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TECHNICAL MANUAL

ELECTRICAL MACHINERY REPAIR; VOLUME 1, ELECTRIC MOTOR, SHOP PROCEDURES MANUAL

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NOTE

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FOREWORD

This Electric Motor Repair Shop Procedures Manual is for use by IMA personnel engaged in electric motor repair. For maximum effectiveness, this manual should be used as a supplement to any ongoing on-the-job training in the IMA electrical repair shop.

Both mechanical and electrical test equipment and tools are discussed with detailed ″how-to-use″ information. This manual provides specific step-by-step inspection and test procedures with related safety precautions. Troubleshooting procedures with symptom recognition and listings of probable faults are explained. ″How-to-do-it″ step-by-step disassembly, checkout, repair, replacement and reassembly procedures are all illustrated with ″hands-on″ diagrams for easy understanding. To ensure reliable equipment operation and equipment long life, installation procedures are provided with quality control provisions.

Navy equipment technical manuals and NAVSEA technical manuals provide the necessary instructions about what must be done for the maintenance and repair of equipment. This Shop Procedures Manual supplements the information in the preceding Navy references and other publications and provides the necessary details on how the repair work is to be done to ensure equipment reliability.

This Electric Motor Repair Shop Procedures Manual has been developed with a primarily functional format instead of a topical format. This is designed to facilitate equipment repairs. A repair technician finds useful information in the necessary sequence and can perform a single task, or a related series of tasks, by referring to only one section of the manual. Necessary descriptive information has been retained, but is presented as part of the relevant functional procedures. This functional format improves the effectiveness of the manual and is especially suited to the improvement of technician performance.

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SAFETY SUMMARY

This publication describes physical and chemical processes which may require the use of chemicals, solvents, paints, or other commercially available material. The user of this publication should obtain the material safety data sheets (Occupational Safety and Health Act (OSHA) Form 20 or equivalent) from the manufacturers or suppliers of materials to be used. The user must become completely familiar with the manufacturer/supplier information and adhere to the procedures, recommendations, warnings, and cautions of the manufacturer/supplier for the safe use, handling, storage, and disposal of these materials. The following are general safety precautions and instructions that people must understand and apply during many phases of operation and maintenance to ensure personal safety and health and the protection of DOD property. Portions of this may be repeated elsewhere in this publication for emphasis.

DANGER, WARNING, AND CAUTION STATEMENTS. DANGER, WARNING, and CAUTION statements have been strategically placed throughout this text prior to operating or maintenance procedures, practices, or conditions considered essential to the protection of personnel (DANGER and WARNING) or equipment and property (CAUTION). A DANGER, WARNING, or CAUTION statement will apply each time the related step is repeated. Prior to starting any task, the DANGER, WARNING, or CAUTION statements included in the text for that task will be reviewed and understood.

ELECTRIC SHOCK. People working around energized electric circuits and equipment must always observe safety precautions. Injury may result from electric shock. Short circuits can be caused by accidentally placing or dropping a metal tool, flashlight case, or other conducting article across an energized line. These short circuits can cause an arc or fire on even relatively low voltage circuits and may result in extensive damage to equipment and serious injury to personnel. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

CAUSE OF ELECTRIC SHOCK. Current rather than voltage is the measure of shock intensity. The passage of even a very small current through a vital part of the human body can cause death. The ability of a circuit to produce a fatal current is dependent upon the resistance of the body, contact conditions, the path through the body, etc. Fatalities have occurred from circuits with voltages as low 30 volts. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

RESCUE FROM ELECTRIC SHOCK. The rescue of electric shock victims depends on their prompt removal from the source of shock and the administration of first aid. Personnel trained in safe removal of a victim from a source of electric shock and cardiopulmonary resuscitation (CPR) procedures should perform this emergency procedure. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

INDIVIDUAL RESPONSIBILITY. Individuals have a responsibility, not only to themselves but also to their shipmates, to always be alert to detect and report unsafe work practices and unsafe conditions. Each individual must

1. Observe all posted operating instructions and safety precautions.
2. Report any condition, equipment, or material that is believed to be unsafe.
3. Caution others to observe safety precautions.
4. Report to the supervisor any injury obtained in the course of their work.

SAFETY SUMMARY - Continued

5. Exercise caution in the event of an emergency, where deranged equipment or abnormal operating conditions could produce additional, unseen hazards.

SHIPBOARD ELECTRICAL SYSTEMS.

EQUIPMENT GROUNDING AND SYSTEM GROUNDING. The word *grounding* is frequently used in ac electrical power systems for referring to both *equipment grounding* and *system grounding.*

Equipment grounding is an important safety measure. Equipment grounding intentionally connects the non-current-carrying conductive parts of electrical equipment to ground through a low-resistance path. If an energized electrical conductor contacts the enclosure due to a fault or mechanical damage, the equipment ground provides the lowest impedance path of electrical current to ground, shunting the current away from a possible human contact. Electrical power systems can be classified by the nature of the connection between the neutral of the power system and ground. The system is said to be *ungrounded* when the electrical system neutral or phase conductors are not intentionally connected to ground expect through potential measuring devices or other very high-impedance devices. Navy ships use an *ungrounded* system. Electric utility service for house wiring ashore uses a *grounded neutral* system so that a fault will produce a high current and quickly trip the circuit breaker or blow the fuse. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

GENERAL ELECTRICAL SAFETY PRECAUTIONS FOR EQUIPMENT MAINTENANCE.

EQUIPMENT MAINTENANCE. Safety from electrical hazards during any form of maintenance work can best be ensured by completely deenergizing equipment. Follow the tag-out instructions for working on deenergized equipment in Chapter 1 of this manual and NAVSEA S9086-KC-STM-010/CH 300. **When it is necessary to work on energized equipment, the requirements of NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.5, shall be carefully adhered to.**

Equipment maintenance covers both preventive and corrective maintenance of electrical equipment and includes any or all of the following work:

Testing

Calibrating

Taking measurements

Troubleshooting

Repairing

Assembling

Disassembling

Making adjustments

GENERAL SAFETY PRECAUTIONS.

SAFETY SUMMARY - Continued

1. Do not touch a conductor, until it is tested, to be sure it is deenergized.
2. Obey all warning signs; read equipment warning labels before use.
3. Do not energize any equipment that is tagged out. Properly clear the tag first.
4. Use authorized equipment to perform maintenance work.
5. Close all fuse boxes, junction boxes, switch boxes, and wiring accessories.
6. Never operate a switch with the other hand on a metal surface.
7. Never use outlets that appear to be burnt.
8. When using a metal-cased tool, ensure it is equipped with a three conductor cord, and three-pronged plug. Verify that the ground prong extends beyond the power blade of the plug.
9. Wear rubber gloves when using metal-cased portable electrical equipment, or when using electric handheld portable tools in hazardous conditions, such as wet decks and bilge areas. Leather gloves shall be worn over rubber gloves when the work being done could damage the rubber gloves.
10. Do not use equipment with worn or damaged cords, or crushed or damaged plugs.
11. Check the portable electrical equipment has been inspected and has a current inspection label affixed.
12. Only use electric equipment in explosive atmospheres if the equipment is approved for such use (explosion proof).
13. Do not allow cords to run over sharp objects, chemicals, or hot surfaces.
14. Do not join more than two 25-foot extension cords together. Single-length extension cords up to 100-foot are permissible.
15. Use a voltmeter or voltage tester to ensure that equipment or circuits are deenergized.

For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

WORK ON DEENERGIZED EQUIPMENT.

EQUIPMENT TAG-OUT PROCEDURES. Safety from electrical hazards can best be ensured by completely deenergizing equipment on which work is to be done. Always deenergize electrical equipment by opening the power supply circuit breaker or switch, or removing the appropriate fuse, and use the equipment tag-out procedure before continuing with work. **For requirements concerning work on energized circuits or equipment, see NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.5.**

SAFETY-RELATED ITEMS. Refer to NAVSEA S9086-KC-STM-010/CH 300, table 300-2-1, for a list of safety-related items used for electrical and electronic maintenance and repair.

CHECKING FOR ENERGIZED CIRCUITS. Be sure electrical equipment is deenergized before working on it. To verify a circuit is deenergized, first connect the leads of a voltmeter or voltage tester across the power source terminals of a known energized circuit to ensure the device is working properly. Next, connect the leads of the device across the power source terminals of the equipment under test and from each terminal to ground to verify it is deenergized. Recheck the voltmeter or voltage tester on the known energized circuit to ensure that the device is still working properly. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

SAFETY SUMMARY - Continued

DISCHARGING DEENERGIZED CIRCUITS. The electrical charge retained by secured electrical equipment may be great enough to cause a severe shock. This danger must be considered before touching the terminals to an apparently deenergized equipment. Discharge the equipment to ground by momentarily connecting the terminal to ground using a short probe (see NAVSEA S9086-KC-STM-010/CH 300, table 300-2-1). Capacitors and picture tubes can develop a charge after a period of time and may need to be shorted several times before being fully discharged. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

WORKING ON ENERGIZED EQUIPMENT.

APPROVAL PROCEDURES. Electrical equipment is a source of great danger if not properly approached. The Commanding Officer is responsible for electrical safety. Energized electrical equipment shall not be disassembled nor undergo any maintenance without approval of such action by the Commanding Officer or, in his absence, the Command Duty Officer. The only exceptions to this policy are in those cases in which approval instructions issued by higher authority (equipment technical manuals, PMS, or an established troubleshooting procedure) permit opening or inspecting equipments in the course of performing maintenance, routine testing, taking measurements, or making adjustments that require equipment to be energized. When external test points are provided on an equipment panel, testing with an instrument using these test points shall not be considered as working on an energized equipment. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

ENERGIZED CIRCUIT WORKING PROCEDURES. When maintenance must be done on energized circuits or equipment, the following precautions shall be observed in addition to the general precautions of NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.5. These precautions do not apply for circuits or equipment less than 30 volts:

1. Never work on energized electrical or electronic equipment by yourself have another person (safety observer) qualified in first aid for electrical shock present at all times. The safety observer should also know which circuits and switches deenergize the equipment and will be given instructions to operate the switch immediately if anything unforeseen happens.
2. Workers shall not wear wristwatches, rings, watch chains, metal articles, or loose clothing that might accidentally contact energized parts or throw some part of their bodies into contact with mechanical/ electrical active components. Clothing and shoes shall be as dry as possible.
3. Insulate the deck or standing surface from ground by covering with insulating material. Rubber mat or rubber blankets shall be used for this covering. If mats or blankets are not available, and the work must be accomplished before the specified material is available, other suitable insulating materials are dry wood, dry canvas, dry phenolic material, or even several layers of heavy, dry paper. Be sure insulating material is dry, has no holes in it, and that no conducting materials are embedded in it. Cover enough area so that workers have adequate space to move about.
4. Use only one hand to do the work, if practical.
5. If the work being done permits, rubber gloves shall be worn on both hands; if not, a rubber glove shall be worn on the one hand not used for handling tools.
6. A face shield or spectacles shall be worn during work on energized equipment, since a short circuit could produce a high fault current capable of producing flying molten particles and intense heat.
7. Cover metal on hand-held tools with an electrical insulating material. One acceptable method is to use

SAFETY SUMMARY - Continued

two layers of rubber or vinyl plastic tape, half-lapped. Another method is to coat tools with Plastisol; see instructions in *NSTM* , Chapter 631, ″Preservation of Ships in Service.″ In an emergency, if time does not permit applying the foregoing materials, the tool handles and tool shafts may be covered with cambric sleeving, synthetic resin flexing tubing, or with insulation tubing removed from scrap of certain kinds of electrical cable.

8. Take the following extra precautions when the nature of the work is particularly hazardous, such as when working in the interior of a switchboard or other cubical where exposed energized bus bars are in the vicinity of the work or the work actually requires contact by tools to the energized components:
   a. Station personnel with communications, as necessary, so that the circuit or switchboard can be deenergized immediately in an emergency.
   b. Provide insulation barriers between the work and any energized metal parts adjacent to the work area as practicable.
   c. Erect barriers to keep unauthorized personnel out of the maintenance area. Erect barrier at a minimum distance of three feet from the energized electrical work site. Place a sign at the barrier that states: **DANGER, Working on Energized Equipment, Unauthorized Personnel, Keep Out.**
   d. A nonconducting safety line or equivalent shall be attached to a safety harness or tied around the waist in case the person performing the maintenance must be pulled from the work area. A person tending the other end of the safety line or equivalent shall be located at a safe distance outside the safety barrier such that any inadvertent action (such as falling) would not jeopardize the person doing the work.
9. While work is being done, a person trained m mouth-to-mouth resuscitation and cardiac massage shall be immediately available in case of electrical shock.

FUSE REPLACEMENT. Fuses are safety devices and should be used as such. When a fuse blows, it should be replaced with a fuse of the same related voltage and ampere capacity. **Never replace with a higher current rating fuse or short out on a blown fuse.** Use fuse pullers listed in NAVSEA S9086-KC-STM-010/CH 300, table 300-2-1, to remove and replace fuses except where fuses are mounted in plug-type fuse holders (e.g., on IC and FC switchboards). Remove these fuses by unscrewing the plugs.

SPECIAL PRECAUTIONS WHILE WORKING ON DAMAGED EQUIPMENT. A maximum degree of alertness and care is required to work on damaged equipment. When working on electrical equipment or circuits that have been damaged and may be deranged internally to impose a possible personnel safety hazard, observe all electrical safety precautions in NAVSEA S9086-KC-STM-010/CH 300, paragraphs 300-2.3 and 300-2.4, and all precautions for maintenance on energized circuits in NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.5, until it is verified that all portions of the circuit are deenergized. Equipment or circuits that are not operating properly, but have not had a casualty, are probably not internally deranged and do not need to be considered as work on damaged equipment.

PORTABLE ELECTRICAL EQUIPMENT.

GENERAL PRECAUTIONS FOR PORTABLE ELECTRICAL EQUIPMENT. Portable electrical equipment is a device that will be plugged into a shipboard isolation receptacle and operate with the ship’s electrical power. Hazards associated with the use of portable power equipment include electrical shock, bruises, cuts, particles in the eye, falls, and explosions. Safe practices in the use of this equipment will reduce or eliminate such accidents. Listed below are some of the general safety precautions that shall be observed when work requires the use of portable electrical equipment. The use of portable electrical equipment can be potentially hazardous. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

SAFETY SUMMARY - Continued

1. Wear rubber gloves when using electric hand-held portable tools in hazardous conditions, such as wet decks and bilge areas. Leather gloves shall be worn over rubber gloves when the work being done could damage the rubber gloves.

2. Wear eye protection when working where particles may strike the eyes.

3. Wear hearing protection (ear plugs or circumaural type muffs that cover the entire outer ear) when working with noise producing tools or in the area of such work.

4. Do not use spliced cables.

5. Do not use any portable electrical equipment that has a frayed cord or broken/damaged plug.

6. Make sure that the on/off switch on the portable equipment is in the off position before inserting or removing the plug from the Ac power receptacle.

7. Always connect the cord of a portable electrical equipment into the extension cord before the extension cord is inserted into an energized receptacle.

8. Always unplug the extension cord from an energized receptacle before the cord of the portable electrical equipment is unplugged from the extension cord.

9. Arrange the cables so that they will not create a tripping hazard.

ISOLATED RECEPTACLE CIRCUITS. To reduce the inherent hazard of leakage currents on receptacle circuits where portable electrical equipment is plugged in, isolated receptacle circuits are installed on all new construction ships. These circuits are individually isolated from the main power distribution system by transformers and each circuit is limited in length to reduce the line-to-ground capacitance to an acceptable level. This design limits ground leakage currents to less than 10 mA, which will produce a non-lethal shock to personnel and should enable them to let go. Ships already in the fleet were provided information for installation of either fixed or portable isolation transformers in the receptacle circuits in 1960. The use of isolated receptacle circuits, and equipment design improvements, have reduced the hazards encountered when using portable electrical equipment However, the best safety device is respect for the hazards present in all electrical systems. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

PORTABLE ELECTRICAL EQUIPMENT TYPES.

Portable Electrical Tools/Devices. If the portable tool/device uses self-contained dc power, such as a battery, then no safety check is necessary. However, if the electric tool/device uses self-contained dc power, but must be recharged through a plugged-in battery charger and the battery charger is operated from shipboard electrical power, then a safety inspection is required no matter how low the output dc voltage.

Metal Cased Portable Tools/Devices. For shipboard application, an equipment safety ground conductor is imperative for metal-cased equipment or equipment with exposed metal parts to ensure personnel safety. The portable cable supplying power to these equipments shall be provided with a distinctively marked grounding conductor in addition to the conductors supplying power to the tool. The equipment safety ground conductor may not be required for portable tools/devices which meet the requirements of NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.7.3.3 or paragraph 300-2.7.3.4.

SAFETY SUMMARY - Continued

Double-Insulated Portable Tools/Devices. Portable tools or devices with the words *double-insulated* or *double insulation* stamped on their enclosure do not require a separate equipment grounding conductor. The *double-insulated* stamping is an Underwriters Laboratories designation. *Double insulation* means there are two separate insulating systems within a tool or device so that failure of one insulation would not result in hazardous voltages on any exposed metal components. Double insulation is designed into the construction of a device and cannot be easily determined by inspection.

Mobile Electrical Equipment. Mobile Electrical Equipment is defined as a unit which is not hard wired, can be moved, but normally is stationery while operating. Any single phase 115-volt mobile equipment which is permanently located and is energized more than 50 percent of the time (such as copiers, personal computers and peripherals, soda machines, and automatic teller machines) shall not be connected to the ship's existing isolated receptacle circuits. Connecting this equipment to the ship's existing isolated receptacle circuits may overload the circuits, resulting in fire hazards. Each piece of equipment of this type should be connected to a separate single-phase circuit through an isolation transformer supplied by the lighting distribution system. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

Approval of Portable Electrical Equipment. The Navy has adopted a policy to use commercially available tools and equipment when feasible. Shipboard 115-volt 60-Hz isolated receptacle circuits are ungrounded; both line conductors and above ground potential The chassis in much of the electrical equipment designed for normal residential circuits ashore (in which one of the line conductors is ″neutral″) forms a part of the circuit. Exposed metal parts in this equipment can be energized when powered from the shipboard ungrounded system, creating a shock hazard to personnel touching them. Moreover, grounding the metal parts to the ship structure would place a ground on the 115-volt system, jeopardizing the continuity of power to the other equipment. For these reasons, commercially available tools and personal equipment must not be used aboard ship unless it has been approved for shipboard use. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

PORTABLE CABLES. Portable cable is the electrical cable attached to a portable electrical device. Portable cables should be of the proper length and cross-sectional area. **Spliced portable cables should not be used.** Always support portable cables above decks, floor plates, and gratings. Never place them where they can be damaged by falling objects, by being walked on, or by contact with sharp corners or projections in the ship's hull or other objects. Where portable cables are passed through doorways or hatches, stops should be provided to protect the cables from being pinched or damaged by a door or hatch cover. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

Grounding Conductor and Grounded Plug. Some portable tools in use on naval ships may not yet be provided with the grounded-type plug. In addition, there is a wide range of miscellaneous portable electric equipment that may be issued without being provided with a cord that has a grounding conductor and a grounded plug. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

TESTING AND INSPECTION OF PORTABLE EQUIPMENT. Test and inspection of portable equipment consists of

1. Initial testing and inspection of new, repaired, or modified equipment.
2. Periodic testing and inspection to verify integrity of the enclosure, insulation and ground conductor continuity.

SAFETY SUMMARY - Continued

3. Routine inspection prior to issue of equipment. Any testing other than visual inspection shall be performed in a workshop equipped with a nonconducting surface workbench and insulating rubber deck covering. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

TESTING GROUNDED RECEPTACLES. A test of any newly installed, repaired, or modified receptacle shall be made in accordance with NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.7.6.1, to verify that all connections have been properly made. In addition, periodic inspections shall be made in accordance with NAVSEA S9086-KC-STM-010/CH 300, paragraph 300-2.7.6.2, to ensure a low resistance from the receptacle safety ground connection to the ship's hull.

PRECAUTIONS FOR MEDICAL SPACES.

MEDICAL SPACES. Power is supplied from isolated receptacle circuits energized from the emergency lighting system for receptacles, switches, receptacles for surgical lights, and relay lanterns in Medical Spaces. These receptacles are for medical user equipment only. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

RESUSCITATION FOR ELECTRIC SHOCK.

SOURCE OF INSTRUCTIONS. The following instructions on resuscitation were provided by the Naval Medical Command.

RESUSCITATION. Resuscitation after electric shock includes artificial respiration to re-establish breathing and external heart massage to reestablish heartbeat and blood circulation. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

1. If the person shows no sign of breathing, immediately apply mouth-to-mouth artificial respiration after removing the victim from contact with the electricity.
2. If there is no pulse, apply heart massage immediately. Do not waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, drier location.
3. If desired, breathe into victim's mouth through a cloth or a handkerchief placed over the victim's face. If assistance is available, take turns breathing into victim and massaging the heart.

CARDIAC ARREST (LOSS OF HEARTBEAT). If the victim has suffered an electric shock and has no heartbeat, a cardiac arrest will result. This can be demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this, the pupils of the eyes will be very dilated, and respiration will be weak or stopped. The victim may appear to be dead. Under these circumstances severe brain damage will occur in 4 minutes unless circulation is reestablished by cardiac massage. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

CARDIOPULMONARY RESUSCITATION. Basic CPR is a simple procedure after the victim has been removed from the shock hazard. It is as simple as A-B-C: Airway, Breathing, and Circulation.

SAFETY SUMMARY - Continued

1. If you find a collapsed person, determine if the victim is conscious after shaking the shoulder and shouting, ″Are you all right?″ If no response, shout for help. Then open the airway. If the victim is not lying flat on the back, roll the victim over, moving the entire body at one time as a total unit.
   a. To open the victim's airway, use the head tilt/chin lift method. Kneel beside the victim's shoulder; lift the chin up gently with one hand while pushing down on the forehead with the other to tilt the head back. The chin should be lifted so the teeth are brought almost together. Avoid completely closing the mouth. Once the airway is open, place your ear close to the victim's mouth.
      (1). Look at the chest and stomach for movement.
      (2). Listen for sounds of breathing.
      (3). Feel for breath on your cheek.
   b. If none of these signs is present, the victim is not breathing. If opening the airway does not cause the victim to begin to breathe spontaneously, you must provide rescue breathing.

2. The best way to provide rescue breathing is by using the mouth-to-mouth technique.
   a. Take your hand that is on the victim's forehead and turn it so that you can pinch the victim's nose shut while keeping the heel of the hand in place to maintain head tilt.
   b. Open your mouth wide, take a deep breath, and make a tight seal over the victim's mouth. Breathe into the victim's mouth two time with complete refilling of your lungs after each breath. Watch for the victim's chest to rise. Rescue breaths are to be given at the rate of 1 to 1-1/2 seconds each, allowing the lungs to deflate between breaths.

3. After giving two full breaths (1 to 1-1/2 seconds each), locate the victim's carotid pulse to see if the heart is beating.
   a. To find the carotid artery, locate the voice box. Slide the tips of your index and middle fingers into the groove beside the voice box. Feel for the pulse. Cardiac arrest can be recognized by absent breathing and an absent pulse in the carotid artery in the neck
   b. If you cannot find the pulse, you shall provide artificial circulation in addition to rescue breathing. **Activate the Emergency Medical Service System (EMSS). Send someone to call 911 or your local emergency number.**

4. Artificial circulation is provided by external cardiac compression. In effect, when you apply rhythmic pressure on the lower half of the victim's breastbone, you are forcing the heart to pump blood.
   a. To perform external cardiac compression properly, kneel at the victim's side near the chest. Locate the notch at the lowest portion of the sternum. Place the heel of one hand on the sternum 1-1/2 to 1 inches above the notch. Place your other hand on top of the one that is in position. Be sure to keep your fingers off the chest wall. You may find it easier to do this if you interlock your fingers.
   b. Bring your shoulders directly over the victim's sternum as you compress downward, keeping your arms straight Depress the sternum about 1-1/2 to 2 inches for an adult victim. Then relax pressure on the sternum completely. However, do not remove your hands from the victim's sternum, but do allow the chest to return to its normal position between compressions. Relaxation and compression should be of equal duration.
   c. If you are the only rescuer, you must provide both rescue breathing and cardiac compressions. The proper ratio is 15 chest compressions to 2 full breaths. You must compress at the rate of 80 to 100 times per minute when you are working alone since you will stop compressions when you take time to breathe.
   d. When there is another rescuer to help you, position yourselves on opposite sides of the victim if

SAFETY SUMMARY - Continued

possible. One of you should be responsible for interposing a breath during the relaxation after each fifth compression. The other rescuer, who compresses the chest, should use a rate of 60 compressions per minute.

RATE OF COMPRESSION.

Rescuers	Ratio of Compressions to Breaths	Rate of Compressions
ONE	15:2	80 times/min.
TWO	5:1	60 times/min.

If you suspect the victim has suffered a neck injury, you must not open the airway in the usual manner. If the victim is injured in a diving or vehicle accident, you should consider the possibility of such a neck injury. In these cases, the airway should be opened by using a modified jaw thrust, keeping the victim's head in a fixed, neutral position. For additional information, refer to NAVSEA S9086-KC-STM-010/CH 300.

Specific warnings and cautions applying to the system/equipment covered by this manual are summarized below. These warnings and cautions appear elsewhere in the manual following paragraph headings and immediately preceding the text to which they apply. They are repeated here for emphasis

WARNING

Electric motors use high voltages capable of causing death. Use extreme caution when working near the power source and load components. Electric motor controllers are not approved for component isolation. Ensure controller power isolation (circuit breaker, fuses) is tagged out. (Page 1-15)

WARNING

High voltages may be present at any of the red binding posts, depending on the switch settings. Handle this instrument carefully. (Page 2-5)

WARNING

DANGER: This instrument provides a high test voltage and can be dangerous to personnel. Particular care should be used in the measurement of capacitor leakage because LETHAL VOLTAGE may be stored in the capacitor being tested. Always set the function switch to discharge before connecting or disconnecting a component. (Page 2-6)

WARNING

DANGER: This instrument provides a high test voltage and can be dangerous to personnel. Particular care should be used in the measurement of capacitor leakage because LETHAL VOLTAGE may be stored in the unknown's capacitor. Always set the function switch to DISCHARGE before connecting or disconnecting the unknown component. (Page 2-11)

WARNING

Do not attach or touch leads to any circuit or unit where a voltage may be present. (Page 2-14)

WARNING

Do not come into contact with test leads during testing. Do not attempt presetting output for high-potential testing. (It is also not recommended for surge testing.) Be sure that all switches and controls are in their proper positions for the testing mode desired. (Page 2-20)

WARNING

Wear rubber gloves to prevent hand contact with bare conductors. (Page 2-30, page 2-31)

WARNING

DANGER: Never leave the Strobotac unattended while in operation. The Strobotac makes a moving object appear to be stationary. A person could be seriously injured by touching a moving object which appears to be stationary. (Page 2-36)

WARNING

DANGER: The output of this instrument can be lethal. It must be used only by qualified personnel. The operator must always be safety conscious. (Page 2-42)

WARNING

Never conduct a high-potential test on a winding that has failed a ground insulation test. (Page 2-45, page 5-15)

WARNING

DANGER: The output of this instrument can be lethal. It must be used only by qualified personnel. (Page 2-47)

WARNING

Both ac and dc jacks are energized when the voltage range selector switch is set to HIGH. To ensure operator safety, an external interlock switch must be used at all times. Follow the procedure in paragraph 2-43 to modify the instrument so that an interlock switch may be mounted. (Page 2-47)

WARNING

NEVER conduct a high-potential test on a winding that has failed a ground insulation test. (Page 2-48)

WARNING

DANGER: The output of this instrument can be lethal. It must be used only by qualified personnel. The operator must always be safely conscious. (Page 2-51)

WARNING

Both ac and dc jacks are energized when high voltage is activated. (Page 2-51)

WARNING

DANGER: Electric motors use high voltages capable of causing death. Use extreme caution when working near the power source and load components.

