INSTRUCTION BOOK

FA MOTORS

Induction and Synchronous Types

Westinghouse Electric Corporation

I. B. 1300-FA-1

INSTALLATION • INSPECTION • MAINTENANCE

INSTRUCTIONS

WESTINGHOUSE F/A MOTORS

Induction and Synchronous Types

WESTINGHOUSE ELECTRIC CORPORATION
POWER APPARATUS DEPARTMENTS • EAST PITTSBURGH, PENNSYLVANIA

NEW INFORMATION

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TABLE OF CONTENTS

TABLE OF CONTENTS

Part Seven — **ACCESSORIES** — **Pages 52-56**

LIST OF ILLUSTRATIONS

Figure — **Page**

LIST OF ILLUSTRATIONS

LIST OF TABLES

Typical F/A Motor

INTRODUCTION

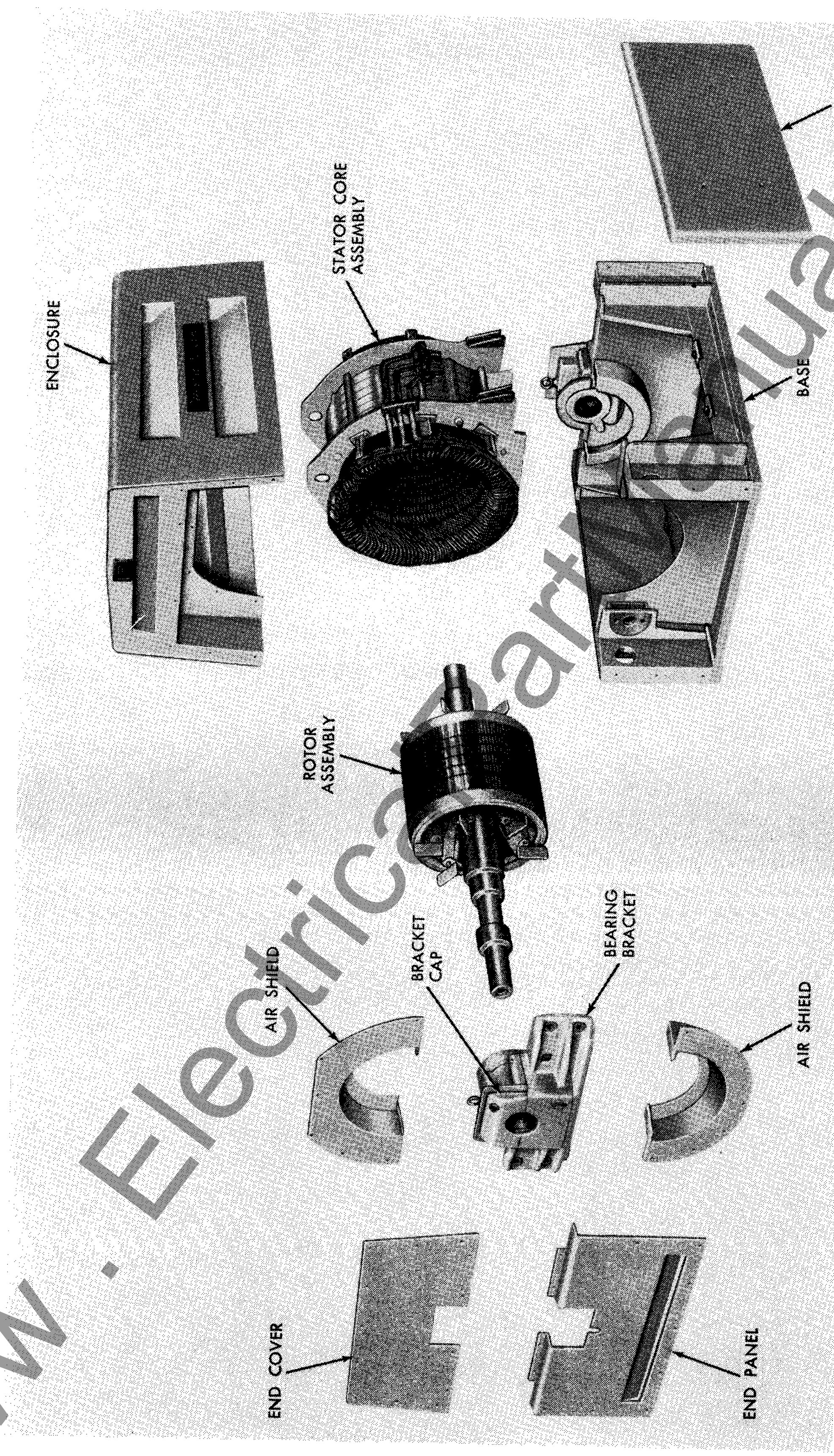


FIG. 1. Component Parts of Typical F/A Motor

This manual has been prepared to enable you to obtain years of trouble-free service from your Westinghouse F/A (Fully Accessible) Motor. Instructions for the proper installation, operation, and maintenance of the full line of F/A motors are given in this manual. Should unusual situations arise which are not covered in the detailed instructions, Westinghouse Sales and Service Engineers are at your service.

The Westinghouse F/A motor line is a family of motors featuring a take-apart housing, easy disassembly, automatically precise reassembly, and a simple and thorough total inspection routine.

Four types of F/A motors are available—

Type CS—Squirrel cage induction motor
Type CS—Two-pole squirrel cage induction motor
Type CW—Wound rotor induction motor
Type G—Synchronous motor

F/A motors are available with any one of seven types of enclosures—

Drip-proof enclosure
Splash-proof enclosure
Weather-protected (NEMA-I) enclosure
Weather-protected (NEMA-II) enclosure
Totally enclosed fan-cooled (TEFC) enclosure
Totally enclosed (with cooler) enclosure
Forced ventilated enclosure

F/A motors are available in power ratings ranging from 200 hp, 514 rpm up to approximately 7000 hp, 3600 rpm. Voltage, frequency, torque, kva rating, and other motor characteristics may be tailored to fit application requirements.

Although the physical characteristics vary from motor to motor in the F/A line, all motors bear a family resemblance. The major components of a typical F/A motor are illustrated in Figure 1.

This manual is divided into seven parts: Introduction, Installation, Electrical Connections and Start-up, Inspection and Maintenance, Bearings and Lubrication, Collectors and Brushes, and Accessories.

Part Two contains information needed for proper installation of any of the F/A motors.

Part Three details the procedural steps necessary for correct electrical connection of an F/A motor and the all-important checks preceding initial start-up. In addition, Part Three includes information concerning starting duty.

Part Four contains instructions essential for inspection and proper operational maintenance of F/A motors. These instructions, organized in such a manner that they apply to all motor types, describe complete and partial motor disassembly required for any inspection or maintenance operation. Part Four also presents a thorough discussion of insulation resistance, and supplies the information necessary for the calculation of the correct value of insulation resistance for a particular type of motor. Approved methods of measuring insulation resistance, interpretation of results, and remedial action are included in Part Four.

Bearings and bearing lubrication are discussed in Part Five. Detailed information on the inspection and replacement of bearings and a discussion of the construction and operation of both the bearings and their lubrication systems are provided.

The collectors and brushes used in synchronous and wound rotor F/A motors are fully described in Part Six.

Accessories used with the various F/A motors are discussed in Part Seven. These accessories include space heaters, resistance temperature detectors, air filters, and noise mufflers.

PART TWO

INSTALLATION

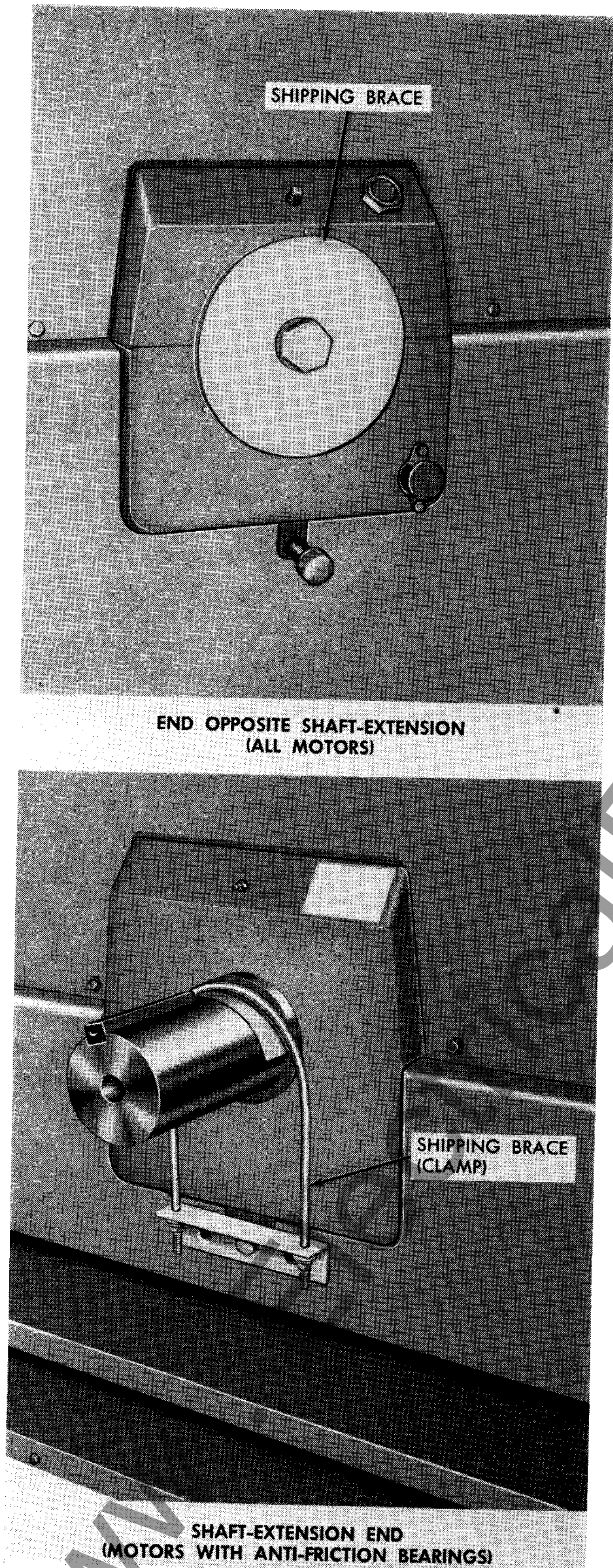


FIG. 2. Shipping Braces for F/A Motors

A. MOTOR SHIPMENT

Prior to shipment, all F/A motors undergo electrical and mechanical testing. After completion of tests, each motor is wrapped with heavy weatherproof paper for shipment by a common carrier. Motors to be shipped overseas are also crated.

Upon receipt of the motor, carefully inspect the wrapping and crate for any signs of damage. Should such damage be evident, unpack the motor at once in the presence of a claim adjuster and immediately report all damage and breakage to the transportation company.

When writing to Westinghouse Electric Corporation concerning the machine, be sure to include the motor serial number which appears on either the coupling end of the shaft or the nameplate.

Note that a shipping brace (Figure 2) prevents motion of the motor rotor. This brace is painted yellow and is bolted to one end of the shaft. Motors with anti-friction bearings are also provided with a shipping brace (clamp) which holds the shaft to the bearing bracket at the shaft-extension end of the motor. These braces **must** be removed before the motor is started, but should remain in place until instructions call for their removal.

B. HANDLING

The equipment needed for handling the motor includes a chain hoist, a two- or four-leg spreader sling, and hard-rubber pads.

A fully assembled motor should be lifted only by means of the motor lifting bars. These bars are located at the top of the upper air discharge openings on the sides of the drip-proof, splash-proof, and NEMA-I weather-protected enclosures (Figure 3), and are found at the top of a recessed pocket at each end of the NEMA-II weather-protected enclosures (Figure 4).

Fasten the spreader sling(s) to the chain hoist and attach the spreader sling hooks to the lifting bars in such a manner that the motor weight is distributed uniformly. Place hard-rubber pads between the sling hooks and the motor enclosure to avoid damage to the finish. After checking for proper placement of the lifting hooks, take up on the chain hoist slowly and carefully (Figures 3 and 4) and move the motor to the desired location.

If the F/A motor is mounted on a bedplate, the assembly should be lifted as follows: Place the spreader sling hooks into the openings provided in the bedplate. Arrange the slings so that equilibrium of the assembly will be maintained. Slowly

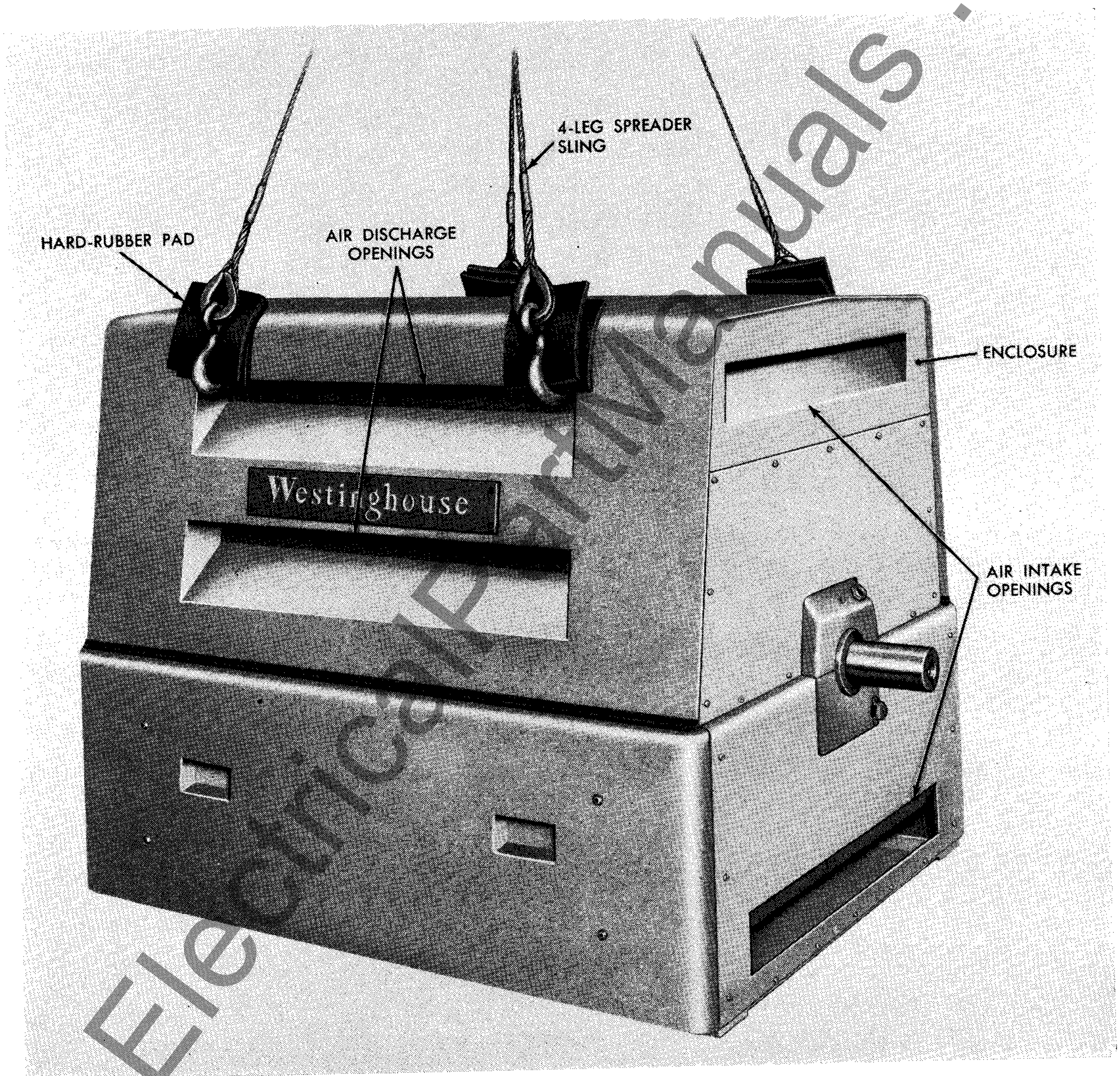


FIG. 3. Lifting F/A Motor with Four-Leg Spreader Sling

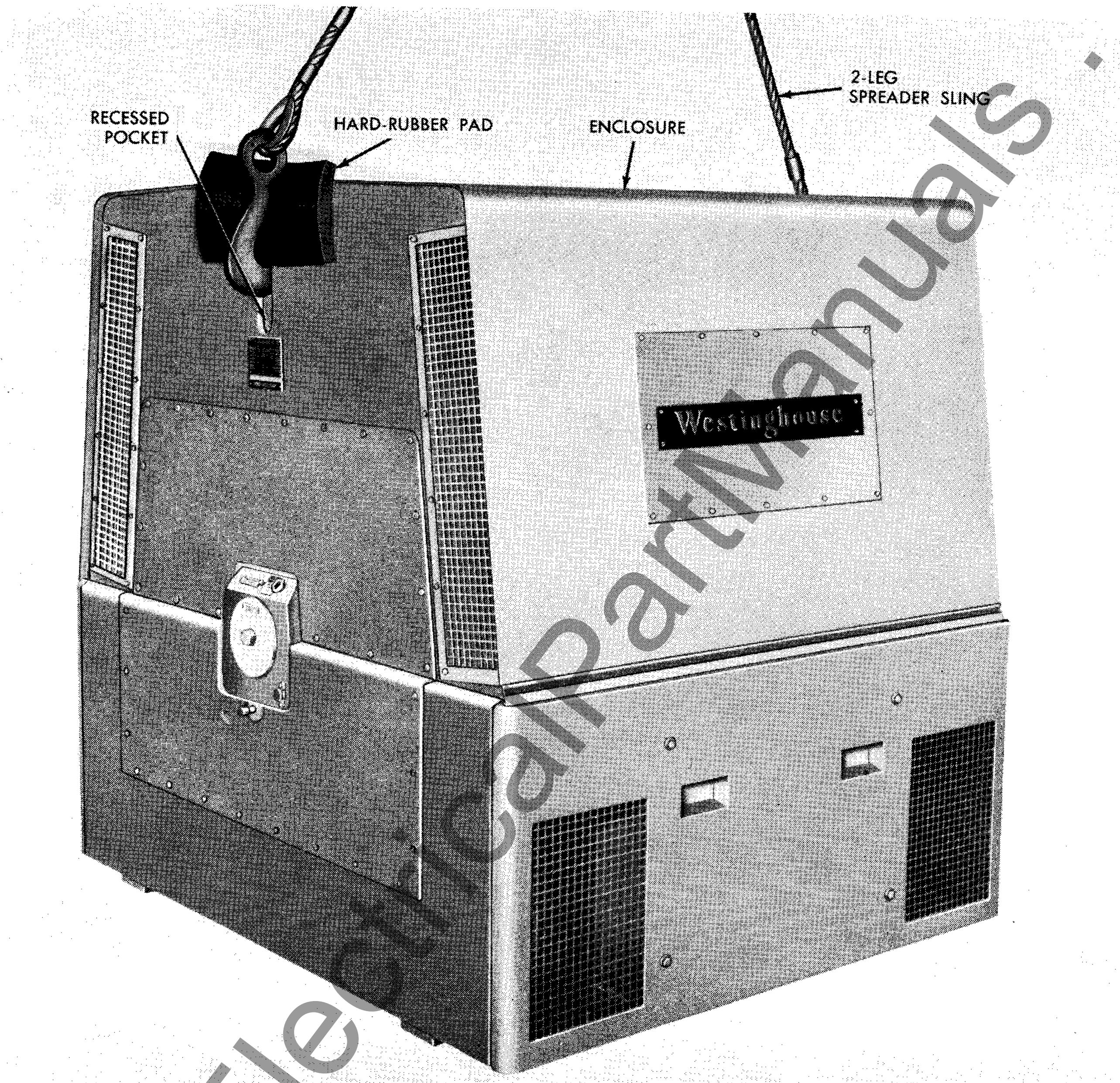


FIG. 4. Lifting F/A Motor with Two-Leg Spreader Sling

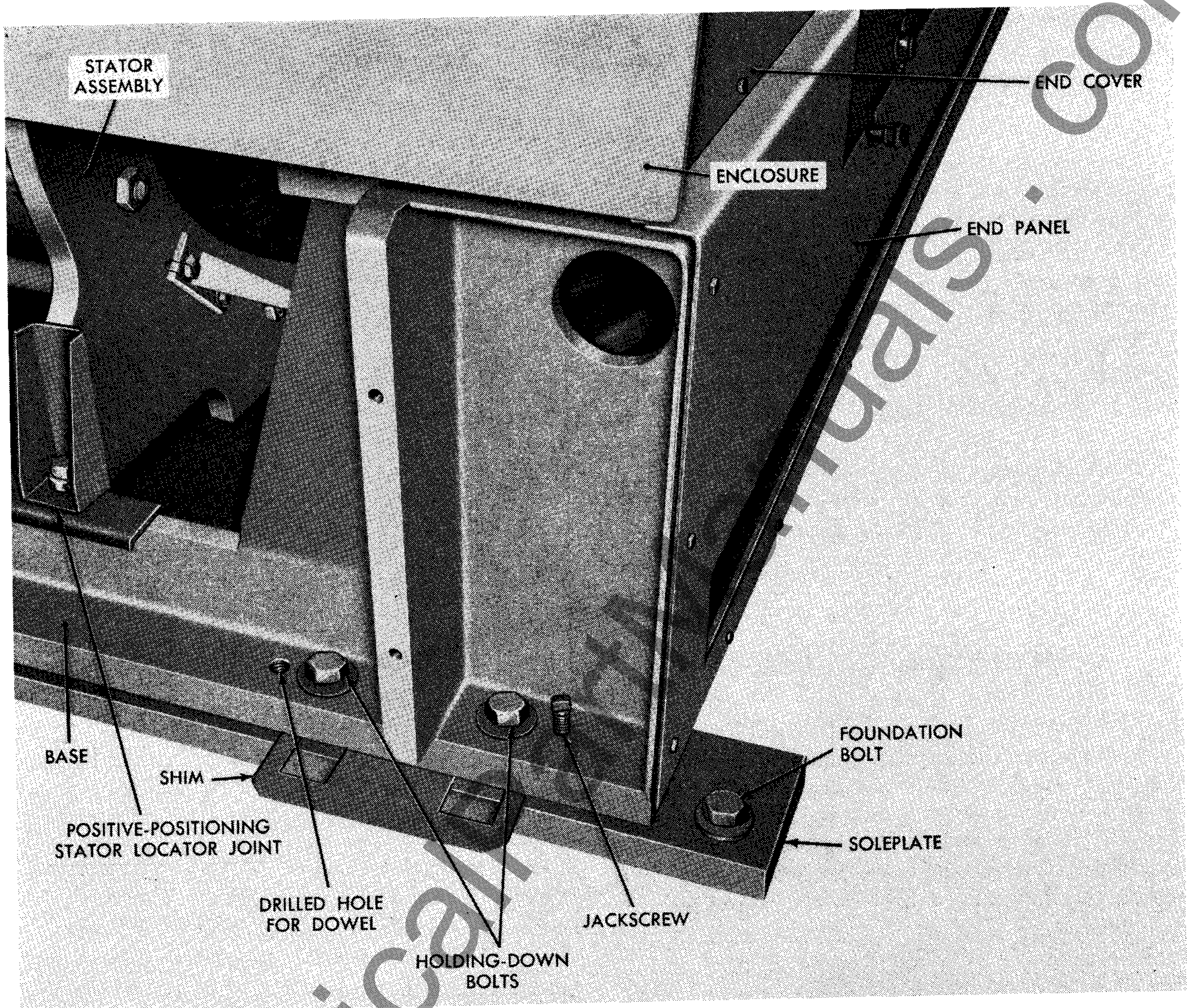


FIG. 5. View of F/A Motor with Side Panel Removed; End Opposite Shaft-Extension End

and carefully take up on the chain hoist and move the motor to the desired location.

If the motor is to be set in a temporary location, lower the motor onto supports placed under each of the four corners. These supports should be reasonably level.

C. MOTOR STORAGE

The Thermalastic winding insulation has excellent inherent moisture resistance, but reasonable care should be exercised to protect the windings from excessive moisture whenever the motor is not operating. Such protection will also prevent rusting of the core and corrosion of metal parts not coated with slushing compound. If possible, the motor should be stored in a room which is clean, dry, and warm. If the motor is equipped with space heaters, the heaters should be energized whenever the storage area is cold and damp. Motors not equipped with space heaters may be kept warm by placing several 100- or 150-watt electric lamps within the motor enclosure and connecting them to a power supply (refer to Part Three, Section A, ELECTRICAL CONNECTIONS for instructions).

Bearing oil reservoirs should be filled to the indicated level with the proper lubricating oil (see Section F, INSTALLATION PROCEDURES). Periodically, the rotor shaft should be rotated a number of times in order to lubricate the journals and prevent rusting.

Before a motor which has been stored for an extended period of time is started, it must be thoroughly inspected and cleaned (see Part Four, INSPECTION AND MAINTENANCE, Sections B and

C). The insulation resistance should be measured at this time in order to determine if it is within allowable limits.

D. MOTOR LOCATION

The location of the motor must be such that all requirements of the National Board of Fire Underwriters and all local codes and regulations are met.

The following additional considerations should also govern the location:

1. Install the motor so that it is well ventilated.

2. Install the motor so that there is enough working space around the motor for disassembly, inspection, cleaning, part replacement, and reassembly.

The motor room must be well ventilated so that the hot air will escape rather than recirculate through the machine. Unless the room is large and well ventilated, natural ventilation will not be sufficient. If the motor is designed to take air from a pit, suitable ducts must be provided in the foundation.

E. FOUNDATION AND ERECTION

A rigid foundation is essential so that vibration and misalignment during operation will be reduced to a minimum. The foundation should consist preferably of solid concrete footings or piers carried down far enough so that they rest on a solid subbase. If it is necessary to support the motor on steel work instead of concrete, the beams or girders should be adequately braced and supported by columns.

Reference should be made to the outline drawing furnished with the motor for all dimensions necessary for location and mounting (holding down bolts, foundation bolts, conduits, condulets, ventilating ducts if required, and soleplate). See Figure 5 for general placement of bolts and soleplate.

A template made to the dimensions on the outline drawing will simplify the work of locating the foundation bolts. It is best to provide for some variation in the location of the foundation bolts. This can easily be done by locating the bolts in steel pipe embedded in the foundation (Figure 6).

The top of the concrete foundation should be roughened, cleaned, and washed before placing the bedplate or the soleplates upon it. A roughened surface permits a good bond between the foundation and any necessary grouting.

Bracket-type motors furnished with soleplates or mounted on the bedplate of the driven equipment should be aligned by means of shims beneath the motor frame feet near the foundation bolts. Jackscrews are provided in the feet to facilitate insertion of the necessary shims. When the alignment is correct, the jackscrews should be removed and the soleplate grouted to the foundation.

