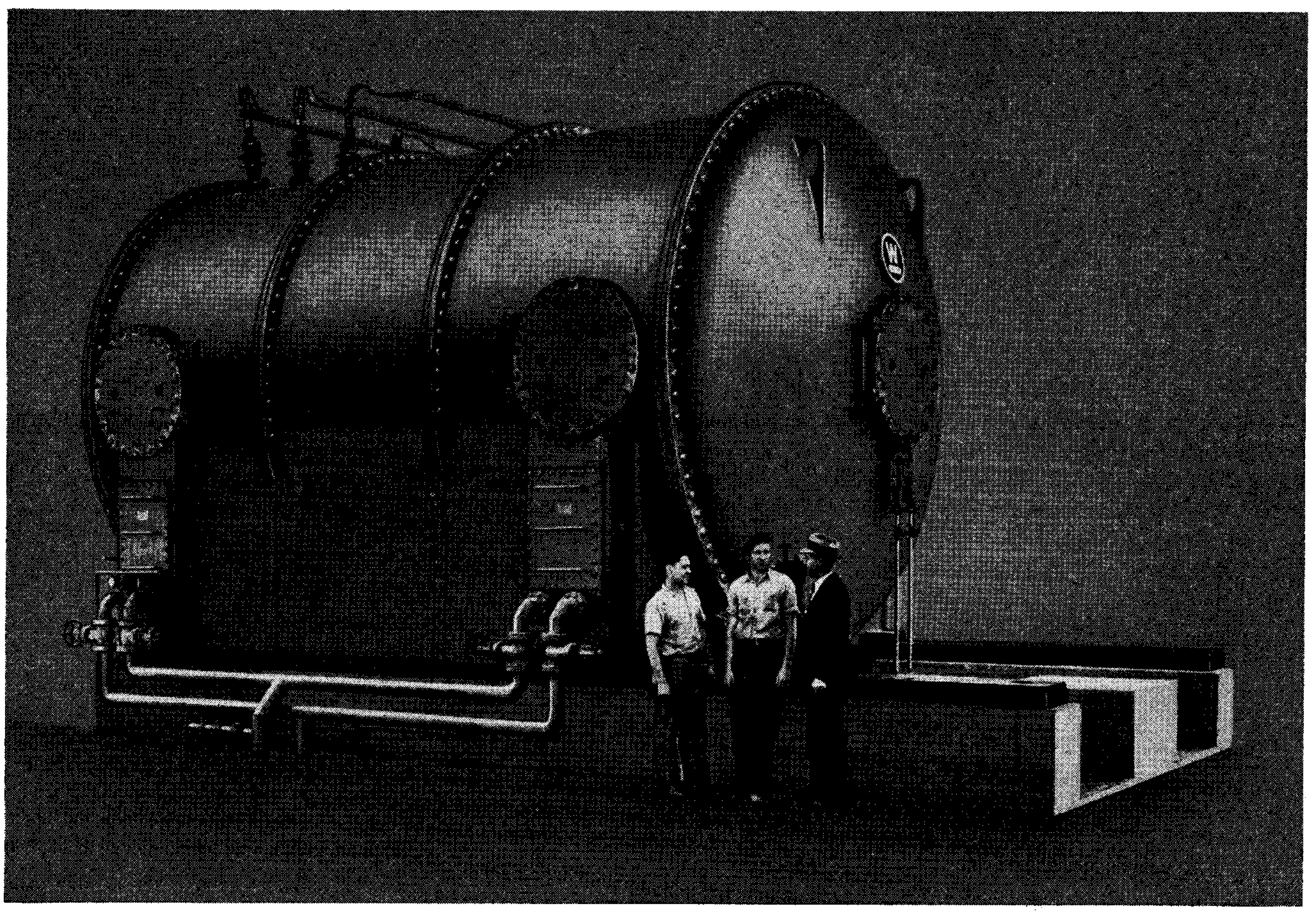


FIG. 17. Installation View (Removable End Domes)

PART THREE

INSTALLATION

FOUNDATIONS

The foundation should consist of solid reinforced concrete walls or piers whenever possible and should be carried down far enough to rest on firm sub-soil or rock. A competent consulting engineer who is familiar with foundation design should be consulted when laying out this part of the installation. If it is necessary to support the sole plates 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 condenser should be deep enough to give ample working space for connecting the leads if they are brought out below the machine and for connecting to the various gas control pipes. The pit should also be adequately drained and ventilated. In some installations the exciter motor-generator set is located in the pit below the machine.

PROCEDURE BEFORE ERECTION

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 the pit below the machine and any cable or bus ducts have been provided in their proper locations and of suitable dimensions to permit correct assembly of the unit.

4. Check the size, location, and elevation of the 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 sole plates. The leveling plates should be of steel approximately 1/4" x 4" and should be sawed or burned in lengths so they will extend about 2 inches beyond each side of the sole plates.

6. Locate the leveling plates where the two end and stator core sections will rest on the sole plates. Use a sufficient number to prevent any distortion of the sole plates.

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

Leveling Sole Plates. After the grout around the "leveling plates" is set and has hardened, the sole plate should be placed in position on the foundation, inserting about 1/8 inch of shims between the sole plates and the leveling plates. When the final adjustments are completed, the centerline and elevation of the sole plates should be checked with the customer's foundation layout and the condenser outline drawing. Grout sole plates as shown on the outline drawing.

Shaft Extension. If the erection is to be done by the Purchaser and erection tools were not purchased as an addition to the contract, 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 hydrogen cooled synchronous condensers but is included with other erection tools if such are purchased as an addition to the standard equipment.

ERECTION METHODS

Hydrogen cooled synchronous condensers are usually installed outdoors. They are therefore designed so that they can be erected or dismantled without the usual power house overhead crane which would be available for an indoor installation. It is only necessary to skid the large parts (rotor, stator and end sections) into place. The inside parts such as bearing shells, bearing caps, and end bell sections can be handled by means of a small chain block and a trolley supplied with the machine and mounted inside the end housing. The bearing shells and bearing cap can be removed through a large opening placed in each end housing at the side of the machine. See Figure 18 illustrating a method of removing the bearing parts. Extension rails for removal of bearing parts (see Figure 18) are available at additional price.