Always use proper safety equipment to include such items as insulated matting and protective gloves. Observe correct tag-out procedures. (Page 3-3)

WARNING

Take care when using metal tools around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidentally cause a short circuit which could harm personnel or damage equipment. (Page 3-3)

WARNING

High voltages capable of causing death are used in electric motors. Use extreme caution when working near the power source and load components. Always wear proper safety equipment. Observe correct tag-out procedures. (Page 3-6)

WARNING

Electric motors use high voltages capable of causing death. Use extreme caution when working near the power source and load components. Always use proper safety equipment to include such items as insulated matting and protective gloves. Observe correct tag-out procedures.

Take care when using metal tools around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidentally cause a short circuit which could harm personnel or damage equipment. (Page 3-11)

WARNING

High voltages capable of causing death are used in electric motors. Use extreme caution when working near the power source and load components. Always wear safety equipment. Observe correct tag-out procedures. (Page 4-2)

WARNING

To ensure that it is working properly, use only a voltmeter that has been checked out on a known live circuit. (Page 4-2)

WARNING

Avoid horizontal lifts which put a bending load on lifting eyes. Use extreme caution if such lifts must be made. They can be dangerous to personnel and equipment. (Page 4-10)

WARNING

DO NOT use a heavily corroded eyebolt. (Page 4-11)

WARNING

Before giving a hoisting signal, check to ensure that all members of the crew have removed their hands from slings, hooks, and loads. See that all personnel are clear of the lifting rig and tag lines, and that loose parts or objects are properly secured.

Know the load capacity of the rig being used. Ensure that its capacity is not exceeded. (Page 4-12)

WARNING

Make sure that all deckplate openings have been roped off along the transportation route. (Page 4-13)

WARNING

Wear safety eyeglasses or goggles when grinding. (Page 6-32)

WARNING

DANGER: Wear lint-free insulated gloves or use clean cloths when handling hot bearings. (Page 6-42)

WARNING

Improper or playful use of the high-pressure hose may cause severe injury to internal organs and eardrums. Never allow compressed air to contact or enter any persons body. Always use proper safety equipment such as face masks and goggles. (Page 7-2)

WARNING

Insulated gloves should be worn when steam cleaning to protect the operator from being burned or scalded. (Page 7-4)

WARNING

Rust preventive compound may produce dizziness if adequate ventilation is not provided. (Page 7-11)

WARNING

Solvents must be used with extreme care while following all applicable safety precautions for the type of solvent used. Most solvents are toxic and can be harmful to personnel if vapors are breathed or if the liquid comes into contact with the skin. Solvents should not be used where contact with open flame or extremely hot surfaces might occur because of the danger of fire or the generation of toxic fumes. Proper personnel protective equipment must be worn and adequate ventilation provided whenever solvents are used. Refer to NAVSEA S9086-KC-STM-010/CH 300 for the names of approved solvents, methods of use, and safety precautions required. (Page 7-11)

WARNING

This solvent is highly flammable. Its use requires the strictest observance of all safety precautions pertaining to open flames, smoking, or spark producing activity. (Page 7-12)

WARNING

Wear insulated gloves when removing the hot stator from the oven. (Page 8-9)

WARNING

Use a clear plastic face mask and insulated gloves since the items being handled are hot and will not quickly cool. (Page 8-16)

WARNING

Use insulated gloves and a plastic face shield when moving the stator. (Page 8-16)

WARNING

Always use insulated gloves when placing the stator in the oven or removing it. (Page 8-18)

WARNING

Always use insulated gloves when dipping and baking. (Page 8-18)

WARNING

Always use insulated gloves when removing a stator from an oven. (Page 8-19)

WARNING

Remove jewelry from hands, remove ties or tuck ties into shins, tuck in shirttails, roll down long sleeves, and button cuffs before operating the winding machine. (Page 9-1)

WARNING

NOMEX insulation has a very sharp edge and can easily cut an operator's hands. (Page 9-15)

WARNING

Do not permit smoking, welding, or open flames near an open tank. Varnish has a very low flashpoint. (Page 10-6)

WARNING

Do not weld, smoke, or allow open flames in the vicinity of an open varnish tank. Varnish thinners have very low flashpoints. (Page 10-11)

WARNING

Running some types of equipment in the wrong direction may injure personnel or damage the motor. (Page 12-2, page 12-5)

WARNING

Test the voltmeter on a known live circuit before using it to ensure that it is working properly. (Page 12-2)

WARNING

DANGER:

Closely follow the established ship procedure. High voltages used in operation of electrical equipment can cause DEATH ON CONTACT if personnel ignore safety precautions. Use extreme caution when working near the power source and load components. (Page 12-4)

CAUTION

Do not slide the instrument along the cover gasket. Sliding will damage the gasket. (Page 2-5)

CAUTION

A left deflection of the needle at this setting means that there is a ground or short and no further measurement is possible. Secure the test at once. (Page 2-7)

CAUTION

Do not slide the instrument along the gasket. This will tear the gasket. (Page 2-10)

CAUTION

If the display does not stop flashing after the higher range switches are depressed (see note below), it indicates an open circuit. (Page 2-15, page 2-16)

CAUTION

Do not operate the TEST LEAD SELECT switch while a test is in progress. (Page 2-21)

CAUTION

When testing very small windings, the tester can generate voltages in excess of the rating, which can damage the windings. Use caution to limit the percent of output to the nameplate rating. (Page 2-21)

CAUTION

Do not operate the tester with a vertical display that exceeds the size of the CRT grid. (Page 2-22)

CAUTION

This test should be stopped when a sharp rise in current is obtained. Do not attempt to preset high-potential voltage. Always begin testing at minimum. Upon completion of test, allow sufficient time for winding to discharge completely. (Page 2-24)

CAUTION

Do not allow the overcurrent relay to trip. Tripping the relay produces an inductive voltage surge which could damage the insulation. Increase the test voltage slowly enough to see an abrupt rise in the slope of the leakage current curve and to stop the test. (Page 2-24)

CAUTION

Use only a 115 Vac power supply. Growlers must have the rotor in place before energizing. Energizing a growler without a rotor in place could damage the growler. (Page 2-27)

CAUTION

Do not rotate the rotor in the V block. Deenergize the growler before lifting the rotor from the growler. Failure to do so will cause damage to the growler. (Page 2-27)

CAUTION

Remove the OHMPROBE fuse and battery attachment from the instrument before measuring volts. The fuse will burn out if it is not removed. (Page 2-30)

CAUTION

Remove the OHMPROBE fuse and battery attachment from the instrument before measuring amperes. The fuse will burn out if it is not removed. (Page 2-31)

CAUTION

Do NOT connect test leads. (Page 2-32)

CAUTION

Ensure all power is secured and all capacitors are discharged before testing for resistance or continuity. (Page 2-36)

CAUTION

Ensure that the power matches the data on the plate next to the power cord on the panel before plugging the power cord into the receptacle. (Page 2-38)

CAUTION

Model 710-1 contains oil-filled transformers. Install the unit on a sturdy, level platform, and strap it down to prevent sliding or tilting. Tilting will cause loss of transformer oil. (Page 2-43)

CAUTION

Ensure that the instrument ground is firmly connected to the ships hull. Connect the ground lead to the instrument and motor. (Page 2-46)

CAUTION

Twist together the leads of the winding not being tested when testing a two-speed, two-layer winding. Ground the winding not under test. (Page 2-46)

CAUTION

Take care not to damage the dial indicator. Installed motors may not have clearance for full 360-degree rotation. (Page 2-55)

CAUTION

Handle standards with extreme care. Keep them on a clean, soft surface. (Page 2-61)

CAUTION

Use a rocking motion with the snap gage to avoid damaging the anvils. (Page 2-63)

CAUTION

Take care when using any conducting tool around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidentally cause a short circuit that could damage equipment. (Page 3-6)

CAUTION

Make sure that equipment serviced by the motor may be safely operated before conducting an operational test. (Page 3-10)

CAUTION

Take care when using any conducting tool around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidently cause a short circuit that could damage equipment or injure personnel. (Page 4-2)

CAUTION

Handle low-noise electric motors carefully. Handling damage can cause high vibration levels and reduce mechanical or electrical reliability. (Page 4-4)

CAUTION

Hooks may straighten out and drop their load when overloaded. A hook should NEVER be rebent and put back in service if it has been stretched or spread by overloading. It should be destroyed by cutting it in half with a cutting torch. (Page 4-7)

CAUTION

The lower hook is usually the weakest part of a chain hoist. Spreading in the hook is a signal to the operator that the chain hoist is nearing the overloading point. Therefore, close observation by the operator is necessary to detect any sign of overloading in time to prevent damage to the hoist. Ordinarily, pull exerted by one or two people on a chain hoist is not enough to overload it. (Page 4-8)

CAUTION

Have the equipment operator conduct a thorough inspection of all safety devices before starting a job. Hoist controls, brakes, and clutches must be inspected. (Page 4-10)

CAUTION

Do not use a hammer to remove the coupling. (Page 4-13)

CAUTION

Never be hasty or careless in disassembling a generator or a motor. Handle the components with care to avoid damaging them, or causing a need for additional adjustment.

Always use extreme care in selecting tools and labeling and storing parts when disassembling a motor. (Page 5-6)

CAUTION

Do not file or stone mating surfaces without expert supervision. Excessive filing can damage the flange. (Page 5-6)

CAUTION

Do not allow the rotor to drop down on the lamination when the motor is being disassembled. Use jacks and a pipe to support the rotor while the end bells are being removed. (Page 5-6)

CAUTION

Be careful not to let the rotor rub against the lamination or the end of the windings. Do not allow the pipe to damage bearing areas. (Page 5-9)

CAUTION

Never use a naked flame to heat a shaft, bearing, or housing. This can significantly distort the components. (Page 6-28, page 6-38)

CAUTION

Never use a torch to loosen a bearing. A torch may cause shaft distortion. (Page 6-29, page 6-32)

CAUTION

Use the chisel to split the bearing race only. Do not try to cut the race with a chisel. (Page 6-33)

CAUTION

Be certain that the tube or nozzle, if used, has no sharp edges which might scrape insulation. (Page 7-1)

CAUTION

Take care when removing the material. Chips or other rough matter adhering to the cloth may scratch or remove insulation.

Foreign matter may be pushed or pressed into an inaccessible opening if the material to be removed is close to such an opening. This will create more serious problems. (Page 7-2)

CAUTION

Ensure that any accumulation of moisture in the air lines has been removed. Remove any moisture by operating the air away from the stator to be cleaned long enough to blow moisture out of the line.

Ensure that foreign material is actually being removed by blowing it from the stator. Ensure that material is not deposited deeper into inaccessible crevices.

Air pressure must not exceed 30 pounds per square inch.

Ensure the removal of dirt-laden air whenever compressed air is used to remove foreign material. Ensure that there is suction on the opening at the end opposite the air jet.

Use compressed air with caution. Abrasive particles may puncture insulation and be forced under insulating tape. (Page 7-2)

CAUTION

Take care to keep live steam from impinging directly on the windings. The temperature of the solutions at the windings should not exceed 194° F (90° C). The pressure should not exceed 30 psi. (Page 7-4)

CAUTION

Always consult and follow the manufacturer's instructions before operating vacuum drying machinery. (Page 7-6)

CAUTION

This product may have a corrosive effect on paint, varnish, and insulation. Keep it clear of windings and fabric insulation. (Page 7-11)

CAUTION

Dry cleaning solvent type II, P-D-680 (NSN 6850-00-274-5421), may be damaging to some types of insulation. A test should be made to a small spot before using. (Page 7-12)

CAUTION

Do not crack the varnish, as leads may be broken. It will then be impossible to determine connections when pulling the leads up.

Cut off the end turns of encapsulated motors to prevent uncontrolled fires in the oven. Some motors have alloy parts which may distort at 600-700° F (316-371° C). High temperatures may adversely affect iron characteristics. To avoid damage to the lamination/insulation motors, burnout should be conducted below 700° F (371° C). (Page 8-9)

CAUTION

Keep the saw clear of stator laminations. (Page 8-13)

CAUTION

Do not allow the heater cables to catch on obstructions while rotating the turntable. The heater leads may be pulled and shorted if leads are allowed to catch. (Page 8-16)

CAUTION

Be careful when sandblasting to ensure that the stator laminations are not loosened. (Page 8-17)

CAUTION

Do not use compressed air to clean slots. It may contaminate the stator with moisture. (Page 8-17)

CAUTION

Do not use silicone glass laminate or varnished glass-fiber cloth in a totally enclosed motor-generator set if one machine is direct current with carbon brushes. This arrangement causes excessive carbon brush wear. (Page 9-13)

CAUTION

Do not allow the scissors to cut or abrade the magnet wire insulation. (Page 9-19)

CAUTION

Be careful not to damage the slot cell material, wedges, or magnet wire insulation when bending the coils. (Page 9-20)

CAUTION

The winding must not touch the end bell at any point or the motor will burn out. (Page 9-26)

CAUTION

Compatibility tests must be conducted between varnish held in the dip tank for over a month and varnish from closed containers. Do this even though manufacturer and batch numbers are the same. (Page 10-2)

CAUTION

Certain varnishes not qualified under MIL-I-24092 are likely to be incompatible with varnish qualified under MIL-I-24092. (Page 10-5)

CAUTION

Do not thin solventless varnish. (Page 10-11)

CAUTION

Varnish should never be applied to the whole or any part of a winding, either by dipping, spraying, or brushing, until the winding has been thoroughly cleaned and dried. Varnishing a dirty or moist winding seals in dirt or moisture and makes future cleaning impossible. (Page 10-12)

CAUTION

Read the operating instructions carefully before starting a motor. Failure to understand the instructions may result in unnecessary delay in recognizing abnormal operation. It may also lead to permanent damage to the equipment. (Page 12-5)

CHAPTER 1

INTRODUCTION SECTION

SECTION

1-1. SCOPE.

This chapter contains three sections. Section I and Section II are brief introductions to quality assurance (QA) and tag-out procedures as they apply to the Intermediate Maintenance Activity (IMA) or Fleet Maintenance Activity (FMA). Section III includes information specifically related to electric motor repair. Topics include:

1-1.1 Introduction to QA (paragraph 1-2).

1-1.2 Definition of terms (paragraph 1-4).

1-1.3 Work packages (paragraph 1-6).

1-1.4 Levels of assurance (paragraph 1-12).

1-1.5 Material requirements (paragraph 1-14).

1-1.6 Departures from specifications (paragraph 1-16).

1-1.7 Responsibilities of shop Quality Control Inspector (QCI) (paragraph 1-18).

1-1.8 Responsibilities of repair personnel (paragraph 1-20).

1-1.9 Introduction to tag-out (paragraph 1-22).

1-1.10 Tag-out responsibilities (paragraph 1-24).

1-1.11 Tags and records (paragraph 1-26).

1-1.12 Tagout of electric motors (paragraph 1-28).

1-1.13 Introduction to electric motors (paragraph 1-30).

1-1.14 Functions of the electrical repair shop (paragraph 1-35).

SECTION I

QUALITY ASSURANCE

1-2. INTRODUCTION TO QA.

1-3.

The QA Program has been developed to provide a system to ensure that repair procedures and materials meet established maintenance standards and specifications. QA has received increased emphasis because of the constantly rising cost of material and manpower. QA is an all-hands responsibility, and repair personnel as well as maintenance managers must meet established requirements. To reinforce the QA Program, each IMA/FMA has a QA office. Detailed QA guidance is provided by CINCLANTFLT/CINCPACFLTINST 4790.3, *Joint Fleet Maintenance Manual (JFMM).*

1-4. DEFINITION OF TERMS.

1-5.

Several terms are frequently used when describing QA requirements. The definitions of some commonly used terms include:

1-5.1 Quality Control (QC). QC consists of all actions taken prior to the start of and during the work process to: (1) obtain the highest confidence level that the work will be completed safely and correctly within technical specifications the first time and (2) minimize expenditure of manpower and material resources.

1-5.2 Quality Assurance (QA). QA consists of administrative and technical procedures to ensure compliance with technical specifications, through a systematic review of QC records and production actions. These procedures provide proof and confidence that work performed or material manufactured will perform as designed and that there is documentary evidence to that effect.

1-5.3 Objective Quality. Any statement of fact, either quantitative or qualitative, pertaining to the Objective Quality of Evidence (OQE) or a product or service based on observations, measurements, or tests which can be verified. (Evidence will be expressed in terms of specific quality requirements or characteristics. These characteristics are identified in drawings, specifications, and other documents which describe the item, process, or procedure.)

1-5.4 Controlled Material. Controlled material is any material which must be identified throughout the manufacturing and repair process in order to meet the specifications required of the end product. Any material which the Repair Officer (RO), Engineering Officer, Planning and Estimating (P&E) Officer, QA Officer, or a division officer determines must be identified throughout the repair process may be considered controlled material. Controlled material is further identified by material markings, as well as applicable QA forms, and is placed in segregated storage. The QA form used to identify controlled material is the Material In-Process Control Tag (QA Form 2) (figure 1-1).

1-5.5 Formal Work Procedures (FWP). FWPs are documents which provide the technician with clear, concise, and technically correct instructions for performing the assigned maintenance task. FWPs will vary in complexity with the type of work being performed, adequacy of existing procedures, and extent of preparation and recovery required. The intent is to provide technicians with a plan with which they can reasonably be expected to complete the job correctly. FWPs should be only as detailed as required by the complexity of the work, technician knowledge, Quality Control (QC) requirements, Quality Assurance (QA) requirements, extent of tests, and level of worker supervision required.

1-5.6 Material Identification and Control (MIC) Number. The MIC is a unique number which is assigned to (and required on) all parts that form the pressure boundary of a completed assembly. This number is used to trace material to certification records, and is used in addition to other markings required by the specifications of a manufacturer's contract.

1-5.7 Certified Level I Material. The Level I category includes material that has been specifically identified by a quality certification activity. Items in this category are assigned MIC numbers and are accompanied by certification documents.

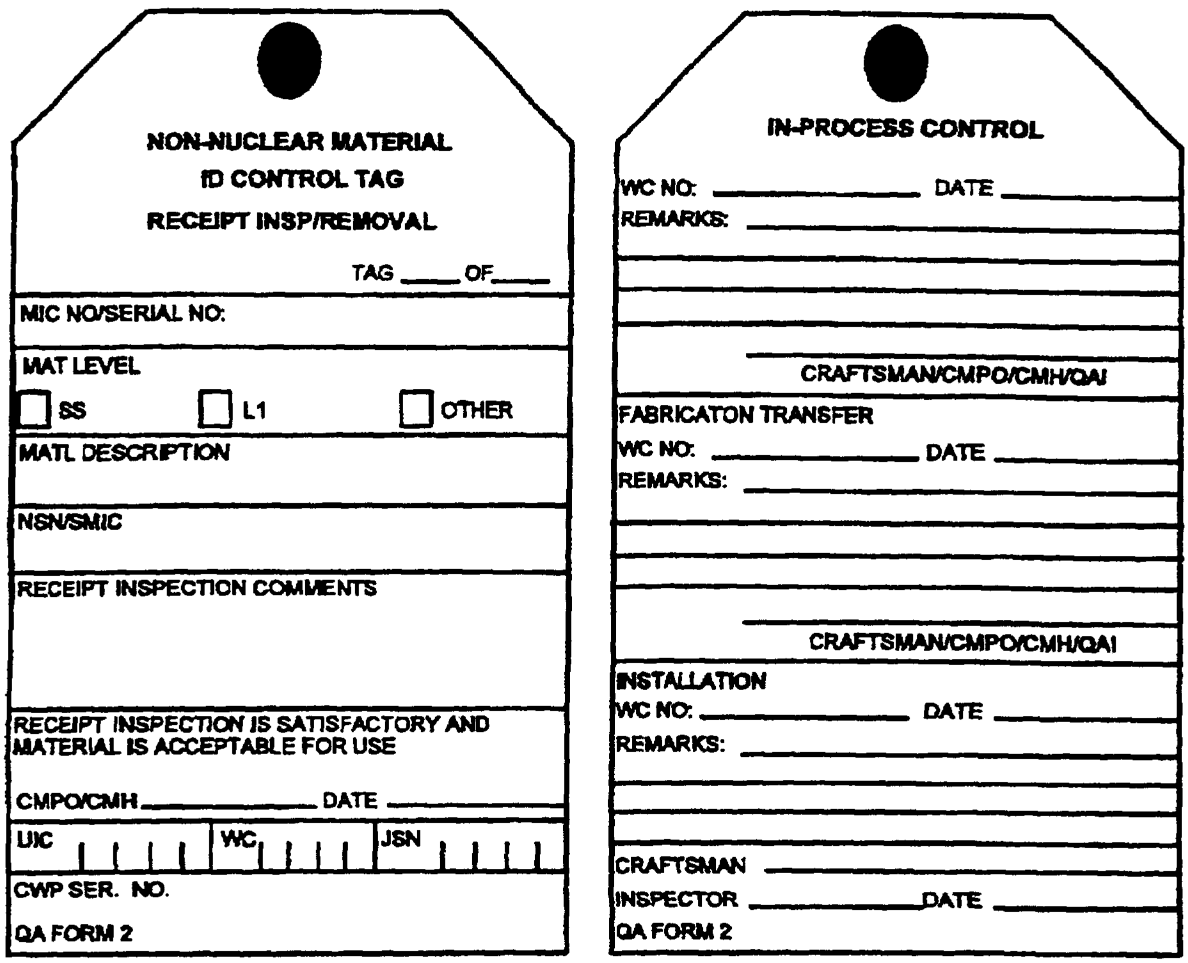
1-6. WORK PACKAGES.

1-7.

The QA Program requires that repair procedures and materials used be properly identified. The means of documenting this information for IMA use is the work package. The work package contains the various maintenance forms and associated documents (drawings, instructions, FWPs, etc.) required to perform a particular maintenance action.

1-8. CRITICAL QUALITY CONTROL POINTS.

Work process, regardless of type (maintenance, training, administrative, etc.), have critical execution points whose proper accomplishment overwhelmingly affects the ultimate first-time quality success of the process. Quality Maintenance Program work processes identify these crucial work process points as Critical Quality Control Points (Q-Points). The concepts below apply to Q-Points:



NON-NUCLEAR MATERIAL
ID CONTROL TAG
RECEIPT INSP/REMOVAL
TAG ____ OF____
MIC NO/SERIAL NO:
MAT LEVEL
☐ SS ☐ L1 ☐ OTHER
MATL DESCRIPTION
NSN/SMIC
RECEIPT INSPECTION COMMENTS
RECEIPT INSPECTION IS SATISFACTORY AND MATERIAL IS ACCEPTABLE FOR USE
CMPO/CMH ____________ DATE ______
UIC | WC | JSN
CWP SER. NO.
QA FORM 2

IN-PROCESS CONTROL
WC NO: ____________ DATE ________
REMARKS: ____________
CRAFTSMAN/CMPO/CMH/QAI
FABRICATON TRANSFER
WC NO: ____________ DATE ________
REMARKS: ____________
CRAFTSMAN/CMPO/CMH/QAI
INSTALLATION
WC NO: ____________ DATE ________
REMARKS: ____________
CRAFTSMAN ____________
INSPECTOR ____________ DATE ________
QA FORM 2

Figure 1-1 Material In-Process Control Tag (QA Form 2)

1-8.1 Q-Points in a work process are typically characterized by requiring high-level skills, proficiency, strong knowledge, working within narrow tolerances, and/or difficult environmental conditions which mandate close supervision.

1-8.2 Q-Points are determined by the organizational unit (work center, division, command, etc.) with cognizance over the specific work process.

1-8.3 Maintenance managers shall give strong focus to Q-Points in working scheduling, personnel assignments, and appropriate supervision.

1-9. SHIPS MAINTENANCE ACTION FORM (OPNAV Form 4790/2K).

The OPNAV Form 4790/2K, known as the *2-Kilo* , is used to provide basic information for a work package. The tended unit is responsible for preparing the 2-Kilo for submission to the IMA. If the 2-Kilo is improperly prepared or incomplete, the Type Commander's Representative (TYCOM Rep) or the IMA will return it to the tended unit for correction. Today, most ships use the 4790/2K only onboard. The planning data are delivered by computer to the repair activity as an automated work request (AWR).

1-10. MAINTENANCE PLANNING AND ESTIMATING FORM (OPNAV Form 4790/2P).

OPNAV Form 4790/2P (figure 1-2) is used to provide planning data to the work package. The form is completed by the IMA Planning and Estimating (P&E) Office and accompanies an OPNAV Form 4790/2K (AWR) which has been submitted by a tended unit.

1-11. CONTROLLED WORK PACKAGES (CWPs).

A CWP (figure 1-3) provides the records (i.e., QA forms such as QA Form 17 [figure 1-4] or QA Form 49 Series [figure 1-5]) to document approval of maintenance, conduct of repair, and recertification of component(s) and system(s) subsequent to repair.

1-11.1 The CWP includes the FWP which provides the step-by-step instructions a technician can follow to properly accomplish work. FWPs vary widely in scope and complexity. A Maintenance Requirement Card (MRC) may serve as an adequate FWP in the case of quarterly PMS inspections. In most cases of complex corrective maintenance, an FWP must be developed for a specific task, such as replacement of a valve welded into a nuclear system. Frequently, Fleet Maintenance Activities (FMAs) and Ship's Force are able to reuse FWPs developed for previously accomplished work. FWPs are also required for some types of non-QA work.

1-11.2 A CWP is an FWP to which appropriate QA forms have been attached. When authorized by higher authority (i.e., Immediate Superior in Command [ISIC]), the QA Form 9 is used and becomes the cover sheet of the work package. The QA forms are generally used to meet Naval Sea Systems Command (NAVSEA)/Naval Air Systems Command (NAVAIR) requirements for documenting OQE of replacement parts, proper assembly of components, or satisfactory testing of systems. An FWP used for QA work becomes part of a CWP and includes steps which list inspections that must be performed by specially trained personnel and QA forms to be completed during accomplishment. The intent of requiring a CWP is to ensure that the proper records are completed during maintenance and retained as required by the applicable standard to support continued certification of the ship. QA Form 17 is used to provide a test or inspection requirement for which there is no other existing document.

1-12. LEVELS OF ASSURANCE.

1-13.

The increased cost of shipboard systems and equipment has generated a need for stricter controls over maintenance actions. These controls include guidelines which repair personnel must follow when performing maintenance on certain systems or equipment. Some of these controls include maintenance requirements which are called levels of assurance. The following paragraphs summarize the levels of assurance. For a full description of levels of assurance, refer to CNCLANTFLT/CINCPACFLTINST 4790.3.

1-13.1 Level A. Level A requires that maximum confidence be placed in the reliability of repairs made to specific systems and equipment.

1-13.2 Level B. Level B allows less confidence to be placed on the reliability of repairs made to specific systems and equipment than on Level A repairs.

1-13.3 Level C. Repairs under the category Level C are assumed to be correct unless there are obvious indications to the contrary.