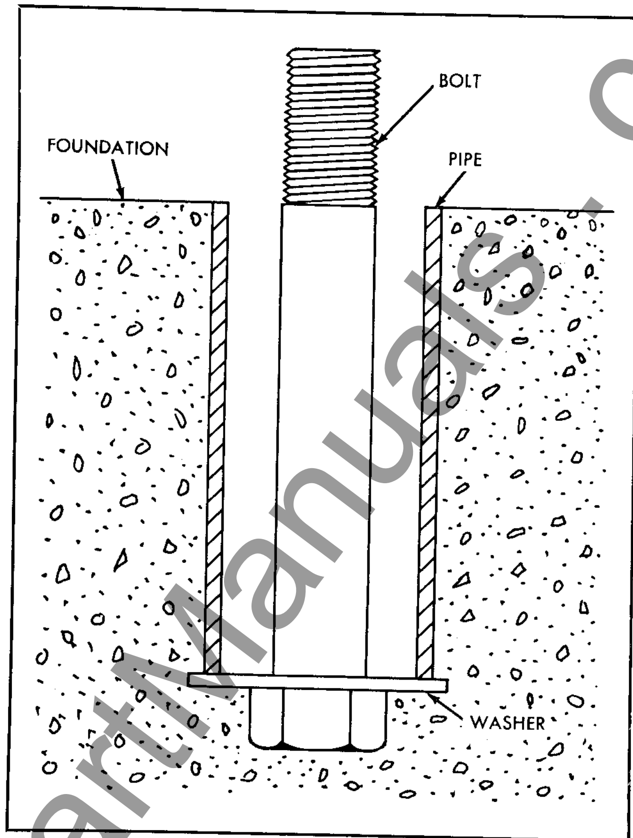


FIG. 6. Method of Anchoring Foundation Bolt

Grout is mixed in the proportion of one part clean sand to one part Portland cement. Add water until the mixture is thin enough to be tamped thoroughly under the base. Rails or soleplates are grouted to within a half inch of the top. The entire operation of mixing and pouring the grout should be completed without interruption and as rapidly as possible.

F. INSTALLATION PROCEDURES

1. Carefully lower motor onto foundation using method described under HANDLING (Part Two, Section B). Position motor to obtain best possible alignment.

2. Remove both side panels with a suitable tool. Do not remove enclosure, end panels, and end covers. (See Figure 1.) This will provide access to the motor terminals and to holes in the base for the holding-down bolts, motor base dowels, and jackscrews, as shown in Figure 5.

3. Remove shipping brace(s) with a suitable tool. (Braces are painted yellow.)

4. The four jackscrews are supplied installed in place. The leveling shims (.014-, .018-, and .025-

inch thicknesses) are furnished by Westinghouse and are enclosed in a packet shipped as a separate item.

5. Motors are shipped with shaft extensions and couplings (if pressed on at the factory) protected with a coating of slushing compound. This compound should be removed by washing the slushed parts with a petroleum solvent such as Stoddard solvent or similar solvents available under various trade names.

The shaft journals are also protected with a slushing compound before leaving the factory. This compound, however, is soluble in the lubricating oil and does not require removal before operating the motor.

6. If the motor half of the coupling has not been mounted by Westinghouse, it should be attached to the shaft at this time according to the instructions provided by the coupling manufacturer.

Many 3000- and 3600-rpm motors are designed with a total end play of ½ inch. If the flexible coupling to be used is of the free-float type, the coupling end play should be limited to a total of $\frac{3}{16}$ inch in order to prevent damage to the motor bearings arising from axial loads not present when the motor is operated uncoupled. In some applications (e.g., boiler-feed pump drives), the motor should be aligned in accordance with instructions supplied by the equipment builder.

7. Adjust the motor vertically using the jackscrews. Make correct axial adjustment, as nearly as possible, before beginning alignment of couplings. Install holding-down bolts with a suitable wrench.

8. Insert required number of shims under motor feet (Figure 5) until coupling halves are in approximate alignment. Back off jackscrews.

9. Connect motor to mechanical load in accordance with the following instructions. The motor should be accurately aligned with its connected mechanical load so that shaft stresses, vibration, and coupling wear will be reduced to a minimum.

All two-bearing motors should be flexibly-coupled or belted to their mechanical loads. Flexible couplings should not be forced to accommodate excessive misalignment; misalignment will produce undue wear and can cause vibration. The following procedure should be used to align flexible couplings:

a. Check angular alignment by using a feeler gauge between hubs at four points 90° apart. Position motor to obtain best possible alignment and correct hub separation.

b. The offset alignment is checked by fastening an indicator bracket on one hub with the dial indicator button contacting the alignment surface of the opposite hub. Rotate shaft on which indicator is attached to the hub, and take readings at four points 90° apart. Move motor until readings are identical. Transfer indicator to opposite hub and check offset alignment. Recheck angular alignment as described in Step a.

After each corrective adjustment, the holding-down bolts should be tightened and the alignment checked. After the alignment is completed, check to ensure that load is removed from jackscrews.

The following procedure should be followed whenever installing belted motors (Figure 7) and when replacing the belts on these motors:

a. Remove outboard pedestal each time before installing new belts (three-bearing belted motors only).

b. Install new belts in matched sets.

c. Tighten belts using slide rails (slide rails shown on the outline drawing provided with the motor). Then decrease belt tension until belts are just tight enough so that there is no slippage.

10. Tighten holding-down bolts securely with use of proper wrench.

11. Check foundation bolts for secure fastening.

12. Dowel base to soleplate using dowel holes (Figure 5). Use dowel holes closest to center of motor, one hole on each side of the base. Drill $\frac{23}{32}$-inch-diameter holes in soleplate, using base as a template. Ream holes to fit ¾-inch-diameter dowels.

13. Remove protective tape from oil sight glasses and oil level gauges. Also remove protective tape from collector rings and brush inspection windows (synchronous and wound rotor motors only) at this time.

14. Fill bearing bracket reservoirs to proper level with a good grade of machine oil. Refer to Part Five, Section D, for correct viscosity. (Refer to Part Five for discussion of forced-flood lubrication systems.)

15. Installation is now complete with the exception of electrical connections. This topic is covered in Part Three.

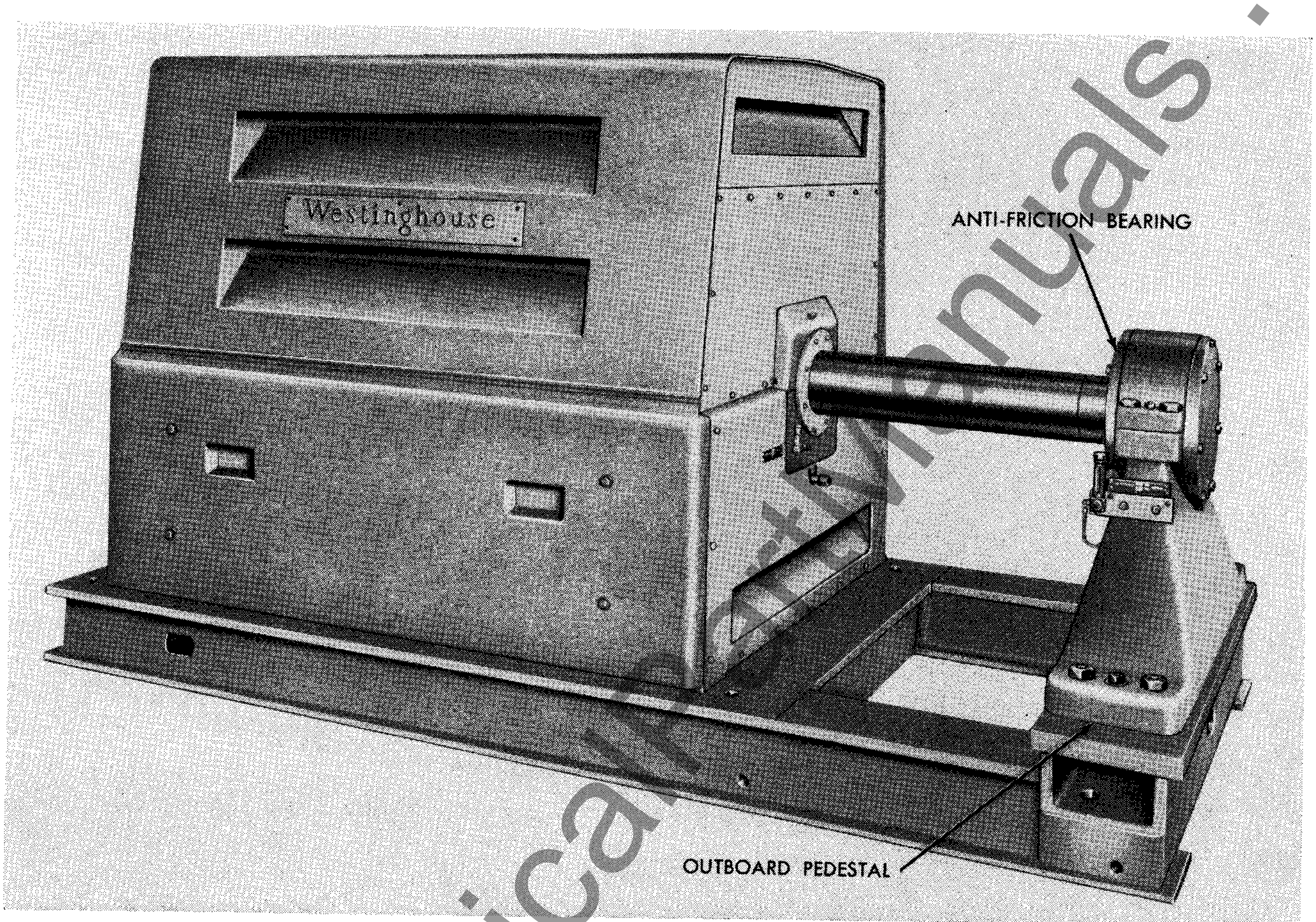


FIG. 7. Three-Bearing Belted F/A Motor

PART THREE

ELECTRICAL CONNECTIONS AND START-UP

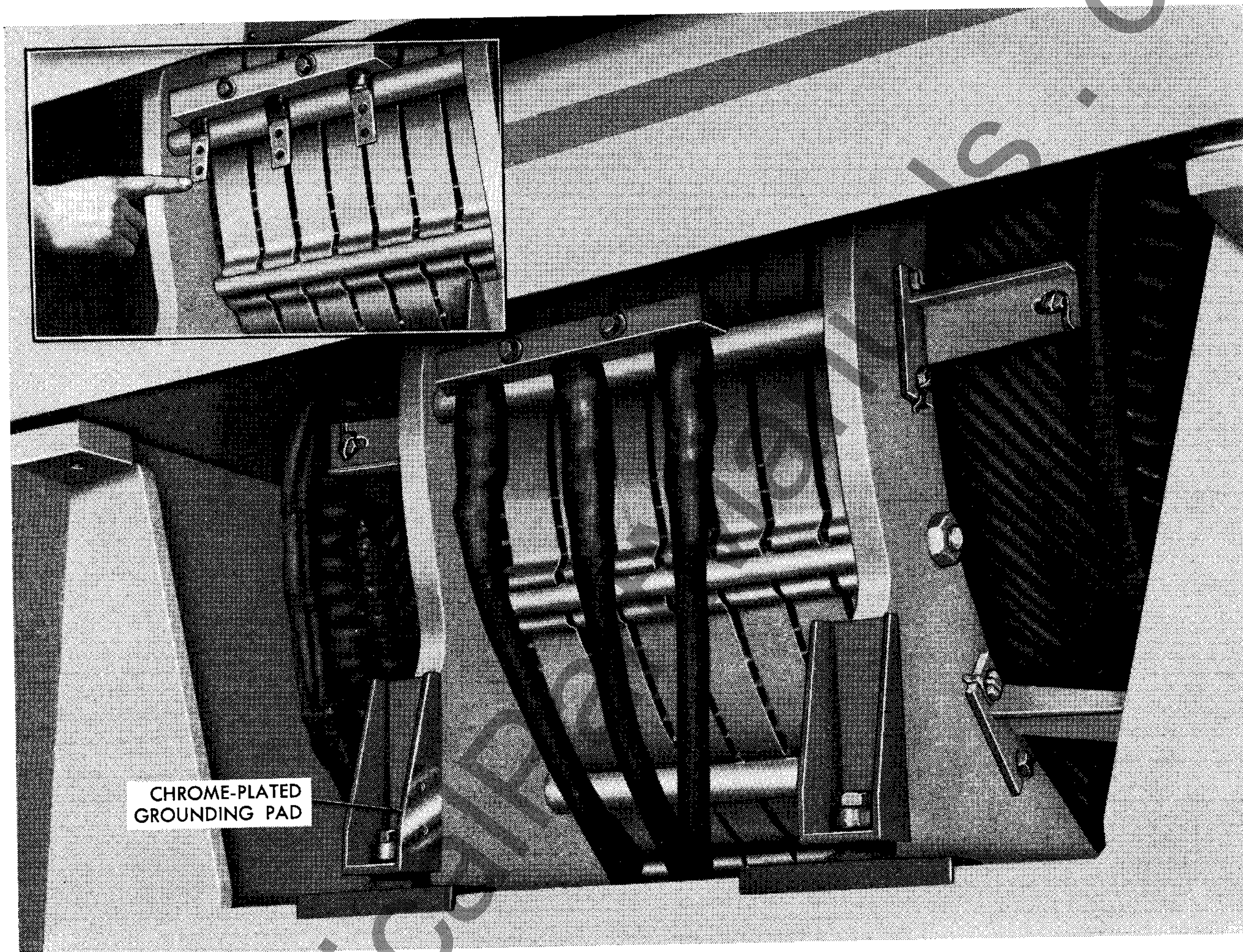


FIG. 8. Power Lead Connections

A. ELECTRICAL CONNECTIONS

The outline drawing supplied with the motor shows the location of the main motor strap terminals and any auxiliary terminal blocks. This drawing also illustrates the manner of connecting the motor to the power source. Both side panels are removed to gain access to the main motor strap terminals and auxiliary terminal blocks. (Motors are provided with conduit boxes, when so ordered.) Connect the power leads to the motor strap terminals, with the proper size lead terminals. (See Figures 8 and 9.)

Synchronous and wound rotor motors are equipped with collector rings and brushes. The collector rings are factory-connected to the rotor, while the brushes are connected as described below.

Synchronous motors require d-c excitation of the rotor; connect the two brush (rotor) terminals to the proper d-c voltage source as shown on the drawings furnished with the motor control equipment. Wound rotor motors require the insertion of resistance in the rotor winding circuit during start-up and the subsequent short-circuiting of these windings when the motor has reached operating speed. Connect the three brush (rotor) terminals to the appropriate motor control terminals in accordance with instructions supplied with the motor control equipment.

The motor may be connected for operation with any of several different power sources (refer to the outline drawing). A standard motor has either three or six motor strap terminals. The power leads are connected to the motor terminals as follows:

1. Three-terminal Motor—Such motors are to be connected to a three-phase, three-wire power supply. Connect the three power leads to motor

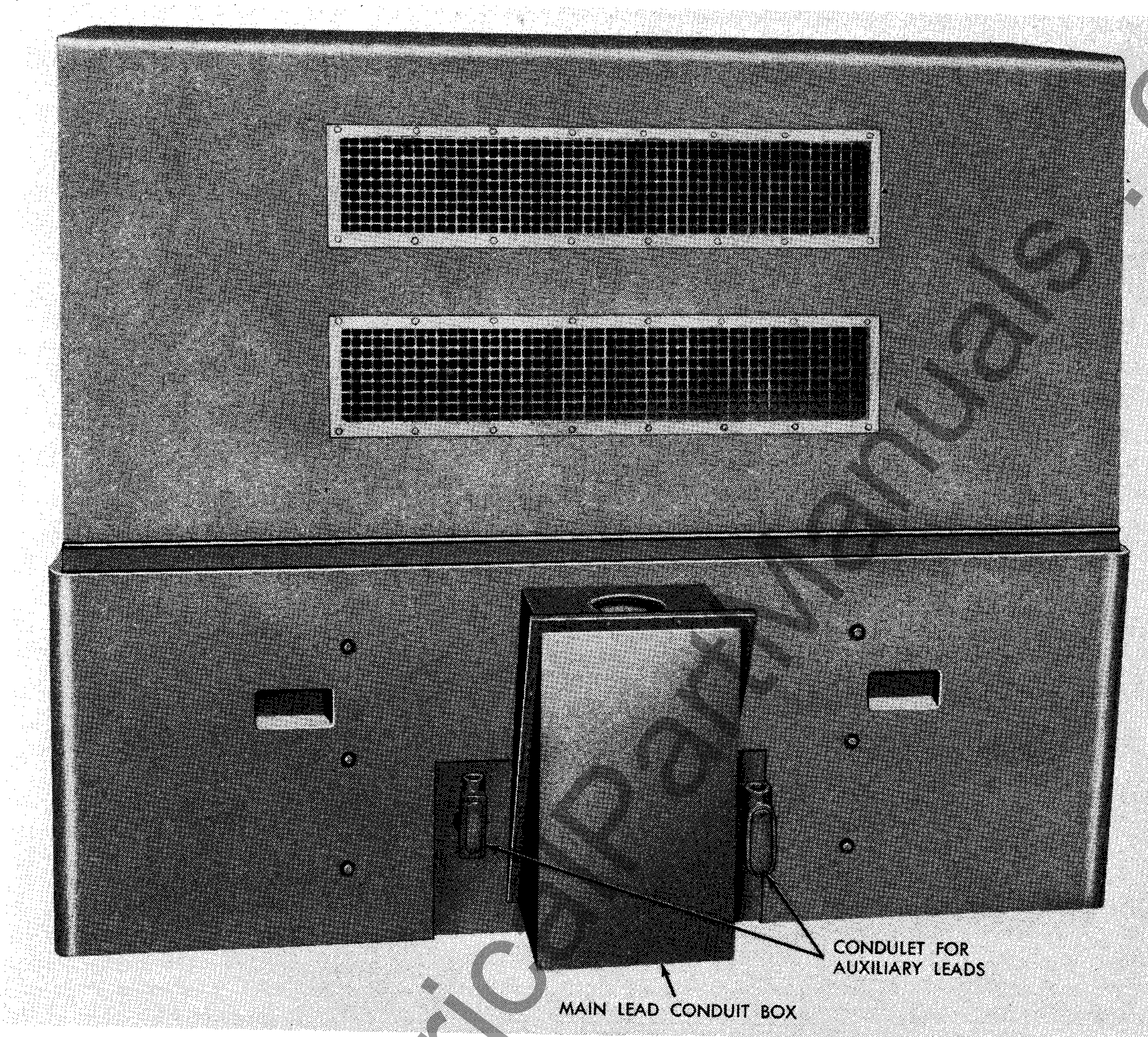


FIG. 9. Side of Motor Showing Conduit Box

strap terminals T_1, T_2, T_3, respectively. To reverse the direction of motor shaft rotation, interchange any two power leads. The rotation arrow (Figure 10) adjacent to the stator leads indicates the correct phase sequence.

2. Six-terminal Motor (Star or Delta)— Six-terminal motors are connected to the power supply as shown on the wiring diagram furnished with the motor control equipment.

3. Multi-speed and Two-phase Motors— Connections for these motors should be made after the motor nameplate and the drawings supplied with the control equipment have been checked.

The motor must be properly grounded to protect personnel against danger from electric shock should the stator-winding insulation break down. A grounding connector should be bolted to the grounding pad within the F/A motor. One of the stator locator joints on the main lead side of the motor (Figure 8) is chrome-plated and tapped to the standard NEMA size (½-13). The user should make sure that the pad is free of all paint before bolting the grounding-cable connector in place. Connect the other end of the grounding cable to a good electrical ground in accordance with standard industrial wiring practices.

Refer to the outline drawing for the location and function of auxiliary terminals. Install the motor control equipment in accordance with instructions. Connect space heaters, and install terminal blocks

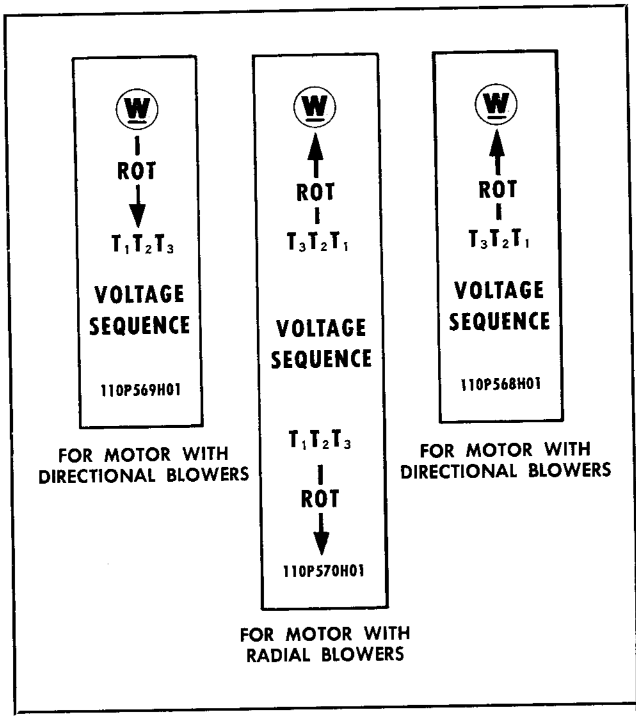


FIG. 10. F/A Motor Rotation Nameplates

for additional wiring, if required (see Figure 11). Check out the electrical circuits as detailed in Section B below.

B. INITIAL START-UP

Before starting the motor for the first time, the following procedure must be strictly followed:

1. Check out power supply to be sure that line voltage, frequency, and phase are correct for the motor (refer to motor nameplate).

2. Inspect all electrical connections for correct termination, clearance, mechanical strength, and electrical continuity.

3. Check to be sure that the yellow shipping brace has been removed from the motor shaft.

4. Inspect lubrication system to ensure that oil reservoirs have been filled to proper level with correct oil (see Part Five for specification of correct lubricant). Do not overfill oil reservoirs.

5. Remove end panels and end covers as required.

6. Carefully inspect interior of motor, coil ends, air gap, and blowers for loose foreign objects.

7. Be sure that there is sufficient clearance between rotating and stationary parts of the motor.

8. If possible, bar rotor over with a barring tool to make sure that it rotates freely.

9. Bump motor to check rotation by momentarily applying power to the machine.

10. Replace all panels so that motor is completely enclosed.

11. Start motor in accordance with instructions supplied with motor control.

12. As soon as the motor starts, inspect oil level in bearing bracket oil gauges to be sure that lubricating system is operating properly. Check that oil rings are turning by looking through the bull's-eye on the bearing bracket cap (bull's-eye set in oil ring inspection hole, Figure 32).

13. If abnormal noise, vibration, or temperature should be detected during motor operation, shut motor off immediately.

14. If a 3000-rpm, 3600-rpm, or a totally enclosed fan-cooled motor is being started for the first time, pay particular attention to rotational direction. These motors are suitable for only one direction of rotation. The outline drawing and the rotation arrow (Figure 10) mounted on the motor frame adjacent to the stator leads indicate the rotational direction for which the motor is designed.

Caution: Any motor which is made to rotate in the wrong direction will be improperly ventilated and will overheat rapidly, causing serious damage to the stator windings and bearings.

C. STARTING DUTY

Each motor is shipped from the factory with a tag indicating the recommended average number of permissible starts. This tag also indicates the recommended frequency of successive starting cycles. THIS TAG SHOULD BE RETAINED WITH THE MOTOR UNTIL THE EQUIPMENT IS PLACED IN SERVICE. When the motor is placed in service, the tag should be filed with this instruction book.

Too-frequent starting may cause damage to the motor windings. Initially, of course, several starts are required to properly adjust the motor control equipment and relays; these starts should be minimized to ensure long life of the motor. If in doubt about your duty cycle, refer to Westinghouse for further information.

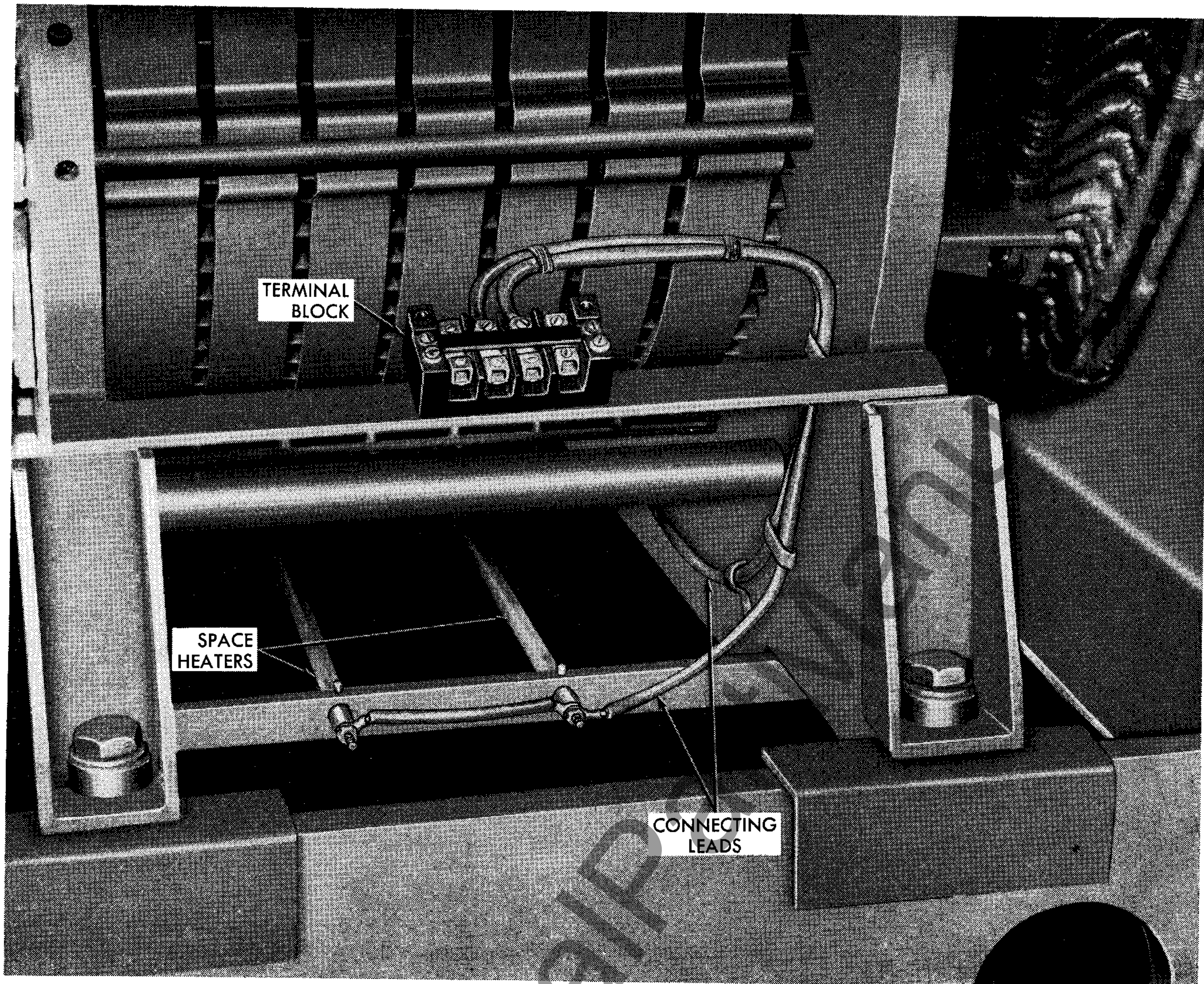


FIG. 11. Terminal Block Connections for Space Heaters

INSPECTION AND MAINTENANCE

A. INTRODUCTION

Instructions and procedures necessary to ensure continued, satisfactory operation of an F/A motor are given in this part.

Note: Further detailed information on maintenance practices is provided in the publication, "Maintenance Hints," available through your local Westinghouse sales office.