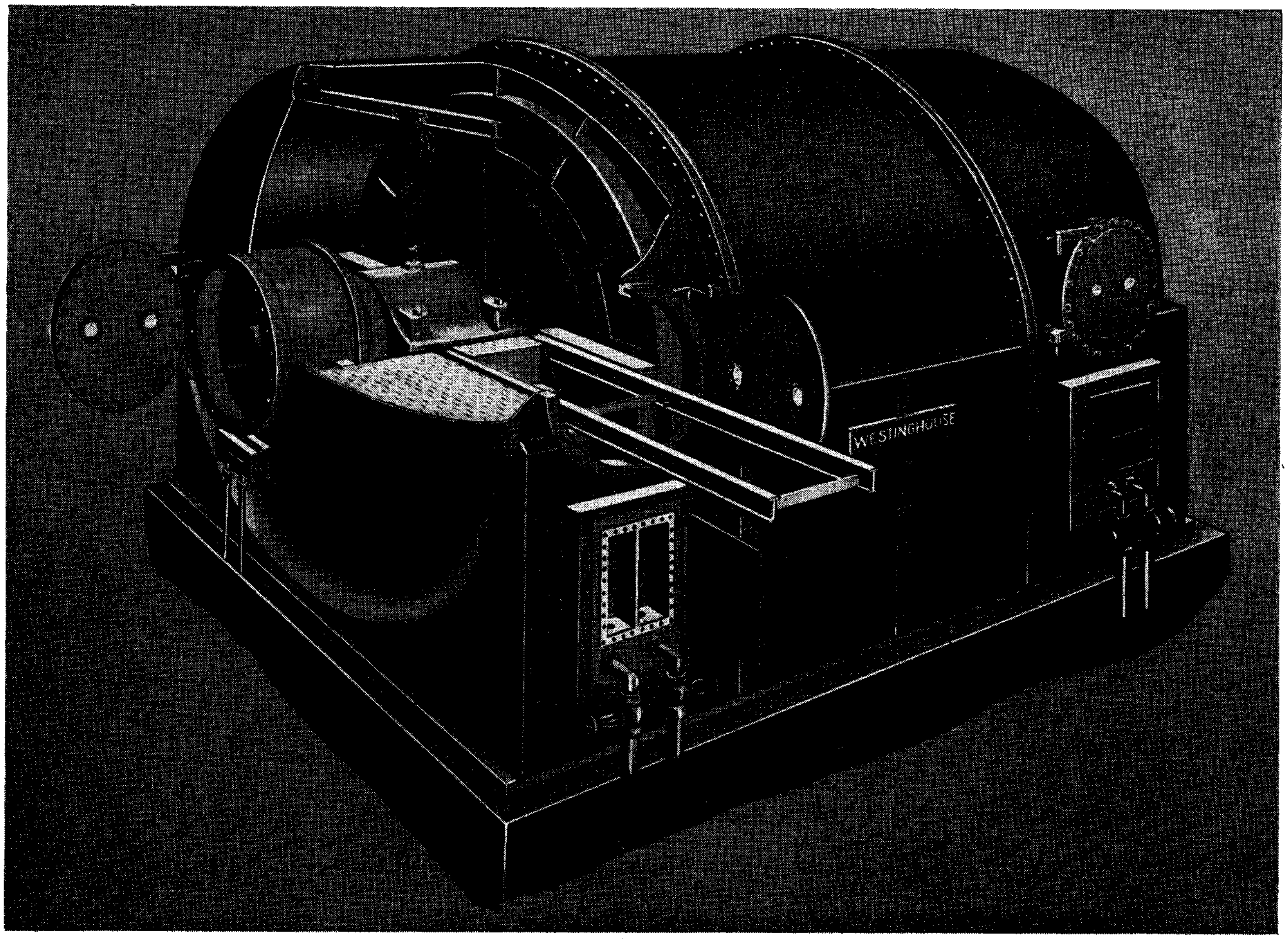


FIG. 18. Cutaway View Showing Optional Extension Rails for Removing Bearing Parts

A pad is provided under the shaft, near each pedestal, to mount a jack which is used to raise the shaft and thereby facilitate removal of the bearing shells or to permit addition of shims under the pedestal for final adjustment.

The large circular doors for the side openings and collector ring housing are provided with hinges and do not require any lifting means for handling.

A light "A" frame or preferably a crane mounted on a truck can be used to handle small parts outside the machine.

The feet of the stationary sections, (usually three, stator and two end sections) are provided with tapped holes and jack screws so they can be conveniently raised from the sole plates to install the rollers which are used when shifting the sections on the sole plates.

By use of the shaft extension, previously referred to, it is possible to support the rotor at points beyond the stator and end sections respectively, and thus make it possible to shift them to their final positions on the sole plates.

Sequence of Operations. Figure 21 shows the sequence of operations involved in the erection of an outdoor hydrogen cooled condenser.

The methods and equipment used in carrying out the operations shown schematically in Figure 21 will depend on local conditions.

If there is a railroad siding close to the site of erection, it is only necessary to remove the equipment from the cars to the site. This can be done by the use of a railroad crane mounted on a car for such purposes, or by improvised temporary crane structures of the types familiar to all experienced erectors.

As indicated by the various steps in Figure 21, it is necessary that timber and structural steel be available to make supporting cribbing and temporary supports while the various parts are being arranged and shifted into their final positions.

No specific routine procedure need be outlined as any competent erector is familiar with various means of handling the apparatus.

Supervision. If the erection is done by the customer's own personnel, it is recommended that he employ the services of a Westinghouse supervising erection engineer. The experience of such a man will frequently expedite the time of erection and insure that the assembly will be done satisfactorily.

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, if the unit is not placed in service within a short period.

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 to dry them out.

Welder Sets. 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 Figure 19.

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.

Temperature Limits. In general, the drying should proceed slowly at first and the heating gradually increased as the insulation dries. The temperature of the insulation as measured by thermometer should not exceed 65°C. If imbedded temperature detectors are used to read temperature, the permissible temperature is 80°C. See Figure 31 on page 38, showing the variation in insulation resistance with temperature.

INSULATION RESISTANCE MEASUREMENTS

Insulation resistance measurements should be taken periodically throughout the dry-out period.

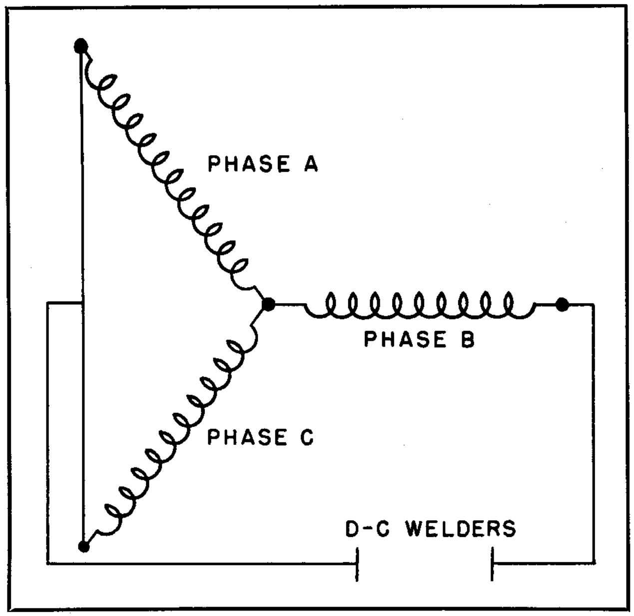


FIG. 19. Connection Diagram for D-C Welders

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 constant and if above the minimum, given by the formula on page 26, the condenser can be placed in service.

Insulation resistance measurements are made to determine the condition of the insulation on the windings and should also 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. Figure 20 shows the diagram of connections for this method of measuring insulation resistance.