OPNAV 4790/2P (6-94)

SECTION I. PLANNING

A. SHIP'S NAME	B. HULL NUMBER	1. SHIP'S UIC	2. WORK CENTER	3. JOB SEQ NO
USS UNDERWAY	AS-48	20888	EA05	2858

JOB CONTROL NUMBER

4. PERIODIC MAINTENANCE REQUIREMENT | 5. PERIODICITY | 6. WMM ISSUED | 7. SPECIAL DATA

8. SCREENING ACTION (UIC / TYCOM): DEPOT ACCOMPLISH; IMA ACCOMPLISH [X]; SHIP'S FORCE (IMA) (DEPOT) ASSIST; SHIP TO SHOP; ACCOMPLISH WITH MODIFICATIONS; DISAPPROVE

9. QUALITY ASSURANCE REQUIREMENT: SUBSAFE; LEVEL 1; NUCLEAR LEVEL 1; NON-DESTRUCTIVE TEST; NUCLEAR WORK PROCEDURES; SUBMARINE ANTENNA ENGINEERING DIVISION; SPECIAL CLEANING [X]; SPECIAL TESTING [X]; SPECIAL IDENTIFICATION; NOISE CRITICAL; RADIOLOGICAL CONTROL; OTHER CONTROLS [X] HAZMAT

10. SPECIAL REQUIREMENTS: KEY EVENT; SPECIAL INTEREST; DRY DOCK REQUIRED; PRE OVERHAUL TEST REQUIRED; POST OVERHAUL TEST REQUIRED [X]; DEPARTURE TEST REQUIRED

C. UIC SIGNATURE: W IZENOFF | D. TYCOM SIGNATURE | 11. NORMALLY DONE BY: S/F; IMA [X]; DEPOT

SECTION II. SCHEDULING

LEAD / ASST WORK CENTER	SCHED START DATE	SCHED COMP DATE	EST MAN-HRS	KEY OP	TASK
25A	4053	4068	0083	02	EVAC & RECHG
03T	4054	4067	0004	03	UNSHIP & CLAD
03A	4051	4069	0049	01	MONITOR FREON
26A	4056	4057	0006	04	BRAZE/WELD
51A	4053	4058	0021	05	REWIND & BAKE

SECTION III. TECHNICAL DOCUMENTATION

	ON BOARD YES	NO
NAVSHIPS TECH MAN. 351-0665	X	

SECTION IV. IUC/REPAIR ACTIVITY/TYCOM REMARKS

COMPRESSOR MOTOR SHORTS

SECTION V. SUPPLEMENTAL PLANNING

50 EST MANDAYS	51 EST MANDAYS COST $	52 EST MATERIAL COST $	53 EST TOTAL COST $	54

Figure 1-2 Maintenance Planning and Estimating Form (OPNAV Form 4790/2P)

MAINTENANCE CERTIFICATION RECORD/RE-ENTRY CONTROL
QA FORM 9

1. PAGE 1 OF

2. [ ]SUBSAFE/RE-ENTRY [ ]NUCLEAR [ ]LEVEL I [ ]SCOPE OF CERTIFICATION [ ]OTHER

3. SHIP HULL	4. CWP/REC SERIAL NO. REV.
5. J.O./JCN	6. ASSOCIATED CPW(s)REC(s)
7. ORIGINATOR BADGE/GRADE/RANK	8. ORGANIZATION
9. SYSTEM REPAIR/RE-ENTERED	10. REPAIR/RE-ENTRY LOCATION

11. COMPONENT(s)

WORK DESCRIPTION INCLUDING BOUNDARIES

12. JID MAP/DWG WITH REV

13. WORK TO BE PERFORMED AND WORK REFERENCE DOCUMENTS

14. APPLICABLE JOINT NO(s), OR IF NOT SUPPLIED, SPECIFIC BOUNDARIES

APPROVAL FOR CONTROLLED WORK/RE-ENTRY

15A. PRIME APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

15B. PRIME APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

15C. PRIME APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

15D. PRIME APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

VERIFICATION AND CERTIFICATION

16. SUPPORTING DOCUMENTATION

VERIFICATION OF WORK COMPLETION

17. THE PRODUCTION WORK DESCRIBED BY THIS MCR/REC HAS BEEN ACCOMPLISHED IN ACCORDANCE WITH THE SPECIFIED INSTRUCTIONS AND THE REQUIRED DOCUMENTATION LISTED IN BLOCK 16 HAS BEEN COMPLETED, REVIEWED AND IS CORRECT.
APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

CERTIFICATION OF DOCUMENTATION OF PRODUCTION WORK

18. ALL DOCUMENTATION AND CERTIFICATION FOR PRODUCTION WORK SPECIFIED IN BLOCK 16 HAS BEEN COMPLETED. THE DOCUMENTATION HAS BEEN REVIEWED FOR ACCURACY AND COMPLETENESS.
APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

CERTIFICATION OF TESTING RESULTS

19. THE TESTING INVOKED FOR THIS MCR/REC HAS BEEN COMPLETED. THE TEST DOCUMENTATION SPECIFIED IN BLOCK 16 HAS BEEN REVIEWED FOR ACCURACY AND COMPLETENESS.
APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

FINAL MCR/REC CLOSEOUT CERTIFICATION

20. ALL CERTIFICATION RELATED TO THIS MCR/REC HAVE BEEN REVIEWED FOR CORRECTNESS AND VERIFIED TO BE COMPLETE. I CERTIFY THIS MAINTENANCE CERTIFICATION RECORD/RE-ENTRY CONTROL IS CLOSED.
PRIME APPROVAL SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & BADGE/GRADE/RANK DATE

21. SHIP'S COMMANDING OFFICER SIGNATURE LEGIBLY PRINTED, TYPED OR STAMPED NAME & RANK DATE

Figure 1-3 Controlled Work Package (QA Form 9) Cover Sheet Maintenance Certification Record/Re-Entry Control

TEST AND INSPECTION RECORD
QA FORM 17

1. SHIP HULL NO.	2. JCN	3. LWC	4. CWP SERIAL NO
5. SYSTEM/COMPONENT	6. FWP STEP NO(s)	7. DWG/PART NO.	
8. DESCRIPTION OF TEST AND/OR INSPECTION			
9. RESULTS			
10. CRAFTSMAN DATE	11. FMA/SHIP INSPECTOR DATE		
12. SHIP REPRESENTATIVE DATE	13. QAS DATE		

Figure 1-4 Test and Inspection Record

SIMA/USS

CONTROLLED WORK PACKAGE

SURFGEN-QA 9090/49 (5-83) S/N 0190-LF-000-5900

P & E SERIAL NO.

LEVEL OF CONTROL STAMP

WORK PACKAGE SERIAL NO.

SHIP	UIC	WC	JSN	WORK PACKAGE SERIAL NO
SYSTEM				DATE PREPARED
COMPONENT				P & E ORIGINATOR
LOCATION	JOB BRIEF			

ROUTE TO	DATE	COMMENTS
QA SUPERVISOR		
QA OFFICER		
REPAIR OFFICER		
LEAD WORK CENTER DIV. OFF.		
LEAD W/C SUPERVISOR		

WORK PACKAGE CONTENTS (SURFGEN QA FORM 9090/XX)	TEST/INSP. TO BE PERFORMED BY CUSTOMER SHIP
2 GREEN TAG	
3 RED TAG	
4 YELLOW TAG	
5 GREEN STRIPE TAG	
8 PRODUCTION TASK CONTROL	
12 DEPARTURE FROM SPECS.	
15 REQ. FOR RELEASE	ENG. OFFICER (TENDED UNIT) / DATE
16 MATERIAL DEFICIENCY	
17 TEST/INSPECTION	SAFETY PRECAUTIONS TO BE OBSERVED
18 HYDRO TEST	
NOT VALID AFTER	RETURN TO QA OFFICE NLT

JOB COMPLETED/ROUTE COMPLETED WORK PACKAGE TO	DATE	COMMENTS
LEAD W/C QC INSPECTOR		
LEAD W/C SUPERVISOR		
LEAD W/C DIVISION OFFICER		

ROUTE TO QUALITY ASSURANCE FOR FINAL DISPOSITION	DATE	COMMENTS
QUALITY ASSURANCE SUPERVISOR		

CLEARED FOR FILING

COMMENTS

REJECTED	ACCEPTED	DATE FILED	QUALITY ASSURANCE OFFICER

Figure 1-5 Controlled Work Package (QA Form 49)

1-14. MATERIAL REQUIREMENTS.

1-15.

The QA Program includes guidelines for the processing of certain types of controlled material Some controlled materials are categorized as Level I. Level I is the designation given to systems which require maximum confidence that the composition of installed material is correct. The use of Level I material is restricted and carefully controlled.

1-16. DEPARTURES FROM SPECIFICATIONS.

NOTE

All references for Departures from Specifications (DFS) are in CINCLANT-FLT/CINCPACFLTINST 4790.3, Chapter 7.

1-17.

The IMA has a basic obligation to perform all repairs in full accordance with specifications. However, there are occasions during the repair process when repairs cannot, or are not, performed according to specifications. The occasions when repairs are not performed according to specifications are referred to as Departures From Specifications (DFS) (QA Form 12) (figure 1-6).

1-17.1 A DFS (non-nuclear only) is a lack of compliance with any authoritative document, plan, procedure, instruction etc.

1-17.1.1 During a maintenance action, a DFS is required for lack of compliance with cognizant documents, drawings, etc. For “as found” conditions during maintenance, the Immediate Supervisor in Command (ISIC) (for Submarines only), ship, and Fleet Maintenance Activity (FMA) (if involved) must evaluate the deviation using the guidance of CINCLANTFLT/CINCPACFLTINST 4790.3, paragraph 7.2.4.

1-17.1.2 For ″as found″ conditions or equipment failures during operations that result in noncompliance with cognizant documents, drawings, etc., the ship and/or ISIC (if inport) must evaluate the condition or failure using the guidance of CINCLANTFLT/CINCPACFLTINST 4790.3, paragraph 7.2.4 to determine if the deficiency meets the criteria as a major DFS. If not, no DFS is required and the non-conforming condition will be entered in the ship’s Current Ship’s Maintenance Project (CSMP). If at sea, the guidance of CINCLANTFLT/CINCPACFLTINST 4790.3, paragraph 7.3.8 will be followed.

1-17.2 Reporting Departures from Specifications. It is incumbent upon ships, FMA and ISICs to discuss potential DFS as early as possible (prior to the work close out or component assembly if possible) to determine direction of actions, and alternatives to the DFS. Every effort must be made to correct each deficiency prior to equipment/system operation or underway of the ship. If a DFS has to be submitted, the request for it must be processed as soon as possible to enable an engineering evaluation of the DFS request and approval/disapproval to be granted without disrupting ship’s operations.

1-17.3 Types of Departures from Specification. A DFS is used for non-nuclear items only. DFSs are classified as either MAJOR or MINOR depending on their significance. Major DFS require TYCOM or NAVSEA approval while minor DFS are approved in accordance with CINCLANTFLT/CINCPACFLTINST 4790.3, paragraph 7.26. Major DFS which are considered temporary repairs are approved by the TYCOM. NAVSEA approval of major DFS is required, if the condition is considered a permanent repair or NAVSEA technical guidance does not exist for the condition identified in the DFS. Care must be exercised in evaluating and determining the type of DFS. DFS must be approved prior to ship’s underway.

1-17.4 Permanent and Temporary Approval of Departure from Specification. DFS are approved as either permanent or temporary depending upon the nature of noncompliance and technical determination of whether the departable condition needs to be repaired.

1-17.4.1 DFS which are approved as temporary DFS require subsequent action to correct the noncompliance and are approved with specific direction regarding duration and actions necessary to clear. Depending on the degree of noncompliance, temporary DFS will be approved by the TYCOM or ISIC.

1-17.4.2 DFS which are approved as permanent DFS require no additional repair effort and will be approved by NAVSEA except for those for which specific and definite guidance allows TYCOM approval.

1-18. RESPONSIBILITIES OF SHOP QUALITY CONTROL INSPECTOR (QCI).

1-19.

QCIs are selected from repair personnel in the various repair shops, and are certified to perform certain inspections under the QA Program. The duties and responsibilities of QCIs include the following:

1-19.1 Coordinating and administering the QA Program within their respective work centers,

1-19.2 Being familiar with the requirements of the QA Program,

1-19.3 Ensuring that repairs performed by work center personnel meet QA requirements,

1-19.4 Maintaining records and files within the work center which support the QA Program,

1-19.5 Ensuring that shop personnel use only calibrated equipment or measuring devices which have current calibration stickers attached or available,

1-19.6 Performing required QC inspections of material repaired within the work center.

DEPARTURE FROM SPECIFICATION REQUEST
QA FORM 12

1. DEPARTURE NO.	2. SHIP	3. HULL NO.
4. JCN	5. CWP SER. NO.	6. DATE
7. ORIGINATOR: TYPED NAME		
8 DEPARTURE TYPE [ ] MAJOR [ ] MINOR		
9. SYSTEM/COMPONENT/LOCATION		SIC CODE
10. NAVSEA DRAWING/PLAN NUMBER/PIECE NUMBER		
11. REFERENCES		
12. APPLICABLE SPECIFICATIONS		
13. SITUATION/DEGREE OF NON-COMPLIANCE		
14. COMMENTS/RECOMMENDATION (TEST CONDUCTED, AFFECTED SYSTEMS)		
15. DATE ANSWER REQUESTED BY:	16. SUBMITTING ACTIVITY: TYPED NAME/SIGNATURE (RO/DH)	
17. APPROVAL ACTIVITY		
APPROVAL ACTIVITY COMMENTS		
ISIC [ ]APPROVED [ ]DISAPPROVED [ ]FORWARDED TO TYCOM FOR ACTION		
TYPED NAME SIGNATURE		DATE
TYCOM [ ]APPROVED [ ]DISAPPROVED [ ]TEMPORARY [ ]PERMANENT [ ]FORWARDED TO NAVSEA/NAVAIR FOR ACTION		
TYPED NAME SIGNATURE		DATE
NAVSEA/NAVAIR TECHNICAL AUTHORITY: [ ]APPROVED [ ]DISAPPROVED [ ]TEMPORARY [ ]PERMANENT		
TYPED NAME SIGNATURE		DATE
18. COPY TO:		

Figure 1-6 Departure from Specification Request (QA Form 12)

1-20. RESPONSIBILITIES OF REPAIR PERSONNEL.

1-21.

Repair personnel also have certain responsibilities under the QA Program. Repair personnel are required to:

1-21.1 Check work packages to ensure that they are complete; incomplete packages should be reported to the shop supervisor.

1-21.2 Follow instructions contained in FWPs or CWPs.

1-21.3 Perform repairs in accordance with established specifications.

1-21.4 Use precision measuring instruments and inspection tools and gages when required.

1-21.5 Ensure that all test and measuring equipment used is properly calibrated.

1-21.6 Report any situations which may require a departure from specifications.

SECTION II
INTRODUCTION TO TAG-OUT

1-22. INTRODUCTION TO TAG-OUT.

1-23.

Proper tag-out procedures are necessary to ensure the safety of personnel and equipment. A repair activity may work on electric motors or generators for which the ship's force has responsibility. In that situation, authorized representatives of both the repair activity and the ship's force must sign the tags. This ensures:

1-23.1 Maximum safety of repair personnel,

1-23.2 Safe operation of the ship,

1-23.3 Safe operation of associated equipment, and

1-23.4 Safe conditions for the ship's personnel.

1-24. TAG-OUT RESPONSIBILITIES.

1-24.1 The tended unit's commanding officer is responsible for tag-out procedures in his command. The Officer of the Deck (OOD), the Engineering Officer of the Watch (EOOW), and the Damage Control Assistant (DCA) also have responsibilities, as discussed in this and subsequent paragraphs.

1-24.2 When repairs are performed by a repair activity, a dual responsibility exists:

1-24.2.1 The tended unit is responsible for, and controls, the tag-out procedures and the equipment being repaired.

1-24.2.2 The IMA is responsible for ensuring compliance with tag-out procedures and for concurring with the tag-out.

1-25. TAG-OUT PLANNING.

Careful planning of tag-outs reduces the number of record sheets and tags, and the nine required to perform audits, particularly during periods of overhaul or repair. Much of the tag-out planning is done during preavailability visits to the tended unit by Planning and Estimating (P&E) personnel. Tag-out planning must include a review of plans and systems to ensure complete tag-out boundaries.

1-26. TAGS AND RECORDS.

1-27.

The specific tags and record sheets involved in the tag-out procedure are as follows:

1-27.1 CAUTION Tag. A yellow CAUTION tag (figure 1-7) limits operation of equipment until specified instructions are followed to ensure the safety of personnel, equipment, systems, or components.

1-27.2 DANGER Tag. A red DANGER tag (figure 1-8) prohibits operation of equipment that could jeopardize safety of personnel or endanger equipment, systems, or components. It is prepared by the ship's force petty officer in charge of the work.

1-27.3 DANGER/CAUTION Tag-out Record Sheet. The tag-out record sheet (figure 1-9) is used to record effective and cleared component and system tag-outs. It is prepared by the ship's force petty officer in charge of work.

1-27.4 Tag-out Log. The tag-out log is the control document for administering the entire tag-out procedure. Tag-out logs are composed of effective and cleared DANGER/CAUTION tag-out index and record of audit sheets and DANGER/CAUTION tag-out record sheets (figure 1-9). Tag-out logs are maintained for all ship's systems and equipment. The logs will ordinarily be maintained in the Damage Control Center (DCC). A copy of the ship's tag-out instructions should be included in the log. This ensures access to the instruction by all personnel.

1-27.5 Preparation of Tags and Record Sheets. For detailed instructions on preparation of tags and tag-out record sheets, refer to OPNAVINST 3120.32 and local tag-out instructions.

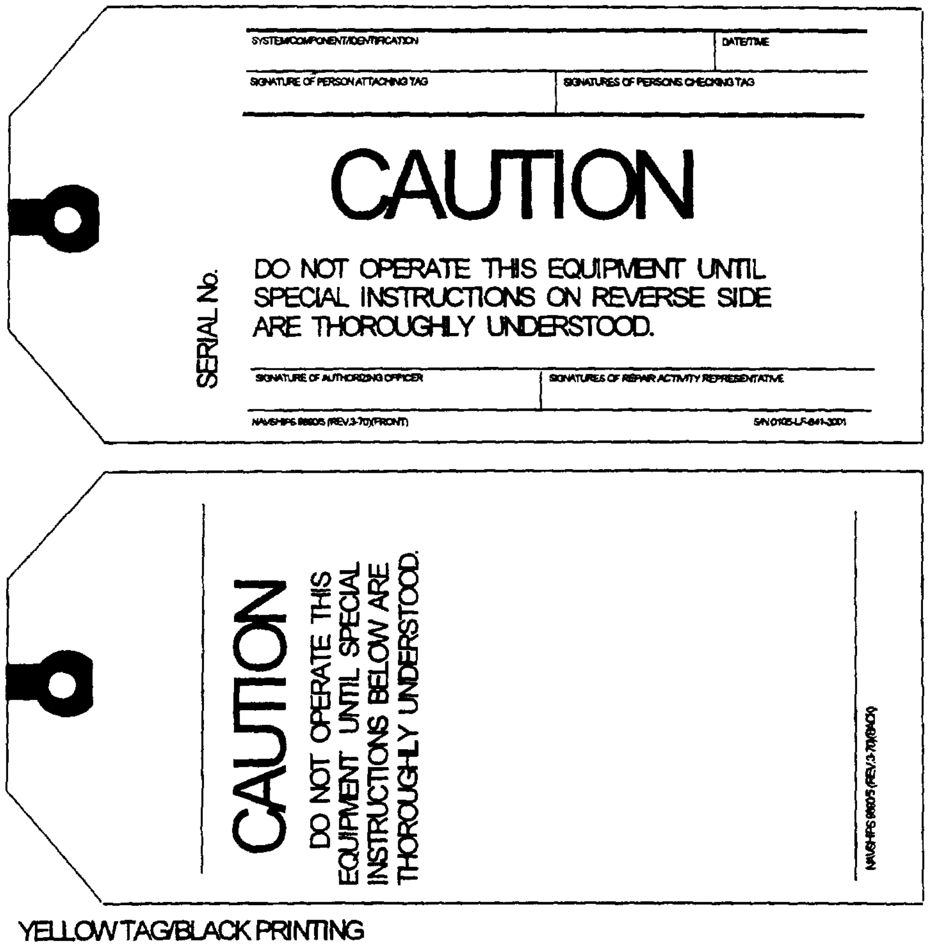


Figure 1-7 CAUTION Tag

1-28. TAG-OUT OF ELECTRIC MOTORS.

1-29.

Repair personnel, whether ship's force or IMA, must observe the following guidelines when removing electrical equipment.

WARNING

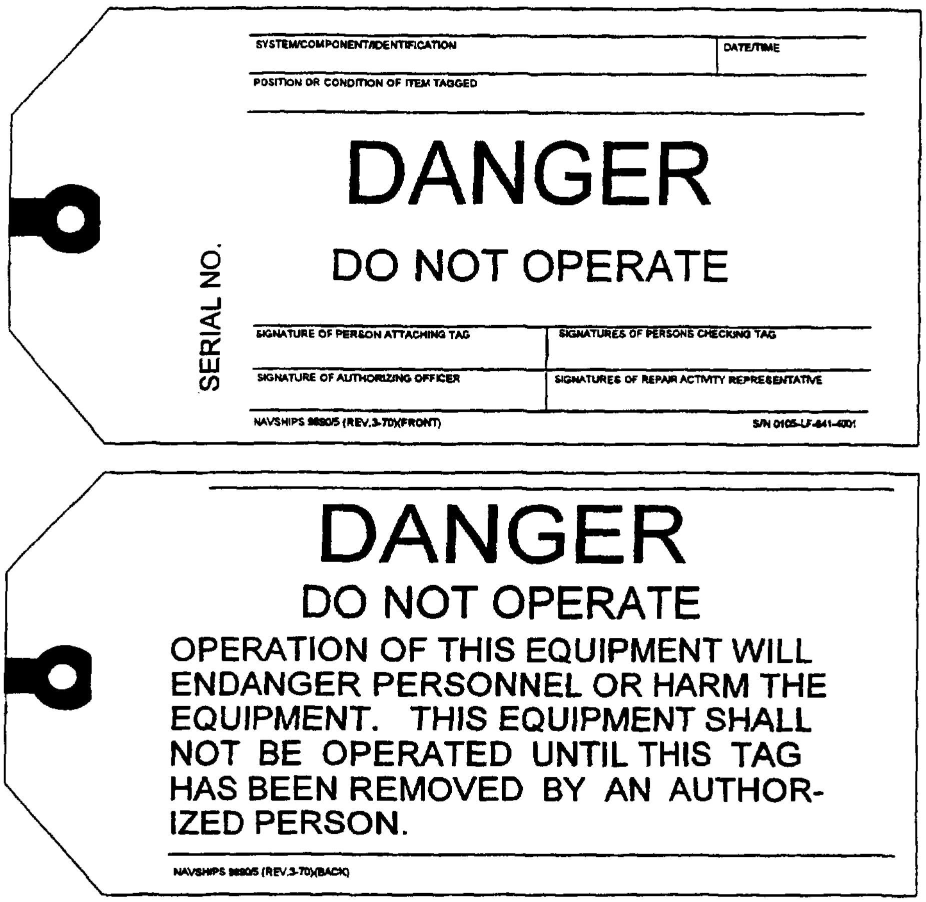
Electric motors use high voltages capable of causing death. Use extreme caution when working near the power source and load components. Electric motor controllers are not approved for component isolation. Ensure controller power isolation (circuit breaker, fuses) is tagged out.

1-29.1 Obtain permission from the ship's force authorizing officer to deenergize the equipment.

1-29.2 Open all power control switches to deenergize motors to be overhauled or repaired. Test the circuit with a voltmeter or voltage tester.

1-29.3 Do not work on loads supplied from controllers in group control centers until the associated circuit breaker is open.

1-29.4 Isolate the load (see NAVSEA S9086-KC-STM-010/CH 300, ″Fuse Replacement″) by removing the fuses if the group controller has fuses instead of a circuit breaker. Do not remove the fuses unless the contactor is first deenergized.



RED TAG/BLACK PRINTING

Figure 1-8 DANGER Tag

1-29.5 If more than one repair technician is engaged in repair work on an electrical circuit, place a tag on the supply switches for each person.

1-29.6 Obtain approval of all persons signing existing tags if the switch position is to be changed. After work has been completed, each party should remove its own tag, but no other.

1-29.7 Prevent accidental operation by attaching metal locking devices to the switch handles (figure 1-10). Obtain these locking devices through the supply system. Most breaker handles now have a 3/32-inch hole. The hole permits fastening the locking device with a standard cotter pin. Attach the DANGER tags in the eye of the cotter pin.

DANGER/CAUTION TAG-OUT RECORD SHEET

DATE/TIME TAG-OUT ISSUED

SYSTEM OR COMPONENT

LOG SERIAL NO.

REASON FOR TAG-OUT

PERSONNEL/EQUIPMENT HAZARDS INVOLVED (MANDATORY FOR DANGER TAGS)

AMPLIFYING INSTRUCTIONS (MANDATORY FOR CAUTION TAGS)

WORK NECESSARY TO CLEAR TAGS(S) (INCLUDING TESTS)

OPERATIONS/WORK ITEMS INCLUDED IN TAG-OUT

APPLICABLE DOCUMENTATION (I.E., JOB ORDER, RIP-OUT, S/P, ETC) NUMBER & TITLE	TAG NUMBERS USED	DATE/ TIME ISSUED OR ADDED	PETTY OFFICER IN CHARGE / SECOND PERSON (SIGNATURE)	AUTHORIZING OFFICER / REPAIR ACTIVITY REP. (WHEN APPROP)	WORK COMPLETE: AUTH.OFFICER / REPAIR ACTIVITY REP. (WHEN APPROP)	WORK COMPLETE: DATE

NAVSEA 9210/9 (REV. 7-87) *(FRONT)*

☐ CHECK BOX IF CONTINUED ON ADDITIONAL SHEET

Figure 1-9 DANGER/CAUTION Tag-out Record Sheet (Sheet 1 of 2)

TAG NO	LOCATION	TAGGED POSITON/ CONDITION	POSTED BY (INITIAL)	POSTING CHECKED BY (INITIAL)	CLEARANCE POSITION/ CONDITION	CLEARANCE AUTHORIZED (SIGNATURE)		DATE/ TIME CLEARED	CLEARED BY (INITIAL)
						AUTHORIZING OFFICER	REPAIR ACTIVITY		

SIGNATURE OF WATCH OFFICER/DUTY OFFICER	DATE/TIME	☐ CONTINUED ON ADDITIONAL SHEET (CHECK IF APPLICABLE)

NAVSEA 9210/9 (REV. 7-87)*(BACK)*

0116-LF-092-1047

Figure 1-9 DANGER/CAUTION Tag-out Record Sheet (Sheet 2 of 2)

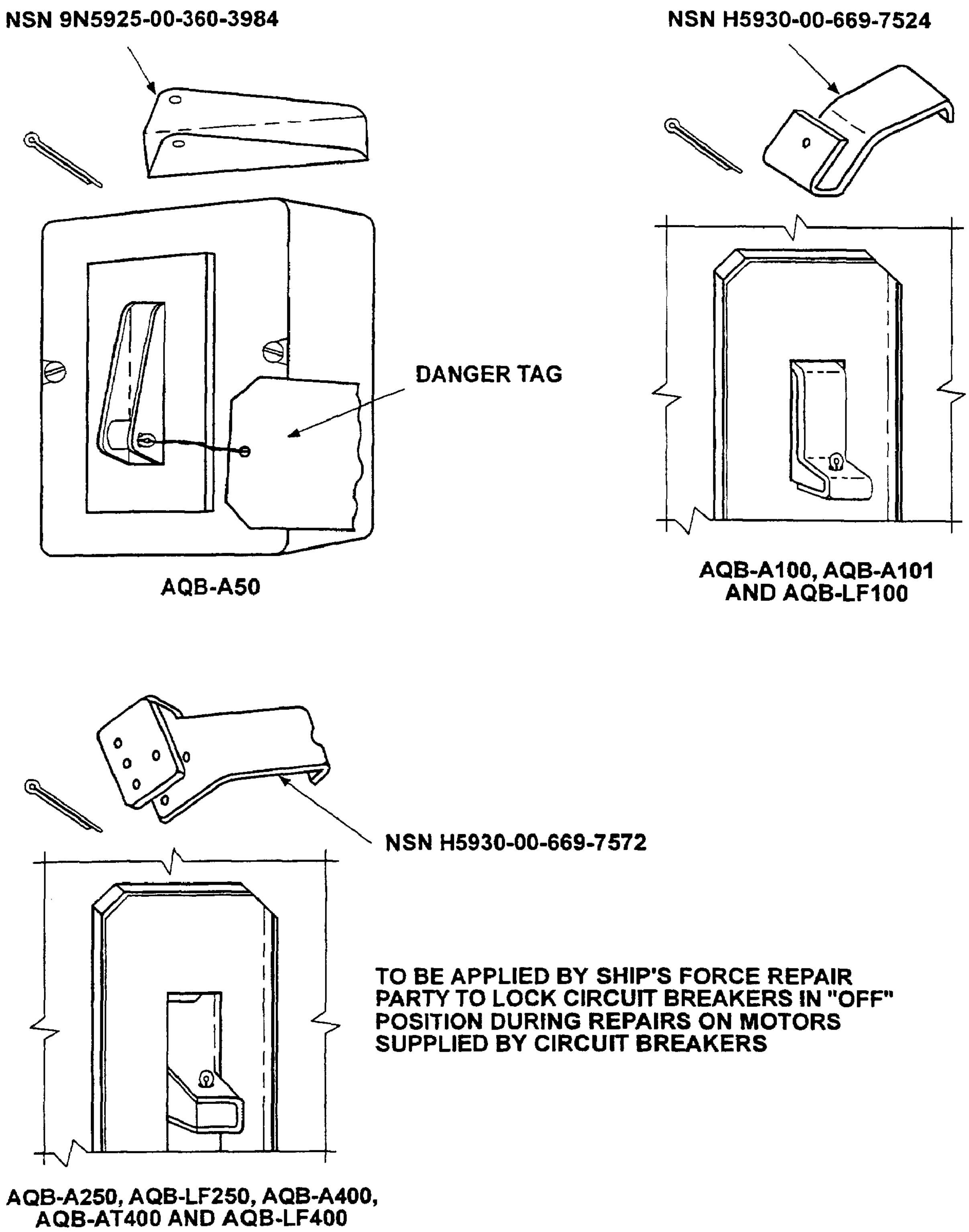


Figure 1-10 Handle Locking Devices for Circuit Breakers

NOTE

On older breakers, it may be necessary to drill a 3/32-inch hole in the handle. Use the locking device as a drilling guide.