The part has been organized so that the instructions and procedures apply to all F/A motors. These motors are structurally identical as to supporting and framing members (side panels; end panels; enclosures; configurations for the stator assembly, the rotor, and the bearing support). Thus, instructions calling for the removal or replacement of such members are referenced to Figure 12, which shows a composite motor typifying the F/A motor line. However, whenever the detailed nature of a motor component or assembly requires it, the reader is referred to appropriate illustrations which augment Figure 12 and the instructions.

The text is presented in such a way that the instructions for complete or partial disassembly are easily followed no matter which type of F/A motor the user may have. Whenever a disassembly step is reached in which specialized instructions are needed, that procedural step is organized so that the reader is given the necessary information and also referred to the part which describes the motor component or assembly in detail. Bearings and lubrication are covered in Part Five, collectors and brushes in Part Six, and accessories in Part Seven.

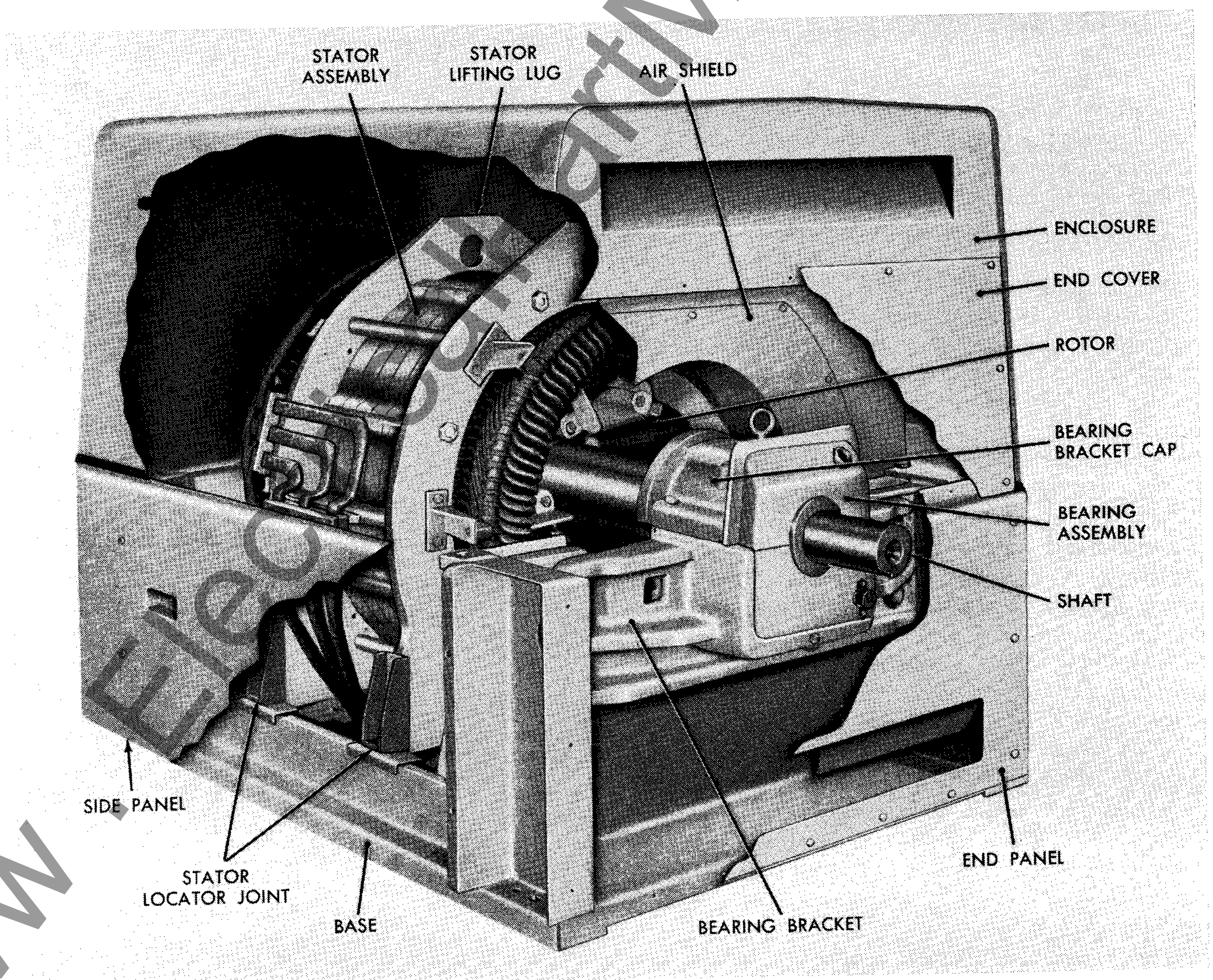


FIG. 12. Typical F/A Motor; Cutaway View

A complete set of standard tools, should be available for the installation and maintenance of the motor. A lifting crane, chain hoist, rope slings, and spreader slings (two-leg or four-leg, as required) are necessary for lifting the motor or its component parts. Foundation bolts, holding-down bolts, alignment dial gauges, air gap feeler gauges, bracket-removal studs, rotor lifting bolt, and a rotor barring tool are also required.

Other necessary supplies include heavy Kraft paper, a bearing puller, a flashlight, large tarpaulins, paint brush, red-lead paint, oil cans, steel pipe (for rotor removal), wooden blocks, and heavy-duty jacks. (The proper lubricants are described in Bearings and Lubrication, Part Five.) Equipment such as a commercial vacuum cleaner, Megger, and high-voltage voltmeter is also necessary.

A renewal parts list may be obtained by contacting the nearest Westinghouse office.

B. PERIODIC INSPECTION AND CHECKS

The F/A motor will provide a long period of trouble-free service if properly cared for. The motor should be kept clean and dust-free. Periodic inspections should be made to ensure that all ventilating ducts are free from the presence of foreign material and that external ventilating systems (when used) are operating properly.

Westinghouse strongly recommends that the lubrication system be inspected each day that the motor is in operation. If any leakage is found, it should be traced to its exact source and the necessary adjustments or repairs begun at once. The oil level in all oil gauges should be checked; add oil as needed. Rotation of the oil rings can be checked by looking through the bull's-eye provided in the oil ring inspection hole. Any excessive noise and/or vibration should be traced to its source and eliminated. These conditions may be due to a change in alignment between the motor and the load, the presence of a foreign object within the motor, contamination of the lubricating system, or other serious malfunctioning.

The temperature of the motor bearings should also be checked at regular intervals. The bearing temperature can be conveniently measured by placing glass chemical-type thermometers in the holes provided in the top of each bearing bracket housing (Figure 13). F/A motors are sometimes equipped with resistance temperature detectors located within the motor windings; these detectors are employed as noted on the outline drawing supplied with the motor.

The maximum allowable temperature of the bearing is 85°C (185°F), while the maximum allowable bearing temperature **rise** is 45°C (81°F).

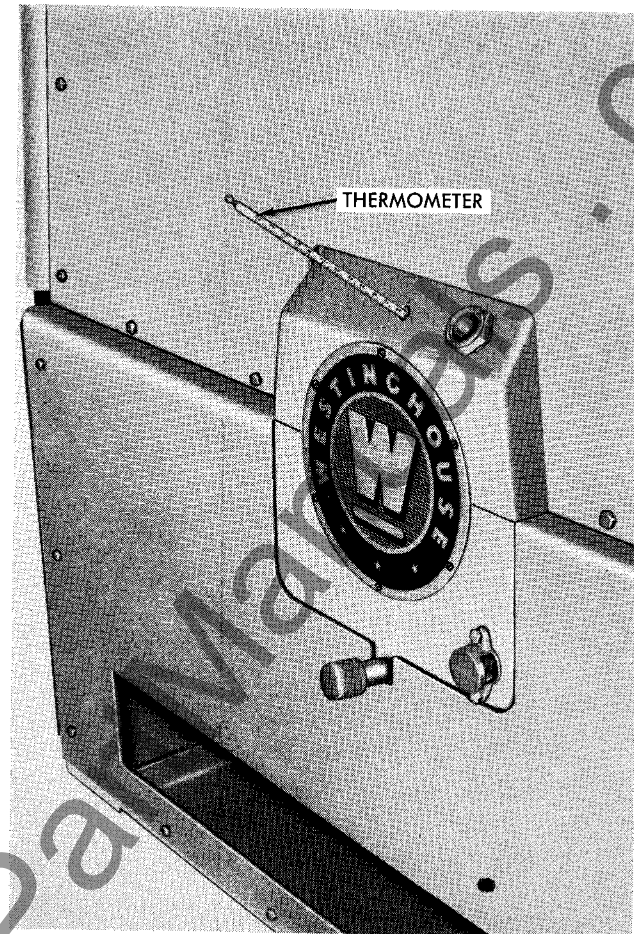


FIG. 13. Measurement of Bearing Temperature for Motors with Sleeve-Type Bearings

In the case of belted motors, check the belt tension. Adjust if necessary as explained in Section F, Part Two.

The semiannual inspection of the motor should include the removal of oil or grease from the bearings, cleaning and flushing the bearings and their housings, and replacement of the lubricants (see Part Five, Bearings and Lubrication.) The rotor ends and windings and the fan blades should be inspected and cleaned after removal of the appropriate panels (refer to instructions given in the following sections). The inspection should also include checking of uninsulated (untaped) electrical connections for tightness and absence of corrosion.

C. INSPECTION AND CLEANING OF WINDINGS

The motor windings can be easily inspected after following steps 1 through 3, and Step 6, of the procedure described for the complete disassembly of the motor (Section E). The ends of the windings of all motors, and the outside surfaces of the windings of motors with the exception of the two-pole squirrel cage type, are then readily accessible. Inspection of these portions of the windings will provide a good indication of the general condition of the windings.

In order to completely inspect and clean the windings it is necessary to remove the rotor as described in Section J; a procedure calling for the removal of the rotor and the stator assembly from the motor base.

Any one of several methods may be utilized to clean the windings; the most effective method depends upon the kind and amount of dirt lodged on the windings. The methods which may be used are listed below in order of preference.

Note: Before cleaning the windings, inspect them for loose wedges or spacers, evidence of damage to insulation, distortion or movement of coils, etc. If these conditions are present, contact local Westinghouse Service Engineers for recommendations.

Dry-Wiping. Cleaning by wiping with a clean, dry, lintless cloth may be satisfactory when the surfaces to be cleaned are accessible and when only dry dirt is to be removed. "Waste" should not be used because lint will adhere to the insulation and increase dirt collection. Lint is particularly objectionable on high-voltage insulation as it tends to cause concentration of corona discharge.

Brushing and Suction Cleaning. Dry dust and dirt may be removed by brushing with bristle brushes, followed by vacuum suction cleaning. (Do not use wire brushes.) This is a desirable method because the dirt is not scattered and does not settle on other apparatus.

Blowing. Blowing out dirt with a jet of air should be done only to remove dirt from almost inaccessible crevices, and only when the motor is dry. Avoid directing the air in such a way that the dirt will be blown into inner recesses from which it would be difficult to remove and where it might clog vent ducts.

Caution: Do not use air pressures greater than 30 psi in order to avoid damaging the insulation and so that dirt will not be blown under loosened insulation. Be certain that the air is dry and does not contain water from condensation in the air lines.

Solvent Cleaning.

Caution: Solvents should never be used on windings with Class H (silicone) insulation. (See nameplate for type of insulation.) Refer to Water, Emulsion, and Alkali Cleaning for the proper method of cleaning silicone insulation.

Solvent cleaning is particularly effective for removing tar, grease, wax, and oil from electrical apparatus. The surfaces can be wiped with a cloth wetted with the solvent, followed by wiping with a dry cloth. ("Waste" should not be used, in order to avoid depositing lint on the insulation.) The solvent may be hosed on if necessary.

Westinghouse recommends that solvents such as Stoddard solvent, mineral spirits, or comparable petroleum solvents be used for cleaning insulation whenever possible. In fire-hazardous areas, inhibited methyl chloroform may be used. While this solvent is not flammable under ordinary conditions, it is moderately toxic. Therefore, local exhaust ventilation is necessary if the odor of solvent vapors is very noticeable.

Warning: When working with solvents, always provide adequate ventilation in order to avoid fire, explosion, and health hazards. In confined areas (such as tanks or pits), provide each operator with an air-line respirator, a hose mask, or self-contained (air) breathing equipment. The operators should also wear goggles, neoprene aprons, and suitable gloves. Solvents should always be stored in safety cans. Always keep open flames and sparks from flammable solvents and their vapors.

Water, Emulsion, and Alkali Cleaning. Motors may be cleaned by hose washing or by pressure spray from a steam generator. Steam from a shop line or a spray of hot water and compressed air may be used. The jet pressure and temperature should not exceed 30 psi and 80°C (176°F), respectively, when cleaning insulation.

It is necessary to add a nonconductive detergent compound to the water for removal of tar, wax, grease, or oil from insulation. These compounds contain non-ionic emulsifying agents. Some, known as emulsion cleaners, also contain solvents to soften the hard deposits so that they can be more easily washed off. These compounds are not electrical conductors and are safe on insulation.

Caution: Windings with Class H (silicone) insulation should be cleaned only with water and a non-conductive detergent such as Dreft (or equivalent).

The following compounds are satisfactory for use in water washing operations:

Wetting agents (non-conductive)
Nacconal NR,
Kreelon 4D,
Westinghouse
7893-7, 7893-13,
7893-19, 9904-1,
9904-5, 9904-10

Emulsion cleaners (nonconductive)
Clepo 9 Solvent,
Westinghouse
8259-1, 8339-1,
8339-2, 8339-5

Alkaline cleaners (conductive)
Westinghouse
Steam Cleaning Compound,
Jenny Compound 50,
Westinghouse 8524-6

Sodium carbonate (conductive)
Westinghouse 1872

Trisodium phosphate (conductive)
Westinghouse 4031

Remove all traces of the cleaning compound by rinsing thoroughly with water. Then remove the water as promptly as possible by blowing and wiping. Blowing hot air through the motor will aid in removing the last traces of moisture.

Shell Blasting. Air blasting with ground nut shells to remove hard dirt deposits from insulation may abrade the insulation and should not be done except under the supervision of Westinghouse Field Service Engineers.

Use only mild abrasives such as 12-20 mesh ground walnut shells (Westinghouse pellets 6822-3) or ground corn cob (Westinghouse 8268-1). The operator should direct the jet of abrasive at a small area long enough to remove the dirt without damaging the insulation. Canopies or other shielding should be erected to prevent unnecessary contamination of other equipment or areas.

Note: If the insulation shows signs of dryness, clean and revarnish the windings, preferably under the guidance of Westinghouse Field Service Engineers.

D. INSULATION RESISTANCE

Introduction. Insulation resistance (of a winding) is defined as the resistance of insulation to a d-c voltage which tends to produce leakage currents through the insulation and over its surfaces. The original insulation resistance is lowered by such factors as aging of the insulation, mechanical damage to the insulation, presence of dirt in the motor, and increased temperature of the insulation. The value of the insulation resistance as obtained by measurement is lowered by increasing the test voltage or by decreasing the time of application of the test voltage.

Measurement of Insulation Resistance. The insulation resistance should preferably be measured at ambient temperature with either a motor-driven Megger, a Rectox-type Megger, or an instrument which produces d-c voltage and has a self-contained voltmeter and a microammeter. If these instruments are not available, a hand-driven Megger may be used or the insulation resistance may be determined by the use of either a voltmeter or a voltmeter and microammeter.

Warning: Use care when measuring insulation resistance. Contact with high-voltage electrical current may be fatal. Ground winding after test to drain off all charging voltage.

Preferred Method of Measuring Insulation Resistance. If facilities are available, Westinghouse recommends that any of the instruments mentioned above be used to measure the insulation resistance over a period of ten- or fifteen-minutes at a potential near the operating voltage. Readings should be taken every fifteen seconds for the first two minutes, and then every minute during the remainder of the test.

Alternate Methods of Measuring Insulation Resistance. Insulation resistance may also be measured by means of a voltmeter or by means of a voltmeter and a microammeter; either method requires a separate source of d-c voltage. These methods, while suitable, are more cumbersome than the Preferred Method. Always take readings periodically during a ten- or fifteen-minute test period as described in Preferred Method.

Voltmeter Method. Insulation resistance may be measured with the aid of a d-c voltage source and a high-resistance (d-c) voltmeter. The procedure is as follows:

1. Connect voltmeter to motor winding through a SPDT switch as shown in Figure 14 (A).

2. Take voltage readings while voltmeter is connected (by the switch) to motor winding and when connected to motor frame. These readings are the voltage when the motor is in series with the winding and the voltage of the d-c source, respectively.

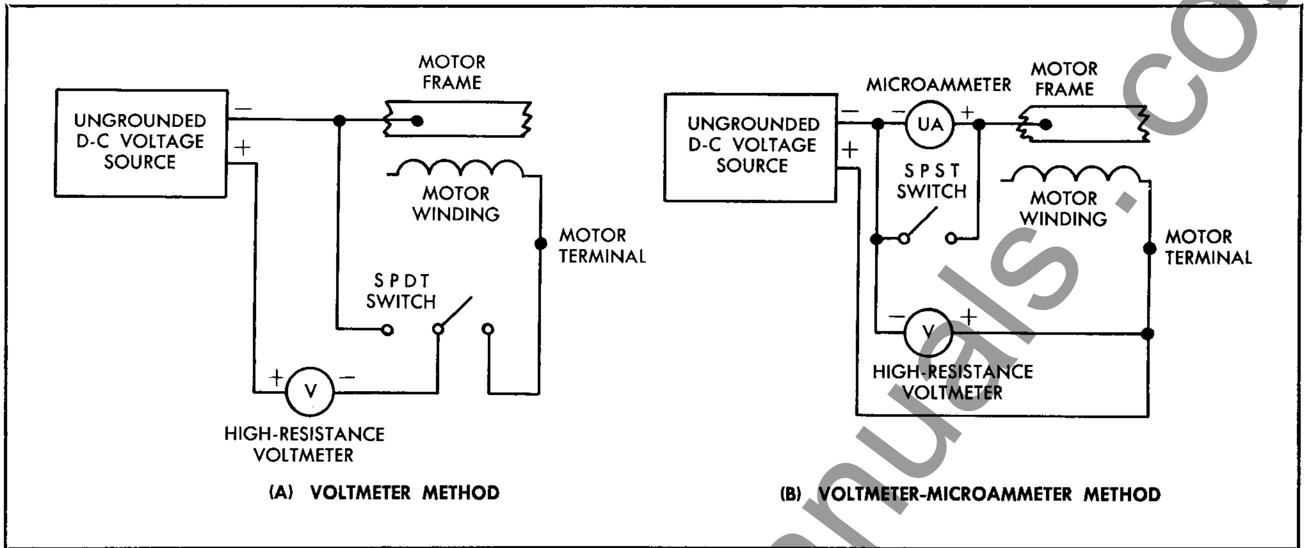


FIG. 14. Connection Diagrams for Measurement of Insulation Resistance

3. Calculate insulation resistance by means of the following formula:

$$R_i = R\left(\frac{E}{E_i} - 1\right)$$

E = voltage of d-c source
E_i = voltage when motor is in series with voltmeter
R = voltmeter resistance (in ohms)
R_i = insulation resistance (in ohms)

Voltmeter-Microammeter Method. The procedure for measuring insulation resistance with a high-resistance (d-c) voltmeter and a (d-c) microammeter (plus a d-c voltage source) is as follows:

1. Connect meters and SPST switch as shown in Figure 14 (B).

2. Close switch and energize voltage source.

3. Open switch and read both meters.

4. Calculate insulation resistance by means of the following formula:

$$R_i = \frac{E}{I}$$

E = reading of voltmeter (in volts)
I = reading of microammeter (in microamperes)
R_i = insulation resistance (in meghoms)

Interpretation of Results. When the test voltage is applied for a period of ten minutes or more, the plotted graph of insulation resistance values obtained represents the dielectric absorption characteristic. This graph may be interpreted as follows:

1. A steadily-rising curve is indicative of a clean, dry winding.

2. A quick-flattening curve is the result of leakage current through or over the surface of the winding insulation, and is generally indicative of a moist or dirty winding. (See Remedial Action.)

Standardized Insulation Resistance Test. Insulation resistance measurements may be taken periodically and compared with earlier measurements. For comparable readings, a standard insulation resistance test should be used.

Where short-time single readings are to be made on windings, and where these results are to be compared with earlier and later date, test at 500 volts (d-c) for a period of 60 seconds. (This test may also be used when a hand-driven Megger is the only test instrument available.) Make this test when the motor is at ambient temperature, and record this temperature. Since the insulation resistance of a winding varies inversely with the winding temperature, all resistance values should be converted to the equivalent resistance at 40°C. The equivalent resistance may be calculated with the following formula:

$$R_{40C} = \frac{R_2}{K_t}$$

R_{40C} = unknown insulation resistance in megohms at 40°C
R_2 = insulation resistance in megohms at temperature t_2
K_t = approximate insulation resistance temperature coefficient (Figure 15) for temperature t_2.

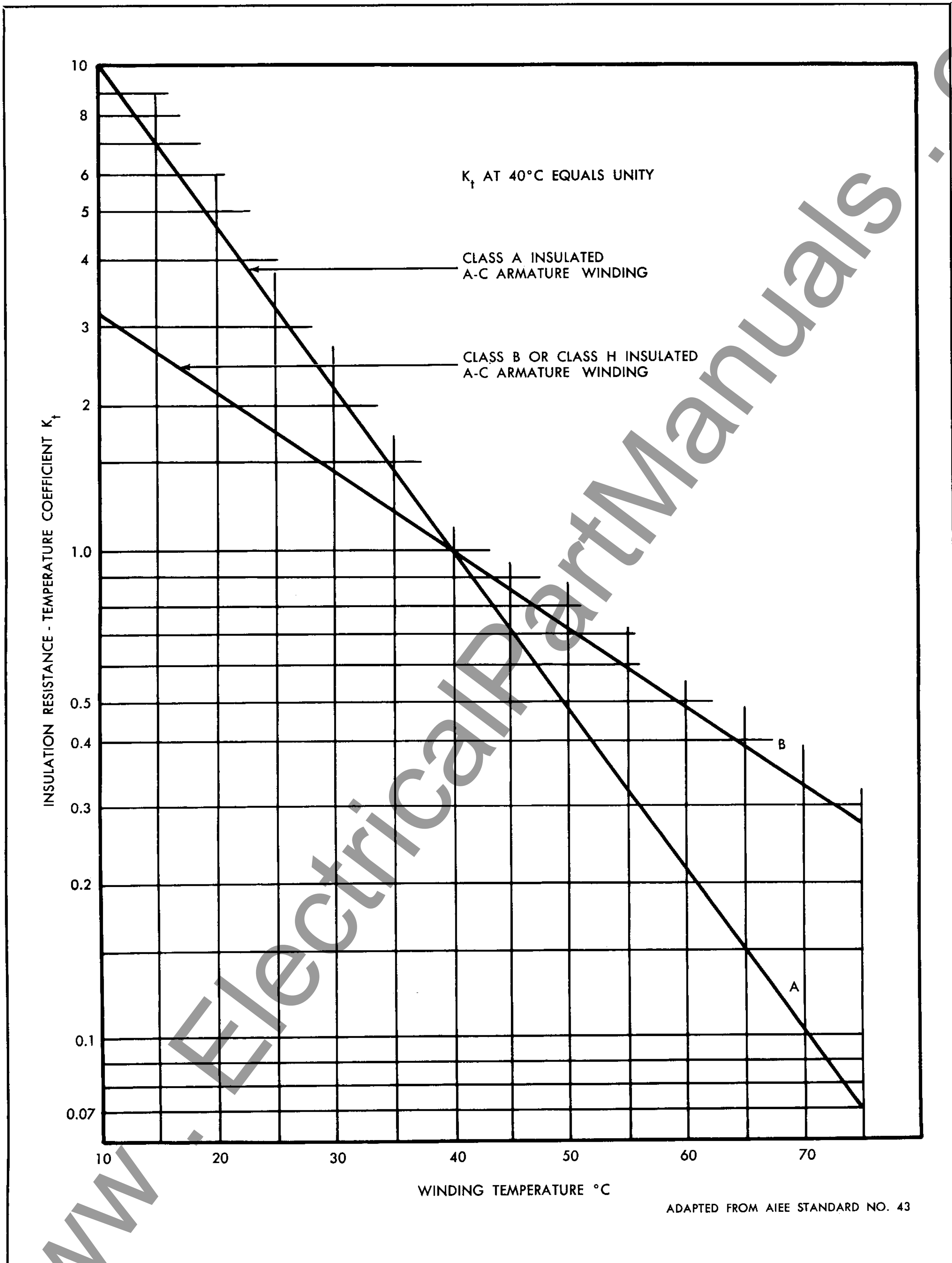
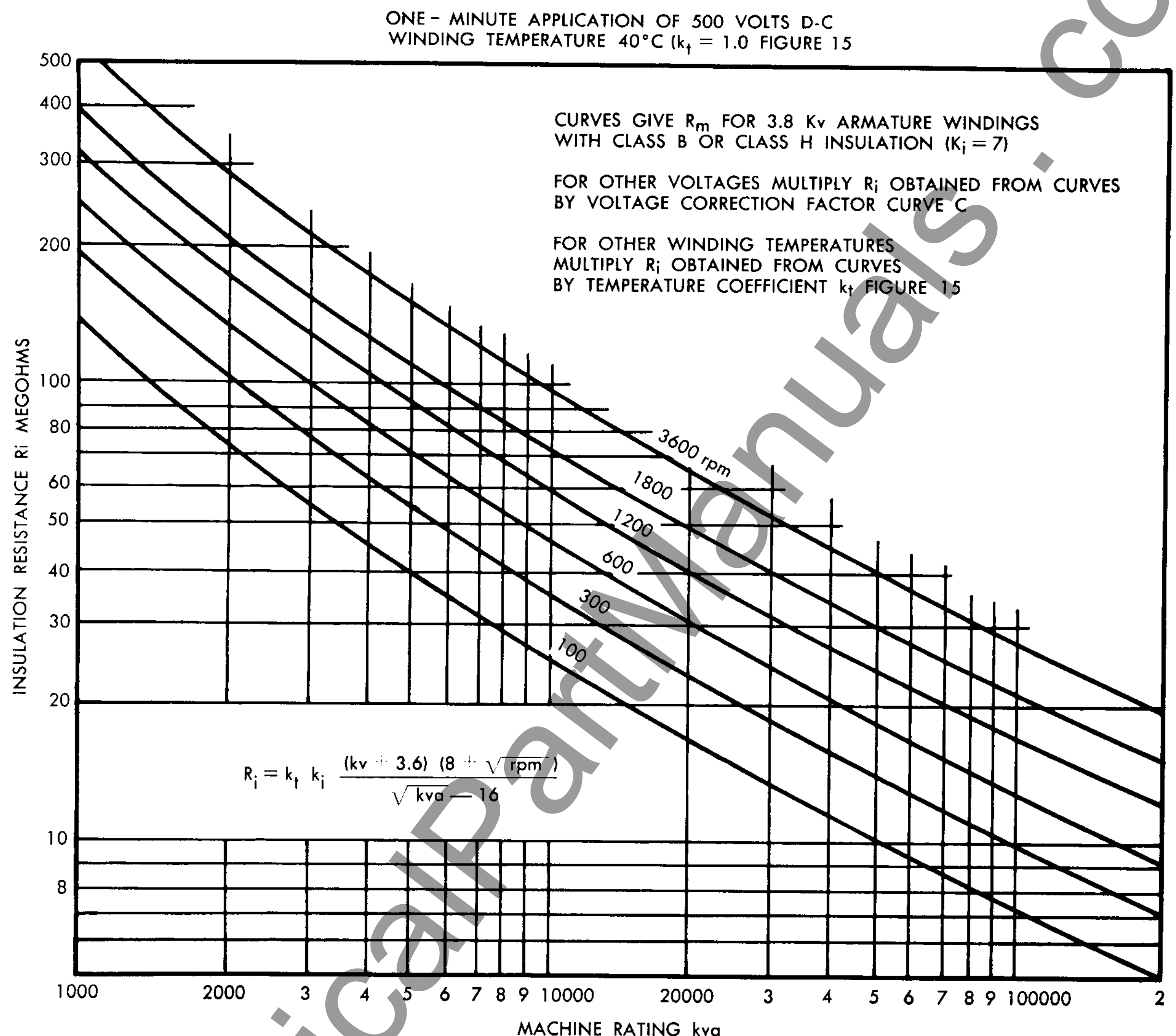
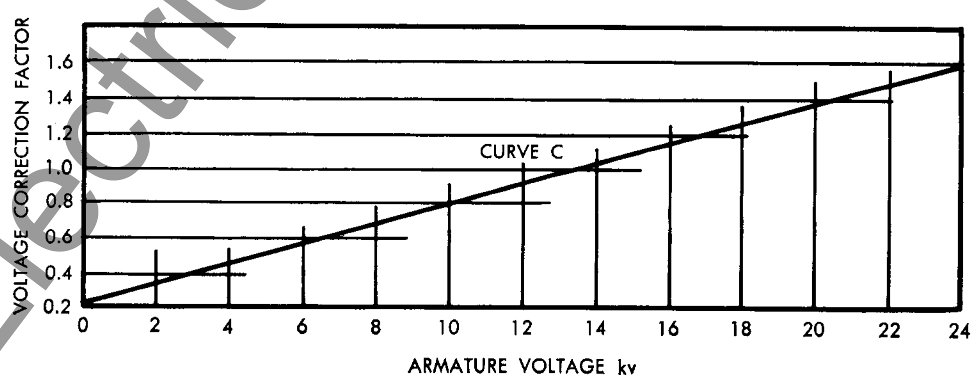


FIG. 15. Approximate Insulation Resistance Temperature Coefficient of Rotating Machine Armature Windings





ADAPTED FROM AIEE STANDARD NO. 43

FIG. 16. Standard Insulation Resistance of A-C Armature Windings of 1000 KA Vor More

The value obtained for insulation resistance should not be less than that given by one of the following formulas (AIEE Standard No. 43, Recommended Practice for Testing Insulation Resistance of Rotating Machinery):

1. Standard Insulation Resistance Formula for Stationary Armature Windings of Alternating-Current Machines Rated 1000 Kva or more.

$$R_i = k_t k_i \frac{(kv+3.6)\ 8+rpm)}{kva\ -16} \text{ (see Figure 16)}$$

R_i = standard insulation resistance in megohms (the least value which a winding should have after cleaning, or if an appropriate over-potential test is to be applied to the winding) of a stationary armature winding at 40°C, obtained by applying 500-volt direct current to the entire winding for 1 minute.

k_t = winding insulation resistance temperature coefficient = 1.0 for a winding temperature of 40°C. If the winding is not at the recommended temperature of 40°C, the approximate insulation resistance temperature coefficient k_t (Figure 15) may be used.

k_i = winding insulation coefficient
= 2.5 for a Class A insulated winding
= 7.0 for a Class B (or Class H) insulated winding

kv = rated machine voltage in kilovolts

rpm = rated machine speed in revolutions per minute

kva = rated machine kilovolt-amperes

2. Standard Insulation Resistance Formula for Stationary Armature Windings of Alternating-Current Machines Rated 1 to 999 Kva Inclusive.