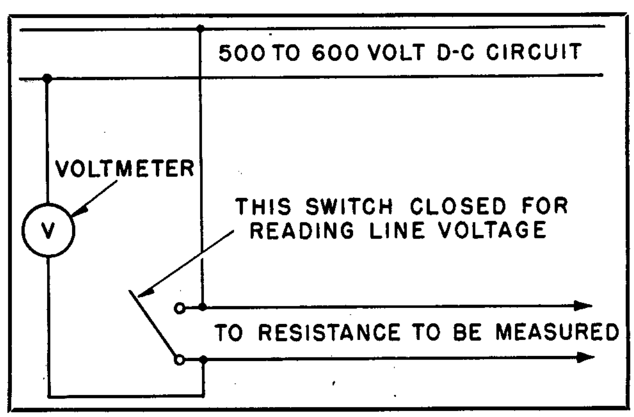


FIG. 20. Connections for Measuring Insulation Resistance

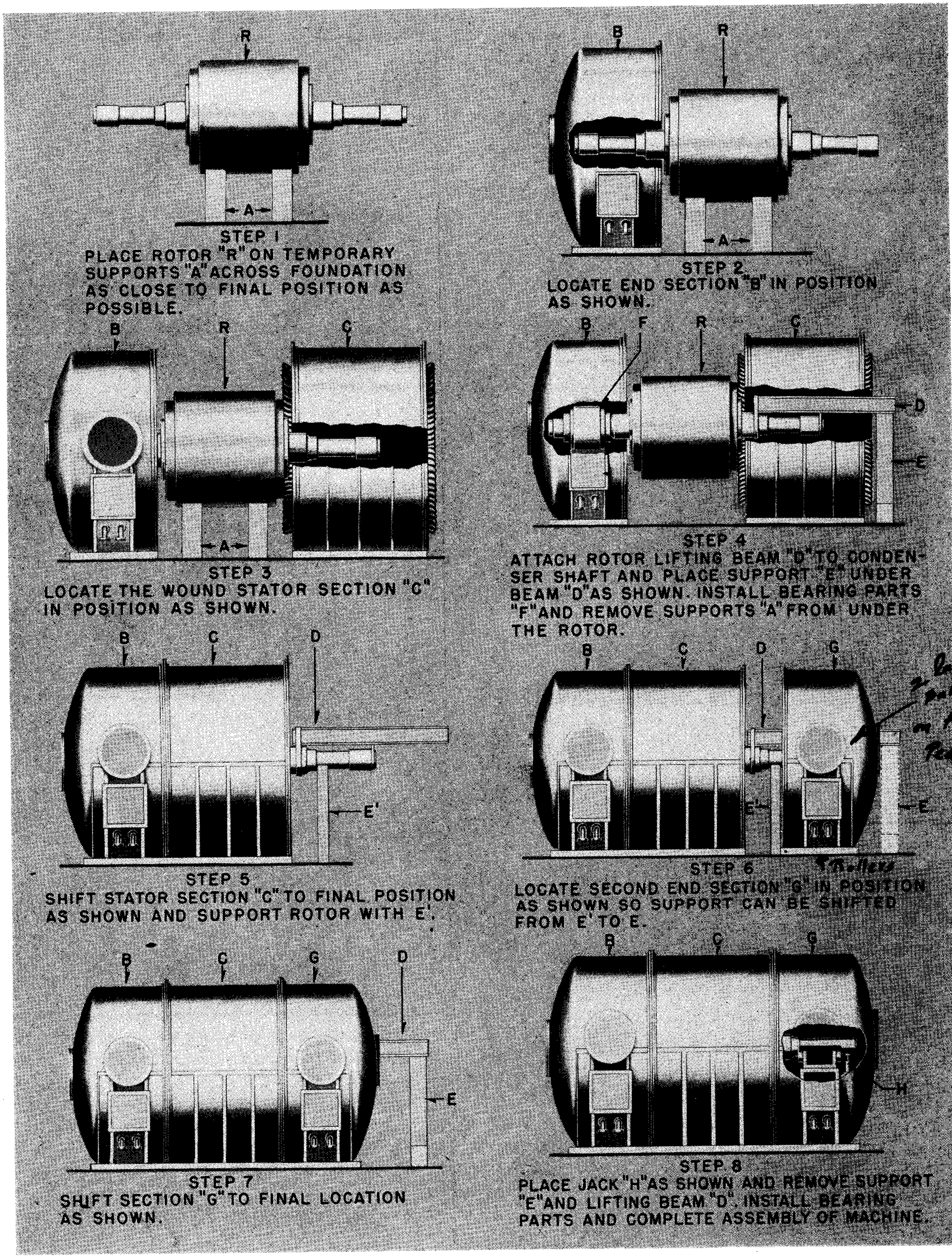


FIG. 21. Sequence of Assembly Operations

See:- Dwg 24-A-8806 - new method

40 MVA 60~ machine

Referring to the diagram (Figure 20) the insulation resistance can be calculated from the following formula:

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

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

$$R(\text{Megohms}) = \frac{\text{Terminal Voltage}}{\frac{(\text{Rating in kva})}{100} + 1000}$$

BEARINGS

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 journals should be carefully examined before assembly for damaged spots and should be honed true if necessary. 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.

If the shaft journals are clean and free from rust or scratches, the lower half of the bearings can be rolled into place in the pedestals.

Oil Groove. Satisfactory operation of the oil lift pumps and motors depends largely on the "relief" at the oil groove under the journal, where the high pressure oil is fed into the bearing.

Important. If this "relief" is not adequate, the oil pump will work close to its maximum capacity and the pressure will fluctuate violently.

It is therefore important to check this oil groove "relief" against the manufacturer's detail drawings to be sure it is correct. The oil groove "relief" should be correct and according to drawings when parts leave the factory and the field checking is only a precautionary measure.

Insulated Couplings. All water or oil piping connected to the bearing must be insulated. 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 can result from any of the following:

Piping which touches both the pedestal and the pedestal support and which has no insulated couplings; conduits; BX cables; thermometer tubing; metal ladder set against the pedestal; tools left in contact with both pedestal and support.

OIL LIFT SYSTEM

Pump Pressures. 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 and check valves are supplied as standard equipment. These gauges will also indidate the pressure being developed by the pump. 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 from rest 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.

Starter Relays. In order to avoid starting trouble due to chattering of the oil pressure gauge contacts, it is the usual practice to connect these contacts to an "SG" auxiliary relay which is also connected to a "CV" timing relay. The "CV" relay is timed to close and energize the starting breaker when the oil pressure reaches 400 lb. per sq. inch, and to remain closed until the machine is put on the line. The pressure gauge is set at 400 lb. per sq. inch to permit re-starting when the shaft is rotating, in which case the pressure developed by the pump is much lower than when the shaft is stationary.

Pressure Damper. 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 very 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.

TESTING PEDESTAL INSULATION

A break in the pedestal 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 disconnecting the grounding strap which is provided for this purpose. By the use of a test circuit the insulation under each pedestal can be checked. Any test circuit consisting of a source of power, such as a battery, station service supply, bell, lamp or a megger can be used. Leads are brought outside of the condenser housing to permit testing the pedestal insulation.

See Figure 22B for location of insulation test lead. If the insulation under both pedestals is satisfactory, then with one side of the test circuit connected to the pedestal lead terminal, and the other to the housing, there should be no indication of a "live circuit". This will be evidenced by a "black lamp", "no alarm" or Megger reading of approximately 5000 ohms with water through bearing cooling coils.

Locating Fault. 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 then be determined.

CHECKING AIR GAP AND COMPLETION OF ERECTION

Before assembling the end bells and after 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.

With the complete unit now assembled, the sole plates should be permanently grouted in.

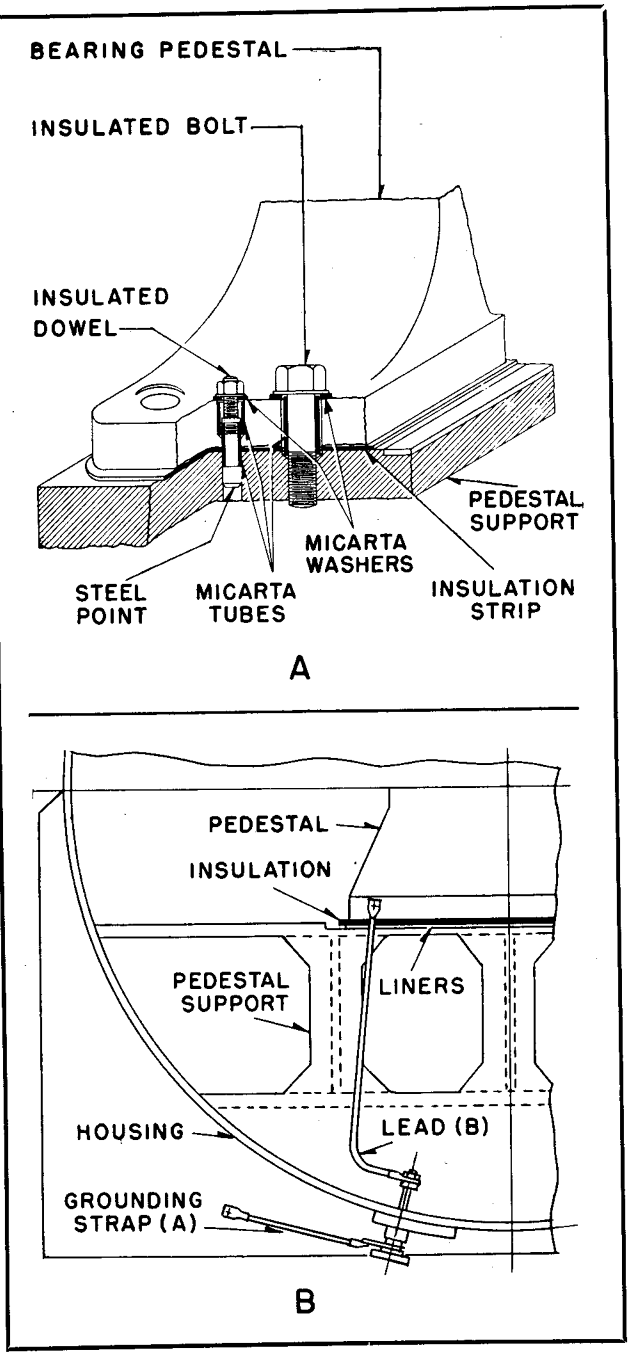


FIG. 22. (A) Pedestal Insulation. (B) Method of Bringing Out Lead to Test Pedestal Insulation.

OPERATION

GENERAL INSTRUCTIONS

Before a hydrogen cooled synchronous condenser is placed in commercial operation, it should be checked very thoroughly to be sure that all of the auxiliary equipment is functioning properly.