1-29.8 Check metering and control circuits as well as power circuits. They must be deenergized. In many cases, metering and control circuits are connected to the supply side of the circuit breaker. When the circuit breaker is opened, a check of power circuits on the load side may show that they are dead. Metering and control circuits must be checked separately.

1-29.9 Check all points and identify all circuits supplying a unit. Many shipboard units have several sources of power. Each source of power must have its own tag.

1-29.10 Authorized representatives of both the repair activity and the ship's force must sign the DANGER tags (figure 1-8) and the DANGER/CAUTION tag-out record sheet (figure 1-9). Tag-out procedures have rigid requirements. When repairs or overhauls are performed by a repair activity, it is responsible for the safety of both repair and ship's force personnel. The tended ship is responsible for and will control the tag-out system. The repair activity is responsible for compliance with the tag-out procedure.

SECTION III

ELECTRIC MOTOR REPAIR

1-30. INTRODUCTION TO ELECTRIC MOTORS.

1-31.

Electric motors are provided for two types of service on combatant ships. Motors for driven auxiliaries that are essential for the military effectiveness of the ship are furnished as Navy Service A. These motors are heavy duty and highly resistant to shock impact. Motors for auxiliaries that are not essential for the military effectiveness of the ship are furnished as Navy Service C. These motors are commercial marine type. On noncombatant ships, motors are normally of the commercial marine type.

1-32. MOTOR RATINGS.

Motors are rated for continuous, intermittent, varying, or short time duty as required by the driven auxiliaries. On intermittently operating motors, the nameplate will indicate the length of time the motor can be operated without overheating.

1-33. VOLTAGE AND FREQUENCY VARIATIONS.

Motors installed in ships are designed to operate at ± 10 percent variation in the voltage indicated on the nameplate. Alternating current motors are also designed to operate at ± 5 percent variation in frequency indicated on the nameplate. Loss in performance or decrease of life may be experienced if the motor operates on input power outside of these limits.

1-34. DESCRIPTION OF AC MOTORS.

Almost all ac motors used on Navy ships that are above the fractional horsepower size are polyphase induction motors.

1-34.1 Polyphase induction motors have a primary winding (the stator winding) that is connected to a power supply and a secondary winding (the rotor winding) which has no electrical connection to the power supply. Currents in the primary winding set up a rotating magnetic field. The rotating magnetic field induces voltages and currents in the secondary winding, and gives rise to a mechanical force which turns the rotor.

1-34.2 A few squirrel cage synchronous and wound rotor motors are used in addition to polyphase induction motors. A squirrel cage synchronous motor is an induction motor in which the secondary winding is a permanently short-circuited winding, usually uninsulated, around the periphery of the rotor and joined by continuous end rings. A wound rotor motor consists of wound coils insulated from each other and laid in slots in the rotor core. These coils are wye-connected and terminate at three slip rings.

1-34.3 Most motors are single speed. However, for some applications, multiple- or variable-speed motors are used.

1-34.4 Figure 1-11 shows across section and schematic of a typical polyphase induction motor. This example is a three-phase induction motor.

1-35. FUNCTIONS OF THE ELECTRICAL REPAIR SHOP.

1-36.

The Electrical Repair Shop (51A) is required to have the following capabilities with respect to the repair of electrical motors:

NOTE

The list below applies only to electric motors and is not a complete statement of the required capabilities of the Electrical Repair Shop. See NAVSEA S9810-AA-GTP-010/IMA for a complete list.

1-36.1 Inspect, test, and repair onboard ships' electrical equipment, such as motors, generators, and motor generators.

1-36.2 Wash, dry, clean, and degrease electrical machinery and components.

1-36.3 Burn out varnish insulation or epoxy encapsulation.

1-36.4 Disassemble, strip, rewind, varnish, dip, bake, reassemble, and test electrical rotating machines, including generators, motors, and motor generator sets.

1-36.5 Wind replacement coils (except square wire) for armatures, field magnets, rotors, stators, synchronous rotors, transformers, and controllers.

1-36.6 Cut and pull old coil insulation, and slot insulations and wedges to completely strip a stator or armature.

1-36.7 Clean stator slots and reinsulate in preparation for rewinding.

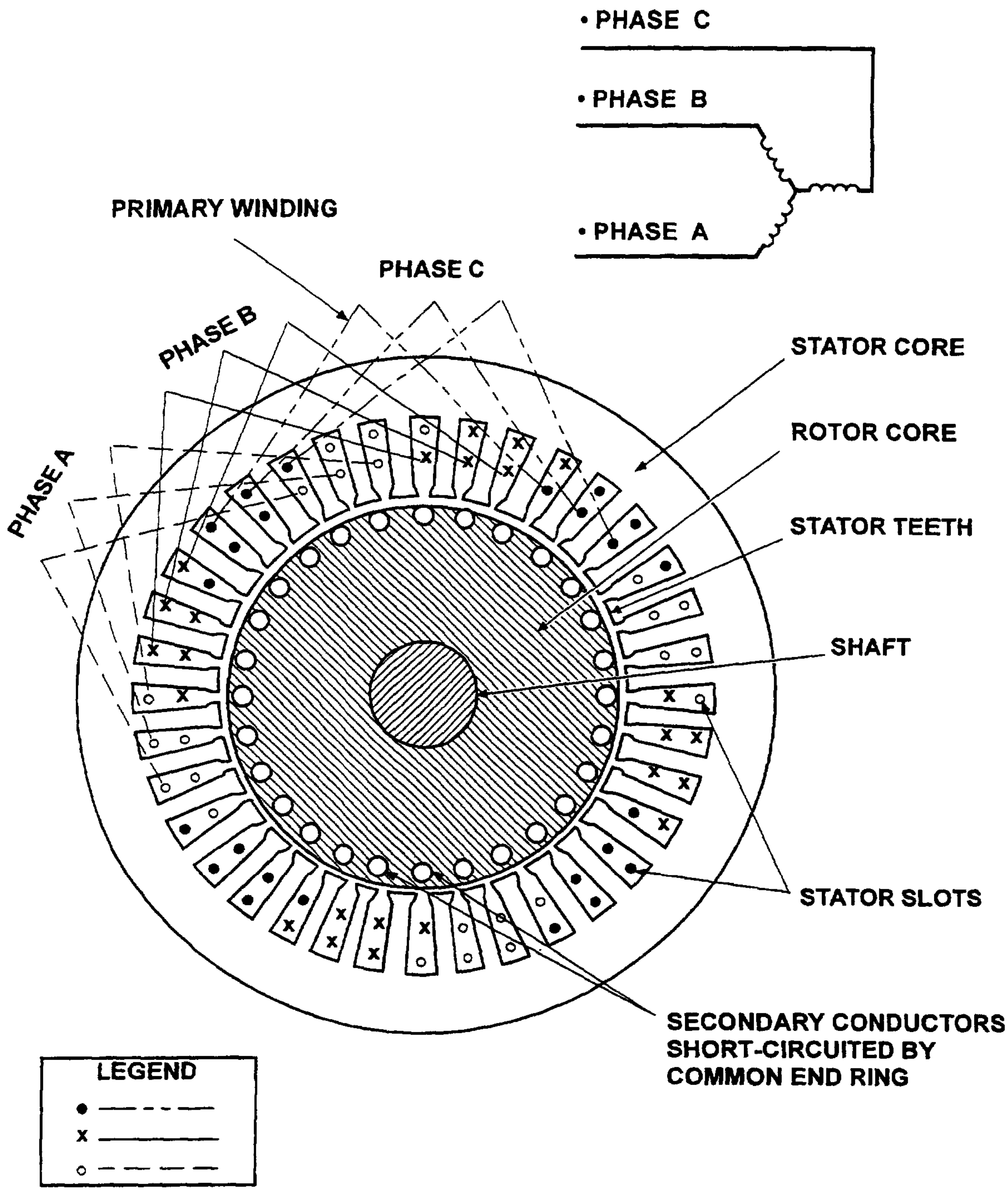


Figure 1-11 Cross Section and Schematic of a Typical Polyphase Induction Motor

CHAPTER 2

TEST EQUIPMENT AND MEASURING INSTRUMENTS

2-1. SCOPE.

This chapter contains descriptions of and operating procedures for typical electrical test equipment and mechanical measuring instruments. Topics include:

2-1.1 Purposes of typical electrical test equipment (paragraph 2-2).

2-1.2 General Radio megohm bridge, Type 1644A (paragraph 2-4).

2-1.3 General Radio megohmmeter, Type 1863 (paragraph 2-8)

2-1.4 Valhalla digital ohmmeter (paragraph 2-15).

2-1.5 Baker ST112E Surge/DC Hipot tester (paragraph 2-19).

2-1.6 External growler (paragraph 2-24).

2-1.7 Typical clamp-on ammeter (paragraph 2-25).

2-1.8 Typical digital ac/dc clamp-on multimeter (paragraph 2-29).

2-1.9 Strobotac, Type 1531-AB (paragraph 2-33).

2-1.10 Polarization Index (paragraph 2-37).

2-1.11 LEXSECO Core Tester 1081D (paragraph 2-38).

2-1.12 AC dielectric test set, Hipotronics, Inc., Model 710-1 (paragraph 2-39).

2-1.13 AC and DC dielectric test set, Hipotronics, Inc., Model 115-A (paragraph 2-45).

2-1.14 Typical dial indicator (paragraph 2-53).

2-1.15 Typical bore gage and ring master (paragraph 2-58).

2-1.16 Typical snap gage (paragraph 2-62).

2-2. PURPOSES OF TYPICAL ELECTRICAL TEST EQUIPMENT.

2-3.

Electrical tests of the windings in a motor or generator are an important part of diagnosing problems and meeting quality assurance requirements. Electrical tests are performed in place, on receipt in the shop, or after rewinding or reconditioning. The types of tests discussed in this manual are as follows:

2-3.1 Measurement of Insulation Resistance. Insulation resistance is a measure of the resistance to current leakage around or through an insulating material. Measurement of insulation resistance in an electrical motor is taken between the windings and the frame. The frame is normally grounded. The purpose of the measurement is to determine the general effectiveness of the insulating material. The megohm bridge or the megohmmeter is recommended for shop use in making this measurement. The hand-cranked megohm tester frequently used for this purpose does not provide for accurate measurement of high values of insulation resistance.

2-3.2 Measurement of Winding Resistances. A digital ohmmeter is used to measure the very low resistance of the windings of an electrical motor. The purpose in measuring winding resistance is to determine that phases are balanced. The resistance of the windings must be within 5 percent of each other for motors over 3 horsepower (hp). This will ensure equivalent currents in each phase with equal power distribution. Excessive differences in winding resistance indicates shorted turns, an incorrect number of turns, or high resistance connections.

2-3.3 Phase Comparison of Windings. Testing motor windings by phase comparison is done through use of the surge comparison tester. This instrument simultaneously applies a voltage pulse to two separate windings (or to two halves of a single winding) to evaluate the condition of the windings. The outputs from the windings are applied to an oscilloscope which produces a trace. The reflected waves from the windings are superimposed on the pulsed wave through a switching delay network. When the electrical characteristics of the windings are correct, the scope presentation appears as a single waveform. Disparities in the winding will appear as separate and distinct traces. Interpretation of these waveforms allows determination of the condition of the windings. Specifically, the windings are tested for turn-to-turn, coil-to-coil, and coil-to-ground short circuits. The voltage pulse applied is adjustable and set to a value which will stress the insulating materials and identify weak spots in the insulation.

2-3.4 Measurement of Phase Current. A clamp-on ammeter is used to measure the current without disrupting the circuitry or disconnecting the load. It is particularly useful in measuring phase currents of an operating three-phase motor. Measurement of phase currents in this manner ensures that the motor is properly connected and is drawing the prescribed amount of current. Comparison of phase currents can confirm that connections are correct and phase balance is satisfactory.

2-3.5 DC High-Potential Test. The dc high-potential (hipot) test is used to determine cleanliness, moisture content of insulation, and dielectric strength of insulation.

2-3.6 Polarization Index Test. The polarization index (P1) is the ratio of the 10-minute insulation resistance to the 1-minute insulation resistance. The P1 test is used with the insulation resistance test to identify insulation whose effectiveness has been compromised due to moisture absorption or contamination with foreign substances.

2-3.7 AC High-Potential Test. The ac high-potential (hipot) test is used to confirm that the motor's insulation system has an adequate dielectric strength. It is performed as a final check to ensure that the motor insulating materials have not been damaged during recondition or rewind.

2-3.8 Core Test. The core test permits determination of the core condition.

2-4. GENERAL RADIO MEGOHM BRIDGE. TYPE 1644A.

2-5.

The General Radio megohm bridge, Type 1644A (figure 2-1), is used to measure the insulation resistance of motors. The unit can be used to apply a constant 500 volts over a period of time allowing dielectric absorption testing. It is portable and can be easily transported for inplace troubleshooting. Although motors are tested at 500 volts, the unit has a voltage switch that can select as much as 1,000 volts. The type 1644A megohm bridge is used to measure:

NOTE

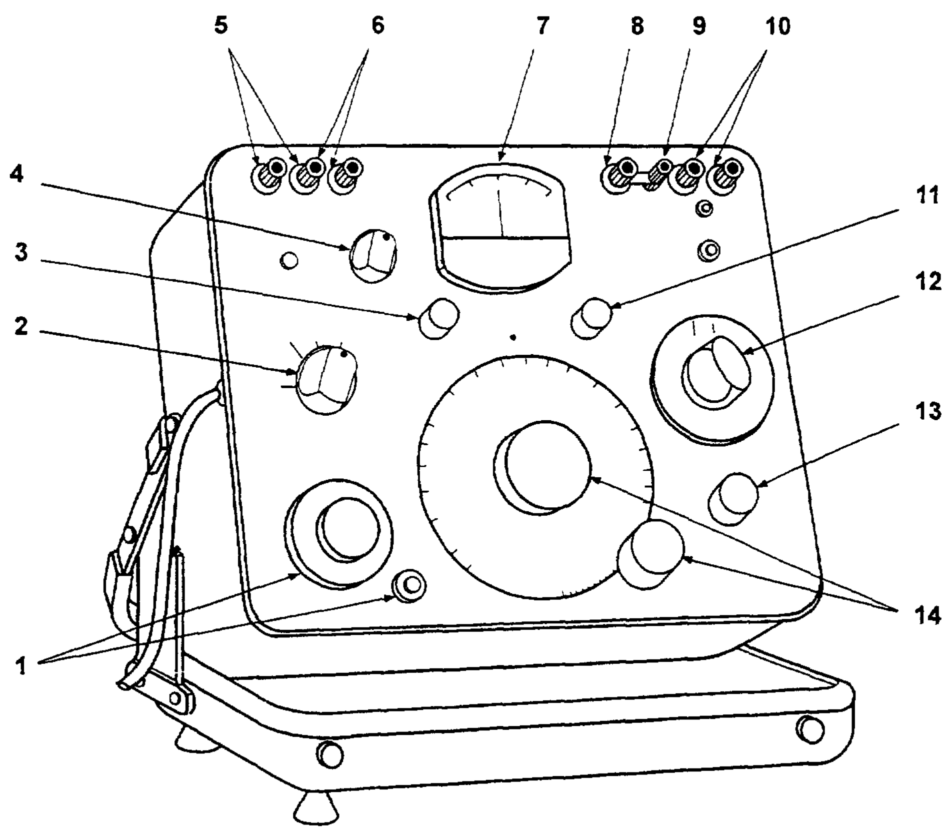
An ohm is a unit of measurement of resistance and is equal to the resistance through which a current of 1 ampere will flow when there is a potential difference of 1 volt across it. The symbol for an ohm is Ω. Other terms used are kilohm (KΩ). megohm (MΩ), gigaohm (GΩ), and teraohm (TΩ). The relationships between these terms are:

1KΩ = 10^3 Ω = 1,000Ω (thousand Ω)

1MΩ = 10^3 KΩ = 10^6 Ω = 1,000,000Ω (million Ω)

1GΩ = 10^3 MΩ = 10^9 Ω = 1,000,000,000Ω (billion Ω)

1TΩ = 10^3 GΩ = 10^6 MΩ = 10^9 KΩ = 10^{12} Ω = 1,000,000,000,000Ω) (trillion Ω)



1. R%
2. FUNCTION
3. COARSE ZERO
4. VOLTAGE ON
5. UNKNOWN EXT GEN
6. EXT ADJ
7. GALVANOMETER
8. GUARD
9. GROUND
10. - UNKNOWN +
11. FINE ZERO
12. RESISTANCE MULTIPLIER
13. SENSITIVITY
14. R

Figure 2-1 Megohm Bridge, Type 1644A

2-5.1 Insulation resistance from 10^3 to 10^{15} ohms (1,000 ohms to 1,000 trillion ohms).

2-5.2 Leakage resistance of capacitors.

2-6. CONTROLS AND CONNECTORS.

Figure 2-1 shows the front panel controls and connectors of the Type 1644A megohm bridge. Table 2-1 lists the functions of each control and connector.

Table 2-1 General Radio Megohm Bridge, Type 1644A, Controls and Connectors

FIGURE 2-1 REF. NO.	NAME	TYPE	FUNCTION
1	ΔR%	Pushbutton switch Continuous rotary control with dial	Inserts R% adjustment in the measurement circuit. Balances bridge ± 5% range
2	FUNCTION	5-position rotary control	Turns instrument on and off, selects DISCHARGE, CHARGE-ZERO, or MEASURE function.
3	COARSE ZERO	Continuous rotary control	For coarse zero adjustment of detector.
4	VOLTAGE ON UNKNOWN	8-position rotary control	Selects magnitude of internal voltage applied to the unknown or connects an external voltage source.
5	EXT GEN	Pair of insulated binding posts	For connection of an external voltage supply.
6	EXT ADJ	Pair of insulated binding posts	For connection of a resistor to adjust the voltage applied to the unknown to values between those supplied.
7	GALVANOMETER	Mirror-back center-scale galvanometer	Indicates balance of bridge.
8	FINE ZERO	Continuous rotary control	For sensitive zero adjustment of detector.
9	GUARD	Insulated binding post	For connection to points to be guarded, such as shields of leads.
10	GROUND	Uninsulated binding post	Ground connection to instrument chassis.
11	-UNKNOWN+	Pair of insulated binding posts	For connection of component to be measured.
12	RESISTANCE MULTIPLIER	10-position rotary control	Selects the measurement range.
13	SENSITIVITY	Continuous rotary control	Adjusts the sensitivity of the detector circuit.
14	R	Continuous rotary control with dial	Balances bridge.

2-7. OPERATION.

To operate the Type 1644A megohm bridge:

NOTE

The covers are not removable. Do not attempt to separate the cover from the unit.

a. Open the instrument case.

(1) Place the case's rubber feet on a flat surface with the handle away from the operator.

NOTE

Do not force the case open.

(2) Pull the handle locks toward the operator.

(3) Push the handle all the way down.

(4) Balance the side closest to the operator with one hand. With the other hand, tilt the instrument up to a convenient reading position.

CAUTION

Do not slide the instrument along the cover gasket. Sliding will damage the gasket.

(5) Let the handle rise and the instrument come to rest on the cover gasket.

WARNING

High voltages may be present at any of the red binding posts, depending on the switch settings. Handle this instrument carefully.

NOTE

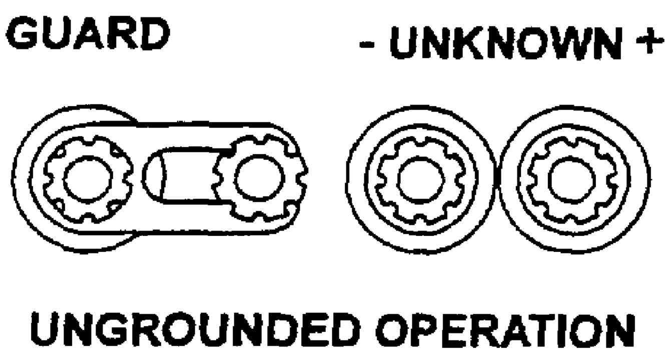
The instrument must have a grounded power cord for shipboard use.

″UNKNOWN″ in the context below refers to the component being tested.

b. Connect the grounding link between the UNKNOWN terminal posts and the metal ground post, if a grounded connection is desired (figure 2-2).

(1) The ungrounded connection is preferred when the component being tested is small and separate, or when it is mounted in a guarded enclosure. A guarded enclosure is one that is protected from buildup of potential.

(2) The grounded connection is preferred if one terminal of the component being tested must be grounded, or if it is a large, exposed surface, such as a motor frame.



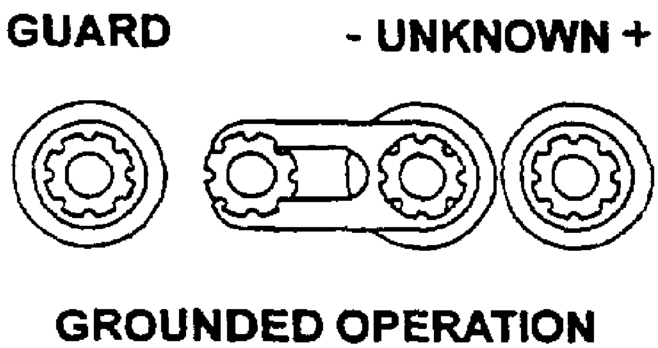


Figure 2-2 Grounding Link Connection, Megohm Bridge, Type 1644A

WARNING

DANGER: This instrument provides a high test voltage and can be dangerous to personnel. Particular care should be used in the measurement of capacitor leakage because LETHAL VOLTAGE may be stored in the capacitor being tested. Always set the function switch to discharge before connecting or disconnecting a component.

c. Turn the function switch from POWER OFF to DISCHARGE. Allow 15 minutes for warmup.

d. Select 500 V (volts) test voltage with the VOLTAGE ON UNKNOWN switch.

NOTE

Avoid changing the test voltage when the function switch is in the MEASURE position. This will severely overload the detector amplifier, which will then require several minutes to recover.

e. Connect the component to be measured to the + UNKNOWN terminal with the - UNKNOWN terminal connected to the motor frame.

f. Set the RESISTANCE MULTIPLIER switch to the 1K range.

g. Set the SENSITIVITY control fully clockwise for measurements either at the highest ranges or at low voltages. Set it halfway (arrow up) for other measurements.

h. Set the function switch to CHARGE-ZERO. Adjust the COARSE ZERO and then the FINE ZERO controls for a meter zero (NULL).

NOTE

Insulation resistance should be read after voltage has been applied for 1 minute and should be in accordance with table 7-2.

i. Set the function switch to MEASURE with the RESISTANCE MULTIPLIER switch on 1K and the main R dial at its lowest (0.9) reading.

CAUTION

A left deflection of the needle at this setting means that there is a ground or short and no further measurement is possible. Secure the test at once.

j. When measuring the insulation resistance of operational motors, the RESISTANCE MULTIPLIER switch should be rotated until a left deflection of the meter needle is obtained. Then return the RESISTANCE MULTIPLIER switch to the next lowest range. Adjust the R dial to obtain a null.

k. The value in ohms of the unknown resistance is the dial reading at null multiplied by the quantity indicated on the RESISTANCE MULTIPLIER dial.

l. Return the function switch to DISCHARGE and remove the component measured.

m. Turn the function switch to POWER OFF.

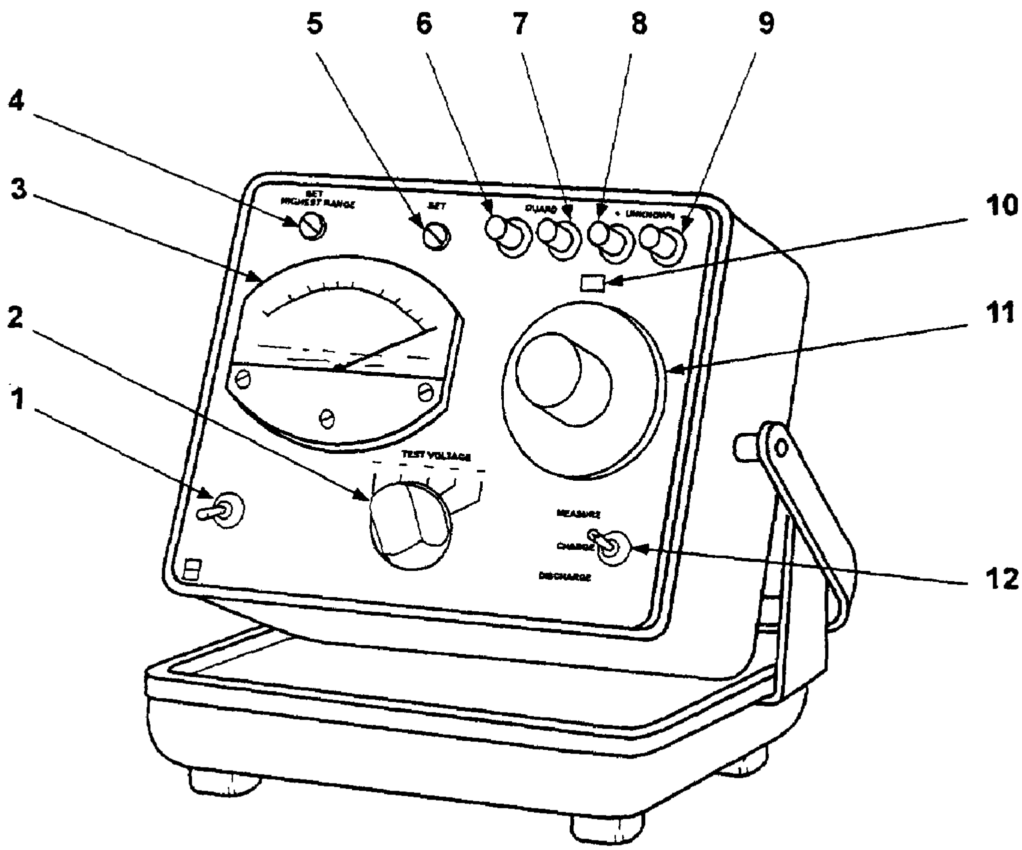
n. Disconnect and restow the power cord and instrument leads.

o. Close the instrument case and return it to stowage.