Since small alternating-current machines (999 kva or less) vary in construction, since they are not likely to be designed for use on high voltages, and since users of these machines seldom need more than a simple test to determine the insulation condition, a simplified formula (such as the following) is recommended. It is, in effect "One megohm per 1000 volts, with a minimum of one megohm." It should be noted that considerable difference exists in the value of insulation resistance obtained with the preceding formula (1000 kva or more) and that obtained with the following formula for kva ratings of 1 to 999.

$$R_i = kv + 1$$

R_i = standard insulation resistance of Class A, Class B, or Class H stationary armature windings in megohms at winding temperatures up to 75°C, obtained by applying 500-volt direct current to the entire winding for 1 minute.

kv = rated machine voltage in kilovolts.

3. Standard Insulation Resistance for Synchronous Machine Rotating Field Windings.

The standard insulation resistance for Class A, Class B, or Class H insulated rotating field windings should be of the order of 1 megohm at winding temperatures up to 75°C, obtained by applying 500-volt direct current to the winding for 1 minute.

4. Standard Insulation Resistance Formula for Induction Machine Insulated Rotor Windings.

$$R_i = kv + 1$$

R_i = standard insulation resistance of Class A, Class B, or Class H rotor windings in megohms at winding temperatures up to 75°C, obtained by applying 500-volt direct current to the entire winding for 1 minute.

kv = maximum (rms) voltage induced in the winding in kilovolts.

Remedial Action. Should the insulation resistance of the motor be less than that given by the appropriate formula, proceed as follows (measure the insulation resistance after each step):

1. Visually inspect windings and clean them if it is thought necessary. (Cleaning methods are described in Section C.)

2. Separate the phases, if possible, so that their respective values of insulation resistance may be compared. This step is especially important if an abnormally low value of insulation resistance is obtained for the entire winding.

Note: The insulation resistance of one phase of a three-phase motor, with the other two phases grounded, is approximately 1.75 to 2.5 times that of the entire winding.

3. If the values of insulation resistance obtained for the individual phases are of approximately the same magnitude and if the surfaces are relatively clean, make sure the winding is dry.

4. If the steps described above do not remedy the low value of insulation resistance, the trouble probably is due to the ground wall (the portion of the insulation which is in contact with the motor frame). One may determine whether such is the case by either of two methods:

FIG. 17. Installed F/A Motor Prior to Disassembly

High-Potential Test. This test is the easier to make. It consists of the application of a high a-c or d-c potential to the motor winding; a fault in the insulation is indicated by burn-out of the insulation at the defective point.

Probe of End-Turn Portions. A probe of the end-turn portions of the winding may localize the trouble, but such a procedure is time-consuming and not always effective.

Should the trouble be confined to the ground wall, call the local Westinghouse Field Service Engineers for assistance.

E. COMPLETE DISASSEMBLY OF MOTOR

A chain hoist, spreader sling (2-leg or 4-leg, as required), and standard tools are necessary for the complete disassembly of the motor. The correct procedure for disassembly of an F/A motor (Figure 12) is as follows:

1. Remove end covers. See Figure 17.

2. Remove end panels and side panels. See Figure 18.

3. Turn off power to motor and accessories by opening correct switches (and/or circuit breakers). Tag these switches to prevent their being closed by careless personnel.

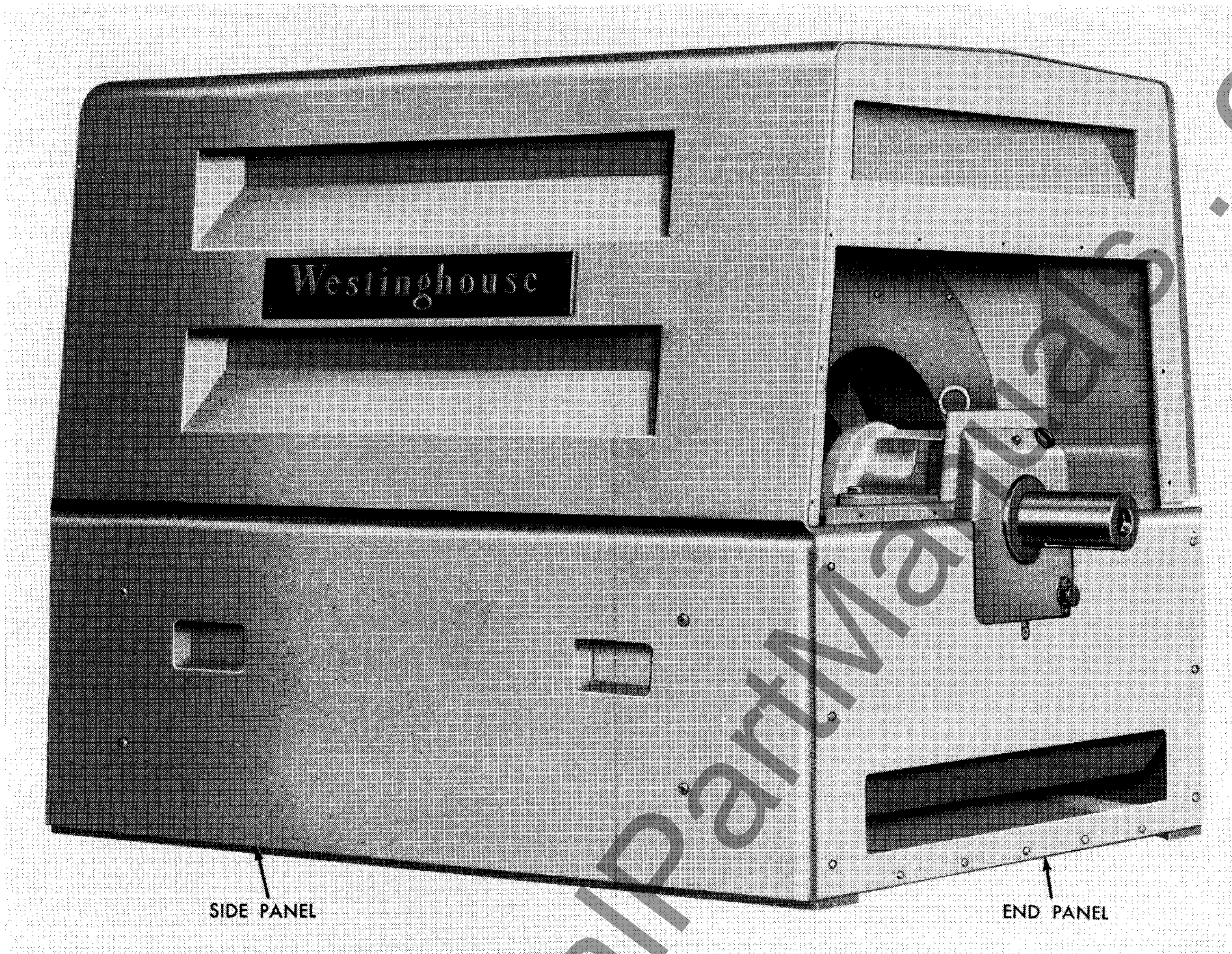


FIG. 18. F/A Motor Showing Location of Panels

4. Open all electrical connections.

5. Tape exposed terminals of power leads.

6. Remove air shields (at both ends of the motor). See Figure 19. The air shields of two-pole squirrel cage motors may be more conveniently removed after removal of the enclosure, but before removal of the rotor or the stator assembly.

Caution: The motor windings may be damaged if the air shields are not removed prior to removal of the stator assembly.

7. Remove bolts which hold enclosure to motor base.

8. Fasten spreader sling to chain hoist.

9. Attach spreader sling hooks to enclosure lifting bars as shown in Figure 3 or 4 (whichever is applicable). Be sure to place hard-rubber pads between the hooks and the surface of the motor.

10. Slowly lift enclosure straight up until it is completely clear of the windings. (In the case of the two-pole squirrel cage motor, Figure 38, remove the air shields at this time.)

Note: Refer to outline drawing for minimum height enclosure must be lifted to clear windings.

11. Uncouple motor from mechanical load in accordance with instructions supplied with coupling.

12. Remove both bearing bracket caps. See Figure 19. (In the case of the two-pole squirrel cage motor, first remove the vent piping.) Break red-lead seal between bearing bracket and bearing bracket cap by inserting prying tool in recess of bearing bracket cap.

13. On synchronous and wound rotor motors, disconnect brushholder leads and brushes. (See Figures 41 and 42.)

14. On motors with sleeve-type bearings, remove top halves of bearings by lifting them off after taking out holding bolts. Then remove oil rings.

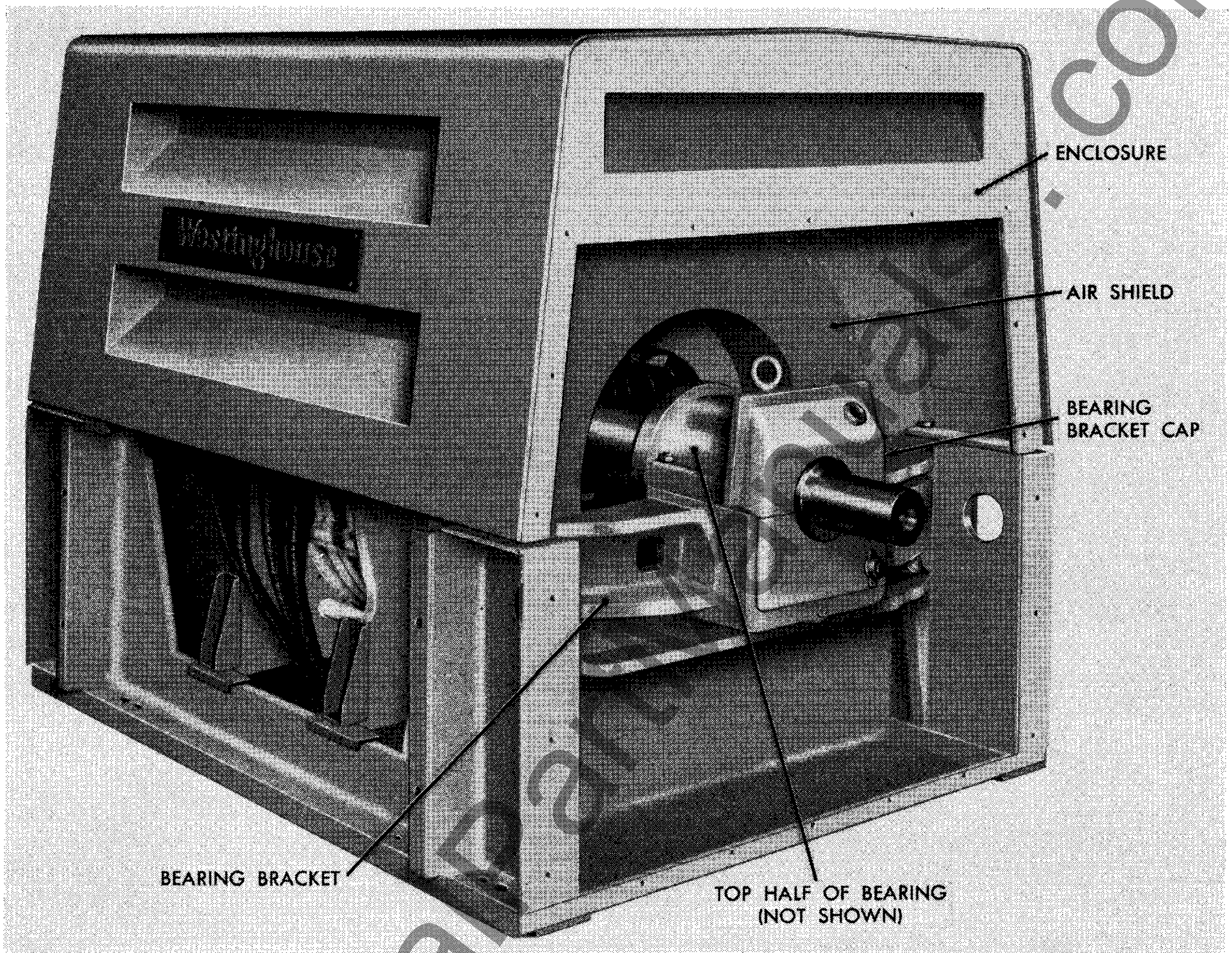


FIG. 19. F/A Motor Showing Power Leads and Bearing Assembly

Note that these rings consist of two half-rings fastened together with small screws. Remove these screws with a small screwdriver, and carefully lift oil rings out of bearings. See Figure 20.

15. On motors with forced-flood lubrication systems, open the pipe couplings, flanges, and adapters at each end of motor.

16. On synchronous and wound rotor motors, remove brush holder assembly. See Part Six.

17. Remove stator locator joint bolts which secure stator assembly (Figure 21).

18. Attach lifting hooks to stator lifting lugs as shown in Figure 21. Carefully lift stator assembly (with rotor resting in stator bore) straight up so that windings clear the base. Move stator assembly to convenient storage area.

19. Remove all thermostats, thermocouples, etc., from bearings.

20. On motors with sleeve-type bearings, remove bottom halves of the bearings by simply lifting them out of the bearing brackets. See Figure 22.

21. On motors with anti-friction bearings, remove the bearings from the shaft with a bearing puller.

22. Unbolt bearing brackets from motor base. Replace uppermost bolts with two-foot studs having 3/4-10 threads, and slide each bearing bracket out from the fit on these studs. Lift bearing brackets off with a chain hoist. Refer to Figure 26. (Figure 26 shows the enclosure, etc., in place, but the method of removing the bearing brackets is the same.)

23. On two-pole squirrel cage motors, unbolt end bells and remove from the stator assembly ends.

24. The motor has now been completely disassembled (except for the removal of the rotor from the stator bore).

F. COMPLETE REASSEMBLY OF MOTOR

Caution: Clean all machined mating surfaces, such as stator locator joints and bearing bracket fits, before reassembling the motor.

Reassemble an F/A motor by reversing the procedure used in the complete disassembly of the motor (described in Section E). On motors with sleeve-type bearings, clean and paint the bearing bracket parting surfaces with red-lead paint before replacing the bearing bracket caps. See Figure 23.

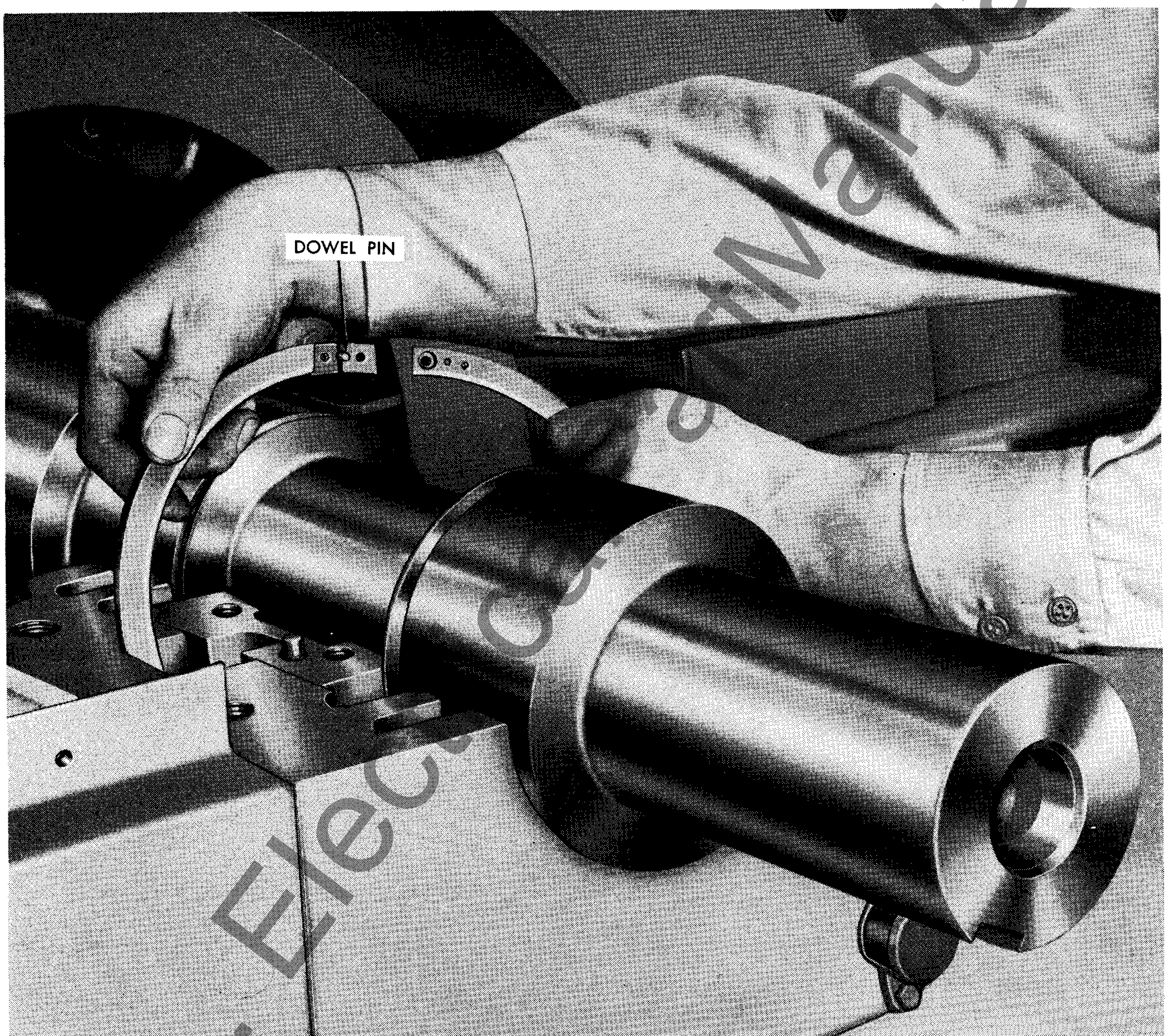


FIG. 20. Removal of Oil Ring

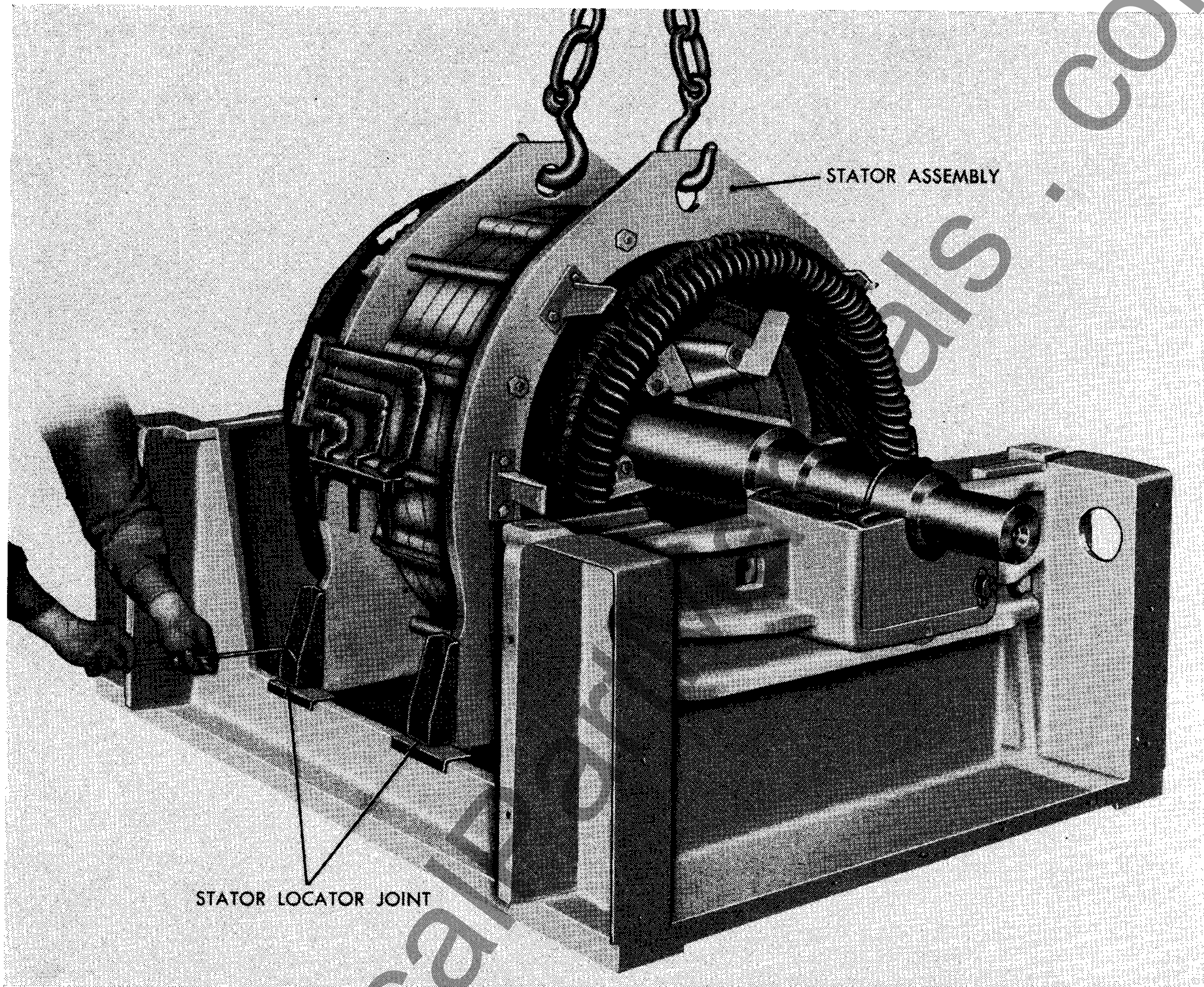


FIG. 21. Unbolting Stator Assembly; Lifting Hooks in Place

Measurements of the air gap serve as a check of the reassembly of the motor. Prepare the motor for measurement by following Steps 1, 2, 3 and 6 of Section E. The air gap should then be measured with feeler gauges at four cleaned points approximately 90° apart on the circumference of the rotor at each end. The allowable gap tolerances should be evaluated separately (see Figure 24) for each end of the rotor. If the gap measured at any point is outside the limits shown in Figure 24, contact the local Westinghouse Service Engineers.

G. BEARING REMOVAL.

Motors with Sleeve-Type Bearings

1. Remove end covers, bearing bracket caps, and top halves of bearings.

2. Jack up end of the rotor (Figure 25) at which the work is being done in order to remove the weight from the bottom half cf the bearing. Be sure to place a hardwood block (concave on the top to conform to the curvature of the rotor shaft) between the jack and the shaft extension. (When working at the end opposite the shaft-extension end, thread a 1-8 bolt of sufficient length into end of shaft. Jack up rotor by means of this bolt.)