The condenser main housing and collector chamber should be filled with hydrogen either when the condenser is at rest or when it is running as outlined on page 31. It is recommended that the hydrogen purity be 95% or better at all times.

As described on page 16, the standard condenser is provided with a number of indicating gauges. These gauges should be observed at regular intervals so that any abnormal operating condition can be detected before serious consequences develop.

The alarm contacts on the gauges will function to sound an alarm, light a lamp, or trip off the machine in the event an abnormal condition persists, but periodic observations may indicate the beginning of trouble and permit correction without a shut-down.

STARTING THE CONDENSER

Synchronous condensers can be started by any one of three generally recognized methods. These methods are as follows:

1. A-C self-starting by means of auto-transformers which impress a reduced voltage (usually 20 to 35% of line voltage) across the terminals of the condenser.

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

3. A-C self-starting by a special series-parallel connection of the stator winding. The stator winding is designed for running on the parallel connection and starting on the series 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 auto-transformers (method No. 1). The starting voltage can be selected to satisfactorily start the condenser with the minimum starting inrush and, hence, minimum system disturbance for this method of starting.

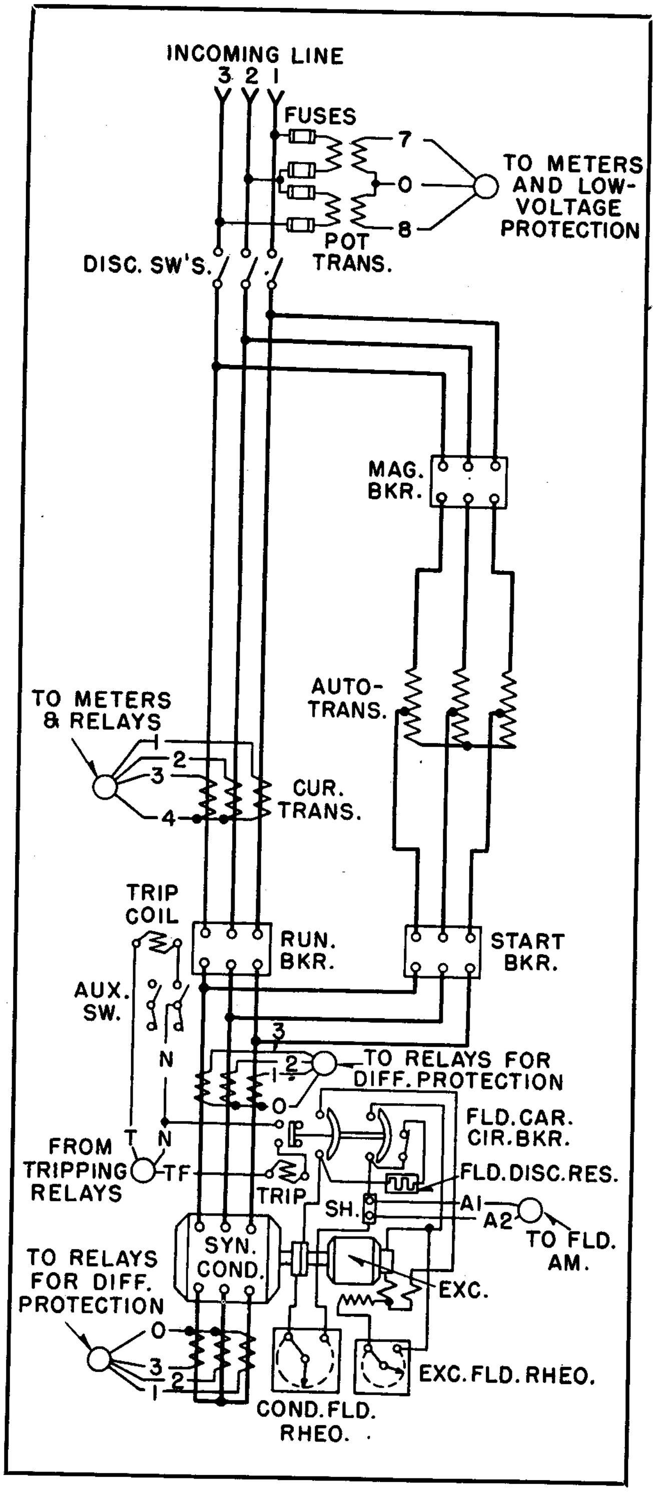


FIG. 23. Typical Diagram of Connections for Manually-Controlled A-C Self-Starting Condenser.

All standard hydrogen cooled synchronous condensers are equipped with oil pressure starting equipment to reduce the starting friction and, hence, that starting voltage and starting inrush. Each bearing has its own lift pump located outside of the housing (usually in the pit) and as close to the condenser as possible to reduce the length of piping to a minimum.

Caution: The lift pumps are to be operating before the circuit to the starting transformer is energized.

Self-Starting Method No. 1. After all sequence devices and auxiliary apparatus 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 through a starting resistor; the exciter armature; or "dead shorted" as specified for each individual unit before the starting cycle is begun.

Caution: Never start with the field circuit open.

2. Close the starter for the oil lift pump motors and observe the pressure developed by the pumps to be sure it is adequate to lift the rotor, as determined by previous preliminary tests. See page 26.

3. Check the starter (if any) for the water circulating pump motors and/or check the valve, to be sure water is available for circulating through the bearing after the condenser has started. Do not circulate water through the bearing cooling coils until the condenser rotor reaches about 25% speed. This is necessary to avoid bending of the shaft by cooling on only one side.

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 condenser field winding should be excited and the transfer made to line voltage.

The alternative method of switching to full voltage first 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 optimum excitation can be obtained as outlined in the following section.

OPTIMUM FIELD CURRENT BEFORE TRANSFER TO LINE VOLTAGE

Figure 24 shows characteristic curves of a hydrogen cooled synchronous condenser.

Curve "A" is the no load "V" curve for a condenser having no load and zero per cent P.F. saturation curves as shown.

The standard hydrogen cooled condenser is designed for 41⅔% 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 zero per cent P.F. leading (over excited).

2. Field current for no load rated voltage and zero stator current.

3. Field current for 41⅔% 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 assumed to be 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 "IF" to be used before transfer to line voltage.

CONDENSER OPERATION

A synchronous condenser 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 kva can be varied from rated capacity leading (over excited) to rated capacity (usually 41⅔% of leading capacity) lagging (under excited). It is this characteristic which permits automatic control of system power factor or line voltage even though the system load and power factor is a variable. The variation in a-c amperes with field excitation is shown by the "V" curve "A", Figure 24.