2-8. GENERAL RADIO MEGOHMMETER, TYPE 1863.

2-9.

The General Radio megohmmeter, Type 1863 (figure 2-3 and figure 2-4), may be used for insulation resistance measurements in place of the megohm bridge, Type 1644A. The Type 1863 is smaller than the Type 1644A and has simpler controls. The compactness of the unit makes it more desirable for in-place troubleshooting. The maximum voltage available from this instrument is 500 volts. Guard and ground terminals permit measurement of grounded or ungrounded two- or three-terminal connectors.



1. POWER
2. TEST VOLTAGE
3. METER
4. SET ∞
   HIGHEST RANGE
5. SET ∞
6. GUARD
7. GROUND
8. + UNKNOWN
9. - UNKNOWN
10. MULTIPLIER
11. DANGER
12. MEASURE-CHARGE
    -DISCHARGE

Figure 2-3 Megohmmeter, Type 1863 (Front)

2-10. RANGE.

The Type 1863 megohmmeter indicates directly on the panel meter any resistance from 0.5 to 2,000,000 megohms. These ranges are suitable for insulation resistance measurements of most types of insulation used in electrical machinery and electronic components. The voltage applied to the unknown may be 50, 100, 200, 250, or 500 V from the Type 1863, as selected by the TEST VOLTAGE switch on the front panel. The 500-volt level is a standard value in measurement of the insulation resistance of rotating machinery.

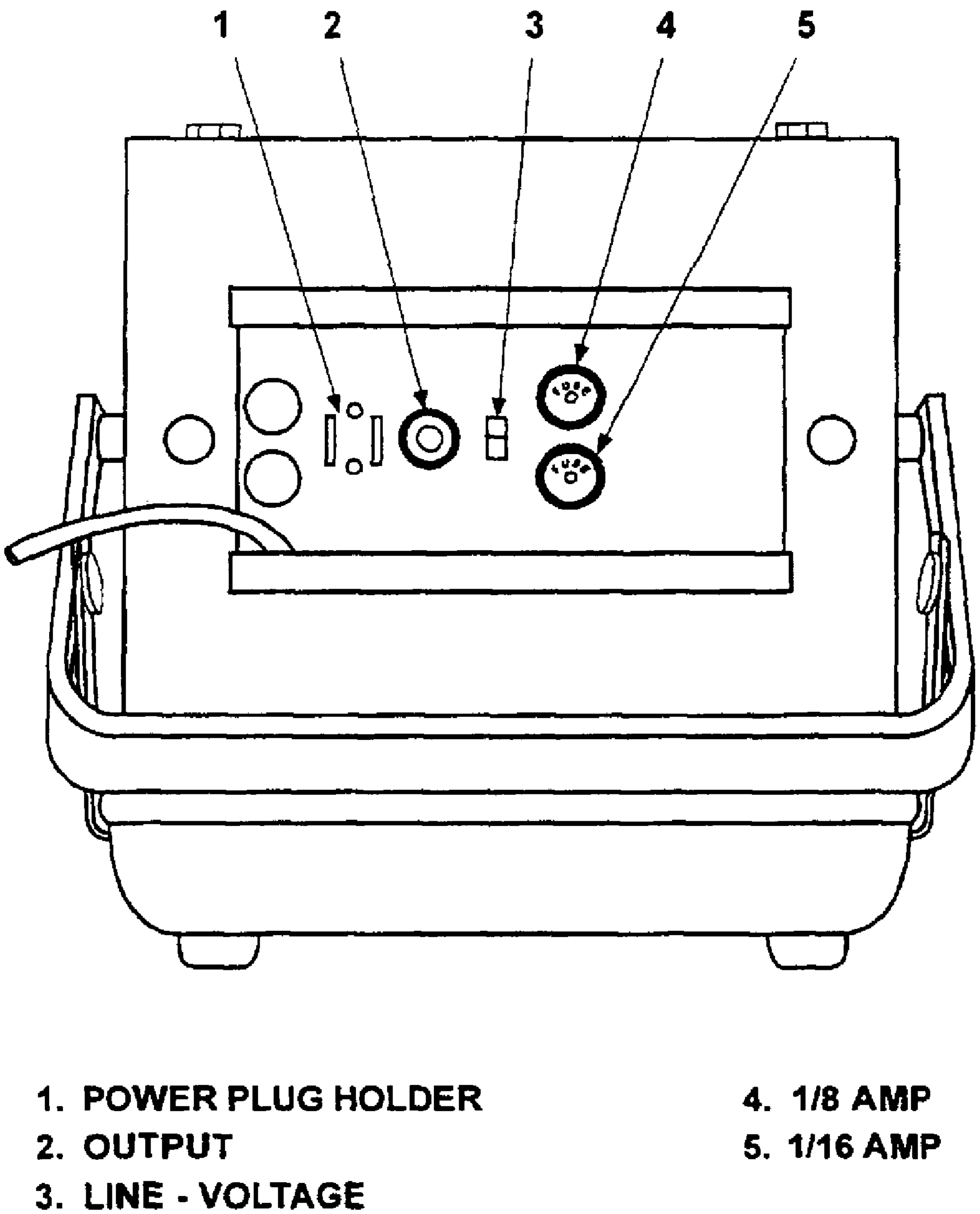


Figure 2-4 Megohmmeter, Type 1863 (Rear)

2-11. CONTROLS AND CONNECTORS.

Figure 2-3 shows the front panel controls and connectors of the Type 1863 megohmmeter. Table 2-2 lists and identifies them. Figure 2-4 shows the rear panel controls and connectors. Table 2-3 lists and identifies them.

2-12. PREPARATION.

To prepare the Type 1863 megohmmeter for operation, open the instrument case as follows:

a. Place the case's rubber feet on a flat surface with the handle away from the operator.

NOTE

Do not force the case open.

b. Push down on the handle and the instrument, located in the upper case, will rotate to a vertical position.

c. Hold the handle down with one hand and rotate the instrument to the desired position with the other hand.

CAUTION

Do not slide the instrument along the gasket. This will tear the gasket.

d. Let the handle rise and the instrument come to rest on the cover gasket.

Table 2-2 General Radio Megohmmeter, Type 1863, Front Panel Controls and Connectors

FIGURE 2-3 REF. NO.	NAME	TYPE	FUNCTION
1	POWER	2-position toggle switch	Turns power on and off.
2	TEST VOLTAGE	5-position rotary switch	Selects the test voltage as 50, 100, 200, 250, or 500 V.
3	METER	4-in. meter with plastic cover	Indicates the value to be multiplied by the multiplier switch.
4	SET ∞ HIGHEST RANGE	Screwdriver-rotated control	Adjusts high end of meter scale on highest resistance range to compensate for offset current.
5	SET ∞	Screwdriver-rotated control	Adjusts high end of meter scale to compensate for offset voltage in the voltmeter.
6	GUARD	Insulated binding post	For guarded measurements. The center of the post is 3/4 inch from the center of the ground posts so that it can accept a shorting link.
7	GROUND	Uninsulated binding post	Grounds the + unknown or guard. Contains captive shorting link.
8	+UNKNOWN	Insulated binding post	Connects the + unknown or guard. Contains captive shorting link.
9	-UNKNOWN	Insulated binding post	Connects the side of the unknown to the megohmmeter.
10	MULTIPLIER	7-position rotary switch	Selects resistance range.
11	DANGER	Indicating light shaded red	Glows red when the function switch is in the CHARGE or MEASURE position.
12	MEASURE-CHARGE-DISCHARGE	3-position toggle switch	Selects MEASURE, CHARGE, or DISCHARGE function.

NOTE

The instrument must have a grounded power cord for shipboard use.

2-13. MEASUREMENT SETUP.

Proceed as follows to set up the Type 1863 for measurement.

a. Grounding Link Connection. The grounding link connected to the uninsulated, grounded binding post can be connected to the GUARD or to the + UNKNOWN terminal. (See figure 2-5.) Connect the + UNKNOWN terminal to the motor frame while testing.

(1) Connect the grounding link to the GUARD terminal if the sample to be measured is a small, separate component or a component mounted in an enclosure that should itself be grounded or shielded.

Table 2-3 General Radio Megohmmeter, Type 1863, Rear Panel Controls and Connectors

FIGURE 2-4 REF. NO.	NAME	TYPE	FUNCTION
1	POWER PLUG HOLDER	Holes cut in rear panel	Holds power plug in place after power cord has been wrapped inside cover.
2	OUTPUT	Phone jack (Accepts Switchcraft No. 440 phone plug)	Provides a dc voltage output for recorder operation
3	LINE VOLTAGE	2-position slide switch	Connects wiring of power transformer for either 100-to 125-V or 200-to 230-V input.
4	1/8 AMP	Extractor-type fuse holder	Holder for 1/8-A fuse for 100-to 125-V operation.
5	1/16 AMP	Extractor-type fuse holder	Holder for 1/16-A fuse for 200-to 230-V operation.

(2) Connect the grounding link to the + UNKNOWN terminal if one terminal must be grounded (as in the motor insulation test).

NOTE

Test voltage selection ties the + UNKNOWN terminal to the instrument case.

b. Test Voltage Selection. The TEST VOLTAGE switch should be set to the desired measurement voltage. Use the 500-volt range for the motor insulation test.

c. Set Adjustment. Proceed as follows to adjust the SET ∞ controls.

WARNING

DANGER: This instrument provides a high test voltage and can be dangerous to personnel. Particular care should be used in the measurement of capacitor leakage because LETHAL VOLTAGE may be stored in the unknown's capacitor. Always set the function switch to DISCHARGE before connecting or disconnecting the unknown component.

(1) Turn the instrument on with the POWER switch.

(2) Set the function switch to DISCHARGE.

(3) Set the multiplier dial to any range.

(4) Make certain that nothing is connected to the UNKNOWN terminals.

(5) Use a screwdriver to adjust the SET ∞ control for a ∞ reading on the meter.

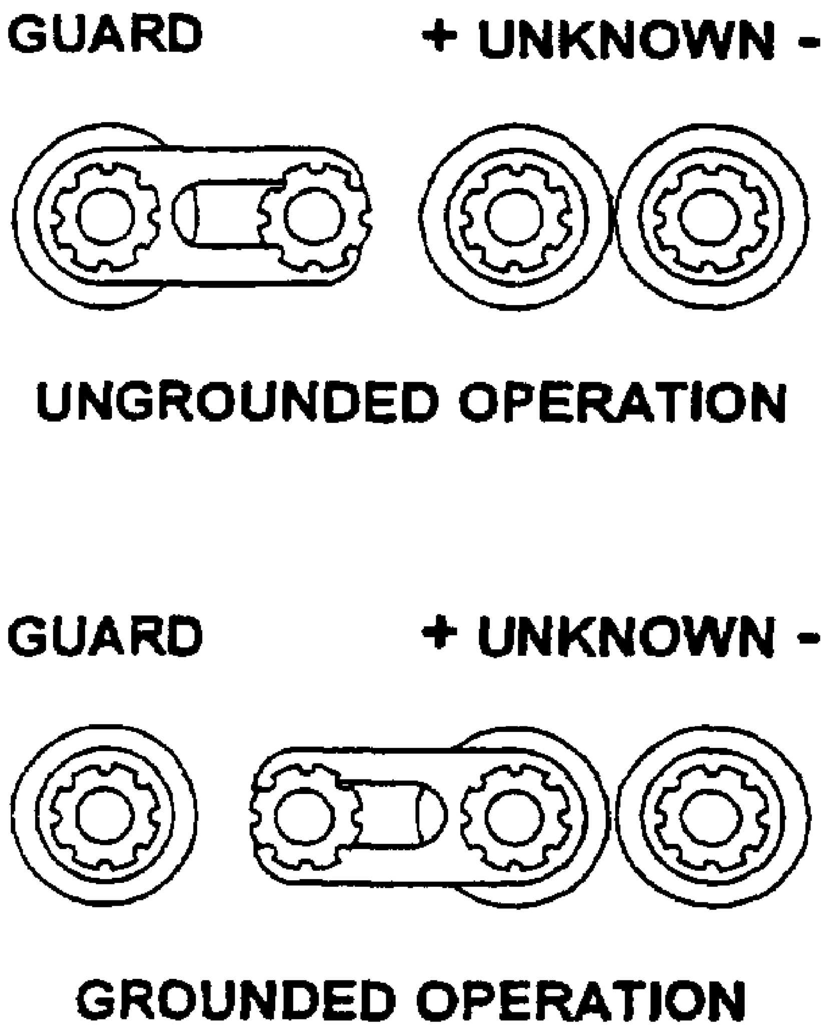


Figure 2-5 Grounding Link Connection, Megohmmeter, Type 1863

(6) Set the multiplier switch on the highest range, 1T-100G.

(7) Set the function switch to MEASURE.

(8) Adjust the SET ∞ HIGHEST RANGE (screwdriver adjustment) for a ∞ reading on the meter.

NOTE

Turn the instrument off if these adjustments cannot be set to give an on-scale reading. Adjust the mechanical meter adjustment (the center screw on the meter) to give a meter reading of less than a line width beyond ∞.

(9) Repeat steps (1) through (7).

d. Connection of the Unknown. Proceed as follows to connect unknown resistances to the UNKNOWN terminals.

(1) Set function switch to DISCHARGE.

(2) Connect small size components (such as fractional horsepower motors) directly to the UNKNOWN terminals.

NOTE

Insulated leads (GR 274-LSR single plug patch cord) may be connected to a nearby unknown resistance. However, if the unknown resistance is high, leakage between the leads will cause a measurement error. Stray lead capacitance to the high lead will cause a transient meter deflection.

(3) Connect high (and remotely located) resistance measurements with shielded leads.

2-14. MEASUREMENT PROCEDURE.

Either of two measurement procedures may be used, depending on whether the correct resistance-multiplier range is known. If the range is not known, the search procedure should be followed. The sort procedure should be used if repetitive measurements will be made on a given range (that is, if similar components are to be sorted).

a. Search Procedure. Proceed as follows when the approximate resistance of the component to be measured is not known:

(1) Set the multiplier switch to the lowest range.

(2) Set the function switch to DISCHARGE.

(3) Connect the ground terminal to the + UNKNOWN terminal using the grounding connection (figure 2-5).

(4) Connect the component to be measured to the + and - UNKNOWN terminals.

(a) Use a shielded lead for remote measurements.

(b) Use the shorting link.

(c) Shield the + UNKNOWN terminal.

(d) Tie the shield to the GUARD terminal.

(5) Set the function switch to MEASURE.

(6) Measure after voltage has been applied for 1 minute.

(7) Rotate the multiplier switch clockwise until the meter gives a reading of less than 5.

NOTE

The resistance of the unknown is the meter reading multiplied by the multiplier-dial indication.

b. Sort Procedure. Proceed as follows when the approximate resistance of the component is known.

(1) Set the function switch to DISCHARGE.

(2) Set the multiplier switch to the desired range.

(3) Connect the component between the + and - UNKNOWN terminals.

(4) Set the function switch to MEASURE.

(5) Measure after voltage has been applied for 1 minute.

NOTE

The resistance of the unknown is the meter reading multiplied by the multiplier-switch indication.

For go-no-go checks, it is often useful to make a limit line on the outside of the meter case with a strip of masking tape.

(6) Return the function switch to DISCHARGE. Remove the component measured.

(7) Turn the instrument off with the POWER switch.

(8) Disconnect and restow the power cord and instrument leads:

(9) Close the instrument case and return it to stowage.

2-15. VALHALLA DIGITAL OHMMETER.

2-16.

The Valhalla Model 4100 ATC digital ohmmeter is capable of precise measurement from 10 micro-ohms to 19.999 kilo-ohms. The lower range of the instrument will allow measurement of the resistance of windings in large motors. It will also detect small variations of resistance. Unsatisfactory differences in phase resistance in large motors will be in milliohms. The precision of an instrument like the 4100 ATC is required to detect such faults.

WARNING

Do not attach or touch leads to any circuit or unit where a voltage may be present.

2-17. CONTROLS AND CONNECTORS.

Figure 2-6 shows the front panel controls and connectors of the digital ohmmeter. Table 2-4 lists and identifies them.

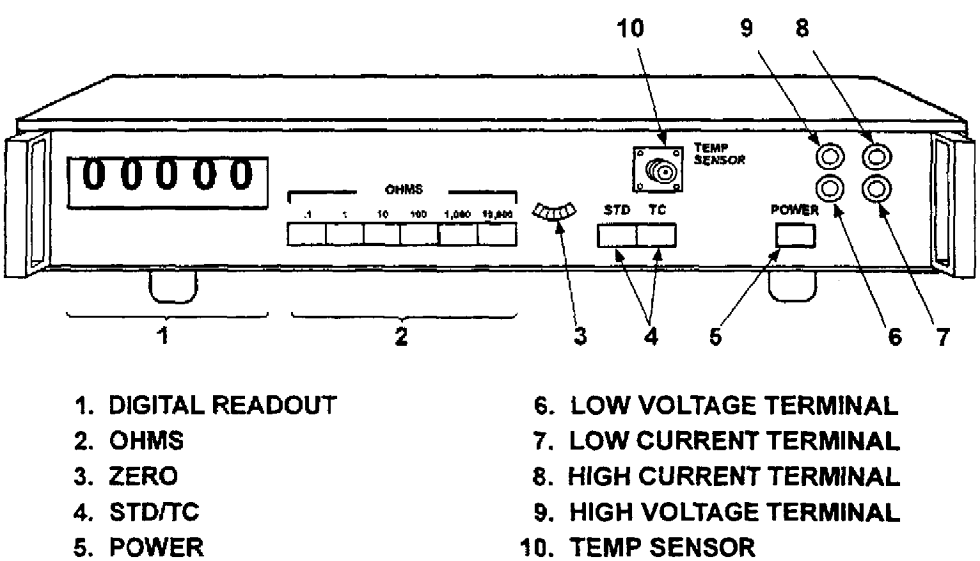


Figure 2-6 Valhalla Model 4100 ATC Digital Ohmmeter

Table 2-4 Valhalla Digital Ohmmeter Controls and Connections

FIGURE 2-6 REF. NO.	NAME	FUNCTION
1	DIGITAL READOUT	Provides direct reading of the resistance of the component under test.
2	OHMS	A 6 station pushbutton switch. Selects ranges of 0.1, 1, 10, 100, 1,000, and 10,000.
3	ZERO	Adjusts zero offset of instrument.
4	STD/TC	A 2 station pushbutton switch. Selects internal zero temperature coefficient or external temperature sensor.
5	POWER	Single red pushbutton. Energizes and deenergizes.
6, 9	VOLTAGE	Lead connection for voltage measurement across the component being tested.
7, 8	CURRENT	Lead connection to supply a constant current across the component being tested.
10	TEMP. SENSOR	Connection for temperature compensating probe.

2-18. OPERATION.

The Valhalla Model 4100 ATC is a precision analog and digital (A/D) converter that measures and displays dc voltages. Resistance measurements are made by passing a constant current into an unknown resistance and measuring the resulting voltage drop with the precision A/D converter. The instrument converts the voltage and presents a readout in ohms.

a. To make resistance measurements:

(1) Connect the instrument to a 115-Volt ac 60 HZ single-phase power source.

(2) Plug the test leads into the voltage and current plugs on the front of the instrument.

(3) Connect the test leads to the unknown resistance to be measured.

NOTE

When individual leads are used, the HI CURRENT lead and HI VOLTAGE lead must connect to the same end of the unknown being measured. LO CURRENT and LO VOLTAGE must connect together to the other end of the unknown.

(4) Turn the instrument on by depressing the POWER switch.

(5) Read the display.

CAUTION

If the display does not stop flashing after the higher range switches are depressed (see note below), it indicates an open circuit.

NOTE

If the display is flashing, depress the higher range switches under OHMS until flashing stops. Read the display.

b. To conduct a phase balance resistance test:

(1) Mark motor leads 1, 2, and 3.

(2) Locate the 4100 ATC next to the motor.

(3) Connect the 4100 ATC to a 115-volt ac, 60-Hz single-phase power source.

(4) Connect the instrument leads to the terminal post on the instrument.

(5) Connect the instrument leads to leads 1 and 2 on the motor to be tested.

NOTE

When individual leads are used, the HI CURRENT lead and HI VOLTAGE lead must connect to the same end of the unknown being measured. LO CURRENT and LO VOLTAGE must connect together to the other end of the unknown.

(6) Select the instrument range by depressing the proper selector under OHMS.

(7) Depress the STD switch.

(8) Depress the POWER switch to turn the instrument on

(9) Read the display.

CAUTION

If the display does not stop flashing after the higher range switches are depressed (see note below), it indicates an open circuit.

NOTE

If the display is flashing, depress the higher range switches under OHMS until flashing stops. Read the display.

(10) Record the reading on a motor data sheet (electrical) (figure 2-7) in the appropriate section.

(11) Disconnect the instrument leads attached to motor lead 1 and connect them to motor lead 3.

(12) Repeat steps (6) through (10).

(13) Disconnect the instrument leads attached to motor lead 2 and connect them to motor lead 1.

(14) Repeat steps (6) through (10).

(15) Turn the instrument off.

SECTION 1. NAMEPLATE DATA

EQUIPMENT ____________ USS ____________
MFGR. ____________ TYPE ____________ FRAME ____________
HP ________ INSULATION CLASS ________ TEMP. RISE ________ °C/°F ________
VOLTS ________ AMPS ________ CYO ________ R/M ________ PHASE ________
SERIAL NO. ____________ ADDITIONAL DATA ____________

SECTION 2. INPLACE INSPECTION

CAUTION: OBSERVE APPLICABLE SAFETY PROCEDURES.

SATISFACTORY		UNSATISFACTORY
________	INSULATION RESISTANCE IN MEGOHMS (REFER TO TABLE 3-2)	________
POLARIZATION INDEX TEST	1 MIN ________ 10 MIN ________ RATIO ________	
________	MECHANICAL CONDITION (REFER TO PARAGRAPH 3-6)	________
________	CONTINUITY OF WINDINGS (REFER TO PARAGRAPH 3-5.1)	________
________	CURRENT BALANCE (USE LIMITS PRESCRIBED IN PARAGRAPH 3-10)	________
________	CONDITION OF BRUSHES AND COMMUTATOR	________
________	CONDITION OF CABLES FROM CONTROLLER TO MOTOR	________
________	CONDITION OF CONTROLLER	________

SECTION 3. INCOMING INSPECTION (GENERAL)

SURGE TEST	1 - 2	________	SAT/UNSAT
	2 - 3	________	SAT/UNSAT
	1 - 3	________	SAT/UNSAT
INSULATION RESISTANCE TO GROUND		________	MEGOHMS
RESISTANCE BALANCE	1 - 2	________	OHMS
WITH DIGITAL OHMMETER	2 - 3	________	OHMS
	1 - 3	________	OHMS

ACTION: RECONDITION ________ REWIND ________

SECTION 4. RECONDITIONING

	AFTER STEPS OF: CLEANING	DRYING
INSULATION RESISTANCE (MEGOHMS)	________	________
PHASE RESISTANCE BALANCE TEST	________	________
SURGE TEST (SAT/UNSAT)		________
DC HIGH-POTENTIAL TEST	________	________

ACTION: VARNISH ________ REWIND ________

SECTION 5. AFTER RECONDITIONING OR REWINDING AND VARNISHING

INSULATION RESISTANCE		________	MEGOHMS
POLARIZATION INDEX TEST 1 MIN ________	10 MIN	________	RATIO ________
RESISTANCE BALANCE WITH	1 - 2	________	OHMS
DIGITAL OHMMETER	2 - 3	________	OHMS
	1 - 3	________	OHMS
SURGE TEST		________	SAT/UNSAT
AC HIGH-POTENTIAL TEST		________	SAT/UNSAT
INSULATION RESISTANCE AFTER AC HIGH-POTENTIAL TEST		________	MEGOHMS
NO-LOAD TEST	PHASE A	________	AMPERES
	PHASE B	________	AMPERES
	PHASE C	________	AMPERES

Figure 2-7 Motor Data Sheet (Electrical)

NOTE

This example assumes the motor is from a surface ship and is over 3 hp, requiring a phase balance of 5 percent (.05).

c. To calculate motor winding difference:

(1) Assume the readings taken using the 4100 ATC were recorded on the motor data sheet as follows:

Phase resistance balance	1-2	0.325 ohms
	2-3	0.326 ohms
	3-1	0.333 ohms

(2) Multiply the highest reading by 0.05. The figure calculated is the maximum imbalance allowed between phases.

$$\begin{array}{l} 0.333 \\ \underline{\times\ 0.05} \\ 0.01665 \end{array}$$

(3) Subtract the lowest reading from the highest reading.

0.333	*High reading between leads 3 and 1*
-0.325	*Low reading between leads 1 and 2*
0.008	*Difference*

(4) The motor must be rewound when the difference between the high and low reading exceeds the calculated allowable imbalance. In the example, the maximum imbalance allowed was 0.01665 ohms. The actual difference was 0.008 ohms. The difference is less than allowed. Therefore, the winding is good.

2-19. BAKER ST112E SURGE/DC HIGH-POTENTIAL TESTER.

2-20.

The Baker ST112E Surge/DC high-potential tester is used to detect defective insulation and winding errors in all types of coils. When used as a surge comparison tester, the tester uses a comparison method for detecting winding faults. Each pair of windings is compared by alternately applying the test voltage to each winding. The resulting waveform from both windings is displayed on an oscilloscope (figure 2-8 and figure 2-9). Waveform can be affected by winding designs and will often indicate a fault, but this is actually an induction difference. This occurs in coupling between windings in a two-speed, two-winding motor and also on concentric (basket) windings. The Baker ST112E is also a dc high-potential tester. DC high-potential tests are made by applying dc voltage in steps and recording leakage current (microamperes) through the insulation. The voltage and current are plotted on graph paper and the shape of the resultant curve is used for checking the cleanliness and moisture content of the machine tested. The dc high-potential test should be used during overhaul to determine cleanliness and moisture content of insulation before or during reconditioning of equipment, since it is less destructive than ac high-potential testing. The dc high-potential test can also be used at a reduced voltage as a preventive or troubleshooting technique.

Figure 2-8 Waveform for Two Good Windings

Figure 2-9 Waveform for a Defective Winding

2-21. CONTROLS AND CONNECTORS.

Figure 2-10 shows the front panel controls and connectors of the surge/dc high-potential tester. Table 2-5 lists and identifies them.

2-22. OPERATION.