3. Roll out bottom halves of bearings as shown in Figure 25.

4. Lower rotor.

Two-Pole Squirrel Cage Motors with Pumps

1. Remove end covers and end panels.

2. Disconnect vent piping.

3. Remove pump after breaking both unions and pulling out holding bolts.

4. Remove bearing bracket caps.

5. Take off top halves of bearings.

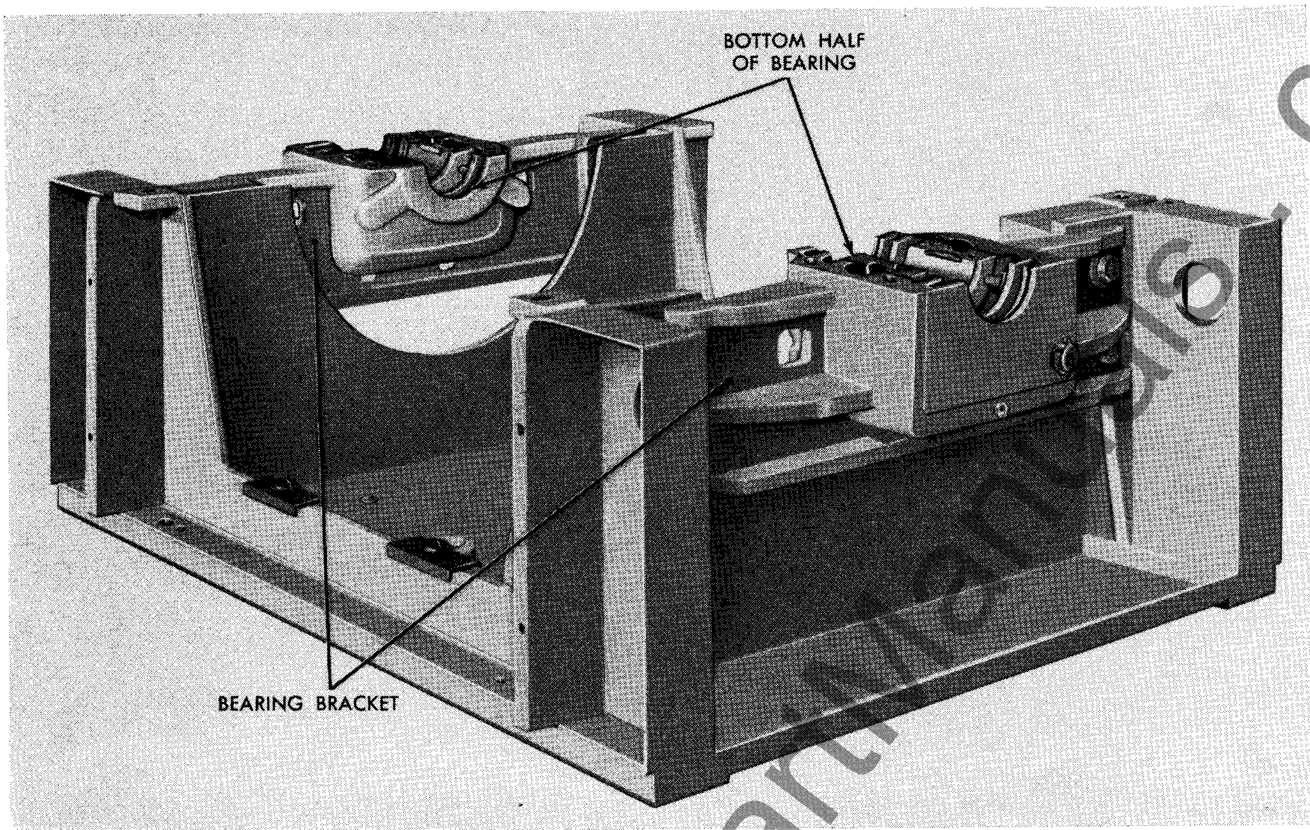


FIG. 22. F/A Motor Base with Bearing Brackets

6. Thread one-inch standard bolt into shaft at end opposite shaft-extension end. (The bolt should be long enough to project beyond the face of the bearing bracket by several inches.)

7. Place a jack under either shaft (at the shaft-extension end of the motor) or bolt threaded into shaft (at the end opposite the shaft-extension end of the motor).

8. Jack up rotor (at the end at which the work is being done) and roll out bearing.

Motors with Anti-Friction Bearings

Remove bearing from shaft-extension end of motor as follows:

1. Remove stator assembly as described in Steps 1 through 18 of Section E.

2. Remove coupling from shaft extension.

3. Pull bearing from shaft.

Remove bearing from end of motor opposite shaft-extension end as described below.

Note: The enclosure and rotor need not be removed in order to take out the bearing at the end opposite the shaft-extension end of the motor.

1. Remove end cover, end panel, nameplate, and bearing cap.

2. Jack up rotor and remove bearing bracket as described in Step 22 of Section E.

3. Remove outboard oil thrower (on oil-lubricated anti-friction bearings only).

4. Pull bearing from shaft.

H. BEARING BRACKET REMOVAL.

The bearing brackets of motors having sleeve-type bearings need not be removed in the course of bearing removal. If desired, a bearing bracket may be removed as follows (see Figure 26):

1. Remove bearing as described under BEARING REMOVAL (Section G).

2. Remove bearing bracket as described in Step 22 of Section E.

I. STATOR REMOVAL.

The stator assembly can be removed from the motor base by following the procedure described in Steps 1 through 18 of Section E.

J. ROTOR REMOVAL.

1. Disassemble motor by following all steps described in Section E. Be sure that stator assembly has been placed where there is sufficient room for removal of rotor.

2. Protect shaft journals by wrapping with heavy Kraft paper. (See Figure 27.)

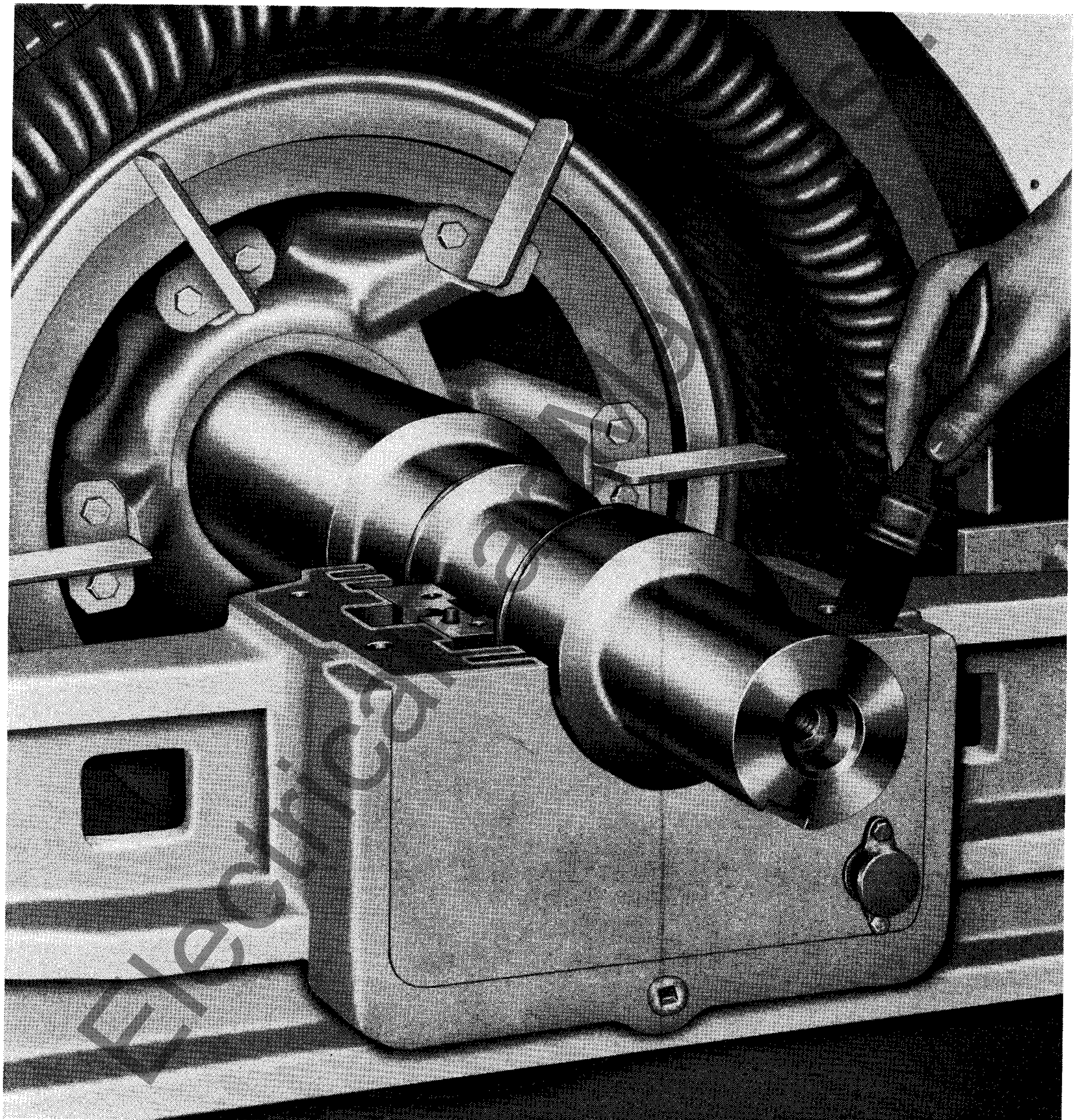


FIG. 23. Painting Bearing Bracket Parting Surface

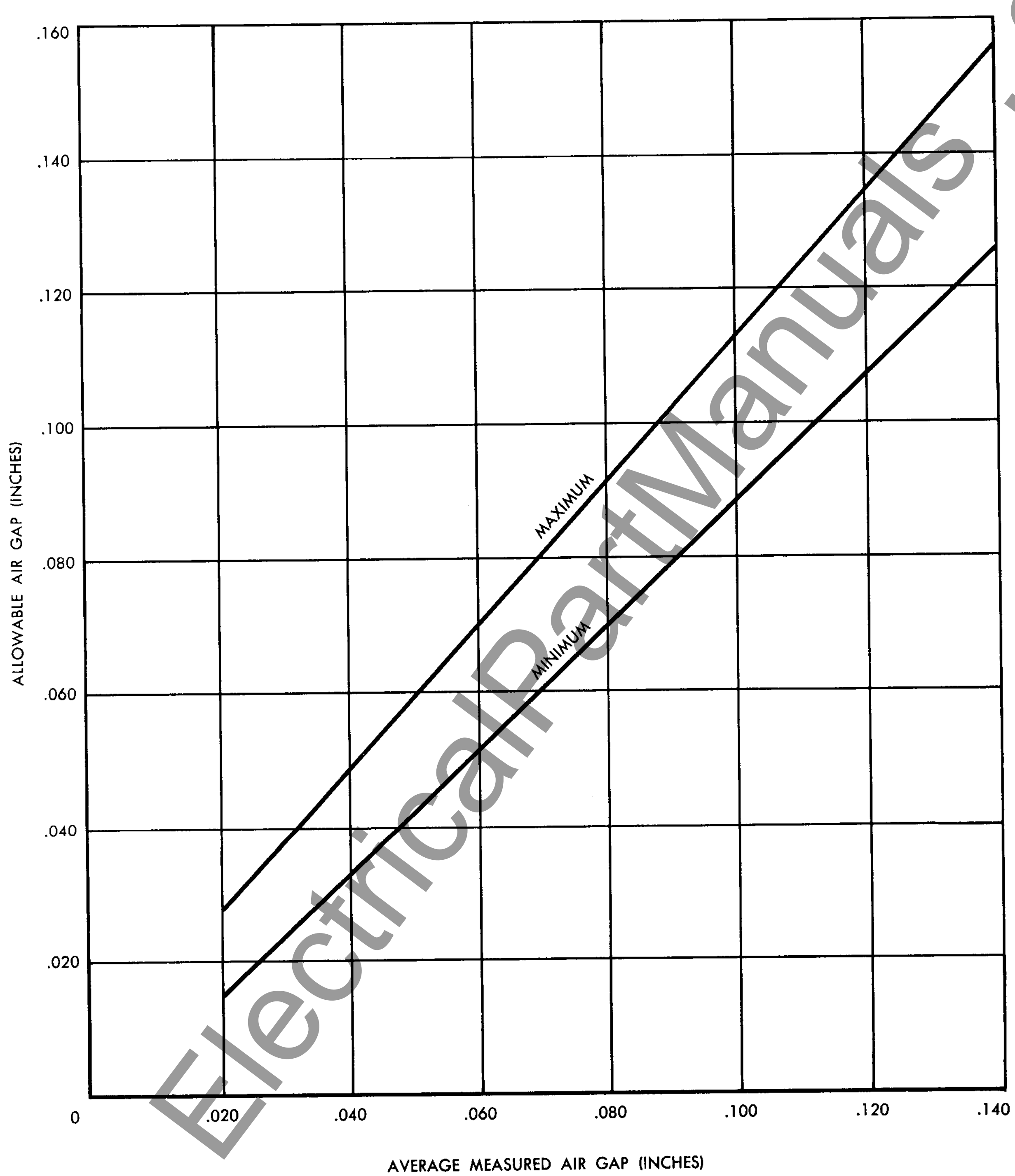


FIG. 24. Maximum and Minimum Air Gap Allowable at Any Point

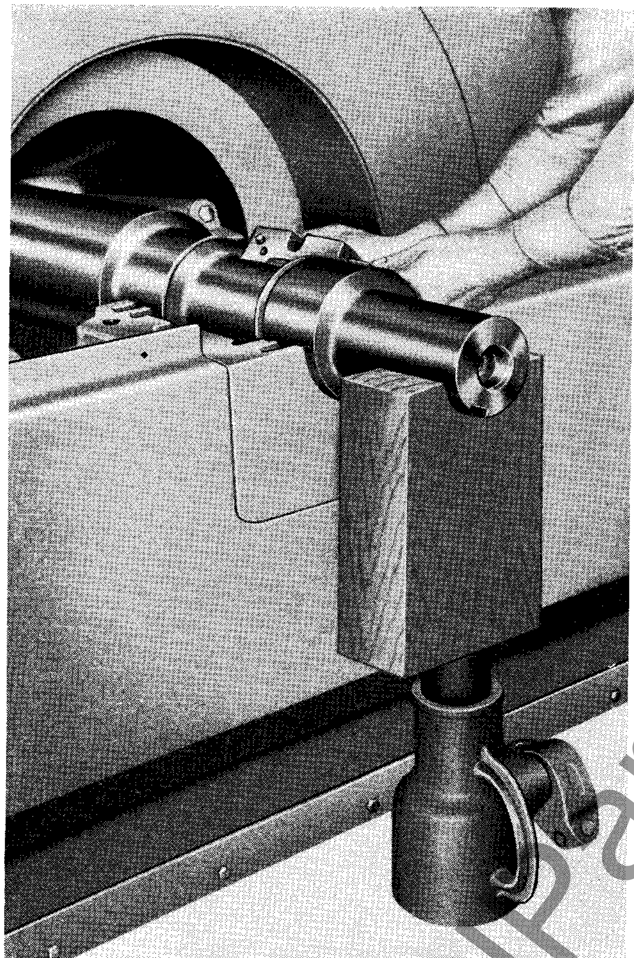


FIG. 25. Removal of Bottom Half of Bearing; Rotor Jack in Place

3. Fit a steel pipe or tube (proper inside diameter, length, and strength) over end of the rotor shaft opposite coupling end of shaft. Do not place pipe over journal, but locate it instead over portion of shaft adjacent to rotor core.

4. Attach rope slings (fastened to hoisting crane or chain hoist) to steel pipe and portion of shaft adjacent to coupling location.

5. Slowly and carefully move rotor through stator assembly until end of steel pipe extends beyond coupling end of stator assembly. Move hoist horizontally and vertically in such a way that rotor does not slide against stator winding.

6. Wrap Kraft paper around the shaft adjacent to end of steel pipe. Secure a rope sling to this wrapped-portion of shaft, and attach sling to an additional hoist (or to same hoist if a turnbuckle or other means of vertical adjustment can be used with this third rope sling).

7. Lift third rope sling until it supports weight of rotor end to which pipe is fitted.

8. Remove steel pipe (and its associated sling) from shaft.

9. Carefully lower rotor onto a large sheet of thick cardboard (or other suitable material) placed on floor. Block rotor in place.

10. The rotor and the interior of the stator assembly may now be inspected or cleaned as desired.

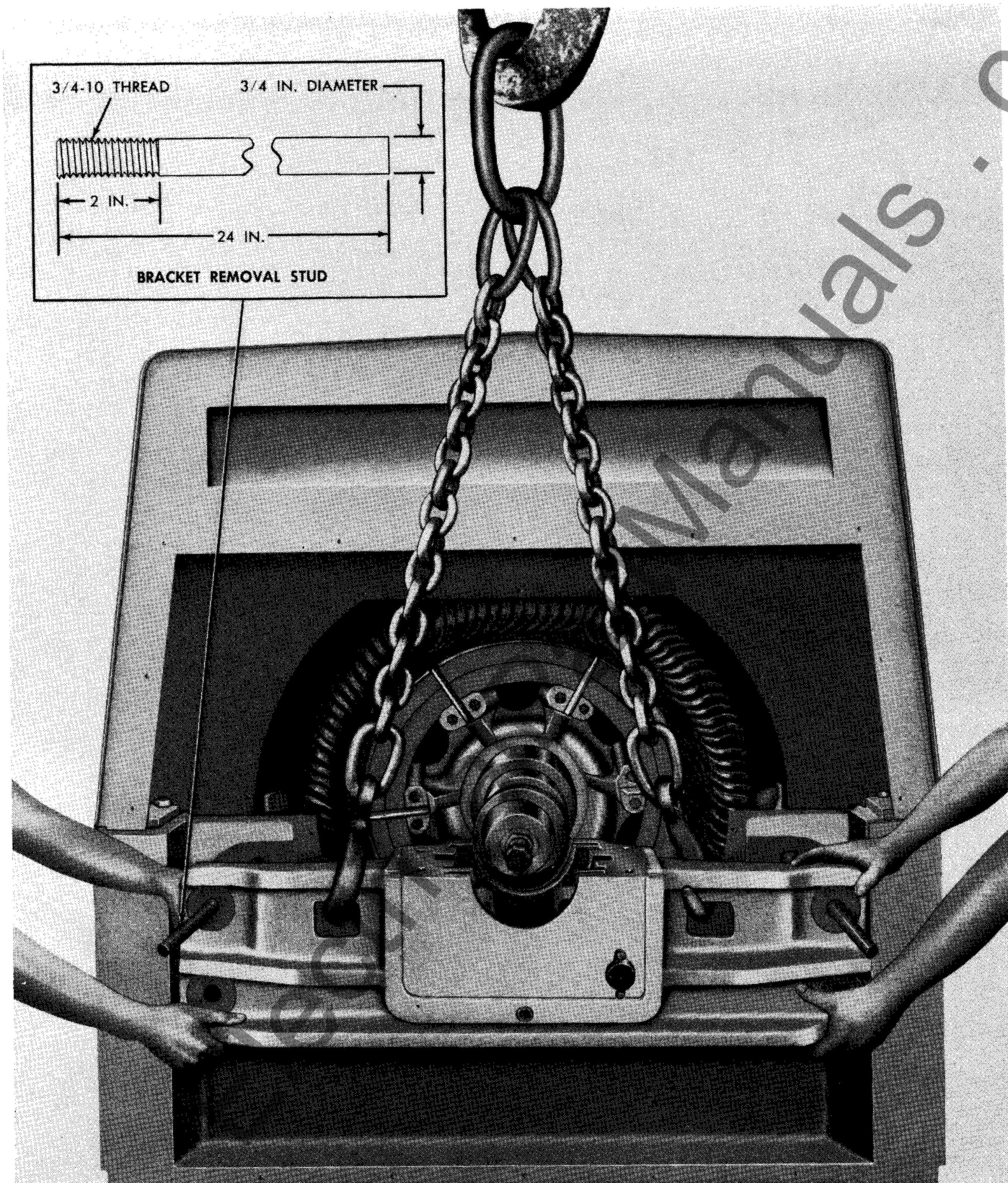


FIG. 26. Removal of Bearing Bracket

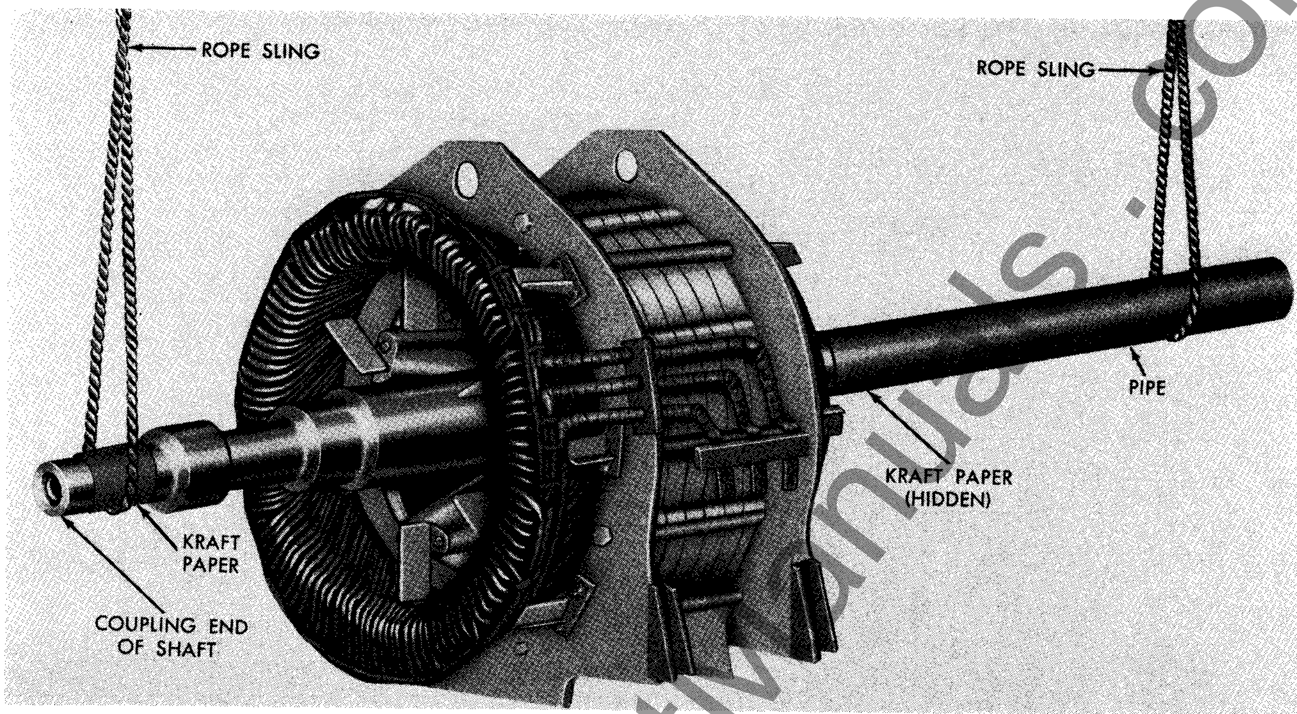


FIG. 27. Removal of Rotor from Stator Assembly

PART FIVE

BEARINGS AND LUBRICATION

A. INTRODUCTION

This part is intended to give the reader the proper and necessary understanding of the construction and operation of the various bearings and lubrication systems used in F/A motors. It also provides the information necessary for the repair or replacement of bearings, and specifies the type and method of lubrication to be used.

The procedure necessary for the removal of bearings is not detailed; the reader should refer to Part Four for this information.

B. SLEEVE-TYPE BEARINGS

Description. A Westinghouse sleeve-type bearing consists of a cast iron shell which is lined with babbitt and split horizontally. The two bearing halves are held in alignment by means of two dowels in the mating surfaces and are fastened together with four bolts. The assembled bearing rests in the bearing bracket, and is held in place by the bearing bracket cap. Bearing rotation is prevented by pins projecting from the sides of the bearing. The bearing bracket cap is fastened to the bearing bracket with four bolts.

Sleeve-type bearings are of either the cylindrical or spherical-seat type; the chief difference between these bearings is their external shape (see Figures 28, 29, and 30). In some cases where end thrust is present, a special type of cylindrical bearing designed to take axial thrust (a Jordan bearing) is used. Spherical-seat bearings are self-aligning, and are used in some two-pole squirrel cage motors. Self-aligning bearings can also be used in other F/A motors, such as single-bearing or belt-driven machines.

The bottom half of a cylindrical sleeve bearing is made adjustable to provide end play in both directions when the motor rotor is on its magnetic center. Spacer bolts are located in each end of the bottom half of the bearing. The bearings are centered and shims are inserted under the spacer bolts until the rotor oscillation which occurs during operation of the motor is eliminated or minimized.