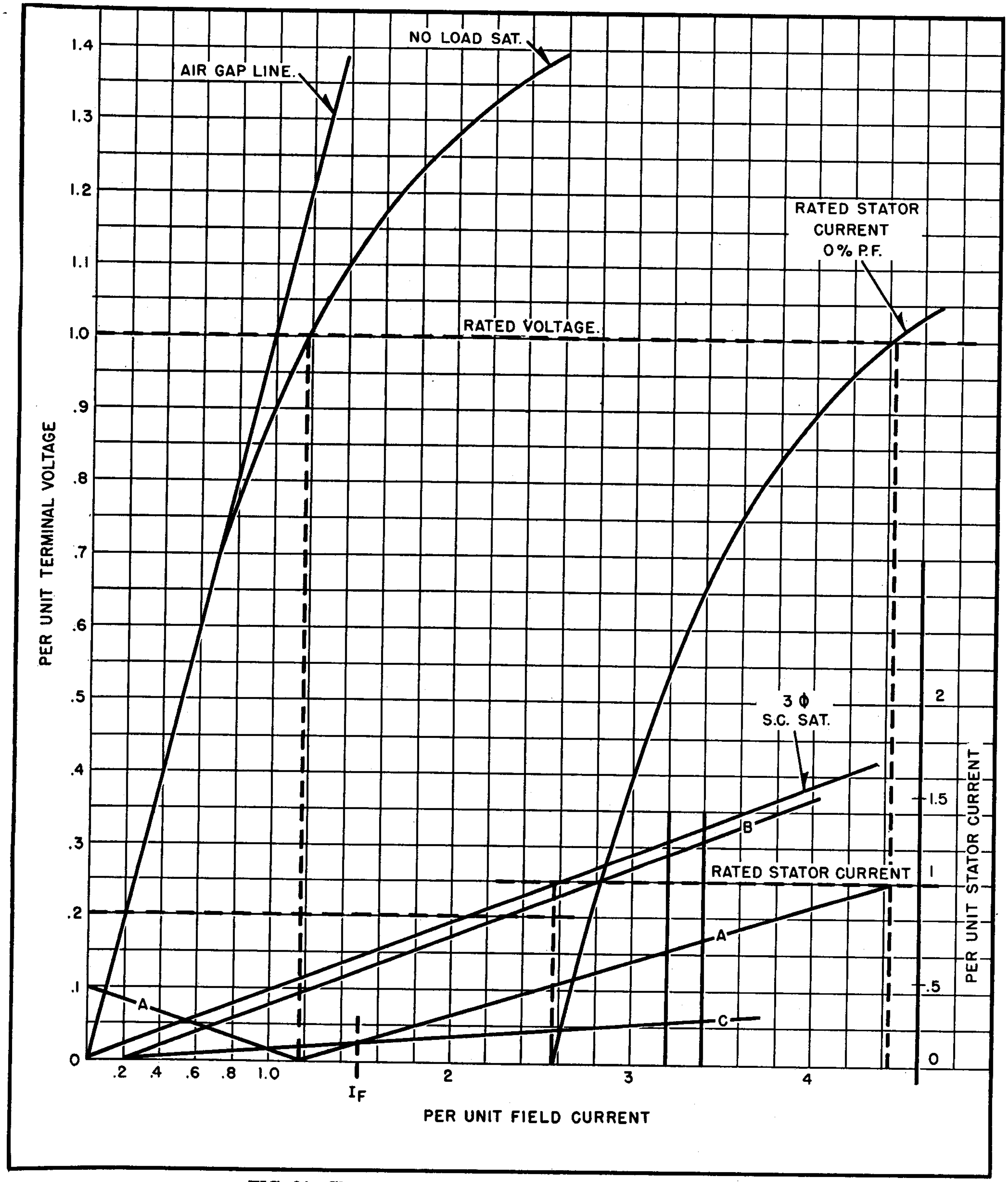


FIG. 24. Characteristic Curves for Synchronous Condenser

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 kva at zero per cent power factor (over excited).

Caution. It should be noted that operation above the kva and voltage range for which the machine is designed will shorten the life of the machine and may result in excessive heating.

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 followed:

1. Unload the condenser by reducing the excitation to the no load value (note saturation curve Figure 24).

2. Trip the main circuit breaker.

3. Trip the field circuit breaker.

4. After the condenser rotor has decelerated to about 25% speed, stop the circulation of water through the bearing cooling coils. *Do not wait until the rotor has come to rest.*

Each of the above operations can be performed manually or automatically.

OPERATING GAS EQUIPMENT DURING FILLING OPERATION

Scavenging. To scavenge air with carbon dioxide gas from the collector chamber and main housing, with the condenser at standstill, first make certain:

1. That all covers are tight.

2. That all valves are closed.

Then open the valves indicated on gas control diagram for that specific machine. To scavenge collector chamber, allow the carbon dioxide gas to flow for 20 seconds. This lapse of time is sufficient to scavenge the collector chamber with approximately two volumes of gas. Admit the CO_2 gas with bottle valves only, as other valves may freeze. A CO_2 relief valve is provided to avoid excessive line pressure during the admission of gas. At the end of 20 seconds of flow to the collector compartment, close and open valves indicated on diagram thereby transferring the flow of CO_2 gas to the main housing. Continue the admission of CO_2 until a test with the Orsat equipment indicates 85% or more carbon dioxide. The next step is to admit the hydrogen gas and displace the CO_2. (See Figure 26).

Filling with Hydrogen. To fill the main housing and collector chamber with hydrogen, close and open valves indicated on diagram, open the 0 to 50 pound regulators and admit H_2 gas alternately through the two valves indicated, while changing bottles. Continue flow until a check with the Orsat equipment indicates 95% or more hydrogen purity. A final check of H_2 purity should be made for machine and collector chamber.

OPERATING GAS EQUIPMENT DURING NORMAL OPERATION

Hydrogen Purity. The degree of hydrogen purity can be determined while the condenser is in normal operation by means of the inclined pressure gauge (fan pressure gauge). This instrument, as indicated on page 16, measures the pressure difference across the fans mounted on the condenser rotor. Since the fan pressure is a function of the gas density, the relative density of the gas and therefore, the purity can be determined, by a comparison of the pressure when operating in air, with the pressure operating in hydrogen. When purchased as a non-standard item, a separate motor driven density meter is supplied. Refer to drawings made for each specific order.

Calibration. To calibrate the inclined pressure gauge, it is only necessary to determine the pressure operating in air. After the condenser has been operated in hydrogen of known purity, the calibration of the gauge can be checked. It is recommended that curves (see Figure 32) then be plotted, using actual pressure gauge readings. To check the inclined gauge while the condenser is in normal operation, Orsat readings should be obtained.

Addition of Hydrogen. A hydrogen cooled synchronous condenser has a number of joints between its various stationary parts. The amount of labor that would be required to make these joints absolutely gas tight cannot be justified economically. The application of gaskets and cements to the various joints has been carefully studied and by so doing the gas leakage has been reduced to a low value. However, due to the small leakage, it will be necessary to add hydrogen at intervals to maintain the operating pressure in the condenser. This is usually done manually but in some special cases provision is made for automatic admission of hydrogen. See Figure 26.

Removing Hydrogen from the Housing. The hydrogen gas must be removed, by displacing it with an inert gas such as carbon dioxide, when it is desirable or necessary to enter the housing. The inert gas, which is heavier than hydrogen, is introduced at the bottom of the housing and the hydrogen is driven out at the top, through the outside vent. Sufficient scavenging gas, about two volumes, should be introduced to reduce the oxygen content of the gas mixture in the housing to 3%, with machine running. If the condenser is at standstill, approximately 1½ volumes of scavenging gas is required. The Orsat equipment should be used for perfect diffusion of the gases. Figure 29 also indicates that the air content will be reduced to 14% by introducing two volumes of inert gas (CO_2). The oxygen content will then be reduced to 21% x 14% or 2.9% which is safe. Therefore two volumes of scavenging gas should be used to reduce the oxygen content to a safe figure before admitting hydrogen.

The foregoing assumes perfect diffusion of the gases as is the case when the condenser is in operation. When carbon dioxide is introduced at the bottom of the condenser and air is driven out at the top, with the rotor at standstill, the air and carbon dioxide do not mix to any great extent due to the higher density of the carbon dioxide, and therefore less than two volumes of carbon dioxide are required to reduce the oxygen content to a safe value.

The exact mixture should be definitely determined by the Orsat method.

Referring to Fig. 29, it can be shown that if 3¼ volumes of hydrogen gas are introduced into the housing, the gas will be 95% hydrogen. Therefore, it is on the safe side to introduce 3½ volumes of hydrogen when filling the condenser with hydrogen. Referring to Fig. 27, the density of a gas mixture containing 95% hydrogen by volume is 12 to 14%, depending on the other gases in the mixture. As is true when removing air from the housing with carbon dioxide, much less hydrogen is required when the rotor is at standstill.

Caution: Before filling the condenser and collector chamber with gas, calibrate the fan pressure gauge as explained under "Operating Gas Equipment During Normal Operation", page 31.