To operate the Baker ST112E as a surge tester:

a. Check that the ON/OFF switch is in the OFF position.

b. Connect the surge tester line cord into a 110 to 120V ac outlet (220 to 240V ac for units so equipped).

c. Preset the following controls as indicated:

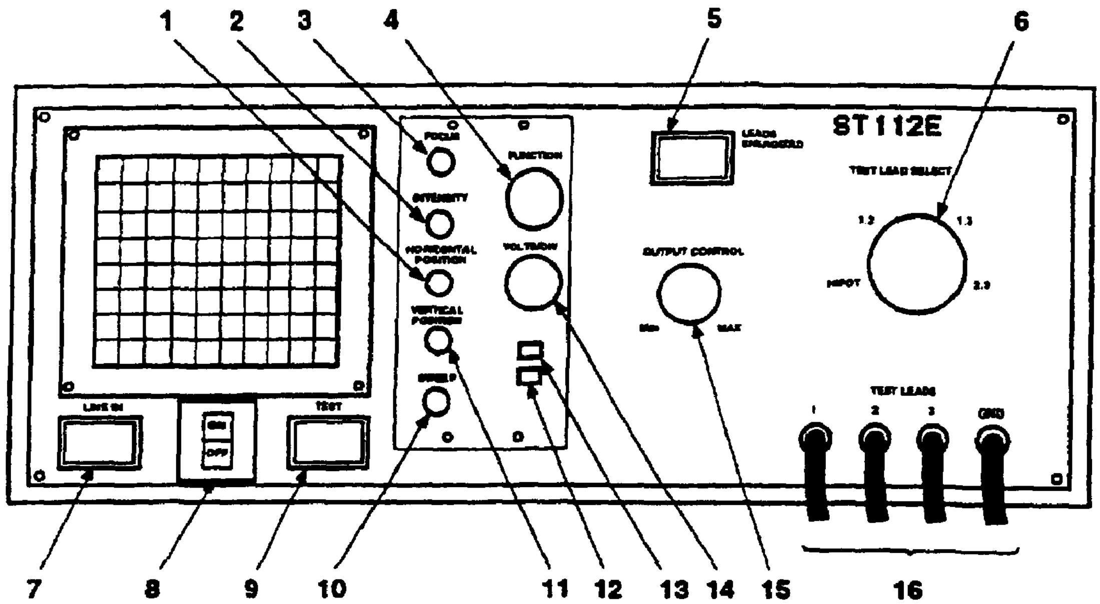
FOCUS	Midscale
INTENSITY	Midscale
VERTICAL	Midscale
HORIZONTAL	Midscale
SWEEP	Midscale
OUTPUT	Minimum (full counterclockwise)

d. Turn unit ON/OFF switch to ON (allow brief period for CRT warm-up) and adjust to midscale.

NOTE

A trace that is too coarse will make small faults in the winding undetectable.

e. Adjust FOCUS for a sharp, well-defined trace.



1. HORIZONTAL POSITION
2. INTENSITY
3. FOCUS
4. FUNCTION CONTROL
5. LEADS ENERGIZED
6. TEST LEAD SELECT SWITCH
7. LINE IN
8. ON/OFF
9. TEST PUSHBUTTON
10. SWEEP
11. VERTICAL POSITION
12. HIPOT TRIP
13. OPEN GROUND
14. VOLTS/DIVISION
15. OUTPUT CONTROL
16. TEST LEADS

Figure 2-10 Baker ST112E Surge/Hipot Tester

WARNING

Do not come into contact with test leads during testing. Do not attempt pre-setting output for high-potential testing. (It is also not recommended for surge testing.) Be sure that all switches and controls are in their proper positions for the testing mode desired.

f. Check that the FUNCTION control is in the SURGE position

g. Center the trace midway between the top and bottom of the grid, using the VERTICAL CONTROL.

h. Move the trace left on the grid until it just touches the left side of the grid, using the HORIZONTAL CONTROL.

i. Adjust the SWEEP to obtain a trace about 3 inches long.

Table 2-5 Baker ST112E Surge/Hipot Tester Controls and Connectors

FIGURE 2-10 REF. NO.	NAME	TYPE	FUNCTION
1	HORIZONTAL POSITION	Rotary control	Adjust horizontal sweep position.
2	INTENSITY	Rotary control	Adjusts the brightness of sweep.
3	FOCUS	Rotary control	Adjusts the sharpness of sweep.
4	FUNCTION	Rotary control	Selects AUX, SURGE, or HIPOT.
5	LEADS ENER-GIZED	115V lamp (red)	Indicates that a test is in progress.
6	TEST LEAD SELECT	4-position rotary switch	Selects test leads for SURGE or HIPOT.
7	LINE IN	Male 2-pole grounded	Primary power input line for tester.
8	ON/OFF	Rocker switch	Applies power to unit.
9	TEST	Pushbutton	Activates the test function.
10	SWEEP	Rotary control	Adjusts oscilloscope sweep time duration (trace length).
11	VERTICAL POSI-TION	Rotary control	Adjusts vertical sweep position.
12	HIPOT TRIP	115V lamp (red)	Indicates that machine has tripped due to excessive HIPOT leakage current.
13	OPEN GRND	215V lamp (red)	Indicates an improperly grounded unit.
14	VOLTS/DIV	Rotary control	Control vertical amplitude of the display waveform.
15	OUTPUT	Variable control	Adjusts the test output voltage.
16	TEST LEADS	Alligator clip marked 1, 2, 3, and GND	For connecting winding to be tested.

j. Connect the test leads to the windings to be tested. Proceed with the test as follows:

(1) Connect the leads as shown on the front of the instrument for a three-phase motor.

(2) Make a good ground connection.

CAUTION

Do not operate the TEST LEAD SELECT switch while a test is in progress.

NOTE

The red LEADS ENERGIZED lamp should light.

(3) Press the TEST pushbutton.

(4) Rotate the OUTPUT CONTROL slightly clockwise. A pattern like the one shown in figure 2-8 or figure 2-9 will appear on the oscilloscope. Measure the voltage from the center of the trace to the top of the first peak by adjusting the initial pulse of voltage for grid readings.

(5) Adjust the SWEEP control to obtain the proper sweep duration for easy observation.

CAUTION

When testing very small windings, the tester can generate voltages in excess of the rating, which can damage the windings. Use caution to limit the percent of output to the nameplate rating.

NOTE

The test voltage should be (2 E +1000) x 1.4 for new windings. E is the rated voltage of the machine. Reconditioned windings should be 2/3((2E + 1000) x 1.4).

(6) Adjust the OUTPUT CONTROL switch for the desired test voltage.

CAUTION

Do not operate the tester with a vertical display that exceeds the size of the CRT grid.

(7) Adjust the VOLTS/DIV to keep the waveform on the CRT grid when the OUTPUT CONTROL is increased.

(8) Release the TEST button. Rotate the TEST LEAD SELECT switch to the next position. Repeat until all three TEST LEAD SELECT positions have been selected.

(9) Compare the observed waveform with figure 2-11 to determine the type of fault when faults are indicated.

(10) Enter the results on the motor data sheet (electrical) (figure 2-7) when the surge test has been completed.

k. The following data must be considered in conducting any test comparing observed waveforms:

(1) Most testing performed is comparison testing in which the inductance of two identical windings (or two windings of a three-phase winding) are tested simultaneously. The output waveforms are compared against each other.

(2) The tester can be used to test for voltage breakdown of a single winding. However, results are difficult to judge due to lack of a comparison.

(3) A single waveshape will result when two matched windings with no faults are being tested.

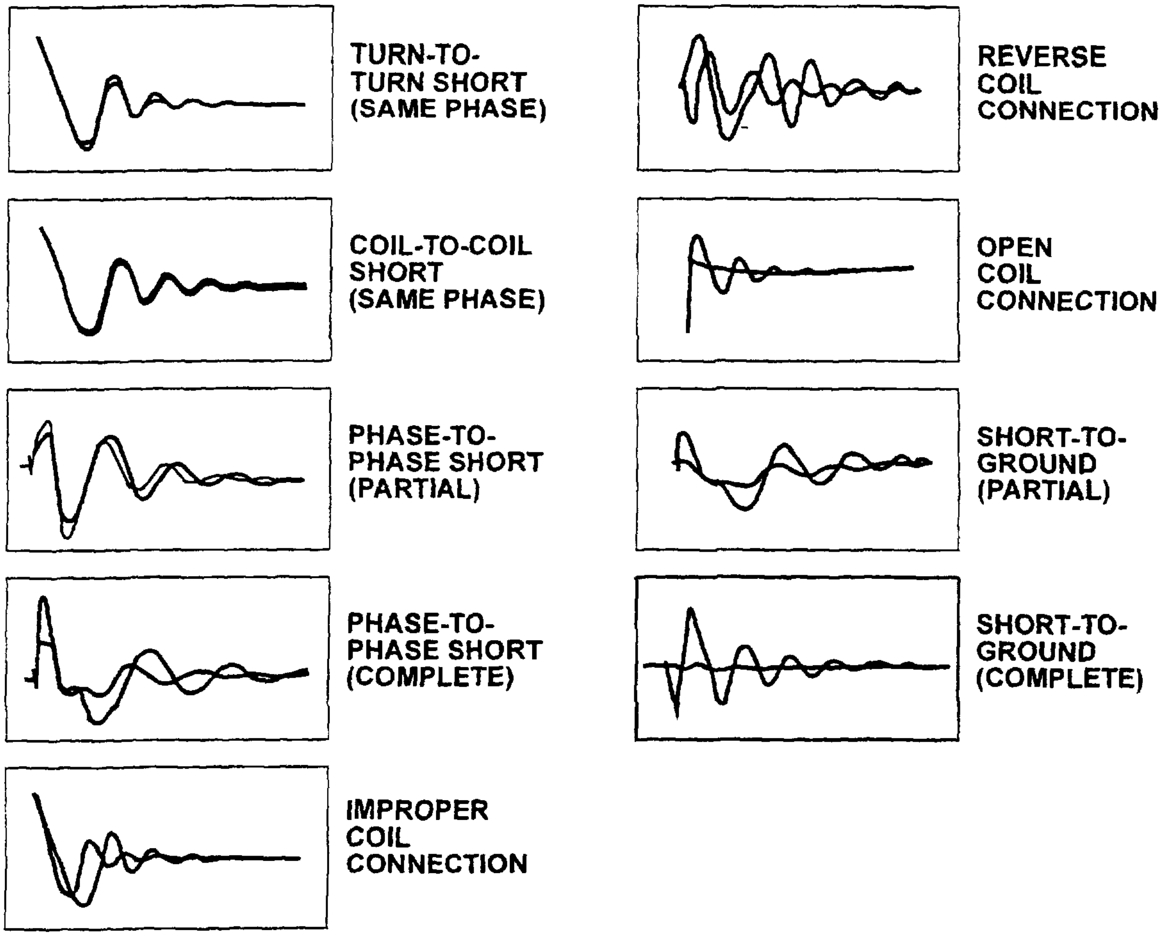


Figure 2-11 Waveshapes of Typical Winding Faults

(4) If the windings are not matched, a dual waveform, such as that shown in figure 2-11, will appear, or one trace will be erratic. The dual waveform indicates the two windings under test have different inductances; e.g., the windings generating the higher frequency waveform have fewer turns or shorted turns. An erratic waveshape indicates that the insulation in one coil is momentarily breaking down.

(5) A flat trace will appear if one or both tester channels are being short circuited. The TEST LEADS should be checked for inadvertent shorting and the TEST LEAD SELECT switch checked before rejecting the winding as totally shorted.

(6) A step function waveform will appear (figure 2-12) if one or both tester channels are operating into an open circuit. Again, TEST LEADS and TEST LEAD SELECT switch settings should be checked before rejecting the winding.

(7) In some cases, it is advantageous to determine which phase contains a fault. It is necessary to test all three phases of a motor to do this.

Figure 2-12 Waveform for an Open Circuit

(8) Note which points of the TEST LEAD SELECT switch indicate faults.

(9) Determine the common lead to the points indicating a fault.
(10) Trace this lead to the winding lead and the faulty phase winding in the motor.

2-23. OPERATION.

To operate the Baker ST112E as a dc high-potential tester:

a. Turn the FUNCTION switch to the 500 microamps per division setting. VOLTS/DIV is always 500. Rotate the TEST LEAD SELECT switch to the HIPOT setting.

b. On multilead equipment, connect all leads together with lead number 1. Connect the black lead of the tester to a clean ground on the frame or core of the unit under test. Rotate the OUTPUT CONTROL to the extreme left, or minimum, setting.

c. Rotate the VERTICAL POSITION control so that the line is positioned near the bottom of the screen, behind one of the grid lines etched on the face of the oscilloscope.

d. Voltage output of HIPOT is read on the screen as with the surge test. The hipot leakage current is also displayed on the screen. The display will be three flat lines: one full-width stationary line is the zero reference, the half-width line on the left indicates the output voltage, and the half-width line on the tight indicates the leakage current.

CAUTION

This test should be stopped when a sharp rise in current is obtained. Do not attempt to preset high-potential voltage. Always begin testing at minimum. Upon completion of test, allow sufficient time for winding to discharge completely.

NOTE

The maximum test voltage for new insulation should be (2E + 1000) x 1.6. E is the rated voltage of the machine. Reconditioned windings should be tested at a maximum voltage of 1.1 x (2E + 1000).

e. To begin the HIPOT test, depress the TEST button and slowly raise voltage with the OUTPUT CONTROL. Some deflection of the leakage current trace will be noted as the voltage is increased. This is due to charging current necessary to saturate the windings.

CAUTION

Do not allow the overcurrent relay to trip. Tripping the relay produces an inductive voltage surge which could damage the insulation. Increase the test voltage slowly enough to see an abrupt rise in the slope of the leakage current curve and to stop the test.

f. The unit is equipped with a HIPOT overcurrent safety trip. If the HIPOT leakage current trace goes very high (off the screen), or approximately 10 times the hipot leakage current micro-amps per division setting of the FUNCTION switch, this overcurrent trip will operate. If the hipot trips, the high voltage is turned off and the hipot trip lamp comes on. To reset the hipot trip, release the TEST switch.

g. Plot a curve of the measured leakage current values, taking at least eight equally spaced voltage points up to full voltage. Select the curve scale to suit the leakage current being obtained. On some machines, this will be less than 1 microampere. On others, it will be in milliamperes. Record the data for each point after the current stabilizes (possibly several minutes on large machines). Use the curve shown in figure 2-13 as guidance. Approximately 25 percent of the calculated maximum test voltage or 500 volts, whichever is less, should be applied as the initial test voltage and the leakage current recorded.

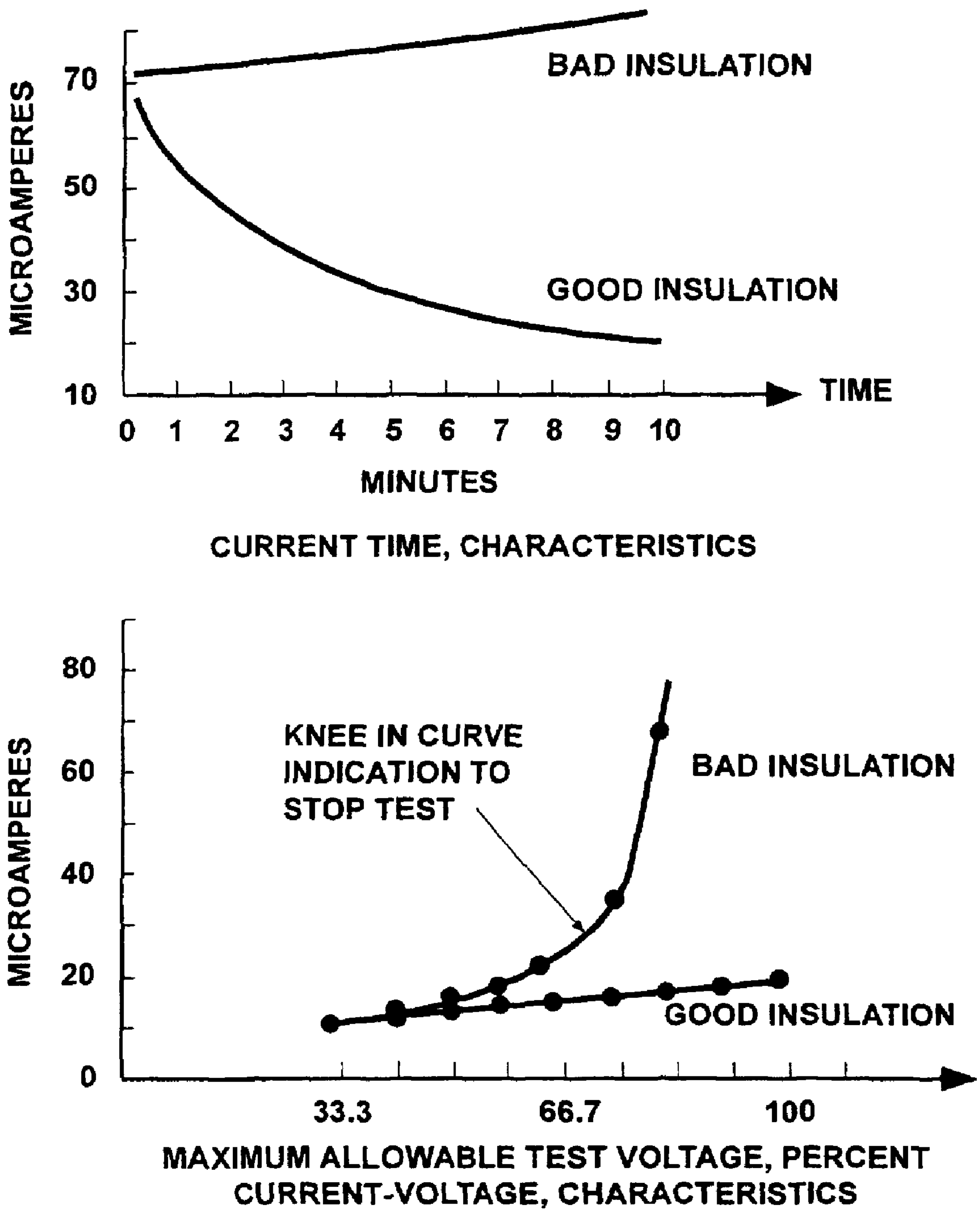


Figure 2-13 DC High-Potential Test Curves

2-24. EXTERNAL GROWLER.

NOTE

There are several models of growlers. They may or may not have on/off switches, indicator lights, test leads, or meters. The growler described below is typical.

2-24.1 A growler is used to test for short circuits in dc armatures or for loose bars in ac squirrel cage motors. The growler comes as both internal and external (figure 2-14) models. Table 2-6 lists and describes the controls and connectors of a generic external growler. Both models operate in a similar manner. The internal growler is hand held and used to test the condition of large stators, particularly ac generators. The V-type external growler is used to test rotors and armatures. This growler may range in size from a bench model to a large floor model on wheels.

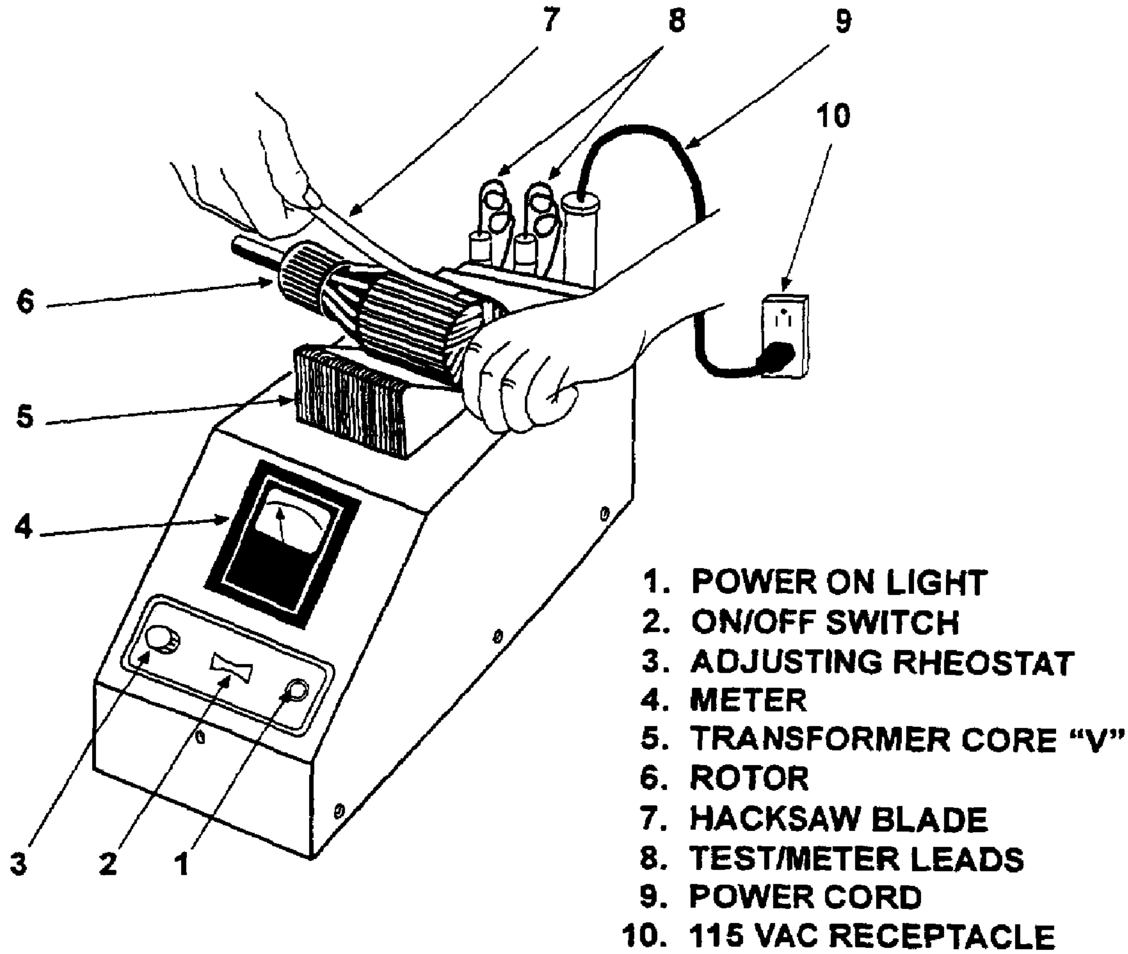


Figure 2-14 External Growler

NOTE

Bench-type growlers with optional installed millivoltmeter and test leads may also be used to test for insulation resistance to ground and open circuits. Consult manufacturers' instructions for this use.

2-24.2 Basically, the growler is half of a transformer. The exposed laminations induce a voltage in the device to be tested. Follow the procedure below to perform tests.

a. Place the growler on an electrical workbench with access to 115 Vac power.

CAUTION

Use only a 115 Vac power supply. Growlers must have the rotor in place before energizing. Energizing a growler without a rotor in place could damage the growler.

b. Rest the rotor in the laminated V block of the growler.

c. Plug in the growler and turn the ON/OFF switch to ON, if a switch is provided.

Table 2-6 Typical Growler Components

FIGURE 2-14 REF. NO.	NAME	FUNCTION
1	POWER ON LIGHT	Indicator light is illuminated when there is power to the unit.
2	ON/OFF SWITCH	Energizes/deenergizes the unit.
3	ADJUSTING RHEOSTAT	Used with meter and test leads for dc armature.
4	METER	Used for dc armature commutator bar to bar test.
5	TRANSFORMER CORE V	Supports rotor, induces voltage.
6	ROTOR	Item being tested.
7	HACKSAW BLADE	Vibrates when a fault is detected.
8	TEST/METER LEADS	Used for bar to bar test on dc armatures.
9	POWER CORD	Connects to 115 Vac receptacle.
10	115 VAC RECEPTACLE	Provides power to growler.

d. Hold a hacksaw blade, or similar piece of thin metal, in your hand. Touch the metal loosely to the winding or bars area of the rotor. The hacksaw blade will vibrate if there is a shorted coil in a dc armature, or loose bars in an ac squirrel cage rotor.

CAUTION

Do not rotate the rotor in the V block. Deenergize the growler before lifting the rotor from the growler. Failure to do so will cause damage to the growler.

e. Turn off or unplug the growler, lift and rotate the rotor, replace it in the V block, and reenergize the growler. Repeat steps a through e until all windings or bars have been tested.

2-24.3 Some commands are employing reusable magnetic paper for inspecting squirrel cage or solid rotors using a growler. A sheet of the specially treated paper is wrapped around or laid across a rotor. When used with a typical bench growler, the paper displays the magnetic field induced by the bars of the rotor. If a bar is open, loose, or not connected to the shorting ring, a blank space will appear in the bar pattern on the magnetic sheet. To restore the paper for reuse, erase it by stroking permanent magnet across the paper at 90 degrees to the induced flux pattern. The paper is available from most suppliers of motor repair and rewind supplies.

2-24.4 Iron filings can also be used to indicate the condition of rotor bars in conjunction with a growler. Iron filings are placed on a sheet of paper and the paper is placed on the surface of the rotor. The iron filings will stick through the paper to good bars and will *not* be attracted to open bars. The rotor shall be rotated in the growler's magnetic field until all the bars have been checked. A LEXSECO core loss tester (paragraph 2-38) or equivalent can be used (in lieu of the growler) to magnetize the core. When using a core loss tester, use a relatively low amperage which is just enough to create a flux pattern in the iron filings.

2-24.5 An ammeter, in series with the line cord of the growler, can also be used to check rotor bars. The ammeter should not show any current variations in excess of 5 percent while the rotor is rotated in the growler's magnetic field. Limit the current to the growler to the ammeter's capability by placing a dropping resistor in the growler supply line. Rotate the rotor in the growler for at least two full revolutions to ensure repeatability of the readings and to ensure that all bars were checked.

2-25. TYPICAL CLAMP-ON AMMETER.

2-26.

The clamp-on ammeter can be used to measure current without connecting any special equipment or disturbing the circuit. Clamp-on ammeters may have a capability for voltage measurement as well as resistance measurements through the use of external leads.

2-27. CONTROLS AND CONNECTORS.

Figure 2-15 shows typical front panel controls and connectors for the clamp-on ammeter. Table 2-7 lists and identifies them.

NOTE

Some models of clamp-on ammeters may have more controls than others.

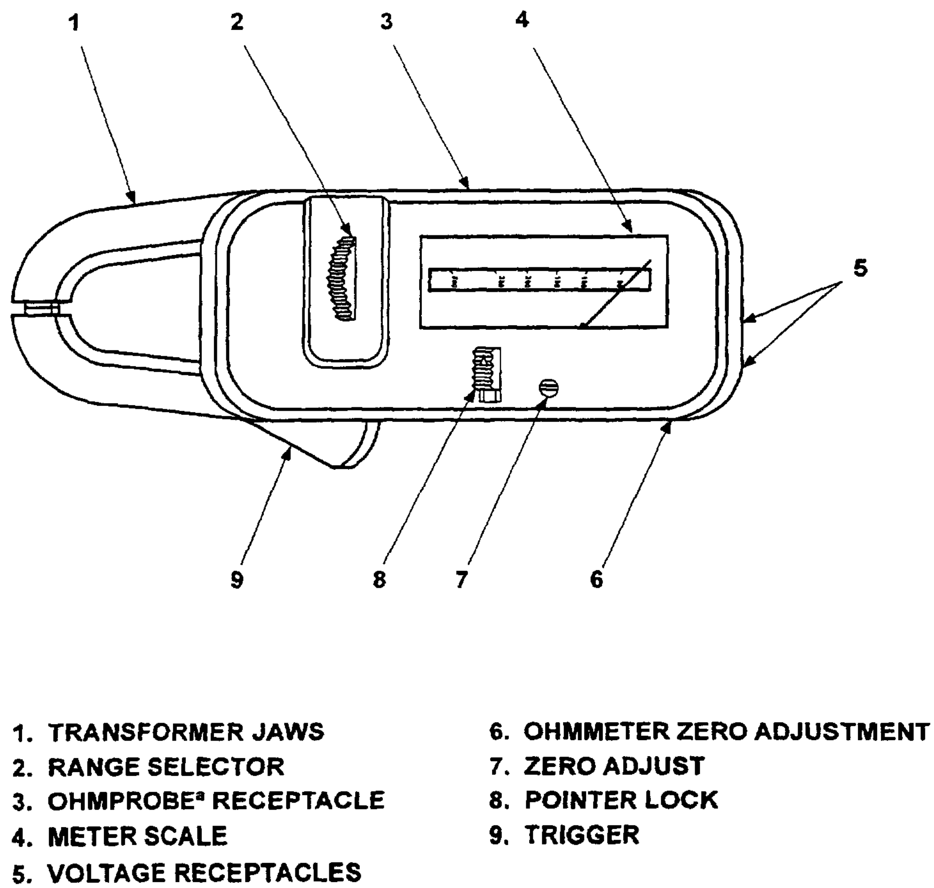


Figure 2-15 Clamp-on Ammeter, Model SPR-300

2-28. OPERATION.