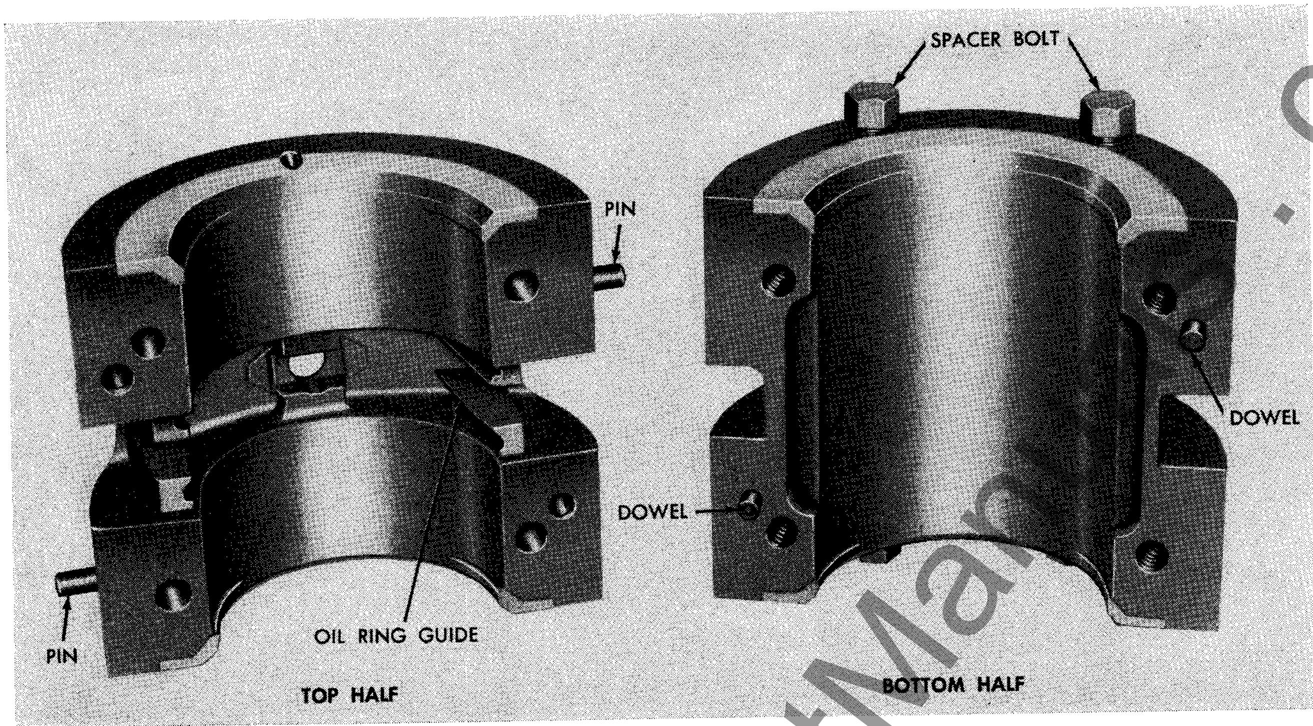


FIG. 28. Cylindrical Bearing

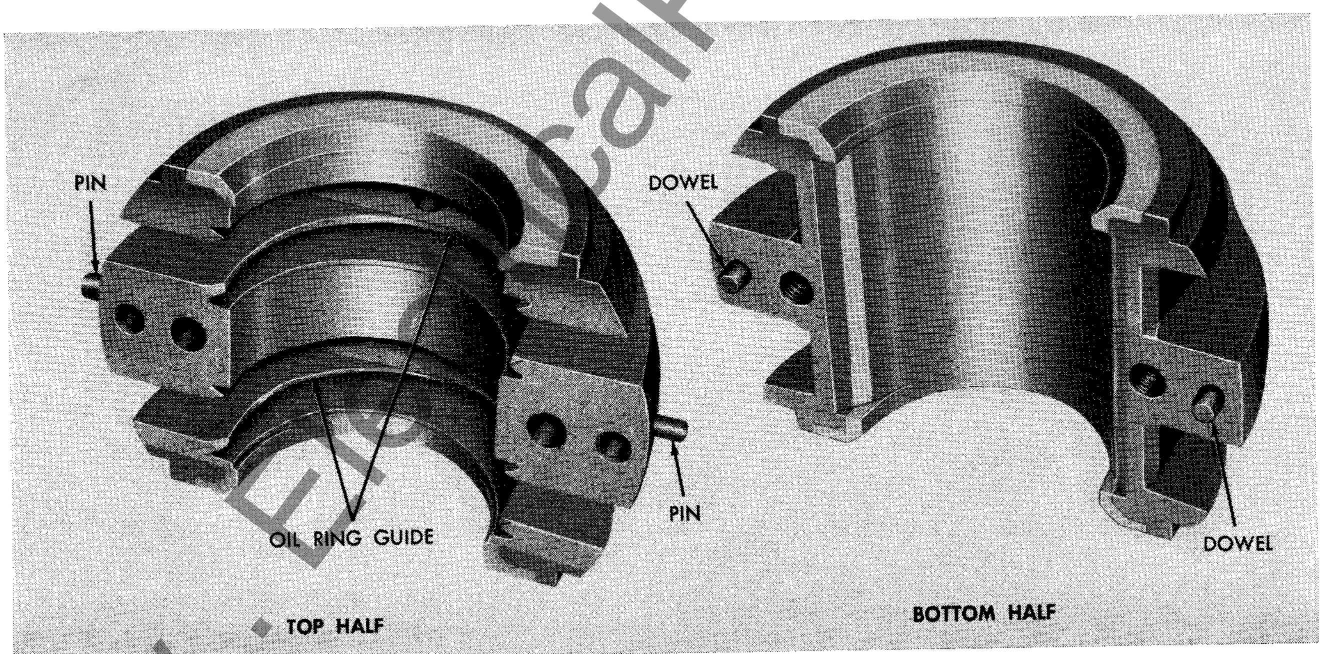


FIG. 29. Spherical-Seat Bearing with Two Oil Rings

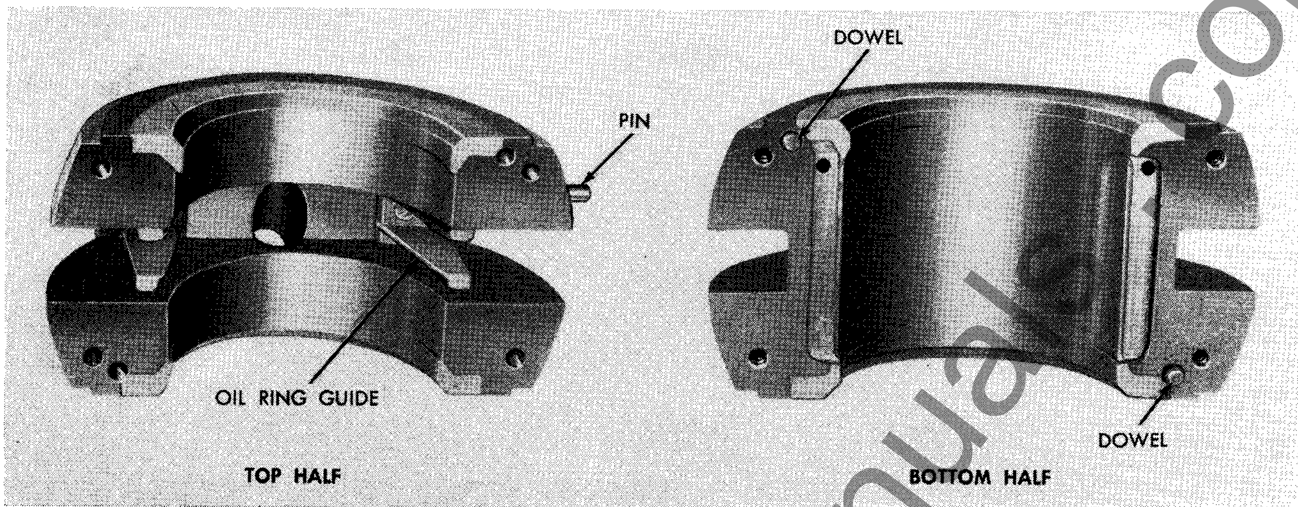


FIG. 30. Spherical-Seat Bearing with Single Oil Ring

The bearing surfaces are oil-lubricated by either self-lubrication or forced-flood lubrication, depending upon the speed and rating of the motor in which the bearings are used. (See Lubrication Systems.) All sleeve-type bearings have carefully balanced, accurately machined, split oil rings (see Figure 31) and oil ring guides.

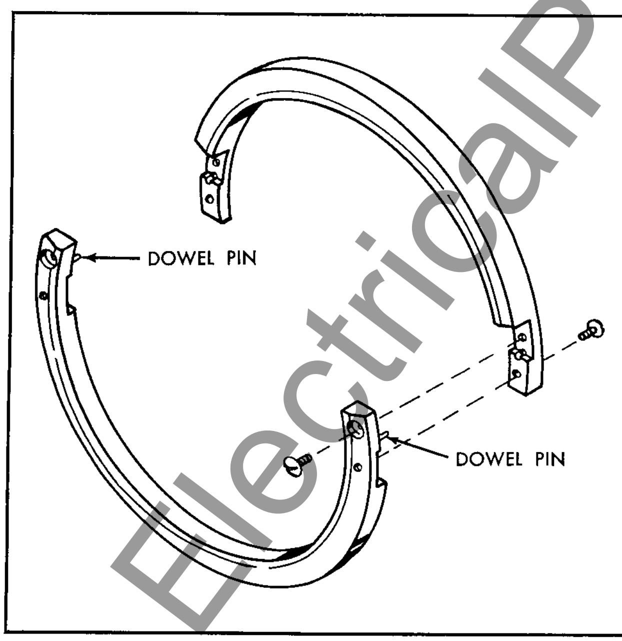


FIG. 31. Oil Ring Used in Sleeve-Type Bearings

Oil rings fit loosely around the shaft journals. The rotation of the shaft causes the oil rings to rotate with the shaft; in so doing, they pick up oil from the bearing housing and lubricate the entire journal portion of the shaft. Each bearing housing is provided with an oil gauge which makes it possible to check the level of the oil in the bearing housing. Oil is added to a bearing through the oil ring inspection hole (see Figure 32); this hole is provided with a bull's-eye which enables a viewer to check the rotation of the oil rings. A hole is provided in the bearing housing for the insertion of a thermometer to measure bearing temperature (see Figure 13).

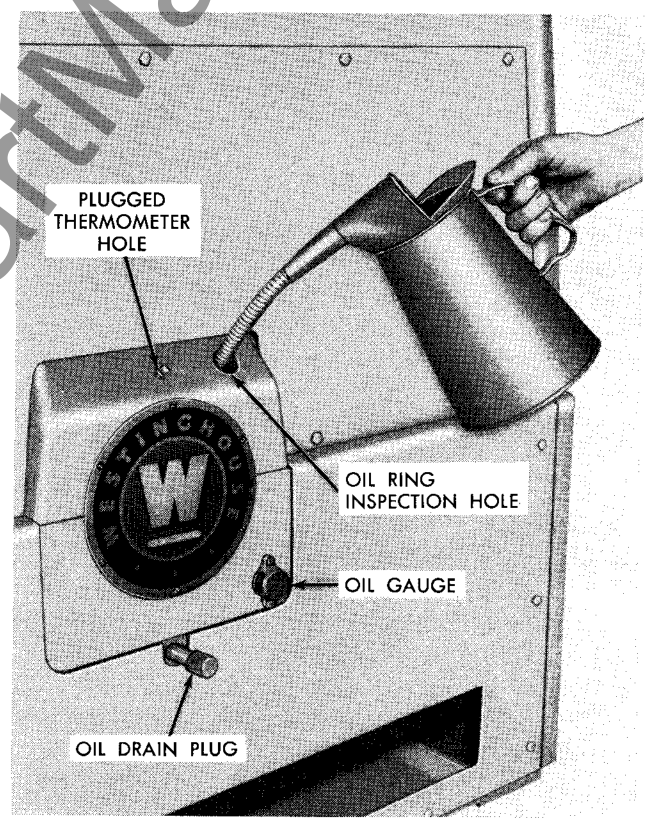


FIG. 32. Filling Bearing with Oil

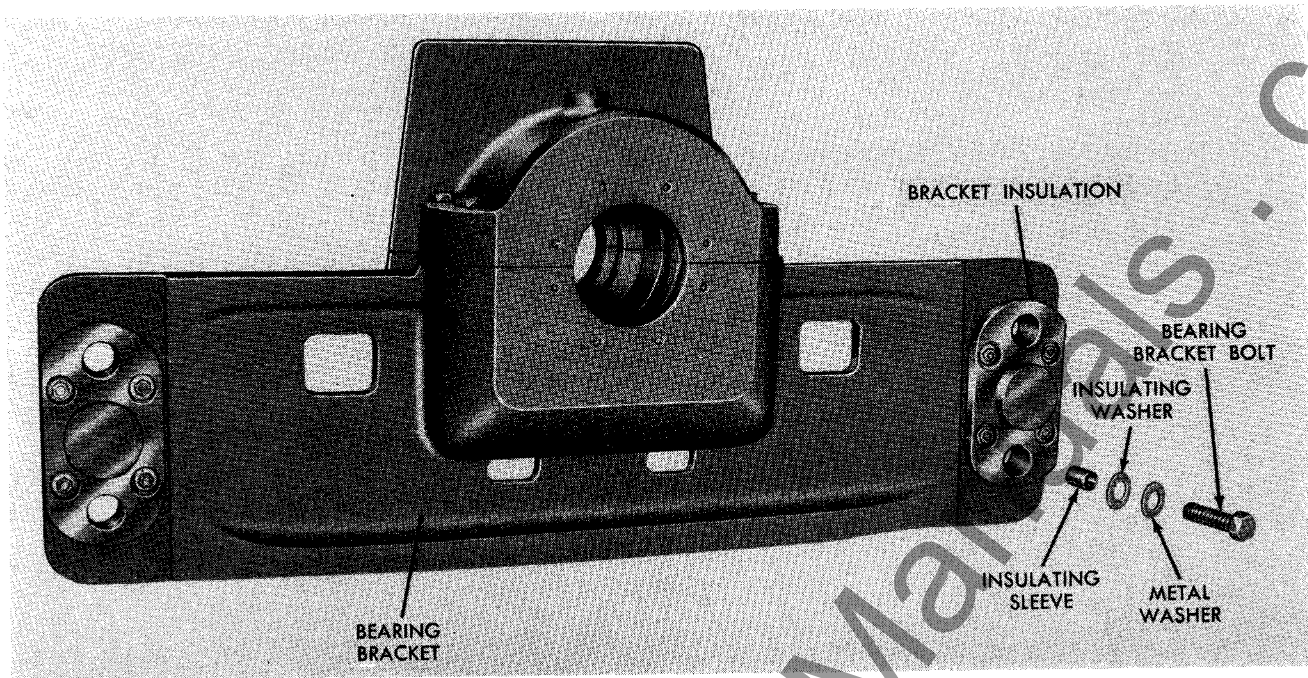


FIG. 33. Insulated Bearing Bracket

Note: Certain motors have a tendency to produce harmful circulating currents through the bearings. In such cases, the bearing bracket at the end of the motor opposite the shaft-extension end is insulated (see Figure 33); this insulation must not be short-circuited. Factory-installed piping and conduit are insulated from the bearing bracket, and any other piping or conduit added must also be insulated from this bracket.

Inspection. The bearing temperature may be measured by using temperature detectors (if supplied with the motor) or by using a thermometer inserted into the hole provided for this purpose in each bearing housing (see Figure 13). The maximum allowable temperature of the bearing is 85°C (185°F), while the maximum allowable bearing temperature rise is 45°C (81°F).

Overheating of a bearing may be caused by one or more of the following factors:

Improper Lubrication

1. Insufficient oil in bearing bracket to cover bottom of oil rings.

2. Dirty oil or oil of the wrong type.

3. Oil of poor quality.

4. Too much oil.

5. Failure of oil rings to revolve.

Improper Seating of Shaft Journal in Bearing.

1. Bent shaft.

Miscellaneous

1. Pitting of bearing surfaces due to bearing currents.

2. Rough bearing surfaces due to corrosion or careless handling.

3. Excessive end thrust from the mechanical load.

4. Poor alignment.

A bearing which overheats should be carefully inspected. Bearings may be removed from the motor after removing the appropriate panels and the bearing bracket caps. The top half of the bearing to be checked and its associated oil ring(s) should be removed, and the rotor jacked up to remove weight from the bottom half of the bearing. The bottom half of the bearing may then be removed and the rotor lowered onto the stator bore.

The bearings should be cleaned with lintless rags impregnated with clean oil, and then inspected. The bearings should be checked to ensure that no foreign material is present. It is extremely important to determine if any changes have occurred in the bearing surface. If the bearing surface no longer resembles the original bearing surface, the cause of the change should be found and eliminated. The shaft journals should also be checked, and the journal surfaces smoothed if required.

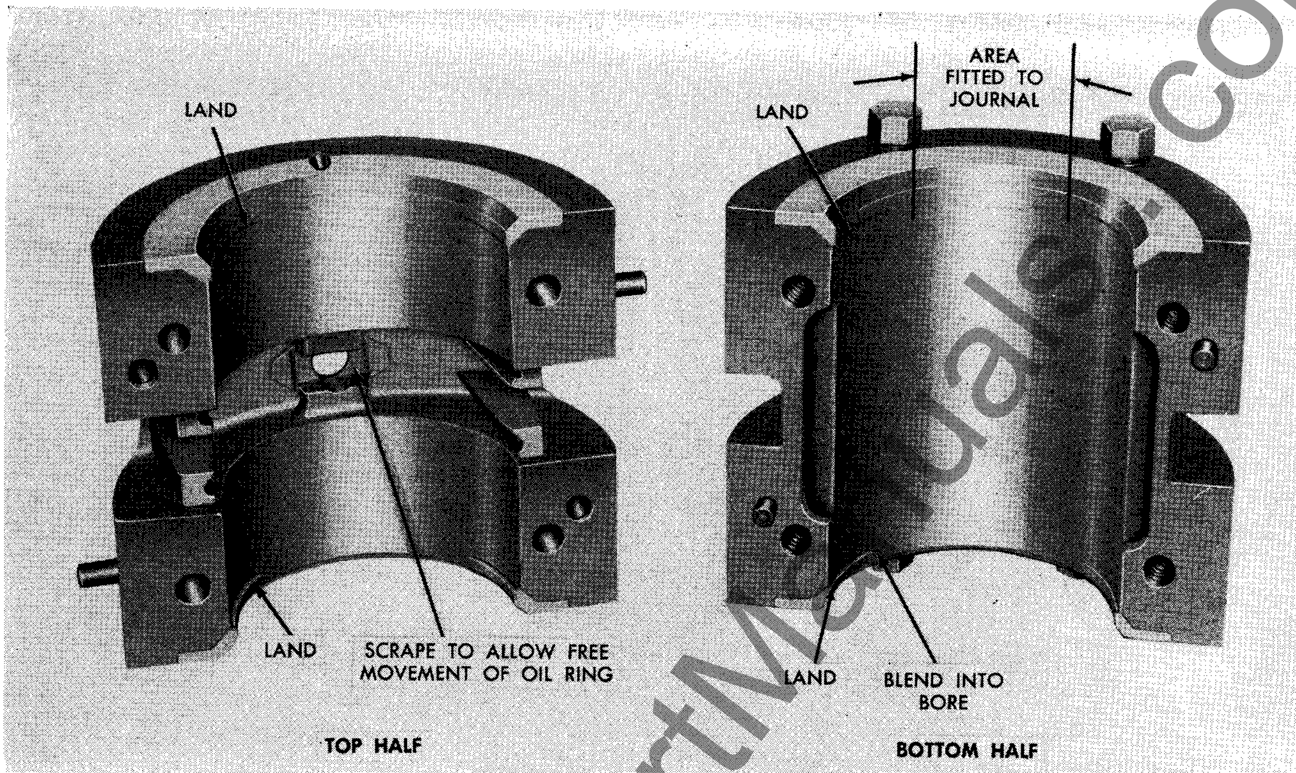


FIG. 34. Fitting Sleeve-Type Bearing

FIG. 35. Proper Method of Scraping Bearing

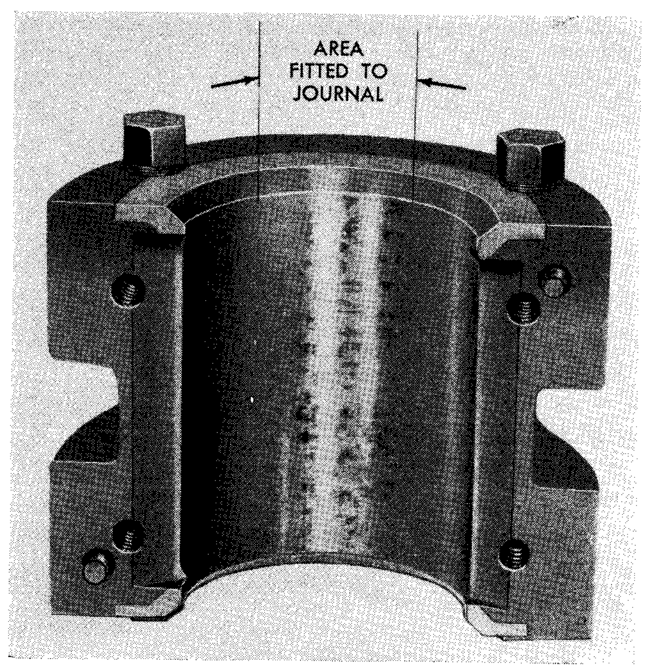


FIG. 36. Properly Scraped Bearing

Replacement. If localized scraping does not result in proper operation, the bearings must be immediately replaced. THE FOLLOWING FITTING PROCEDURE MUST BE FOLLOWED PRIOR TO BEARING INSTALLATION TO ENSURE PROPER BEARING OPERATION AND LONG BEARING LIFE (see Figures 34, 35, and 36).

Bottom Half of Bearing

1. Blend reliefs into bore so as to prevent sharp edges.

2. If insufficient clearance (less than .003 to .004 inch as measured by feeler gauges) exists between lands and journals, scrape lands so that there is a side clearance of .003 to .004 inch between the bearing and journal.

3. Fit that portion of bearing between reliefs (bottom part of bearing half) to journal and roll bearing into position. Rotate journal three complete revolutions in both directions and roll out bearing. Scrape bearing until a uniform pattern of high and low areas is obtained over this bearing surface. Repeat until this surface is properly fitted.

4. Check for proper clearance between oil ring and oil ring guide. If necessary, scrape to obtain proper clearance.

Top Half of Bearing

1. The reliefs in the top half are not scraped.

2. Scrape the lands at the ends of the reliefs (the bottom part of the bearing half) approximately the same amount as the corresponding lands in the bottom half of the bearing

Note: When fitting a Jordan bearing, fit bearing faces to the journal so that there is at least 75 per cent contact area. (This should be done in addition to the procedure described above.) After *any* bearing has been fitted, a bearing temperature run should be made. See Figure 13 and refer to Inspection above.

C. ANTI-FRICTION BEARINGS

Description. Anti-friction bearings are used where the loading is other than radially down or when their installation has been requested by the user. Anti-friction bearings consist of two rings, a set of rolling elements (balls or rollers), and a cage. The cage separates the rolling elements and spaces them evenly between the two concentric rings. The cage, therefore, makes the bearing a completely self-contained unit.

Anti-friction bearings are either grease- or oil-lubricated. It is recommended that lubricant (as specified in Table 1) be added at intervals of approximately six months, depending upon operating conditions. (Some motors may require more frequent lubricant changes.) DO NOT OVERLUBRICATE! Overlubrication causes churning, overheating, and grease breakdown and/or leakage; this may result in permanent damage to the bearings.

Inspection. The bearing temperature should be measured frequently, as noted in Part Four. This may be done by placing a glass chemical-type thermometer in the hole provided for this purpose in each bearing housing. (Resistance temperature detectors may be used for this purpose when they are supplied with the motor.) The maximum allowable temperature of the bearing is 85°C (185°F), while the maximum allowable bearing temperature **rise** is 45°C (81°F).

Overheating of a bearing may be caused by one or more of the following factors:

Improper Lubrication

1. Dirt within bearings.

2. Grease (oil) of wrong type.

3. Grease (oil) of poor quality.

4. Too much or too little grease (oil).

Improper Seating of Bearing in Bracket

1. Bent shaft.

Miscellaneous

1. Pitting of bearing surfaces due to bearing currents.

2. Rough bearing surfaces due to corrosion.

3. Poor alignment of motor.

4. Fatigue failure due to overloading.

A bearing which overheats should be carefully inspected. Inspection can be accomplished after removing the bearing(s) from the motor as described in Section G of Part Four. The bearings should always be cleaned with new, good-quality oil (light transformer oil, spindle oil, or automotive flushing oil) and repacked whenever they have been removed from the shaft. Before repacking the bearings, inspect them carefully (without disassembling the bearing units) for any evidence of pitting or scoring. If such defects are found, the bearings must be replaced.

Note: Most bearing troubles are caused by contamination of the bearings with dirt. Anti-friction bearings are very sensitive to dirt; for this reason, it is important that the utmost cleanliness be observed. The grease used for lubrication must be absolutely free of dirt. When bearings are removed from the shaft, they should always be placed on a clean sheet of paper; care should be taken to ensure that no dust or other foreign material (metal chips,

Table 1

LUBRICANTS FOR F/A MOTORS

TYPE OF BEARING	MOTOR RATING (HP)	RATED SPEED (RPM)	VISCOSITY OF LUBRICANT (SSU)*
Sleeve	200 and up	Up to 1800	180 to 250 at 100°F
Sleeve (Self-Lubricated)	200 and up	3600	180 to 250 at 100°F
Sleeve (Forced-Flood)	200 and up	3600	140 to 160 at 100°F
Anti-Friction (Grease-Lubricated)	All	All	*Westinghouse* P.D.S. 8750-2 (Sodium-base grease of the channeling type)
Anti-Friction (Oil-Lubricated)	200 and up	Up to 1200	457 to 550 at 100°F

* Sayboldt Second Universal

filings, core sand) enters the bearings at any time. When a new bearing is installed on the motor shaft, it is not necessary to remove the slushing grease used for protection of the bearing during storage. When lubricating grease is added, the slushing grease will dissolve in the lubricating grease to form a satisfactory lubricant.

Replacement. Bearings must be immediately replaced when proper operation is not obtained.

Caution: Order replacement anti-friction bearings only from Westinghouse. The bearing style number is stated on the outline drawing supplied with the motor.

The new bearings should be carefully unpacked, placed on a clean sheet of paper, and inspected prior to installation. Do not unpack bearings until they are needed for replacement purposes.

After the worn bearing has been removed from the shaft with a bearing puller, heat the replacement bearing in an infrared oven, temperature-controlled furnace, or oil bath to a temperature no greater than 95°C (205°F) in order to expand its inner diameter. While the new bearing is hot, it may be driven onto its proper place on the shaft with a length of clean, steel drift pipe and a steel hammer. The drift pipe should have a wall thickness sufficient to assure even application of driving force to the inner ring of the bearing. The bearing will be held securely in place upon cooling to room temperature. Check to be sure that the bearing rotates properly.

D. LUBRICATION SYSTEMS

Self-Lubricated Bearings

General Description. Self-lubricated bearings are those in which the bearing surfaces are lubricated by the action of oil rings and their accessory components. (Note that anti-friction bearings are also self-lubricated. Refer to Section C for a description of these bearings.) The oil rings are free to rotate and to move in a vertical plane within the bearing; in so doing, they pick up oil from the bottom portion of the bearing housing and distribute this oil over the shaft journal. Axial reliefs within the bearing aid in the proper distribution of the oil. Oil throwers and seals at each end of the bearing prevent leakage of oil from the bearing housing.

Lubrication. Only a good grade of clean, high-quality, turbine oil which is free of fillers and other additives should be used for the lubrication of self-lubricated bearings. Refer to Table 1 for the correct lubricant.

Oil is added to a bearing by pouring it through the oil ring inspection hole at one side of the top of each bearing housing. Add oil until the oil level reaches the mark located on the oil gauge. See Figure 32.

Caution: NEVER ADD LUBRICANT TO A MOTOR WHILE IT IS IN OPERATION! The bearing must never be underlubricated or overlubricated; bearing damage may result in either case.

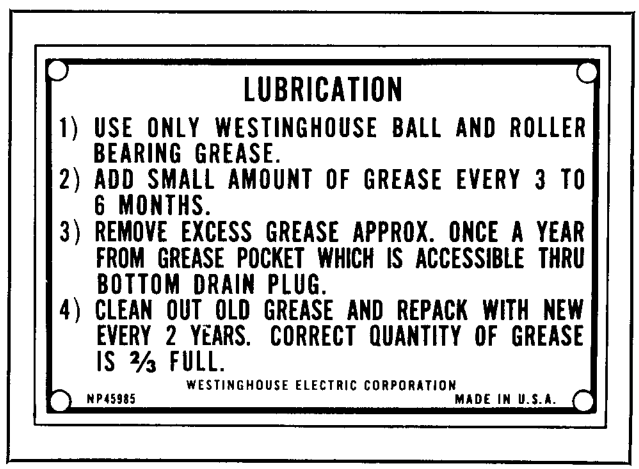


FIG. 37. Nameplate for Grease-Lubricated Anti-Friction Bearings

Oil may be drained from a bearing by removing the oil drain plug with a socket wrench. The plug is located at the bottom of the bearing housing. See Figure 32 for details.

Grease-lubricated anti-friction bearings are supplied with a nameplate which provides general lubrication data. (See Figure 37.) The procedure to be used in filling grease-lubricated anti-friction bearings is as follows:

1. Remove drain plug at bottom of bearing housing.

2. By means of the alemite fitting and a grease gun, fill bearing with grease until lubricant is forced between the rolling elements and flows into the overflow sump in the bottom of the bearing housing. The overflow of grease may be seen through the drain plug hole.

FORCED-FLOOD LUBRICATION SYSTEMS

General Description. Forced-flood lubrication systems are those in which lubricant is supplied under pressure to the bearing surfaces. Systems of this type are used in two-pole squirrel cage motors rated at more than 1250 hp (motors of this type are equipped with single-oil-ring spherical-seat bearings). The pressurized oil is supplied either by a pump system located within the motor or by a driven unit (pressurized) lubrication system. Motors equipped with forced-flood lubrication systems (and only those motors) have pressurized oil seals.

Self-Contained System. The pump system supplied with a large F/A two-pole squirrel cage motor consists of an oil pump which is driven directly from the F/A motor shaft or from a separate electric motor, an oil tank, an oil strainer, and an orifice plug for fixing the rate of oil flow to the bearings, plus the necessary piping and connectors. An oil cooler is provided in the system where it is necessary; a cooler of this type should be connected to a cold-water line and a drain as shown on the outline drawing supplied with the motor. Vents (pipes) connect the air shields to the bearing housings; pressurized air from the motor blowers is therefore transferred to the four oil seals in order to prevent leakage of pressurized oil from bearings. See Figures 38 and 39.