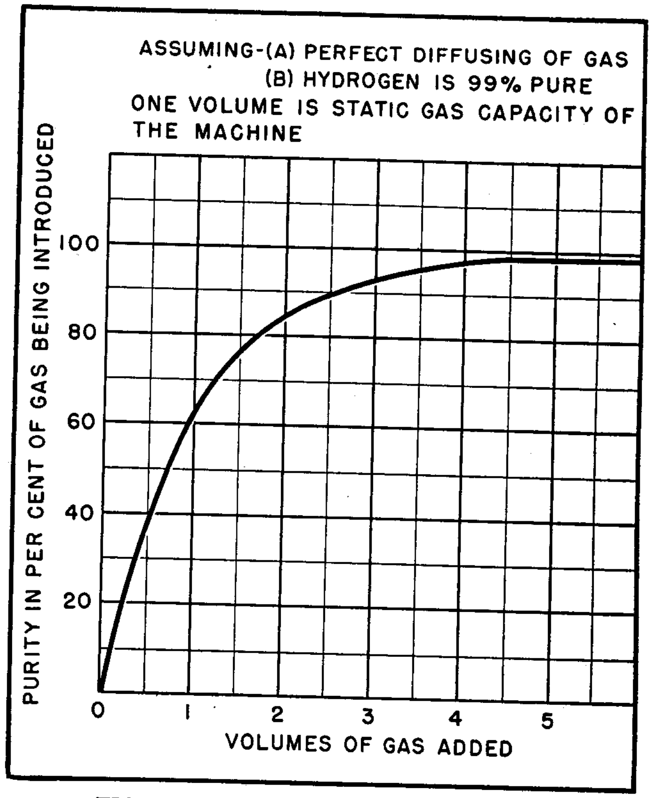


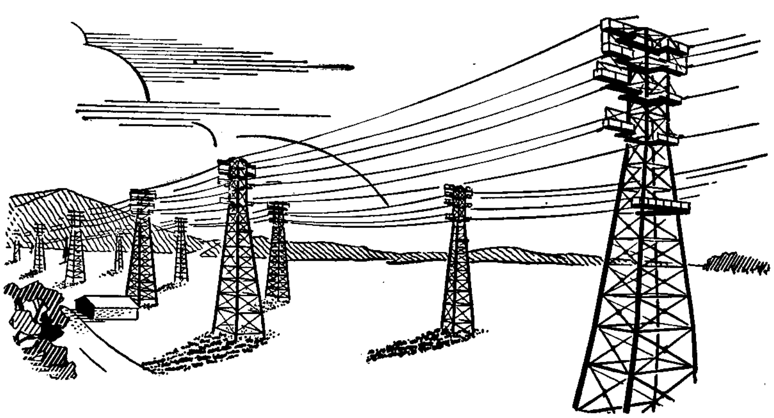
FIG. 29. Amount of Gas to Fill Machine

CHARACTERISTICS OF HYDROGEN REFERRED TO AIR

Weight density	0.07
Thermal conductivity	7.00
Heat transfer coefficient from surfaces to gas	1.35
Specific heat	0.98

Does not support combustion.

Is not an oxidizing agent.



PART FIVE

MAINTENANCE

Important: 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. 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 pounds per square inch.

Warm Water. 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. 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 more generally recommended and 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

Sparking

If sparking between the brushes and the collector rings should develop, investigate for one of the "usual causes" listed below and apply the suggested remedy.

SPARKING BETWEEN COLLECTOR RINGS AND BRUSHES

USUAL CAUSES	SUGGESTED REMEDY
1. Insufficient brush pressure	Adjust to 2 lbs. for grooved rings and 3 lbs. for smooth rings.
2. Brushholder vibration	Remove source of vibration.
3. Brush chatter	Change to less abrasive brush. (Check with manufacturer.)
4. Oil vapor	Clean ring and brush surfaces and remove source of oil vapor.
5. Collector ring trueness	True up by grinding or turning surface of rings—preferably at full speed.
6. Spotted rings	Change to a more abrasive brush. (Check with manufacturer.)

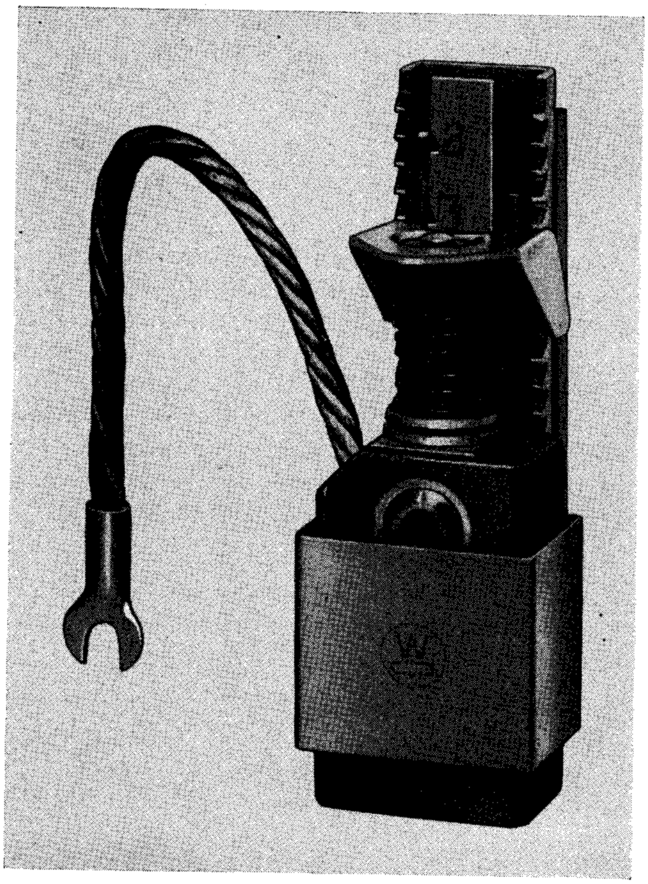


FIG. 30. Typical Brushholder and Carbon Brush

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.

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

Collector Ring Troubles

The collector rings of standard hydrogen cooled synchronous condensers are made of tool steel or bronze. The surface of the rings is generally grooved to eliminate selective action of the brushes. In some cases grooving is eliminated at the specific request of the purchaser.

In general, collector ring troubles can be attributed to four causes:

1. Uneven wear
2. Unclean surface
3. Development of spots
4. Formation of brush imprints

Uneven Wear. 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.

Unclean Surface. 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.

Spots. 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.

Brush Imprints. 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 producing 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 AND OIL

The horizontal sleeve bearings for hydrogen cooled synchronous condensers are ring lubricated and water cooled by cooling coils imbedded in the bearing shell. The oil reservoir in the bearing pedestal is large and, when filled with oil to the level indicated on the oil level gauge, adequate lubrication is assured.

Bearing Oil. Before starting, the bearing reservoir should be filled with a high grade light machine oil having a viscosity from 180 to 220 seconds Seybolt Universal Viscosity at 100°F. This oil should be well refined pure petroleum oil, free from acid, sediment, dirt or other foreign materials. A pour point of +35°F is satisfactory for bearing operating ambient temperatures down to 45°F. If the ambient temperature should drop to 32°F under some operating conditions an oil having a pour point of 0°F should be used.

The above oil is satisfactory for operating temperatures of 80 to 85°C as measured in the babbitt. At the higher operating temperature oil change will be required more frequently because of more rapid sludging and increase in acidity. Highly refined turbine oils are more resistant to sludging and will require less frequent changes.

The oil in the bearing reservoir should be maintained at the proper level. The oil level may drop slightly when the machine is running. If continued loss of oil is noted, a careful check should be made to determine the cause. Inspection should be made at intervals. The oil rings should run smoothly and continuously. If evidence of sludge is noted, the housing should be flushed with a new oil which should be drained and the housing refilled.

Bearing Temperature. The temperature of the bearing should be observed regularly by the operator so that a sudden change or rapid rise in temperature can be detected. A normal continuous operating temperature as determined by the embedded detectors can be as high as 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.

The internal water cooling coils embedded in the bearing shell should be cleaned periodically to be sure they are free from scale or sludge and are operating efficiently.

Overheated Bearings. 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 the water pump motors or water supply.

4. Pitting due to bearing currents.

5. Rough bearing surface due to corrosion or mishandling.

Oil Change. 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 degree of cleanliness, etc., that no definite instructions can be given. A conservative recommendation would be to clean and refill the bearing oil reservoirs every six months.

ROTOR WINDINGS

Maintenance of the rotor winding 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, loose connections of each bar to the ring segment, and poor joints between the ring and the segments.

2. Check clearance between blower and coils.

3. Check for movement or shifting of field coils.

4. Check the stator and rotor windings for dirt, and take cleaning steps necessary.

5. Inspect strap field coils for condition of turn-to-turn insulation and if any doubt, apply A-C voltage to measure coil impedance. Coils with shorted turns will have a low impedance relative to those coils which do not have shorted turns.

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.