To operate the clamp-on ammeter, remove the instrument and the test leads from their case and proceed as follows:

Table 2-7 Clamp-on Ammeter Controls and Connectors

FIGURE 2-15 REF. NO.	NAME	TYPE	FUNCTION
1	TRANSFORMER JAWS	Insulated tapered Jaws; accepts up to 1-3/8 in OD cable	Measures current; snaps around one conductor
2	RANGE SELECTOR	Rotary switch and dial drum mechanism	Selects volt or amp scale.
3	OHMPROBE RECEPTACLE	Female; twist-to-lock	For connection of ohmmeter test leads.
4	METER SCALE	Selectable scale; 0-300 ac amps; 0-600 ac volts; 0 ohms; 50-400 Hz; ± 3%	Indicates volt, ohm, or amp measurements.
5	VOLTAGE RECEPTACLES	Female; twist-to-lock	For connection of voltmeter test leads.
6	OHMMETER ZERO ADJ.	Rotary control	Zeros meter with test leads shorted.
7	ZERO ADJUST	Rotary control	Zeros meter for greatest accuracy.

Table 2-7 Clamp-on Ammeter Controls and Connectors - Continued

FIGURE 2-15 REF. NO.	NAME	TYPE	FUNCTION
8	POINTER LOCK	Slide-to-lock	Freezes pointer when readings are taken.
9	TRIGGER	Press-to-open	Opens transformer jaws.
10	OHMPROBE BATTERY/FUSE ATTACHMENT (NOT SHOWN)	Sperry type F-1 fuse and Sperry type B-1 battery	Fuses the OHMPROBE to prevent damage to the instrument if a resistance measurement is taken on a live circuit.

a. Voltage Measurement.

CAUTION

Remove the OHMPROBE fuse and battery attachment from the instrument before measuring volts. The fuse will burn out if it is not removed.

NOTE

Some models may not have this fuse or feature.

(1) Insert the test lead plugs into the voltage receptacles and twist them clockwise to lock them into position.

(2) Set the range selector switch to the highest voltage range scale.

(3) Unlock the pointer lock.

WARNING

Wear rubber gloves to prevent hand contact with bare conductors.

NOTE

Connect the instrument to a known ″live″ source to ensure proper operation before making voltage measurements. Voltage ranges are printed in red.

(4) Connect an alligator clip to any side of the ac line to be measured.

(5) Hold the instrument in one hand and touch the other side of the ac line with the second test lead.

(6) Connect the second alligator clip to the other side of the line and take a voltage reading if the reading does not exceed the highest voltage scale.

(7) Set the range selector switch to the next lowest voltage range if the reading is in the lower half of the scale.

(8) Repeat step (7) until the reading is in the upper half of the scale.

b. Current Measurement.

CAUTION

Remove the OHMPROBE fuse and battery attachment from the instrument before measuring amperes. The fuse will burn out if it is not removed.

NOTE

Some models may not have this fuse or feature.

(1) Set the range selector switch to the highest current range scale.

WARNING

Wear rubber gloves to prevent hand contact with bare conductors.

(2) Unlock the pointer lock.

NOTE

Separate the conductors to ensure that the point of attachment is easily accessible before making a current measurement. Be sure that the meter may be attached and read correctly without contacting ″hot″ wires.

(3) Open the transformer jaws by depressing the trigger.

(4) Snap the transformer jaws around one conductor.

NOTE

Make certain that the transformer jaws are completely closed before a reading is taken.

(5) Set the range selector switch to the next lowest current range if the reading is in the lower half of the scale.

(6) Repeat step (5) until the reading is in the upper half of the scale.

NOTE

The current may be read directly from the meter.

(7) Record the current reading of each phase of the motor under test on the motor data sheet (electrical) (figure 2-7).

(8) Return the instrument to its case after completing the measurement.

2-29. TYPICAL DIGITAL AC/DC CLAMP-ON MULTIMETER.

2-30.

The digital ac/dc clamp-on multimeter can be used to measure ac or dc current in a circuit without connecting, disconnecting, or disturbing circuit components or wiring. Modern digital clamp-on digital meters have the ability to measure ac and dc voltages, frequency, motor starting current, and duty cycle. They measure resistance in ohms and have continuity check and diode test capabilities. They have a data hold feature, which locks the reading on the liquid crystal display (LCD) panel for easy interpretation.

NOTE

Some models of clamp-on digital multimeters have more controls than others.

2-31. CONTROLS AND CONNECTORS.

Figure 2-16 shows typical front panel controls and connectors for the clamp-on digital multimeter. Table 2-8 lists and identifies them. Table 2-9 identifies and describes the symbols used on the LCD panel.

2-32. OPERATION.

To operate the digital clamp-on multimeter, remove the instrument and the test leads from their case and proceed as follows:

a. AC Current Measurement.

CAUTION

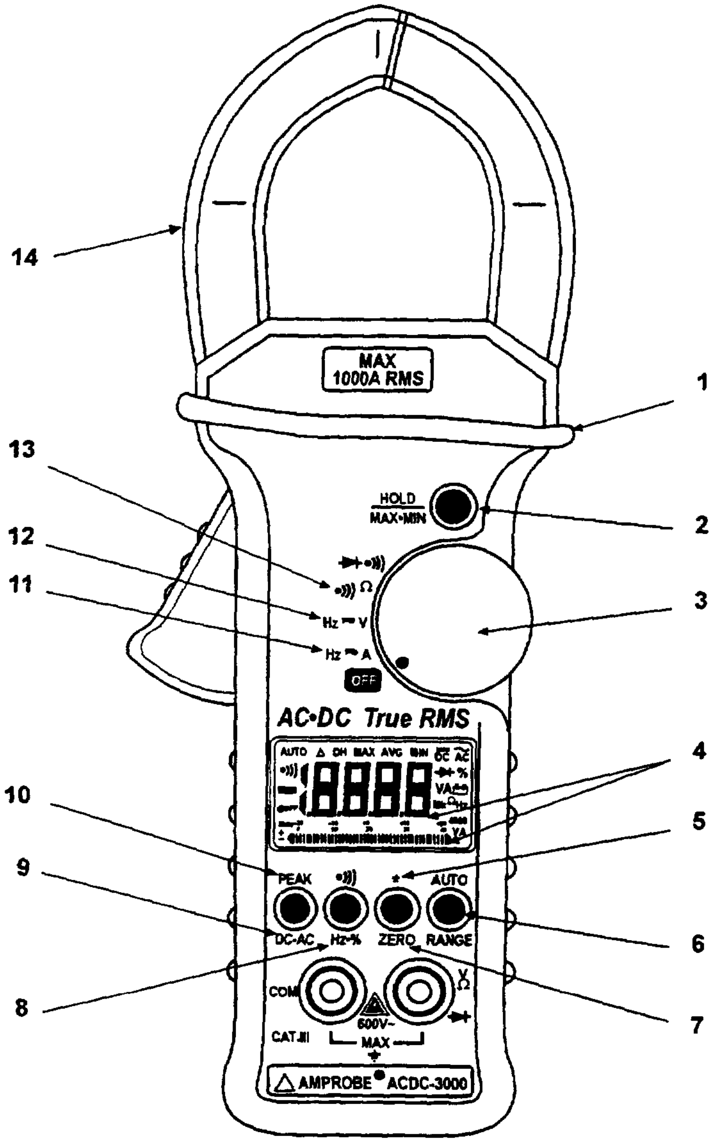
Do NOT connect test leads.

(1) Set the rotary switch to A.

(2) Momentarily press the DC/AC pushbutton to select AC.

(3) Press the handle to open the jaws and clamp them around a single conductor. For the most accurate reading, keep the conductor aligned with the centering marks on the jaws.

(4) Read the display.



1. HAND GUARD
2. DATA HOLD
3. ROTARY SWITCH
4. DUAL DISPLAYL
5. BACK LIGHT
6. AUTO MANUAL SELECT
7. ZERO MODE
8. FREQUENCY
9. RMS MEASUREMENT
10. PEAK HOLD
11. CURRENT MEASUREMENT
12. VOLTAGE MEASUREMENT
13. OHM MEASUREMENT
14. JAWS

Figure 2-16 AC/DC Digital Clamp-On Multimeter

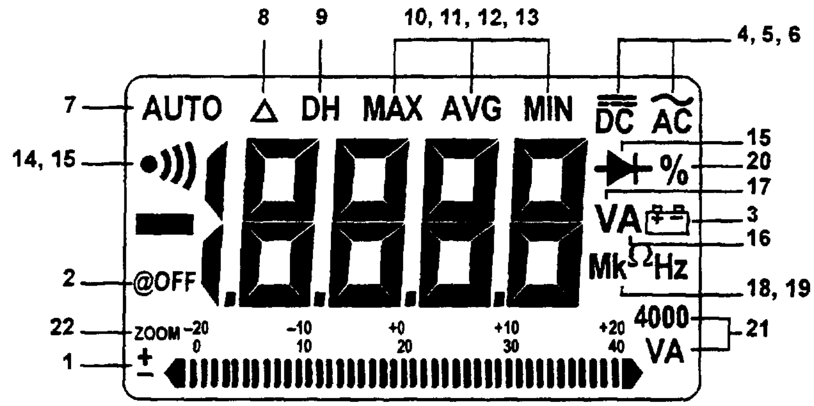
Table 2-8 AC/DC Digital Clamp-On Multimeter Controls and Connectors

FIGURE 2-16 REF. NO.	NAME	TYPE	FUNCTION
1	HAND GUARD		Prevents hand from slipping into jaws when reading a cable.
2	DATA HOLD	One-touch button	Provides Dynamic Recording and holds reading on screen for evaluation after instrument is removed from source.

Table 2-8 AC/DC Digital Clamp-On Multimeter Controls and Connectors - Continued

FIGURE 2-16 REF. NO.	NAME	TYPE	FUNCTION
3	ROTARY SWITCH	Rotary selector	Selects between modes of measurement: ac volts, dc volts, ac amps, dc amps, ohms, diode, or frequency.
4	DUAL DISPLAY	Liquid crystal display (LCD) screen	Panel where readings are observed. Digital display of frequency/duty cycle and bar graph display of current/voltage.
5	BACKLIGHT	Pushbutton	When selected, provides backlight LCD display for easier reading in dark areas.
6	AUTO/MANUAL SELECT	Two-function pushbutton	Selects range. Push to step through the range r push and hold button to shift to automatic range selection.
7	ZERO MODE	Pushbutton	Sets relative zero for deviation measurements.
8	FREQUENCY	Two-function pushbutton	Selects between frequency and duty cycle function on and off.
9	RMS MEASUREMENT	Two-function pushbutton	Press to select between ac, dc, or ac+dc modes. Press and hold to toggle between peak and dc readings.
10	PEAK HOLD	Two-function pushbutton	Press and hold for 1 second to toggle (see DC-AC above)
11	CURRENT MEASUREMENT	Rotary selector position	Selects current operation of meter.
12	VOLTAGE MEASUREMENT	Rotary selector position	Selects voltage operation of meter.
13	OHM MEASUREMENT	Rotary selector position	Selects ohm (resistance) operation of meter.
14	JAWS	Insulated, tapered jaws. Accept up to 1-3/8-inch OD cable.	Clamp around cable to make various measurements. Open jaws by pressing handle. Most accurate readings will be obtained when cable is centered in alignment marks on jaws.

Table 2-9 AC/DC Digital Clamp-On Multimeter LCD Display



REF. NO.	DESCRIPTION AND FUNCTION
1	Analog bar graph annunciator with scalar indicators
2	Indicates the auto power off enable
3	Indicates the battery power is weakening
4	Direct current or voltage
5	Alternating current or voltage
6	Indicates the measurement is dc+ac (alternating + direct current or voltage)
7	Indicates AUTO range mode
8	Zero (Delta) mode annunciator
9	Data hold annunciator
10	Dynamic recording mode, indicates the present reading
11	Indicates the maximum reading
12	Indicates the average reading
13	Indicates the minimum reading
14	Continuity function annunciator
15	Diode/audible continuity function annunciator
16	Unit of current measurement
17	Unit of voltage measurement
18	Units of resistance (ohm) measurement
19	Units of frequency measurement
20	Units of duty cycle measurement
21	Used to indicate the range of voltage, current, diode, and ohm measurements
22	Indicates ZOOM bar graph mode

b. AC Voltage Measurement.

(1) Set the rotary switch to V.

(2) Connect the test leads.

(a) Insert the black test lead into the black **COM** terminaL

(b) Insert the rest test lead into the red **V** Ω → | - terminal.

(3) Momentarily press the DC/AC button to select AC voltage measurement.

(4) Touch the probes to test points and read the display.

c. Resistance and Continuity Measurement.

CAUTION

Ensure all power is secured and all capacitors are discharged before testing for resistance or continuity.

(1) Set the rotary switch to **•)))Ω.**

(2) Connect the test leads.

(a) Insert the black test lead into the black COM terminal.

(b) Insert the red test lead into the red **VΩ** → | **-** terminal.

(3) Momentarily press the **•)))** button enter the continuity function.

(4) Touch the probes to the circuit and read the resistance an the display. A beeper sounds if the continuity is less than 10.0 ohms.

2-33. STROBOTAC, TYPE 1531-AB.

2-34.

The Type 1531-AB Strobotac is a variable flashing light source. It is used to measure the speed of rotating objects, or to produce the optical effect of stopping or slowing high-speed motion. The exact speed of a motor can be measured quickly if its approximate speed is known.

2-35. CONTROLS.

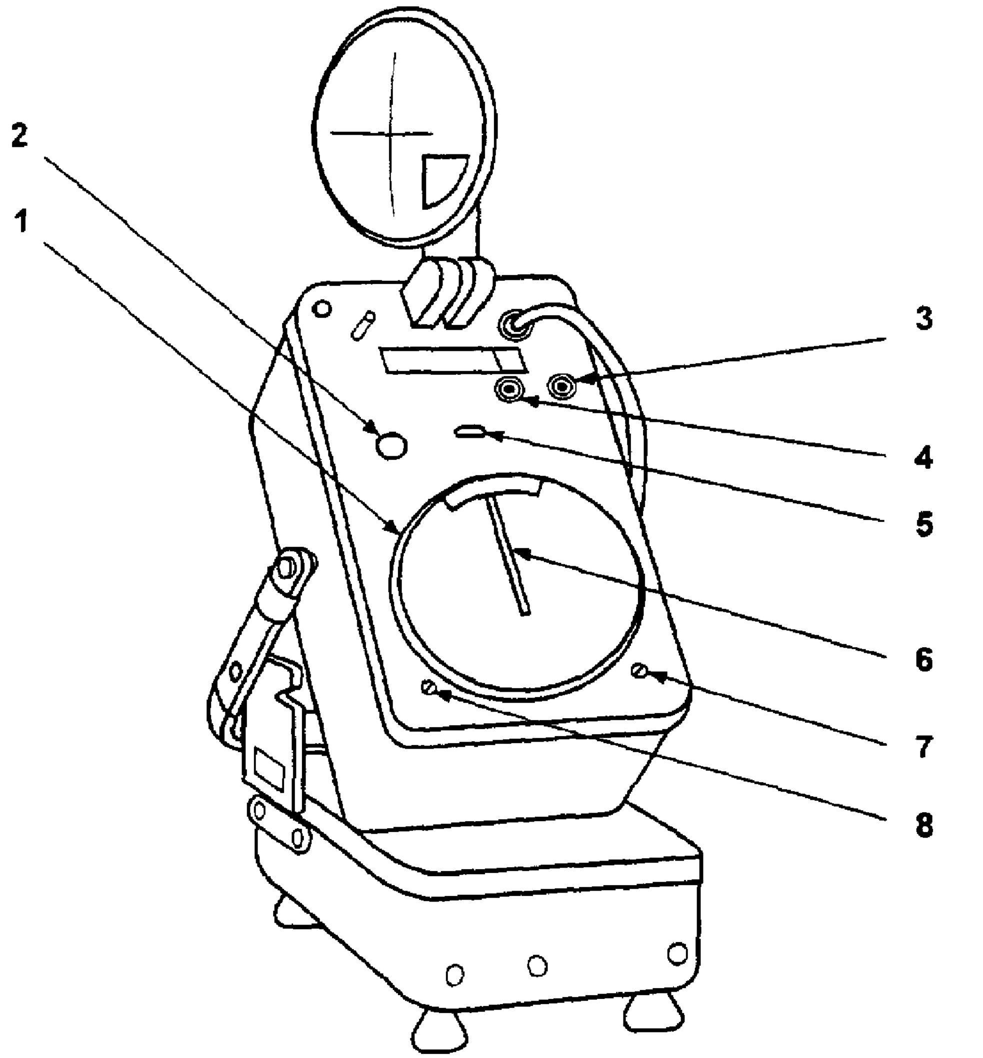
Refer to table 2-10 for a description of Strobotac controls (figure 2-17).

2-36. OPERATION.

Use the following procedure to operate the Strobotac.

WARNING

DANGER: Never leave the Strobotac unattended while in operation. The Strobotac makes a moving object appear to be stationary. A person could be seriously injured by touching a moving object which appears to be stationary.



1. R.P.M. CONTROL DIAL
2. POWER SWITCH
3. INPUT JACK
4. OUTPUT TRIGGER JACK
5. CALIBRATION INDICATOR
6. RANGE SWITCH
7. LOW CAL SCREW
8. HIGH CAL SCREW

Figure 2-17 Strobotac Type 1531-AB

NOTE

Irregularly shaped objects are usually easy to measure. However, round objects, such as motor shafts, must be marked to provide a visual reference point.

a. Set the Strobotac on a flat surface so that it rests on its rubber feet.

b. Unlock the case by sliding the slide locks (one on each side) away from the handle.

c. Use the palm of one hand to push the handle down as far as possible. Use the other hand to swing the Strobotac to the desired position.

d. Slowly release the handle to lower the Strobotac onto the rubber gasket.

Table 2-10 Strobotac Controls

FIGURE 2-17 REF. NO.	CONTROL	TYPE	FUNCTION
1	R.P.M.	Control dial	Flashing rate.
2	POWER	Switch	Power on-off.
3	INPUT	Jack	External synchronization.
4	OUTPUT	Trigger jack	Trigger pulse output.
5	CALIBRATION	Indicator light	Indicates correct setting of calibration adjustments.
6	RANGE	Switch	Selects r/m range.
7	LOW CAL	Screw	Adjusts the ON-OFF pattern of the neon light.
8	HIGH CAL	Screw	Adjusts the ON-OFF pattern of the neon light.

CAUTION

Ensure that the power matches the data on the plate next to the power cord on the panel before plugging the power cord into the receptacle.

e. Ensure that the power cord has a ground terminal. Ground the chassis if it does not.

f. Plug the Strobotac into the power supply.

g. Raise the reflector lamp to an upright position.

h. Position the Strobotac. The light beam can be pointed in almost any direction by the swivel arm and the rotating reflector.

i. To calibrate the Strobotac:

(1) Allow the Strobotac to warm up for 10 minutes.

(2) Refer to the calibration chart in the cover for the HIGH CAL and LOW CAL R.P.M. dial settings indicated for the power line frequency being used.

(3) Turn the RANGE switch to the range required to make these settings.

(4) Set the R.P.M. dial to the exact HIGH CAL R.P.M. dial setting indicated by the calibration chart.

(5) Adjust the HIGH CAL screw until the ON/OFF pattern of the neon CALIBRATION indicator light stops or nearly stops. The light does not have to be completely off.

(6) Set the R.P.M. dial at the exact LOW CAL R.P.M. dial settings indicated on the calibration chart.

(7) Adjust the LOW CAL screw until the ON/OFF pattern of the neon light stops or nearly stops. The light does not have to be completely off.

(8) Return the R.P.M. dial to the HIGH CAL R.P.M. setting. Repeat the above steps if the neon light blinks on and off too quickly.

(9) The R.P.M. dial is now calibrated to within 1 percent on all scales.

j. Select the range on the RANGE selector switch. The speed limits for each range are marked near the appropriate window.

NOTE

The motor may run at a slightly lower speed than nameplate data indicates. To compensate, set the R.P.M. dial at a flashing rate that is higher than the speed of the motor.

k. Slowly reduce the flashing rate until the first single image is observed. At this point, the flashing rate of the Strobotac will be equal to the speed of the motor. The speed can then be read directly from the R.P.M. dial.

l. Switch to the next higher range when using low or midspeed ranges. Do not move the R.P.M. dial setting. Check to see if the Strobotac is flashing at the fundamental speed of the object being measured. Because the ratio between ranges is six to one, six images will appear at the next higher range if the Strobotac has been set to the design speed.

m. Secure the Strobotac after use. Push the reflector down against the panel Keep the reflector cover up to prevent damage to the reflector.

n. Turn the RANGE switch to the 4,000 to 25,000 R.P.M. scale.

o. Wrap the power cord clockwise around the RANGE switch and the reflector.

p. Secure the power cord plug by sliding the ground terminal of the plug onto the pin holder.

q. Lift the Strobotac until it is free to pivot on the handle. Lower it into the case.

r. Slide both locks into place. Ensure that the locks are in place to keep the Strobotac case from falling open.

2-37. POLARIZATION INDEX TEST.

2-37.1 Polarization index (P1) is the ratio of the 10-minute insulation resistance value to the 1-minute insulation resistance value. The change in insulation resistance with the duration of the test potential application is useful in appraising the cleanliness and dryness of a winding. Insulation resistance of a winding will normally increase with the duration of the test voltage. The measured insulation resistance of a dry winding in good condition will reach a fairly steady value in 10 to 15 minutes. If the winding is wet or dirty, the steady value will usually be reached in 1 or 2 minutes. The slope of the curve is an indication of insulation condition. If the winding temperature has changed during the interval between the 1- and 10-minute measurements, the values of the insulation resistance used to determine the PI must be temperature-corrected. Temperature corrections should be made to 25° C using the nomograph in figure 2-18.

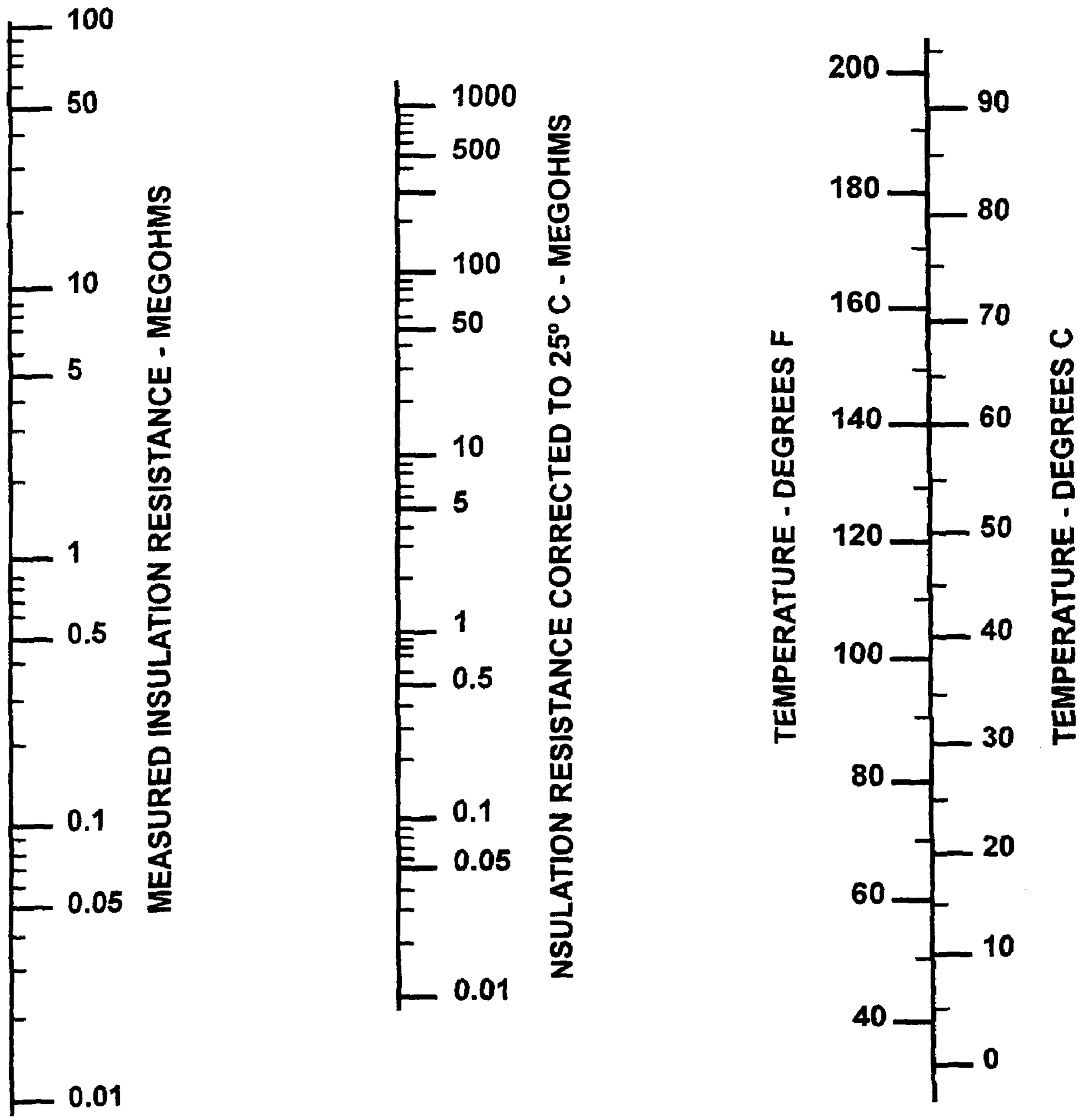


Figure 2-18 Insulation Resistance-Temperature Nomograph

2-37.2 The P1 test may be used as a diagnostic tool at any point in the reconditioning or rewind process to identify the level of insulation contamination. The P1 test should be used during incoming inspection. Used in conjunction with the 1-minute insulation resistance test (paragraph 2-4 or paragraph 2-8), motors that have absorbed moisture or other contaminants will be identified for reconditioning. Requirements applicable to the P1 test are as follows:

a. The PI test should be performed at incoming inspection if the temperature-corrected value of the 1-minute insulation resistance is greater than or equal to the ″Minimum for Operation″ and less than 5 times the applicable ″After Reconditioning″ value in table 3-2.

b. An exception to ″a″ is for motors with a sealed insulation system. If the value of 1-minute insulation resistance of a motor with sealed insulation is greater than or equal to the ″Minimum for Operation″ and less than 500 megohm, a PI test should be performed.

c. For most equipment, including induction motors, the minimum acceptable value of PI is 2.0. There are unique equipments that because of their construction cannot achieve values of PI as high as 2.0. Examples of such equipment are some exciters and dc armatures. The repair activity is responsible for establishing minimum values of PI for these equipments that cannot attain a PI of 2.0.

d. If the polarization index is unacceptable, the equipment should be reconditioned.

2-38. LEXSECO CORE TESTER 1081D.

2-38.1 Core testing, as described in this paragraph, is mandatory for all motors when repairs are accomplished at a depot level or contractor facility. For motors being repaired in a shipboard repair facility, core testing is optional. If a core tester is readily available to the shipboard repair facility, core testing, as described in this paragraph, is recommended. Core testing is a valuable tool that will identify deteriorated stator and rotor cores with unacceptably high core losses. The core is a crucial element in completing the magnetic circuit. High core losses seriously reduce the efficiency of the motor. If a core fails the core test, the feasibility of repair should be evaluated as described in NAVSEA S9086-KC-STM-010/CH 300. If the core is not repaired, either the core or the entire motor should be replaced. If immediate repair or replacement is not possible and the core is still viable, the core may be rewound for use on a temporary basis while a permanent replacement is obtained. The end user should be advised of this condition since the motor will have a reduced life due to an increased operating temperature. A core test should be performed prior to burnout, stripping, and cleaning of the core. In this way, the time and effort to strip and clean the core can be saved if the test shows an unacceptable core. By the same token, a core test should also be performed after stripping and cleaning to ensure that the core was not damaged during the process. A core test should be performed on motors which are to be reconditioned if core damage is suspected.