Driven Unit System. Some F/A two-pole squirrel cage motors rated at more than 1250 hp are designed for use with a driven unit (pressurized) lubrication system. Motors of this type are supplied with two threaded apertures (located at the end of the motor which has the shaft extension, the "rear" end), an oil inlet and an oil outlet, at which piping connections are made to the lubrication system. (See Figure 40.) The oil-inlet aperture has 3/8-inch pipe threads, while the oil-outlet aperture has 1 1/4-inch pipe threads. Each bearing is supplied with oil by a separate pipe connected to the oil-inlet line. Each pipe has an orifice plate, located between the flanges. Unless otherwise specified, the orifice diameter is 3/32-inch, which will supply the required oil flow of 1/2 to 3/4 gpm with a system oil pressure of 5 to 12 psi. If the driven unit lubrication system supplies oil at a different pressure, the orifice plates must be changed to suit. The oil drainage line should be sloped at least 1/2-inch per foot continuously to the sump tank to ensure proper oil drainage.

Note: The bracket on the end of the motor opposite the shaft-extension end is insulated to prevent currents circulating through the bearing; this insulation must not be short-circuited. Factory-installed piping and conduit are insulated from the bracket, and any other piping or conduit added must also be insulated from the bracket.

Lubrication. Only clean, high-quality, petroleum-base turbine oil which is free of fillers and other additives should be used for the lubrication of motors with forced-flood lubrication systems. Refer to Table 1 for proper lubricant.

The oil should be at the proper level in the bearing bracket (also in the oil tank of motors having self-contained lubrication systems). Oil gauges are located on the bearing housings and on the motor frame oil tank for motors with self-contained lubrication systems. From standstill to running, the oil level may rise 1/2-inch in the oil gauges.

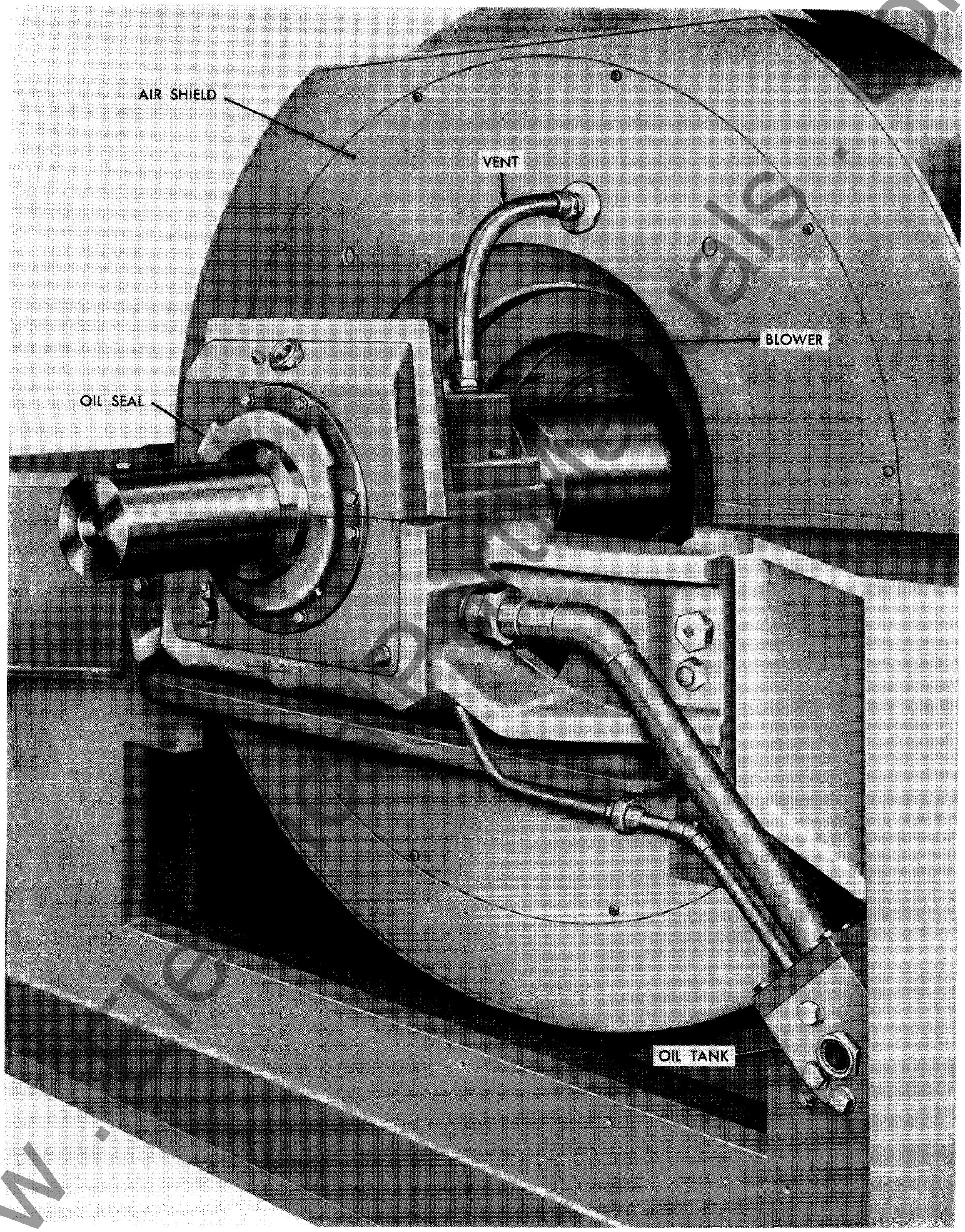


FIG. 38. Two-Pole Squirrel Cage Motor with Forced-Flood Lubrication System

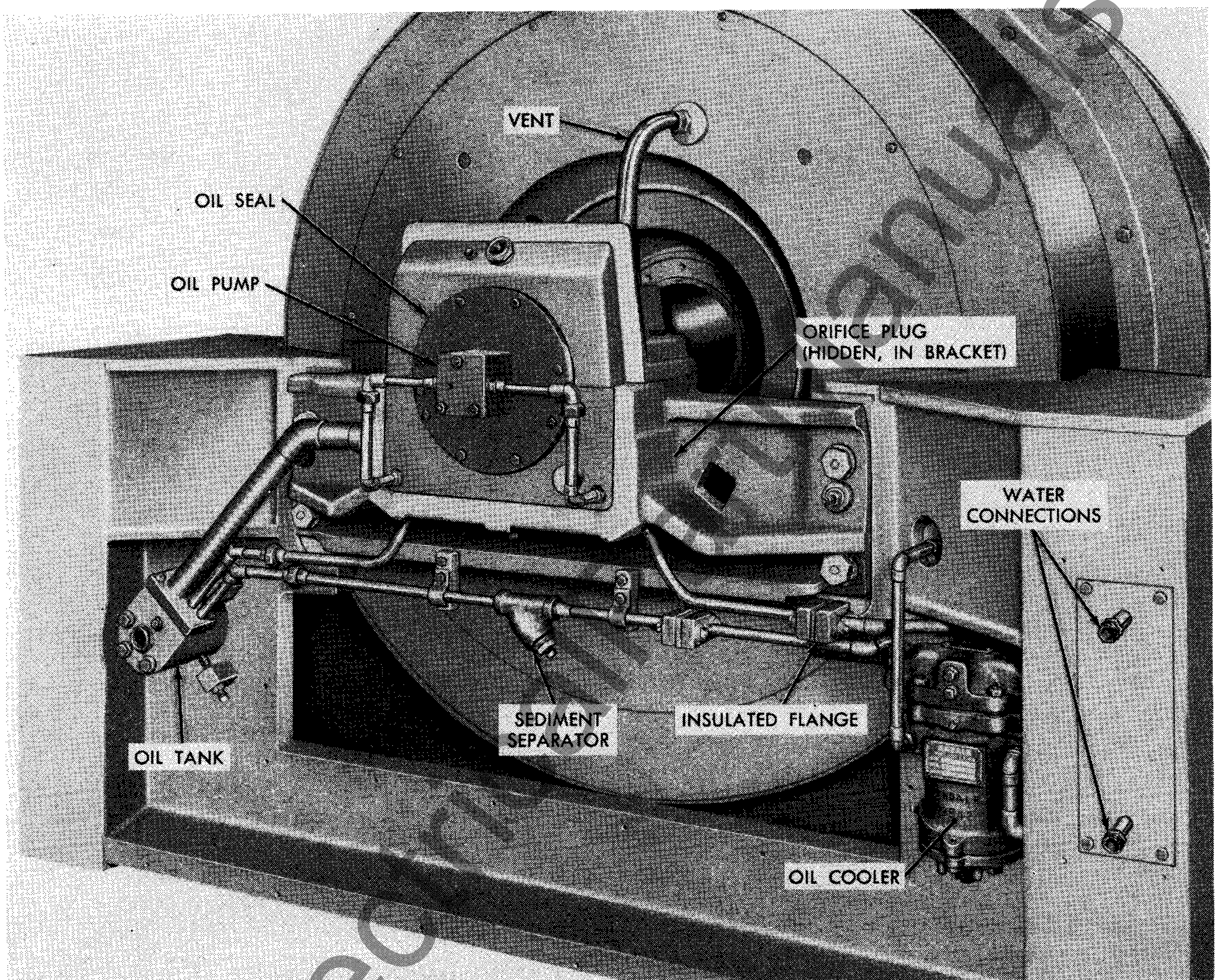


FIG. 39. Two-Pole Squirrel Cage Motor with Forced-Flood, Cooler-Equipped Lubrication System

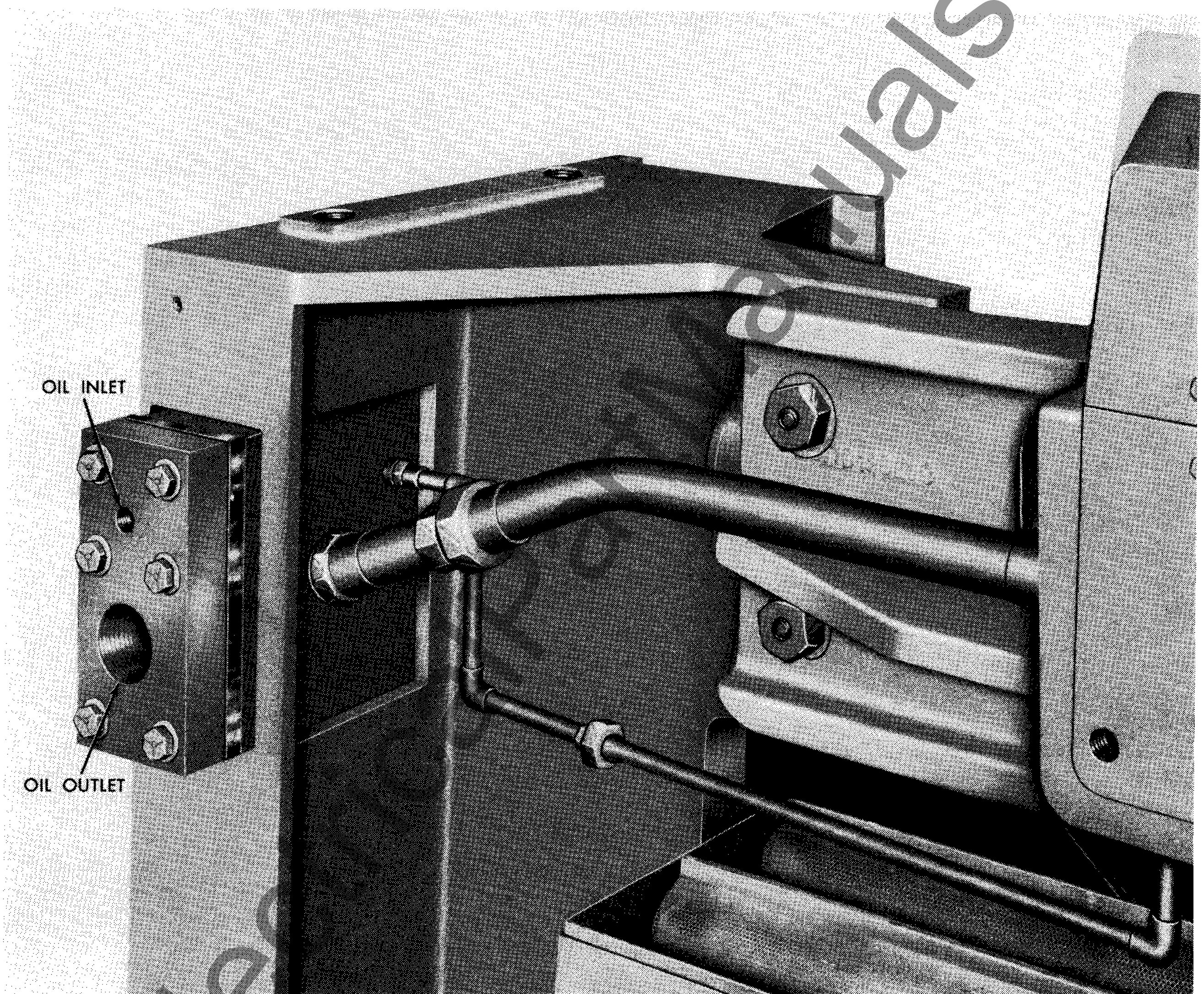


FIG. 40. Two-Pole Squirrel Cage Motor for Connection to Driven Unit Lubrication System

PART SIX

COLLECTORS AND BRUSHES

A. INTRODUCTION

This part describes the construction, operation, and maintenance of collectors and brushes used in Westinghouse F/A synchronous (type G) and wound rotor (type CW) motors.

The collectors are factory-connected to the rotor, while the brushes must be properly connected by the motor user. The rotor of a synchronous motor is provided with its required d-c excitation voltage through the brushes. Connect the brush terminals to the proper d-c source as shown on the drawings provided with the motor control equipment.

During start-up, resistance must be inserted in the rotor winding circuit of wound rotor motors. The rotor windings are short-circuited when the motor has reached its operating speed. The brushes provide connections to the rotor for these purposes. The instructions supplied with the motor control equipment describe the connection of the motor brushes to the motor control equipment.

B. COLLECTORS

Description. Each collector assembly is shrink-fitted to the rotor shaft. Collector rings (two are used in a synchronous motor and three are used in a wound rotor motor) are electrically connected to the rotor winding by copper leads. See Figures 41 and 42. Collectors must be kept round, smooth,

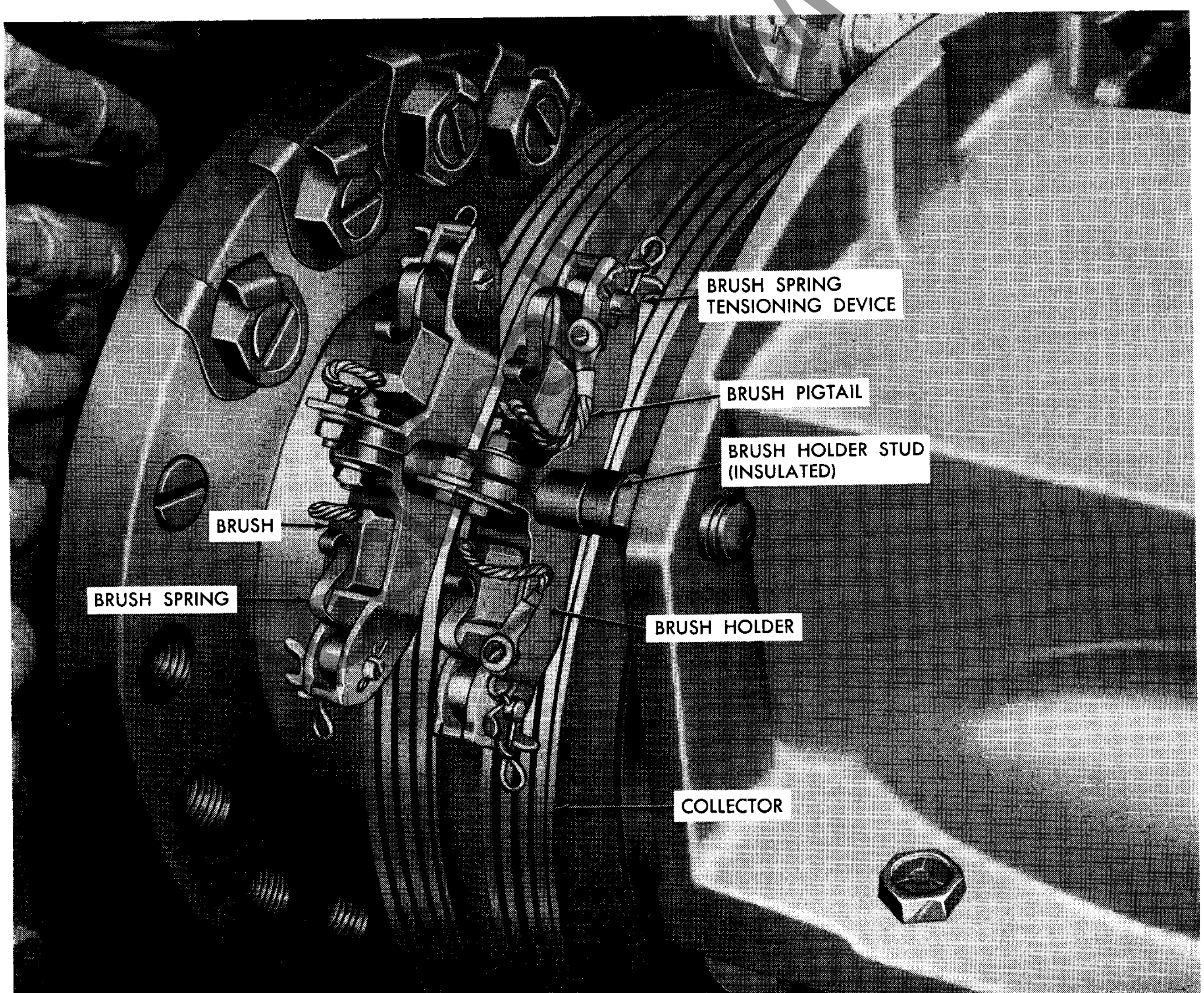


FIG. 41. Collector and Brush Assemblies for F/A Synchronous Motor

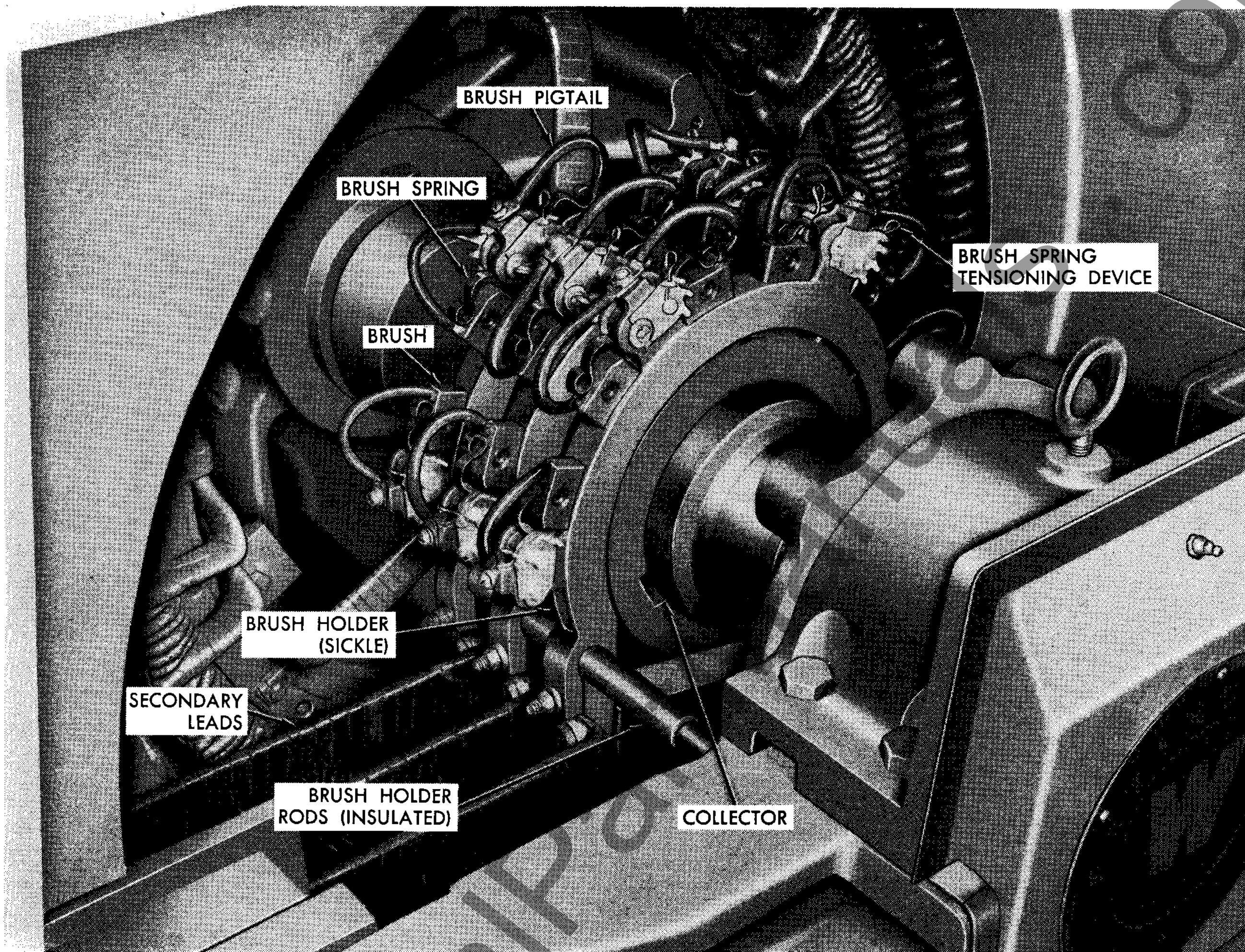


FIG. 42. Collector and Brush Assemblies for F/A Wound Rotor Induction Motor

and clean to ensure their proper operation. Lubricants must never be used on collectors!

Maintenance. The collectors will provide excellent service if they are properly maintained. They should, therefore, be inspected at weekly intervals. It is important that the collectors and brush rigging be kept clean at all times. If dirt and dust are permitted to accumulate, a flashover is likely to result.

In about two weeks' time, a new, properly operating synchronous or wound rotor motor will develop a uniform, glazed, dark-brown polish on the rings where the brushes ride; a nonuniform color or rough surface is indicative of improper operation. Sparking is indicative of improper collector (or brush) operation; however, improper operation may occur without such sparking. Sparking can be checked for by looking through the brush-inspection window (Figure 43) in the end cover at the end of the motor opposite the shaft-extension end.

Warning: Be extremely careful when working on the motor while it is in operation. Contact with high-voltage circuits can be fatal.

In time, black spots may develop on the rings; while these spots are not harmful in themselves, they should always be removed with No. 00 sandpaper as they may eventually lead to pitting of the rings. The sandpaper should be attached to a wooden block with a face shaped to the same curvature as the ring; move the paper very slowly back and forth parallel to the shaft axis as the rotor is rotating.

Caution: Only sandpaper of the proper grade should be used for polishing or cleaning collectors, brushes, or their component parts. Emery cloth, emery paper, emery stone, or Carborundum should never be used for this purpose since they will cause damage to these motor parts.

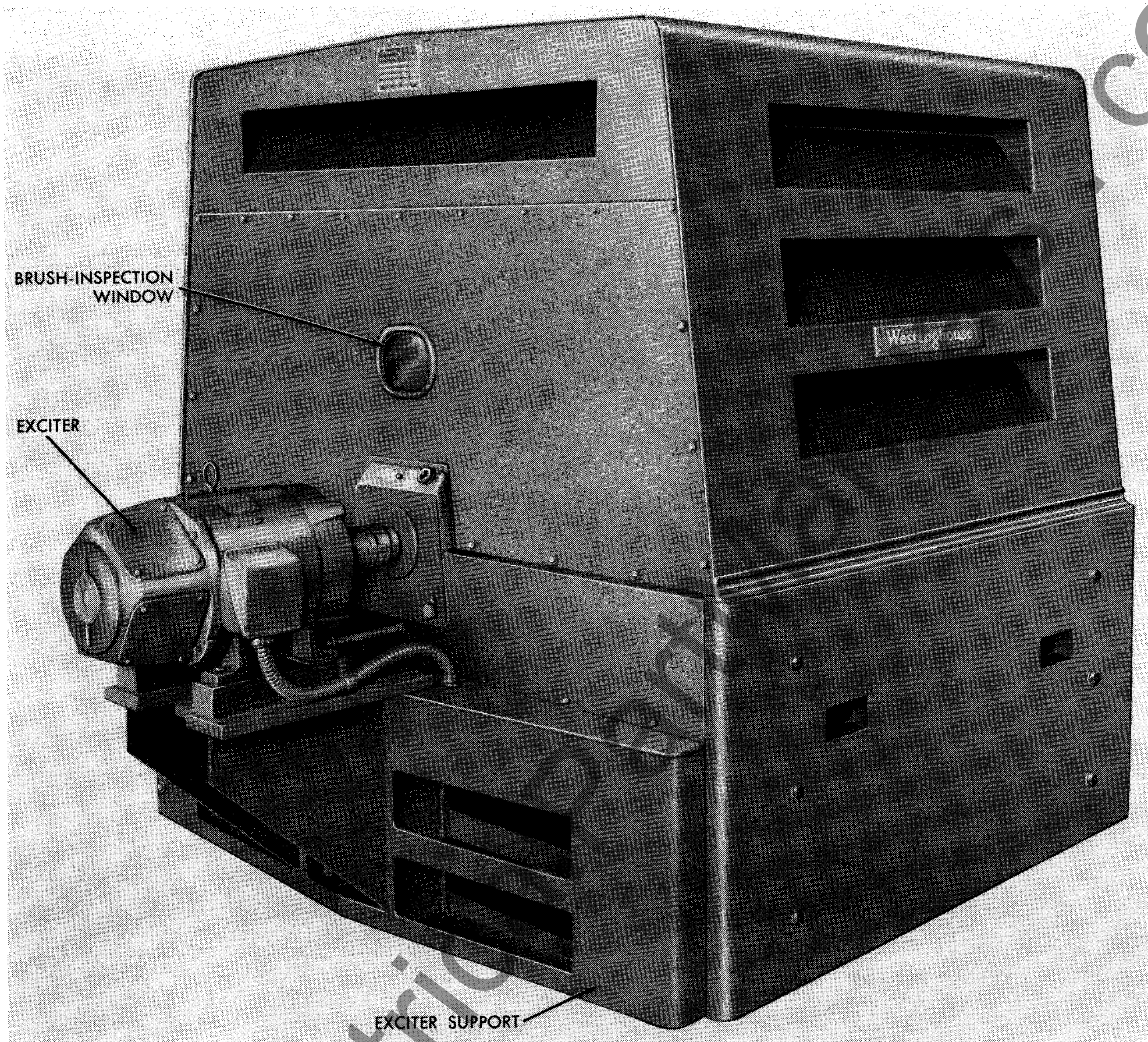


FIG. 43. F/A Synchronous Motor with Direct-Connected Exciter

Sometimes an imprint of the brushes will be found on the surface of the collector rings. This usually occurs on a machine which is subjected to moisture or acid fumes which act on the surface of the rings. When the machine is shut down, the fumes will act upon the ring surfaces except where the rings are in contact with the brushes. The difference in surface caused by this condition may cause a slight burning as the rings rotate.