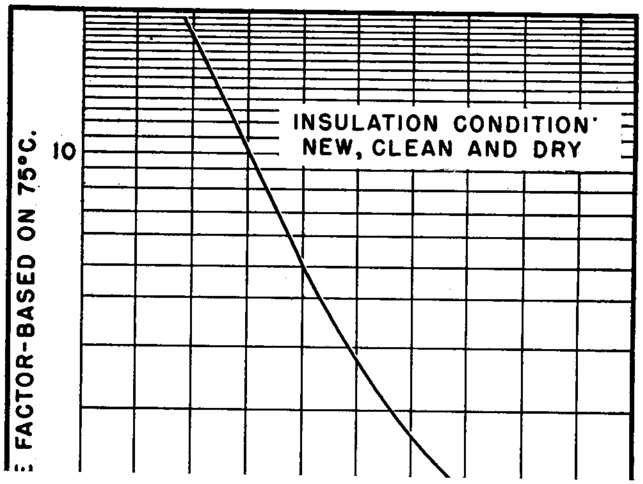
9. Refinish with suitable, recommended varnish as required.

STATOR WINDINGS

Maintenance of the stator winding 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, at the elevated temperature, as this would provide a more nearly correct "bench mark" for future reference. Take these readings in line with rules outlined in these instructions.

Annual Inspection. 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 winding 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 winding is sufficiently dirty, take necessary cleaning steps with solvents as described under "Cleaning" on page 35.

After the first annual inspection, subsequent in-



PART SIX

OVERHAUL AND REPAIR

Application. For securing a gas or oil tight joint between two metal surfaces which have been lapped.

Procedure No. 2

Fiber Sheet Packing #1925 (Vellumoid) with Cement #672. In applying the Fiber Sheet Packing #1925, brush one of the surfaces of the joint with a medium heavy coat of cement #672. Immediately after coating the metal member apply a thin uniform coat of the cement to one side of the gasket and allow the cement to air dry until the cement becomes tacky to the touch (about 5 to 10 minutes) then place the gasket in position on the previously coated member with the coated surfaces together. Press the gasket against the surface with a soft rag to remove any wrinkles, unevenness or air pockets. When assembling the part with the gasket attached, apply a medium heavy coat of the cement to the gasket surface and allow to dry until it becomes tacky to the touch (approximately 5 to 10 minutes) and then complete the joint.

Note. In some applications, the Vellumoid packing M #1925 will have a tendency to squeeze out of the joint as the bolts are tightened. This can be prevented by making the joint as follows: Brush a thin coat of cement #672 on both metal surfaces and permit the cement to dry hard before assembling the gasket. Use only enough cement to fill the machine marks on the metal surfaces.

Application. For securing a gas or oil tight joint where metal surfaces may be lapped or have a finish machine surface.

Procedure No. 3

Oil Resistant Packing #7249-1 (Corprene) with Cement #672. Special care must be observed in making a joint with oil resistant packing #7249-1 and cement #672. It is absolutely necessary that the cement be permitted to dry hard before the joint is pulled up tight. The Corprene will flow out of the joint if the cement is not hard and gas leaks will result. A thin coat of cement #672 should be brushed on each of the metal surfaces, using just enough to fill the machine marks. Permit the cement #672 to dry hard. Test the cement for slippage by pressing downwards and sideways with a finger. Be sure the cement is more than just skin hard. If the skin on the cement surface is hard and the cement below the skin is soft, the Corprene will

APPLICATION CHART OF MATERIALS USED FOR PACKING JOINTS

PROCEDURE	APPLICATION	MATERIALS
No. 1	Metal to metal joints	Cement #672 Alcohol (Thinner) #1701
No. 2	All joints requiring Vellumoid packing Collector chamber seal gasket Gas, oil and water line gaskets	Fibre Sheet Packing (Vellumoid M #1925 Cement #672

flow out of the joint, the soft cement acting as a lubricant. Use the above method where possible as this is preferred.

In some few applications, it will be desirable to stick the Corprene gasket to a metal surface with cement #672. When this is necessary, brush one of the surfaces of the joint with cement #672, using a thin coat. When the cement has become quite tacky to the touch, apply the gasket. Then let this assembly dry until it is impossible to make the gasket slip. Apply a light coat of cement to the other member of the joint, using just enough to fill the machine marks. Permit the cement to dry hard so it will not slip as covered in the preceding paragraph.

A joint made with oil resistant packing #7249-1 and cement #672 is not satisfactory if there is evidence that the Corprene squeezed out of the joint. This always results in gas leaks.

Application. For gas or oil tight joints having medium bolt pressure and having a finish machined surface.

Procedure No. 4

Oil Resistant Packing #7249-1 (Corprene) Without Cement. The oil Resistant Packing 7249-1 shall be applied without cement.

Application. For gas or oil tight joints with medium bolt pressure and finish machined surfaces. This application covers joints where it is practical to assemble the gasket dry, such as main lead bushing gaskets.

Procedure No. 5

Cloth Inserted Rubber Sheet #8566-1 With Cement #672. In applying the cloth inserted rubber sheet #8566-1, brush a thin coat of cement #672 to both surfaces of the metal members. Use just enough cement to fill the machine marks. Permit the cement #672 to dry hard. Test the cement for slippage by pressing downwards and sideways with a finger. Be sure the cement is not just skin hard, as this may result in flow of the rubber when the joint is pulled up.

Application. For gas tight joints for diaphragm applications, for joints with medium bolt pressure, and finish machined surfaces.

Procedure No. 6

Asbestos compressed Sheet #4331 with Cement #7247. In applying the asbestos compressed sheet gaskets, brush one of the surfaces of the joint with a medium heavy coat of cement #7247, thinned with Toluol #5052, such that it can be applied readily by brushing. The thinning requires the addition of approximately 20 to 25%, by volume, of Toluol. When the cement becomes quite tacky to the touch, which will occur in about 20 minutes, apply the gaskets. When applying the gaskets to sections in a vertical position hold in place with "U" shaped springs, and when applied on sections in a horizontal position weight the gaskets. Place the other member in position without cement and complete the joint.

Application. For gas tight joints having high bolt pressure and rigid metal members having finish machined surfaces.

LIST OF PACKING MATERIALS

MATERIAL	NUMBER
Fibre Sheet Packing (Vellumoid)	1925
Oil Resistant Packing (Corprene)	7249-1
Cloth Inserted Rubber Sheet	8566-1
Asbestos Compressed Sheet	4331
Cement (Synthetic Varnish)	7247
Cement	672
Toluol	5052
Lacquer Thinner	2525
Alcohol	1701

Refer to the specific drawing list applying to each individual condenser order, as this book plus the supplementary list of specific drawings will constitute the only instructions applying to this type of apparatus.

PART SEVEN

SUPPLEMENTARY DATA

Safety Rules

Important. The standard hydrogen cooled synchronous condenser housing is designed to resist, without rupture, the pressures incident to an explosion with normal operating gas pressure of ½ lb. per sq. in. gauge.

Care should be taken to prevent an explosive mixture when operating condenser at any gas pressure, and particularly at pressures above ½ to 1 psi gauge.

Note. The following rules have been reprinted from a pamphlet published by the Compressed Gas Manufacturers' Association and are based upon accident prevention experience within the compressed gas industry.

GENERAL

1. Never drop cylinders nor permit them to strike each other violently. (Cylinders should be chained to prevent them from falling over.)

2. Never use a lifting magnet nor a sling (rope or chain) when handling cylinders. Provide a safe cradle or platform to hold the cylinders whenever a crane is used.

3. When returning empty cylinders, remove lower portion of the shipping tag attached to the cylinder. Bill of lading should specify number of cylinders, consignee and the fact that cylinders are empty. A copy of bill of lading should be sent to the consignee. Close valve before shipment. See that cylinder valve protective caps and outlet caps, if used, are replaced before shipping.

4. Where caps are provided for valve protection, such caps should be kept on cylinders except when cylinders are in use.

5. Never use cylinders for rollers, supports, or for any purpose other than to carry gas.

6. Never tamper with the safety devices in valves or cylinders.

7. Open cylinder valves slowly. Never use wrenches or tools except those provided or approved by the gas manufacturer. Never hammer the valve wheel in attempting to open or close the valve.

8. Make sure that the threads on regulators or other auxiliary equipment are the same as those on cylinder valve outlets. Never force connections that do not fit.