Brush imprint on the rings may also be caused by a slight unbalance in the rotor, which may cause a jerk or movement in the ring once every revolution. This causes a brush to jump slightly with each revolution, causing arcing, which, in time, burns an imprint of the brush on the ring.

Elliptical or egg-shaped rings may also cause brush imprints. Trueness of a collector ring may be checked by placing an insulated dial indicator on the back of the associated brush while barring the rotor over with a barring tool.

Brush imprints due to moisture or fumes will occur at any point where the motor happens to stop. Imprints due to unbalance will always occur at the same place on the ring. If the motor must be shut down for a prolonged period in a harmful atmosphere, be sure to run the motor a short time each day to prevent ring corrosion. An alternate method is the application of a protective coating or cellulose tape.

Burnt rings (and brushes) on a wound rotor motor may have been caused by an attempt to start a heavy load with too little resistance in the rotor winding circuit.

Since there is always an electrolytic action on the surface of the rings, the collector operation of a synchronous motor is improved by reversing the polarity of the rings at intervals of about two weeks.

Replacement. Collectors should be replaced only if improper ring operation cannot be remedied by grinding, sanding, or polishing. Collectors should be replaced only by Westinghouse factory personnel or by local Westinghouse Manufacturing and Repair Shop personnel.

C. BRUSHES

Description. The carbon brushes used in Westinghouse F/A synchronous and wound rotor motors are held in place against the collector rings by a brush holder assembly fastened to the bearing bracket at the end of the motor opposite the shaft-extension end. The brushes are spring-loaded, and the spring tension is adjustable so that the required brush pressure of 2 to 2½ lbs per square inch of brush contact area can be set. The brush holders are factory-aligned to their correct tangential position and are set so that the clearance between collector rings and brush holders is not less than 1/16 inch.

If necessary, brush holders may be easily replaced. It is then only necessary to correctly position the brushes over the collector rings, since other alignments (tangential and clearance) are automatically accomplished.

MAINTENANCE

General. Brushes provide a long period of excellent service if they are properly adjusted and cared for. This requires a periodic inspection, which may be accomplished after removing the end cover having the brush-inspection window.

Warning: Before the brush inspection is made, turn power off and tag power switches and circuit breakers to prevent their being closed by mistake.

Inspection and Adjustment. The brushes may be checked daily for excessive sparking while the motor is in operation by viewing them through the brush-inspection window (Figure 43). Excessive sparking is an indication of incorrect brush operation; brush sparking accompanied by chatter will result if the motor is operated without a load.

The brushes and brush holders should be carefully inspected at frequent intervals. This inspection should include the following:

1. Measure brush force by attaching a small spring scale to each brush spring. Brush spring must be adjusted as brushes wear so that brush pressure is maintained at its proper value (2 to 2½ lbs per square inch of brush contact area). The brushes in each brush holder should be set at equal brush force so that the current will be divided equally.

2. Brush springs should be inspected to see that they have not reached their limit of travel; they should be replaced when their length has reached one-half of original length. Brushes should also be placed if they have badly-chipped corners or edges.

Caution: Brushes should be replaced with exact duplicates of the original brushes. The use of improper brushes will result in unsatisfactory motor operation and may cause serious damage to the motor.

3. Be sure that the brush contact area accurately conforms to the curvature of the collector rings. If this is not the case, shape the brushes to fit (described in Step 9 of Brush Replacement), or replace them if necessary.

4. Be sure that brushes are free to slide in their holders but that they are not so loose that they can vibrate. If brushes stick, remove them and rub their sides SLIGHTLY with fine (No. 00) sandpaper.

5. Make certain that brushes are accurately centered over the collector ring centers; readjust if necessary by loosening setscrews, sliding brush holders to the correct position, and re-tightening setscrews.

6. Make sure that the brush assembly is free from vibration. Tighten if necessary.

7. Carefully inspect brushes, brush holders, and associated parts for cleanliness. Any dirt, oil, grease, brush particles, or other contamination must be removed from these components with a clean, lint-free cloth moistened with a suitable solvent (such as Stoddard solvent). Do not neglect the inside portions of brush holders.

Note: Wound rotor induction motors are frequently supplied with some empty brush holders. Never place brushes in these empty brush holders.

8. Make sure that brush pigtails are securely connected to brushes and brush holders. Brush pigtails must not be allowed to contact each other.

Brush Replacement. In order to replace a brush, follow this procedure:

1. Turn power off, and tag power switches and circuit breakers to prevent their being closed by mistake.

2. Remove end cover from end of motor opposite shaft extension.

3. Raise brush spring.

4. Slide brush from its holder.

5. Clean brush holder if necessary.

6. Install a new brush which is an exact duplicate of the original.

7. Release brush spring.

8. Set brush pressure at 2 to 2½ lbs per square inch of brush contact area.

9. Shape new brush to fit its collector ring by inserting a strip of fine sandpaper with abrasive side up between brush and collector. Draw sandpaper in direction of shaft rotation while pressing brush against collector ring. Lift brush, return paper, and repeat shaping operation until the brush has the same contour as that of the ring.

10. Replace end cover removed in Step 2.

D. EXCITATION

Westinghouse F/A synchronous (type G) motors require d-c excitation of the rotor windings. The necessary excitation current may be obtained from any suitable source. This may be an exciter driven from the synchronous motor by means of belting or coupling (see Figure 43), a separate motor-generator set, a transformer-rectifier power supply, or the user's bus-line system if it can supply a constant-voltage output of the proper value. The proper excitation voltage and amperage requirements are specified on the motor nameplate.

PART SEVEN

ACCESSORIES

A. SPACE HEATERS

Construction and Use. Space heaters (Fig. 11) are furnished in some Westinghouse F/A motors. The heaters may be manually energized, or they may be automatically energized by a suitable control device, to maintain a 5 to 10°C (9 to 18°F) temperature differential between the inside of the motor and the ambient air.

The space heaters are tubular units which are supported within the stator core assembly by two bars. The heater units are fastened in place by setscrews.

Electrical Connections. The heaters are connected to an accessory terminal block located on the stator core assembly. The appropriate switch leads or controls are connected to these accessory terminals. The voltage and wattage ratings of the heaters are shown on the outline drawing.

Replacement.

Warning: Before replacing burned-out space heaters, turn off all power to the motor by opening the appropriate switches and circuit breakers. Tag these controls to prevent their being closed by mistake.

The space heaters may be replaced as follows:

1. Remove both side panels.

2. Disconnect leads from heater terminals.

3. Loosen the setscrews which hold heaters in place.

4. Remove heaters by sliding them from holding bars.

5. Slide new heaters into holding bars and tighten setscrews (replacements must be exactly the same as original equipment; consult the Westinghouse factory for style number).

6. Replace leads on heater terminals.

B. RESISTANCE TEMPERATURE DETECTORS

Resistance temperature detectors are installed in some F/A motors for measurement of the temperature of motor bearings and windings. The outline drawing supplied with the motor specifies the type and location of the temperature detectors if any are installed in the motor. The proper temperature detector connections are shown on the drawing furnished with the temperature control.

C. AIR FILTERS

Installation. The air filters used in Westinghouse F/A motors are mounted in such a way that all air drawn into the motor must pass through them.

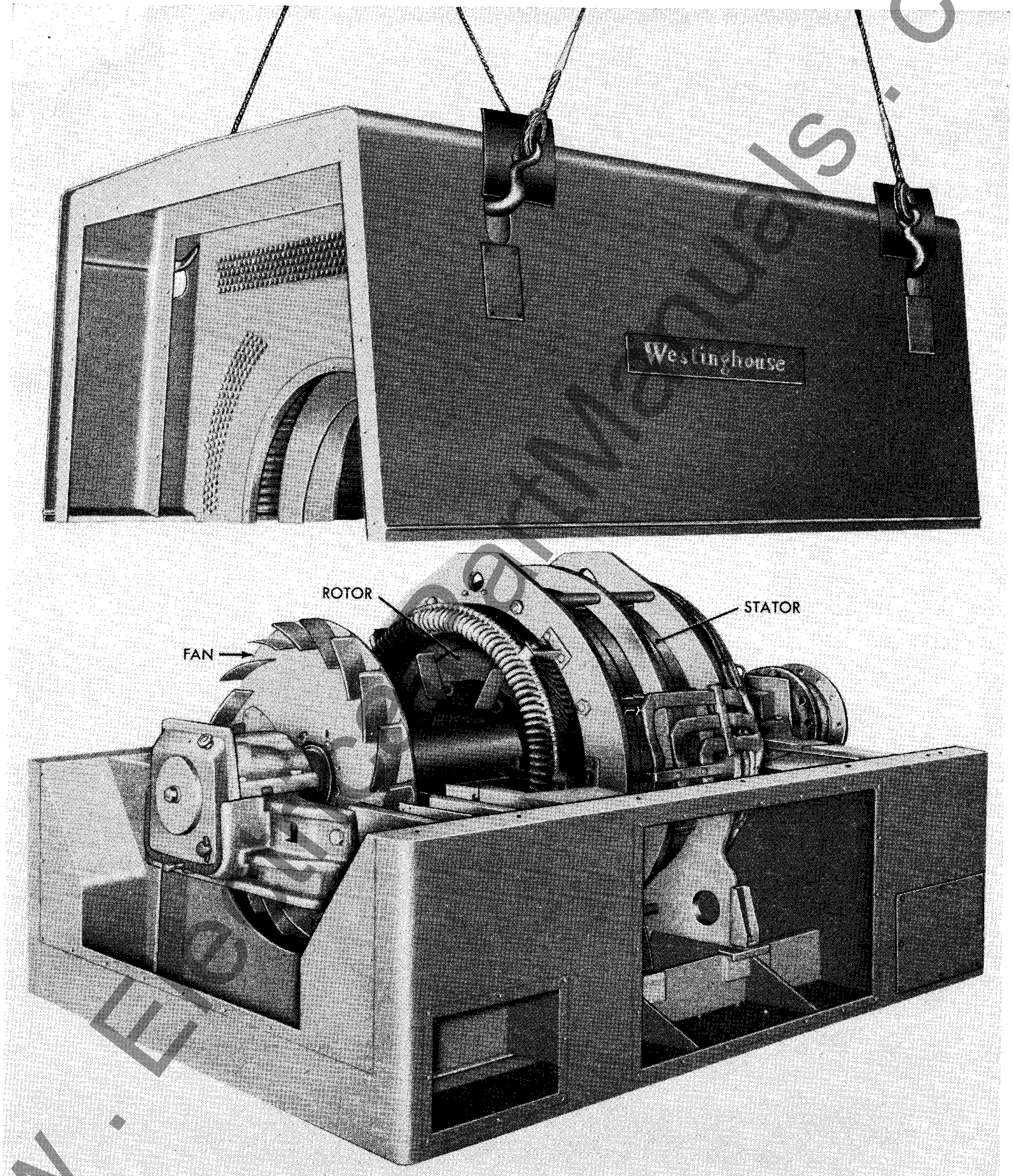


FIG. 44. Totally Enclosed Fan-Cooled F/A Motor; Partially Disassembled to Show Construction

Note: Air filters are not used with totally enclosed fan-cooled motors. Motors of this type are completely enclosed. The air within a totally enclosed fan-cooled motor (Figure 44) is circulated by a fan attached to the motor shaft.

Air filters are fastened in place in the filter holding frames by spring clips, and are easily removable for cleaning after removal of the filter access covers. See Figure 45.

Construction. The air filters used in F/A motors consist of crimped layers of galvanized wire mesh (bronzed in motors for outdoor use) enclosed in heavy-gauge steel channel frames (see Fig. 46). Both faces of a filter are protected by expanded metal which facilitates handling and makes the filter a rigid assembly. The wire mesh is coated with commercial filter adhesives or lubricating oil; this fluid "captures" any dust particles which strike it.

Cleaning. Air filters should be removed and cleaned at intervals determined by operating conditions. Cleaning may be accomplished after the filter access covers are taken off and the filters removed from their holding frames.

Caution: Motors may overheat if filters become excessively clogged.

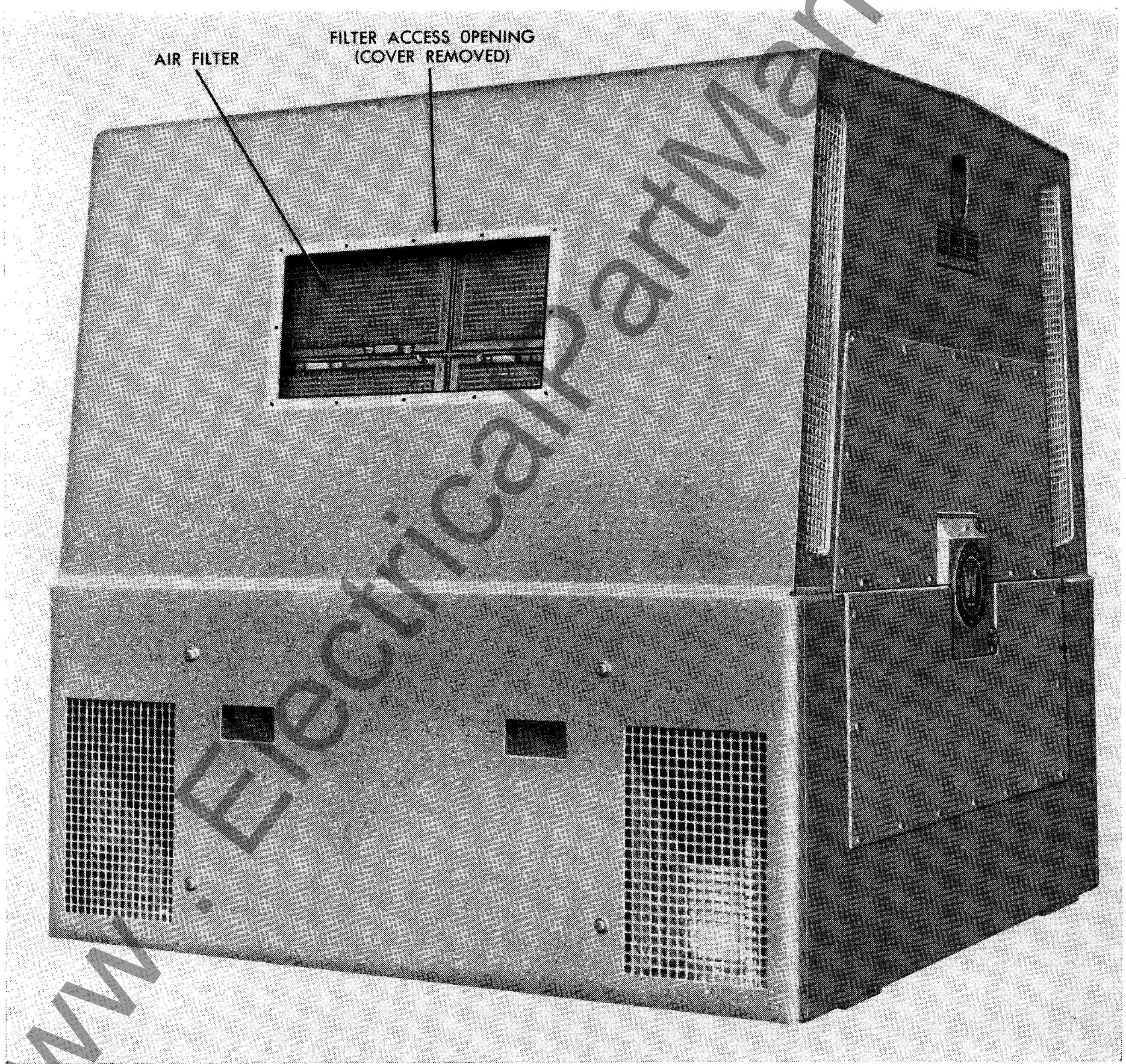


FIG. 45. Location of Air Filters in NEMA-II Weather-Protected Motor

Filters may be cleaned by hosing the fine-mesh side with hot water if the filter adhesive is of the water-soluble type, or by agitation (fine-mesh face down) in a solution of Oakite No. 20 (3 pounds to 5 gallons of water), trisodium phosphate (1½ pounds to 5 gallons of water), or other suitable cleaning compounds. Never use caustic soda or other strong alkalies. If more convenient, the filter may be boiled (fine-mesh face down) for five minutes in one of the cleaning solutions mentioned. After cleaning, look through the filter toward a bright light; no cloudy areas will be seen if the filter has been thoroughly cleaned. It is not necessary to wash the blackened oil coating from the wire.

Replacement. Before the air filters are replaced, they must be properly charged with the correct adhesive; commercial adhesives (such as Air-Maze Filterkote) or SAE 30-50 motor oil may be used for this purpose. Charging may be accomplished by dipping the filter in the adhesive, spraying it thoroughly with a power-spray gun, or by liberally coating both sides by means of a brush. After charging, allow the filters to drain thoroughly face down or on edge over a suitable receptacle. When excess adhesive has drained off, replace the filters and filter access covers.

D. NOISE MUFFLERS

Installation. Noise mufflers are provided in some high-speed F/A motors. When used, they are fastened to the inside portion of the motor enclosure (see Fig. 47).

Maintenance. Noise mufflers normally will not require maintenance. Contact local Westinghouse Service Engineers should these units give any trouble.

Note: Most Westinghouse F/A motors are designed so that noise mufflers may be added if they are not supplied originally.

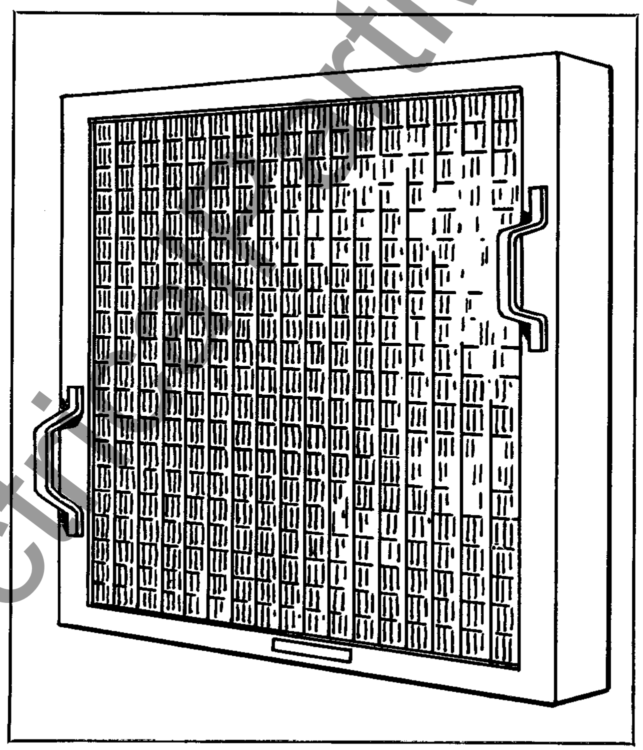


FIG. 46. Air Filter

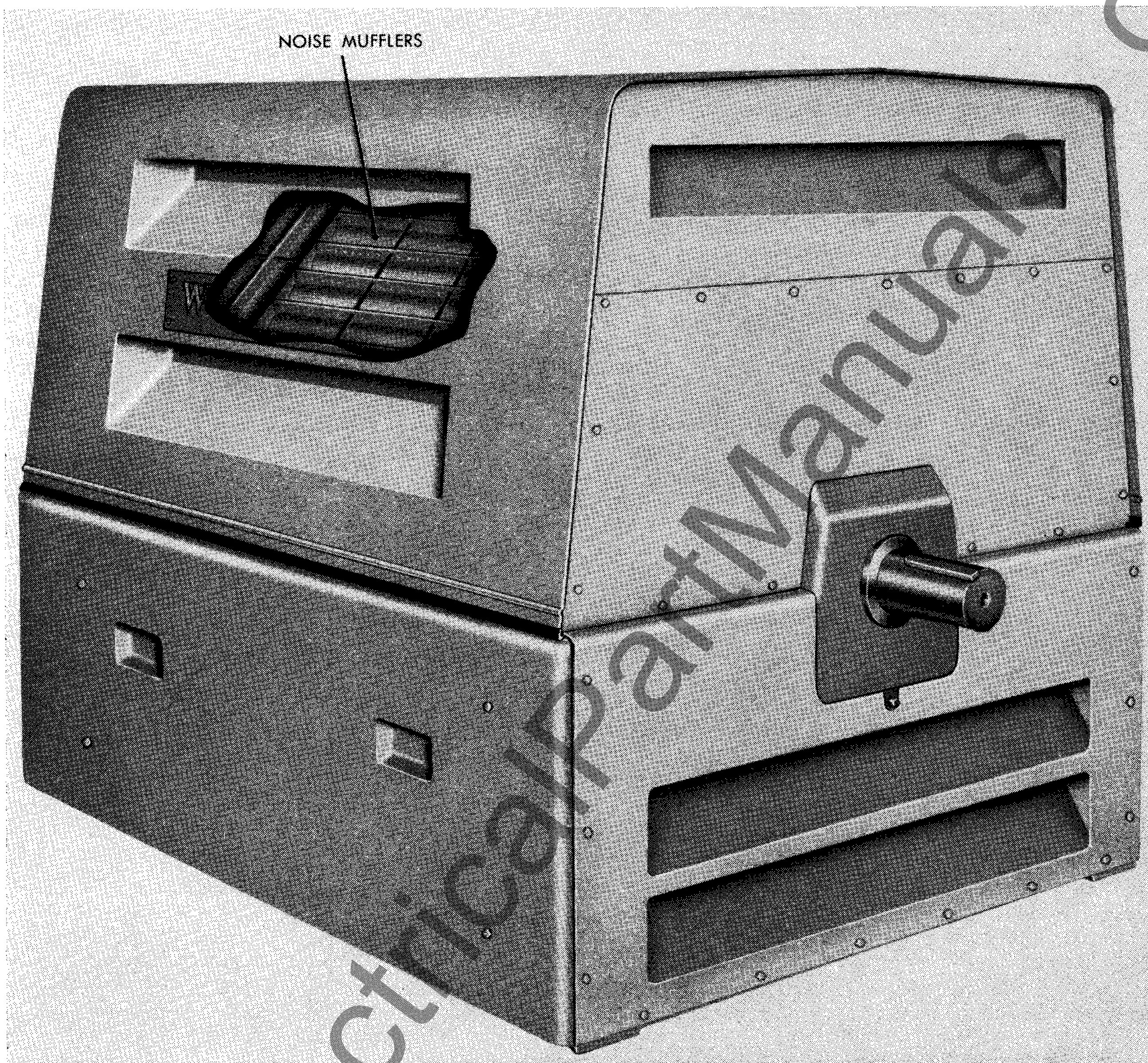


FIG. 47. Installed Noise Mufflers

WESTINGHOUSE ELECTRIC CORPORATION

HEADQUARTERS: 3 GATEWAY CENTER, P. O. BOX 2278, PITTSBURGH 30, PA.

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*DES MOINES 17, IOWA, 2515 Dean Ave.
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*GRAND RAPIDS 2, MICH., 148 Monroe Ave., N.W.
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HAMMOND, IND., 6355 Indianapolis Blvd.
*HARTFORD 3, CONN., 119 Ann St.
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*JACKSON, MICH., 120 West Michigan Ave.
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*JACKSONVILLE 6, FLA., 1520 Prudential Building, 841 Miami Rd.
JOHNSON CITY, N. Y., 419 Grand Ave.
JOHNSTOWN, PA., Wallace Bldg., 406 Main St.

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*MILWAUKEE 2, WIS., 538 N. Broadway
*MINNEAPOLIS 13, MINN., 2303 Kennedy St., N.E.
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*NEW ORLEANS 19, LA., 400 N. Carrollton Ave., P.O. Box 7497
*NEW YORK 5, N. Y., 40 Wall St.
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OLEAN, N. Y., Exchange Nat'l Bank Bldg., 201 N. Union St.
*OMAHA 2, NEBR., 117 North Thirteenth St.

PEORIA 3, ILL., 2800 N. Adams St.
*PHILADELPHIA 4, PA., 3001 Walnut St.
*PHOENIX, ARIZ., 1110 N. 21st Ave.
*PITTSBURGH 30, PA., 306 4th Ave., P.O. Box 1017
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ROANOKE, VA., 303 1st St., S.W.
ROCHESTER 8, N. Y., 711 Exchange St.
*ROCKFORD, ILL., 2121—15th St.
RUTLAND, VT., 98 Merchants Row

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*ST. LOUIS 1, MO., 411 North Seventh St.
*SALT LAKE CITY 1, UTAH, 235 W. South Temple St.
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*SPRINGFIELD 1, MASS., 160 Tapley St., Box 1611
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*SYRACUSE, N. Y., 4030 New Court Rd., East Syracuse

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TAMPA, FLA., 4062 Henderson Blvd., P.O. Box 10597
*TOLEDO 4, OHIO, 245 Summit St.
TUCSON, ARIZ., 2020 E. 13th Street
*TULSA 3, OKLA., 703 Enterprise Bldg.

*UTICA 1, N. Y., Truck Route 5-A, P.O. Box 270

VAN NUYS, CALIF., 15217 Burbank Blvd.

*WASHINGTON 6, D. C., 1625 K St., N.W.
WATERLOO, IOWA, 300 West 3rd St.
WATERTOWN, N. Y., 32 The Arcade
WHEELING, W. VA., Nat'l Bank of W. Va., P.O. Box 329
WICHITA 16, KANSAS, 2938 So. Minneapolis Ave., P.O. Box 967
*WILKES-BARRE, PA., 267 N. Pennsylvania Ave.
WILLIAMSPORT, PA., 221 Williamsport Bldg., 460 Market St.
WINSTON-SALEM, N. C., P.O. Box 5463, Ardmore Station
WORCESTER 8, MASS., 507 Main St.

YORK, PA., 153 East Market St.
*YOUNGSTOWN 3, OHIO, 25 E. Boardman St.

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HUNTINGTON 1, W. VA., 1029 Seventh Ave., P.O. Box 1150

INDIANAPOLIS 25, IND., 551 West Merrill St.
JOHNSTOWN, PA., 107 Station St.
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LOS ANGELES, CALIF., 18020 S. Santa Fe Ave. (Compton)
MILWAUKEE 9, WIS., 1500 W. Cornell St.
MINNEAPOLIS 13, MINN., 2303 Kennedy St., N. E.
OMAHA, NEBRASKA, 3805 N. 16th St.
PHILADELPHIA 4, PA., 3001 Walnut St.
PHILADELPHIA 34, PA., Erie Ave. & D St.
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PITTSBURGH, PA., 1000 Ohio Ave., (Glassport)
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SEATTLE 4, WASH., 3451 East Marginal Way
SPRINGFIELD 9, MASS., 160 Tapley St.
SUNNYVALE, CALIF. (Sunnyvale Plant), Hendy Ave.
SYRACUSE, N. Y., 4030 New Court Rd., East Syracuse
UTICA 1, N. Y., Truck Route 5A, Yorkville
WILKES-BARRE, PA., 267 N. Pennsylvania Ave.

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EAST PITTSBURGH, PA., (Headquarters) Braddock Ave.
PHILADELPHIA, Crum Lynne, PA., Box 68

* Addresses for District Engineering and Service Department Offices not listed here are the same as above Apparatus Sales Offices when marked with an asterisk.