9. Never attempt to repair or alter cylinders or valves.

10. Protect cylinders against excessive rise of temperature. Cylinders may be stored in the open but in such case should be protected against extremes of weather and from the ground beneath to prevent rusting. During winter, cylinders stored in the open should be protected against accumulations of ice or snow. In summer, cylinders stored in the open should be screened against continuous direct rays of sun.

11. No part of any cylinder containing a compressed gas should ever be subjected to a temperature above 125°F. A direct flame should never be permitted to come in contact with any part of a compressed gas cylinder.

12. Never store cylinders near highly inflammable substances such as oil, gasoline, waste, etc.

13. Cylinders should not be exposed to continual dampness.

14. Store full and empty cylinders apart to avoid confusion.

15. Do not store cylinders near elevators or gangways, or in locations where heavy moving objects may strike or fall on them.

16. When in doubt about the handling of a compressed gas cylinder or its content, consult the manufacturer of the gas.

17. Be careful to protect cylinders from any object that will produce a cut or other abrasion in the surface of the metal.

HYDROGEN

1. Keep sparks and flame away from cylinder.

2. Connections to piping, regulators, and other appliances should always be kept tight to prevent leakage.

3. Never use an open flame to detect hydrogen leaks. Use soapy water. During freezing weather linseed oil may be used.

4. When cylinders are not in use, keep valves tightly closed.

5. After removing valve cap, slightly open valve an instant to clear opening of particles of dust or dirt.

6. If valve is difficult to open, point the valve opening away from you and use greater force. Avoid, however, the use of a wrench on valves equipped with handwheels.

7. After attaching regulator and before opening cylinder valve, see that adjusting screw of regulator is released.

8. Never permit the gas to enter the regulator suddenly. Open tne cylinder valve slowly. (When the high-pressure gauge registers full cylinder pressure the valve handle shall then be screwed to its "full open" position.)

9. Before regulator is removed from a cylinder, close the cylinder valve and release all gas from regulator.

10. Do not exhaust cylinders completely. Leave at least 5 psi pressure in each. Make sure the cylinder valves are closed tightly. Mark empty cylinders "M".

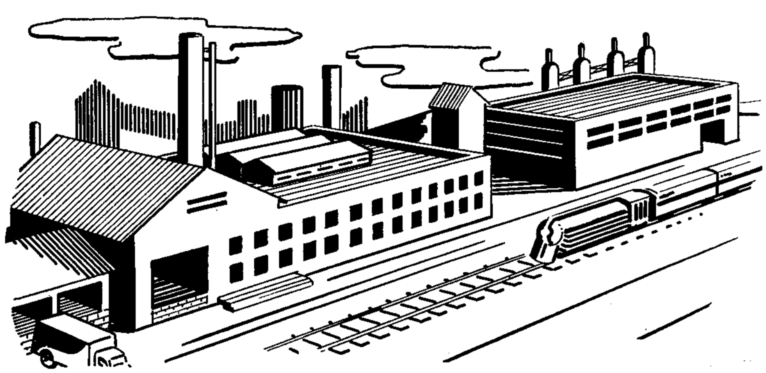
11. Store all cylinders containing hydrogen in a well ventilated place.

12. If a cylinder is found to be leaking it should be immediately moved out of doors. If the leak cannot be stopped, a warning should be placed near the cylinder not to approach it with lighted cigarettes or other means of ignition.

CARBON DIOXIDE

1. If it is necessary to immerse a cylinder in a bath of warm water to facilitate discharge, care must be taken to assure sufficient discharge at all times to prevent a dangerous pressure in the cylinder. The temperature of the water bath should never exceed 125°F. In no event should the cylinder valve be submerged—nor more than 20 per cent of the surface area of the cylinder be under the water.

2. Great care should be taken to avoid the backing up of water into the cylinder—particularly during the winter on account of the danger of freezing—or the entry of any foreign matter, such as oil, into or around the valve.



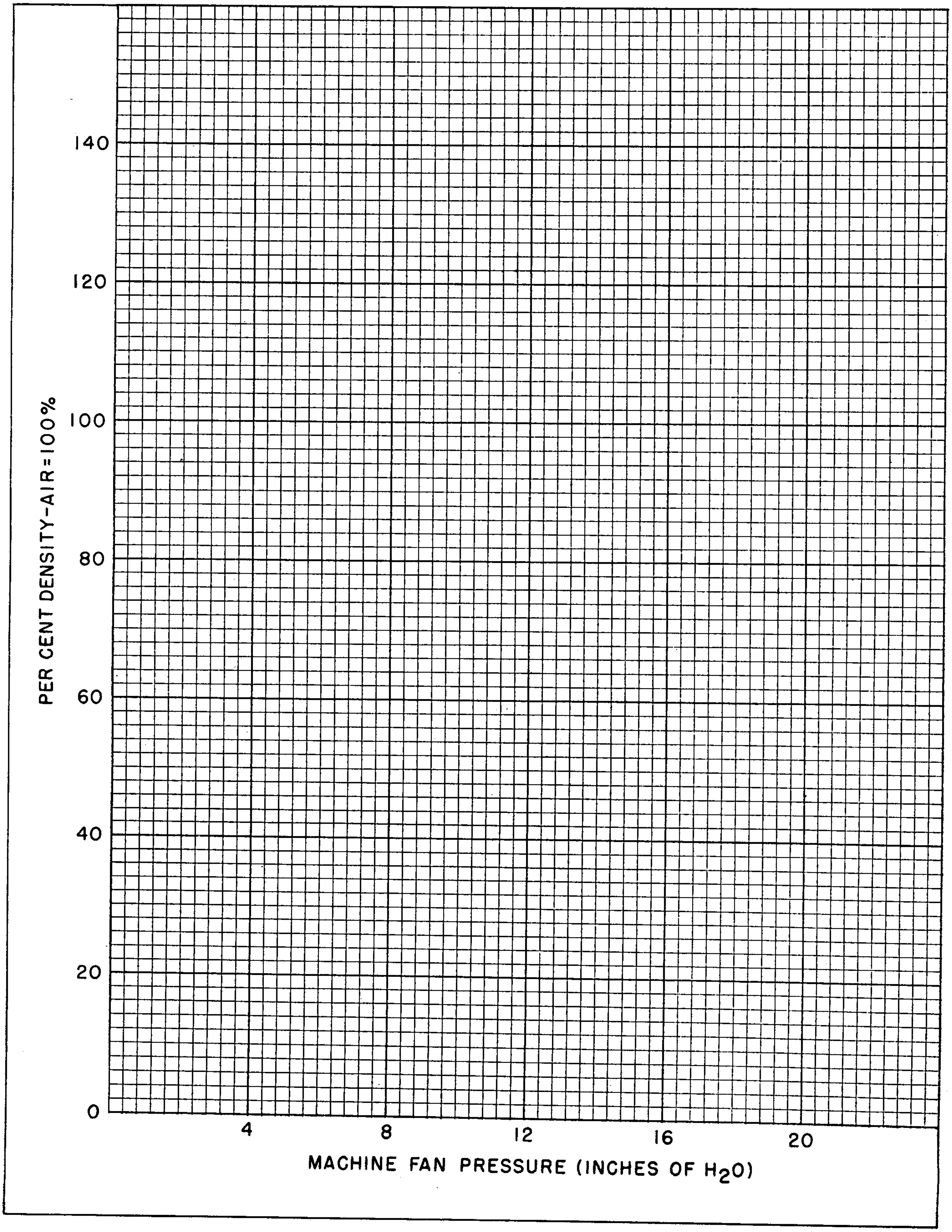


FIG. 32. Work Sheet for Determination of Density—Fan Pressure Constant

DENSITY—FAN PRESSURE RELATIONSHIP

The ratio between the density meter and fan pressure gauge readings is a constant. Therefore, it is only necessary to secure a reading of the fan pressure and density meter gauges at a time when both are operating satisfactorily. Thereafter either gauge reading may be transferred to the other gauge reading by multiplying or dividing by this constant as the case may be:

Density = Fan Pressure x Constant
and
Fan Pressure = Density ÷ Constant

Since a straight line relationship exists between the density and Fan Pressure readings, a chart may readily be prepared. Fig. 32 is provided for this purpose. The straight line will go through 0-0 and some other point to be determined when the density meter and fan pressure gauges are both operating.