2-38.2 To perform a core test, proceed as follows:

a. A core tester such as a LEXSECO 1081 or equivalent shall be used.

b. If a core tester is not available, the following loop tests may be conducted to determine armature and stator core acceptability. Keep records of all data collected.

c. Initial ac stator core test made prior to stripping and cleaning.

   (1) Using the 1/64th scale on an engineer’s rule, measure the stator core length (CL), core depth (CD), core bore diameter (CID), and slot depth (SD).

   (2) Effective stator core length is obtained as follows: *CL = Measured core length x 0.80*

   (3) To determine the stator core depth, measure from the bottom of the coil slot to the core’s outer circumference.

   (4) *Effective core cross section area = (CL) x (CD).*

   (5) *Estimated voltage per turn = 0.26 x core area.*

   (6) The number of cable turns to be placed through the stator core = supply voltage divided by the estimated volts per turn.

   (7) *Effective stator core diameter (ECD) = CID + (2SD) + CD.*

   (8) *Ampere turns (AT) = 45 x ECD*

   (9) *Current required = AT/Turns*

   (10) Select a cable size that has a current rating not less than that required to conduct the test as is calculated in step (9) above.

(11) Wrap the required number of turns of insulated cable (calculated in step (6)) around the stator axially (i.e., each cable loop or turn should be passed through the ID of the stator and then looped back over the OD of the stator).

(12) Energize the cable to the supply voltage value and measure the current.

(13) After 1 or 2 minutes with the cable energized, feel the surface of the core, identify one or two of the hottest areas, mark with chalk and designate them as hot spots. Determine also, and mark, an area which is closest to room temperature. Designate this as a cold spot. Deenergize the coil. See the note for optional temperature measurement technique in step (16).

(14) Attach thermocouples to the areas designated as hot spots and cold spots and cover the thermocouple with plastic sealer (Duxseal). See the note for temperature measurement option in step (16).

(15) Reenergize the coil at the supply voltage value and record the current and temperature of the hot and cold spots at 10-minute intervals for a period of 1 hour unless severe overheating occurs. During testing, a nominal core temperature of 10 to 15° C above room ambient indicates sufficient flux to produce hot spots. Changing the number of cable turns may be required to maintain the core in the desired temperature range. If the temperature is less than desired, remove turns (two at a time) and observe the temperature.

NOTE

An infrared scanner may be used to monitor the temperature as an option.

(16) If, after 1 hour, the difference in temperature between the hot spots and cold spots exceeds 59° F (15° C) or the temperature of the hot spot exceeds 185° F (85° C) at any time during the test, the laminations must be replaced in the high-temperature area. Replacement laminations shall have C-5 core plate in accordance with American Iron and Steel Institute (AISI) surface insulation designations.

2-39. AC DIELECTRIC TEST SET, HIPOTRONICS, INC., MODEL 710-1.

2-40.

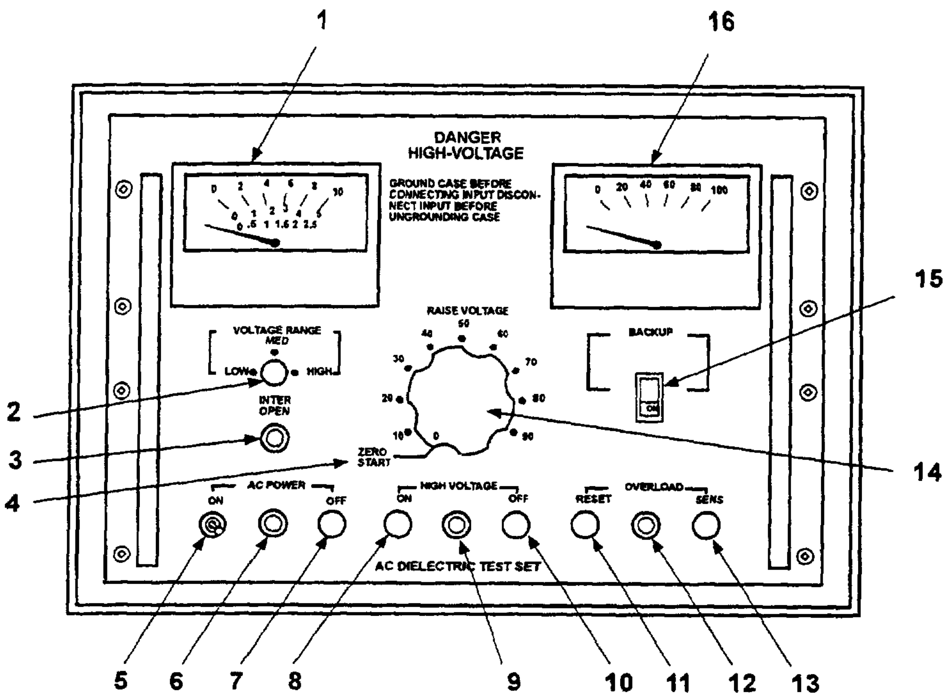
The ac dielectric test set, Hipotronics, Inc., Model 710-1, is used to apply a high-potential test to rewound and reconditioned motors. Testing is performed in accordance with NAVSEA S9086-KC-STM-010/CH 300. This instrument is capable of an output of 10,000 volts and 100 milliamps.

WARNING

DANGER: The output of this instrument can be lethal. It must be used only by qualified personnel. The operator must always be safety conscious.

2-41. CONTROLS.

Figure 2-19 shows the front panel controls and connectors of the ac dielectric test set. Table 2-11 lists the functions of each control and connector.



1. AC VOLTIMETER
2. VOLTAGE RANGE SELECTOR SWITCH
3. INTERLOCK OPEN INDICATING LIGHT
4. ZERO START
5. AC POWER ON SWITCH
6. AC POWER INDICATOR LIGHT (WHITE)
7. AC POWER OFF SWITCH
8. HIGH VOLTAGE ON SWITCH
9. HIGH VOLTAGE INDICATOR LIGHT (RED)
10. HIGH VOLTAGE OFF SWITCH
11. OVERLOAD RESET SWITCH
12. OVERLOAD INDICATOR LIGHT (RED)
13. SENSITIVITY CONTROL
14. RAISE VOLTAGE CONTROL
15. BACKUP CIRCUIT BREAKER SWITCH
16. MILLIAMP METER

Figure 2-19 AC Dielectric Test Set Front Panel Controls

CAUTION

Model 710-1 contains oil-filled transformers. Install the unit on a sturdy, level platform, and strap it down to prevent sliding or tilting. Tilting will cause loss of transformer oil.

2-42. CONNECTIONS.

Use the following procedure to make connections:

a. Ground Connections. Two ground connections should be provided to the unit. Take the following steps to make these connections.

(1) Remove the eight screws from the back of the instrument cabinet.

(2) Remove the outer back cover.

Table 2-11 AC Dielectric Test Set Controls and Connectors

FIGURE 2-19 REF.NO.	NAME	TYPE	FUNCTION
1	AC VOLTMETER	Meter	Three-range. Connected across output of instrument. Allows continuous monitoring of voltage.
2	VOLTAGE RANGE	Selector switch	Selects maximum output necessary for test.
3	INTER OPEN	Indicator light (amber)	Indicates position of interlock switch when switch is installed.
4	ZERO START	Rheostat position	Zero-interlocked. Allows continuous adjustment to variable transformer to raise voltage transformer to increase voltage from 0 to maximum. Must be zeroed to start each test.
5	AC POWER ON	Switch	Turns power on and off.
6	AC POWER	Indicator light (white)	Indicates power on and off.
7	INTERLOCK MOUNTED EXTERNALLY	Pushbutton	When locked in depressed position test cannot be performed.
8	HIGH VOLTAGE ON	Pushbutton	Normally open. Energizes relay to apply power to primary of high-voltage (NV) transformer.
9	HIGH VOLTAGE	Indicator light (red)	Indicates output of HV transformer. Is energized and connected to test leads.
10	HIGH VOLTAGE OFF	Pushbutton	Normally closed. Deenergizes the NV transformer.
11	OVERLOAD RESET	Pushbutton	Resets overload after overload trips.
12	OVERLOAD	Indicator light (red)	Indicates overload tripped. Do not run test when lit. Light will go out when OVERLOAD RESET is pushed.
13	SENS	Control (rheostat knob)	Adjust sensitivity of the trip overload element from minimum to maximum. Should be set at minimum or full clockwise (CW) for test.
14	RAISE VOLTAGE	Control	Interlocked. Allows continuous adjustment of the variable transformer to raise voltage from zero to maximum. Must be at zero to start each test.
15	BACKUP	Circuit breaker switch	Provides backup tripping capability if overload fails to trip.
16	MILLIAMP	Meter	Indicates leakage current between high-voltage line and ground.

NOTE

Note the two studs welded to the cabinet. One is adjacent to the gray power supply cable. The other is adjacent to the black high-voltage cable.

b. Instrument Ground Strap Connection. To connect the instrument ground strap:

(1) Connect the ground strap to the stud adjacent to the gray instrument power supply cable.

(2) Pass the ground strap through the grommet in the instrument back cover that is occupied by the power cable.

(3) Connect the ground strap securely to the ship’s hull.

c. Test Ground Strap. To connect the test ground strap:

(1) Measure a length of ground strap the same length as the black high-voltage cable.

(2) Connect one end of this ground strap to the stud adjacent to the high-voltage line.

(3) Pass the other end of the strap through the grommet occupied by the high-voltage line.

(4) Fit the bitter end of the ground strap with a 25A alligator clamp.

(5) Bend the high-voltage line and its ground strap together, starting 2 feet above the alligator clamps. Tie them together with nylon ties.

(6) Replace the back panel of the instrument.

(7) Replace the eight screws in the cover.

(8) Mount the unit in its permanent position.

2-43. INTERLOCK SWITCH.

The Hipotronics Model 710-1 uses extremely high voltage. The instrument must not be used without proper supervision. An interlock switch may be mounted externally to prevent unauthorized use of the equipment. Use the following procedure to modify the instrument so that an interlock switch may be mounted:

a. Mount a single gang switch box adjacent to the instrument.

b. Remove the back of the instrument.

c. Locate terminals 4 and 5 in the instrument.

d. Remove the jumper from terminals 4 and 5.

e. Connect a length of DSGA-4 cable to terminals 4 and 5.

f. Bring the cable out of the instrument through the gray power cable grommet.

g. Replace the back of the instrument.

h. Lead the DSGA-4 cable from the instrument to the switchbox.

i. Connect the DSGA-4 to the single pole toggle switch, and mount the switch in the switch box.

j. Mount a locking attachment for switches (Hubbell Catalog No. 96062 or its equivalent) over the switch.

2-44. OPERATION.

Use the following procedure to conduct a high-potential test on a rewound or reconditioned winding:

WARNING

Never conduct a high-potential test on a winding that has failed a ground insulation test.

a. Conduct an insulation resistance test (paragraph 2-4 or paragraph 2-8) on the winding before using the high-potential tester. Use a megohm bridge or a megohmmeter. If the 1-minute insulation resistance measurement corrected to 25° C is less than *2 x (1 + E/1,000) megohms* where E is the machine's rated voltage, the winding is not suitable for application of the high-potential test.

b. Erect barricades to keep personnel from passing through the test area.

c. Plug the Hipotronics Model 710-1 into a 115V ac 60-Hz, single-phase outlet.

CAUTION

Ensure that the instrument ground is firmly connected to the ships hull. Connect the ground lead to the instrument and motor.

d. Twist together the line leads of the winding that is being tested.

CAUTION

Twist together the leads of the winding not being tested when testing a two-speed, two-layer winding. Ground the winding not under test.

e. Connect the black high-voltage lead to the winding under test.

f. Connect the alligator clip of a shorting stick to the alligator clip of the ground or to the frame of the motor.

g. Connect the test ground strap to the frame of the winding.

h. Calculate the test voltage for the winding using the design voltage.

New windings: *2E* + 1,000 = *test voltage* where E = design voltage of the winding.

Reconditioned windings: *2/3* (2E + 1,000) = *test voltage* .

i. Select the voltage scale for the test. Use the VOLTAGE RANGE selector to obtain midscale range.

j. Turn the RAISE VOLTAGE control fully counterclockwise (CCW) to zero.

k. Turn the SENS control fully CW to the MIN position.

l. Press the RESET.

NOTE

If there is an interlock switch, it must be on. The amber light will be out.

m. Place the backup circuit breaker in the ON position.

NOTE

The white indicator light should light.

n. Turn the AC POWER switch to ON.

NOTE

The red light in the HIGH VOLTAGE section should light.

o. Press the HIGH VOLTAGE switch ON.

p. Turn the RAISE VOLTAGE control CW to raise the voltage until the calculated test voltage can be read on the ac kilovoltmeter.

q. Apply the test voltage for 1 minute.

r. Reduce the voltage after 1 minute at a rate which will bring the voltage to one-fourth of the test voltage in 15 seconds. Turn the RAISE VOLTAGE control CCW to reduce the voltage.

s. Reduce the voltage to zero by turning the RAISE VOLTAGE control CCW and pressing the HIGH VOLTAGE OFF switch.

NOTE

Failure of the winding under test is indicated by the red OVERLOAD light coming on, by the voltage dropping to zero, and by an increasing current reading on the ac milliammeter.

t. To run another test, return the RAISE VOLTAGE control to zero, push the OVERLOAD RESET, ensure the BACKUP is in the ON position, and push the HIGH VOLTAGE ON switch.

u. Repeat steps p through t.

v. Short the high-voltage lead to the ground strap using the shorting stick.

w. Turn the AC POWER switch off.

x. Disconnect the high-voltage lead and ground strap from the test winding.

y. Make the leads up and stow them on the high-potential tester.

z. Conduct a ground insulation test on the test winding. The ground reading must be in accordance with NAVSEA S9086-KC-STM-010/CH 300.

2-45. AC AND DC DIELECTRIC TEST SET, HIPOTRONICS, INC., MODEL 115-A.

2-46.

The Hipotronics Inc., Model 115-A dielectric test set is used to apply an ac or dc high-potential test to new, rewound, or reconditioned motors. Testing is performed in accordance with NAVSEA 9086-KC-STM-010/CH 300. This instrument is capable of an output of 12,000 volts ac at 0 to 5 milliamps (mA) and 15,000 volts dc at 0 to 50 microamps (µA).

WARNING

DANGER: The output of this instrument can be lethal. It must be used only by qualified personnel.

2-47. CONTROLS.

Figure 2-20 shows the front panel and controls of the dielectric test set Model 115-A. Table 2-12 lists the functions of each control and connector.

WARNING

Both ac and dc jacks are energized when the voltage range selector switch is set to HIGH. To ensure operator safety, an external interlock switch must be

Warning - *precedes*

used at all times. Follow the procedure in paragraph 2-43 to modify the instrument so that an interlock switch may be mounted.

2-48. SETUP.

a. To ensure accurate meter readings, place the instrument on a solid surface so that the meters are at eye level.

b. Secure all external interlock switches and ensure that the AC POWER ON switch is off.

c. Ensure that the case is grounded before connecting input power. A ground post on the front panel may be used for this purpose.

d. Plug the cord into a 115-volt, 50/60 Hz grounded (three-prong) outlet.

e. Turn the AC POWER switch to ON.

WARNING

NEVER conduct a high-potential test on a winding that has failed a ground insulation test.

2-49. OPERATION.

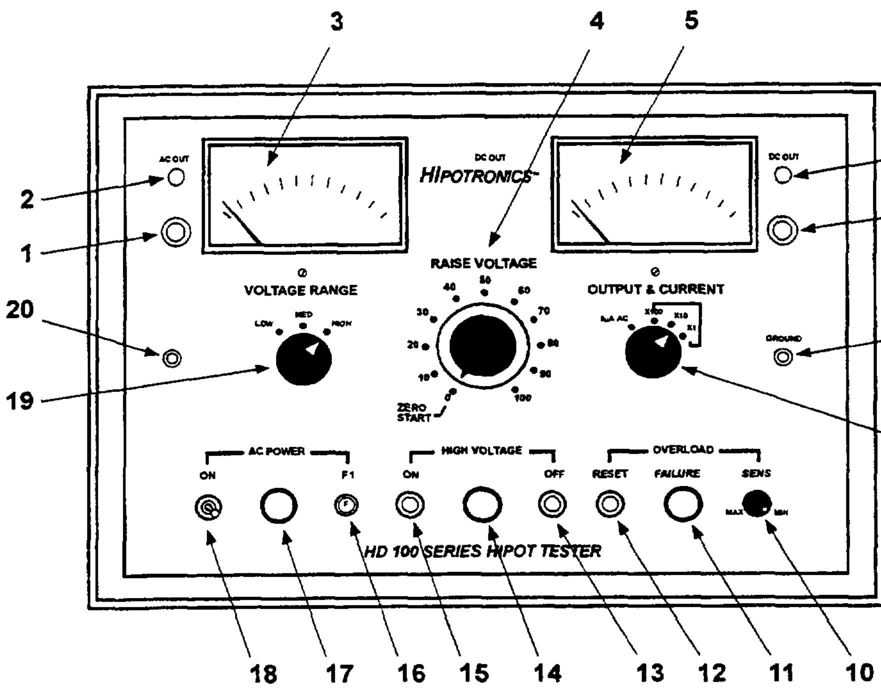
2-50. DC HIPOT TESTING.

NOTE

To ensure that only leakage current from the test sample is recorded on the current meter, remove any other potential sources of leakage in or near the test sample before beginning the test.

a. Set the OUTPUT & CURRENT range selector to the appropriate dc current range.

b. Ensure that the unit is properly grounded and that the RAISE VOLTAGE control is at zero.



1. AC OUTPUT JACK
2. AC MODE INDICATOR LIGHT
3. KILOVOLT METER
4. RAISE VOLTAGE CONTROL
5. CURRENT METER
6. DC MODE INDICATOR LIGHT
7. DC OUTPUT JACK
8. DC GROUND CONNECTOR
9. OUTPUT AND CURRENT RANGE SELECTOR, AC/DC MODE SELECTOR
10. SENSITIVITY ADJUSTMENT
11. OVERLOAD FAILURE LIGHT
12. OVERLOAD RESET BUTTON
13. HIGH VOLTAGE OFF BUTTON (RED)
14. HIGH VOLTAGE INDICATOR LIGHT
15. HIGH VOLTAGE ON BUTTON (BLACK)
16. AC POWER CURRENT LIMITING FUSE
17. AC POWER ON INDICATOR LIGHT
18. AC POWER OFF/ON TOGGLE SWITCH
19. VOLTAGE RANGE SELECTOR SWITCH
20. AC GROUND CONNECTOR

Figure 2-20 AC and DC Dielectric Test Set Front Panel Controls

Table 2-12 AC and DC Dielectric Test Set Controls and Connectors

FIGURE 2-20 REF. NO.	NAME	TYPE	FUNCTION
1	AC OUTPUT	Jack	Connects test lead to equipment for ac hipot test.
2	AC OUT	Indicator light	When light is illuminated, ac mode is selected.
3	KILOVOLT METER	Analog meter	Reads ac or dc voltage on three scales corresponding to the voltage range selector switch (19).
4	RAISE VOLTAGE	Rotary control	Raises voltage to the equipment being tested to the desired level.
5	CURRENT METER	Analog meter	Displays amount of current in ac milliamperes or dc microamperes from equipment being tested. ac is shown in red numbers, dc in black.
6	DC OUT	Indicator light	When light is illuminated, dc mode is selected.
7	DC OUTPUT	Jack	Connects test lead to equipment for dc hipot test.

Table 2-12 AC and DC Dielectric Test Set Controls and Connectors - Continued

FIGURE 2-20 REF. NO.	NAME	TYPE	FUNCTION
8	DC GROUND	Jack	Connects the equipment being tested to ground and completes the high-voltage circuit through the current meter.
9	OUTPUT & CURRENT	Four-position selector switch	Selects between the one ac and three dc current ranges and determines the mode (ac or dc). ac is on red scale, dc on black.
10	SENS	Two-position rotary control	Sets overload control.
11	OVERLOAD FAILURE	Indicator light	Illuminates to indicate leakage current has exceeded SENS setting.
12	RESET	Pushbutton	Resets the overload after failure, turns off FAILURE light, and permits further testing.
13	OFF	Pushbutton	When pressed, deenergizes the high-voltage section.
14	LIGHT	Indicator light	Illuminates when high-voltage section is energized.
15	ON	Pushbutton	Press to activate high-voltage section.
16	F1	Fuse, AC Power Current Limiting	Protects the tester. Access for replacement by pressing and turning the cap counterclockwise.
17	LIGHT	Indicator light, AC Power	Illuminates when tester is connected and turned on.
18	ON	Toggle switch	Turns tester off and on.
19	VOLTAGE RANGE	Three-position selector switch	Selects which scale will be used on the voltmeter.
20	GROUND	Jack	Connects the ac equipment being tested to ground and completes the high-voltage circuit through the current meter.

c. Connect the low end of the test sample to a ground post. The ground lead supplied with the unit may be used for this purpose.

d. Connect the alligator clip of the shielded high-voltage test lead to the high end of the test sample.

e. Set OVERLOAD to desired sensitivity. Refer to paragraph 2-52 for overload adjustment.

f. Press the HIGH VOLTAGE ON pushbutton.

NOTE

If the test sample breaks down, the overload trips and causes the FAILURE indicator to light. Press the RESET button to reset the system. After the RAISE VOLTAGE control reaches zero, connect a ground to the high voltage lead to prevent shock. To resume testing: ensure that the voltmeter is at zero, disconnect the leads from the test sample, and go to step 2-50.c.

g. Increase output voltage to the desired level by turning the RAISE VOLTAGE control.

h. Maintain output voltage at the desired level for the required amount of test time. Note the reading on the current meter.

i. When the test is complete, turn the RAISE VOLTAGE control to zero.

j. Wait for the voltmeter reading to return to zero, then press the HIGH VOLTAGE OFF pushbutton.

WARNING

DANGER: The output of this instrument can be lethal. It must be used only by qualified personnel. The operator must always be safely conscious.

WARNING

Both ac and dc jacks are energized when high voltage is activated.

2-51. AC HIPOT TESTING.

a. Set the OUTPUT & CURRENT range selector to the ac position.

b. Ensure that the unit is properly grounded and that the RAISE VOLTAGE control is at zero.

c. Connect the low end of the test sample to a ground post. The ground lead supplied with the unit may be used for this purpose.

d. Connect the alligator clip of the shielded high-voltage test lead to the high end of the test sample.

e. Set OVERLOAD to the desired sensitivity. Refer to paragraph 2-52 for overload adjustment.

f. Press the HIGH VOLTAGE ON pushbutton.

NOTE

If the test sample breaks down, the overload trips and causes the FAILURE indicator to light. Press the RESET button to reset the system. After the RAISE VOLTAGE control reaches zero, connect a ground to the high voltage lead to prevent shock. To resume testing: ensure that the voltmeter is at zero, disconnect the leads from the test sample, and go to step 2-51.c.

g. Increase the output voltage to the desired level by turning the RAISE VOLTAGE control.

h. Maintain output voltage at the desired level for the required amount of test time. Note the reading on the current meter.

i. When the test is complete, turn the RAISE VOLTAGE control to zero.

2-52. OVERLOAD ADJUSTMENT.

2-52.1 Adjusting the overload point (the amount of leakage current that causes the failure signal to be activated) is important for accurate hipot testing. The HD100 Series hipot testers will test for leakage current at any desired point between 500 µA (maximum sensitivity) and 5.5 mA (minimum sensitivity), depending on the SENS control seating. If AC testing is being performed, do not set the SENS control to the MAX setting, because leakage current in most test samples will exceed 50 µA and repeatedly activate the failure signal.

2-52.2 Adjusting the Overload.

a. Ensure that the unit is properly grounded and that the RAISE VOLTAGE control is at zero.

b. Set the OUTPUT & CURRENT range selector to the appropriate range setting.

c. Connect the low end of the test sample to a ground post. The ground lead supplied with the unit may be used for this purpose.

d. Connect the alligator clip of the shielded HV test lead to the high end of the test sample.

e. Press the HIGH VOLTAGE ON pushbutton.

f. Increase the output voltage by turning the RAISE VOLTAGE control until the desired level of trip current is indicated on the current meter.

g. Turn the SENS control slowly toward MAX until the overload trips and shuts off the high voltage. The FAILURE indicator lights.

h. Turn the RAISE VOLTAGE control to zero. Press the RESET button.

i. Verify the accuracy of the OVERLOAD setting by repeating step 2-52.2.g. Note the reading on the current meter when the FAILURE indicator lights.

j. If the current meter reading matches the value of the desired trip current leakage, turn the RAISE VOLTAGE control to zero and press the RESET pushbutton. If the current meter reading does not match the value of the desired trip current leakage, turn the RAISE VOLTAGE control to zero, press the RESET pushbutton, and begin again at step 2-52.2.f.

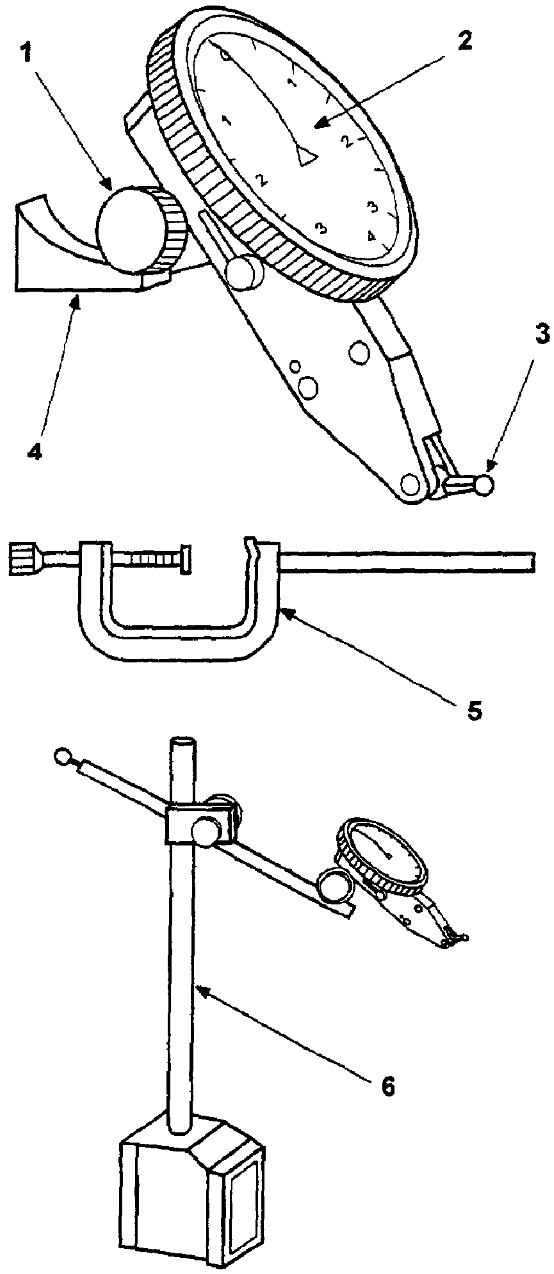
k. Ground the high voltage output lead and disconnect the resistive load.

l. Resume dc or ac hipot testing at step c of paragraph 2-50 (dc hipot testing) or paragraph 2-51 (ac hipot testing).

2-53. TYPICAL DIAL INDICATOR.

2-54.

Dial indicators are used by electricians to measure shaft and bearing runout, as well as coupling alignment. They can be mounted on test stands or mounted directly with clamps or a magnetic base on the equipment to be tested. Figure 2-21 shows a typical dial indicator.



1. SWIVEL CLAMP
2. DIAL
3. SENSOR BUTTON
4. HOLDING BAR
5. CLAMP ATTACHMENT
6. TOOL POST WITH MAGNETIC BASE

Figure 2-21 Dial Indicator (Typical)

2-55. MEASURING SHAFT RADIAL RUNOUT IN PLACE.

See figure 2-22 while measuring shaft radial runout in place.

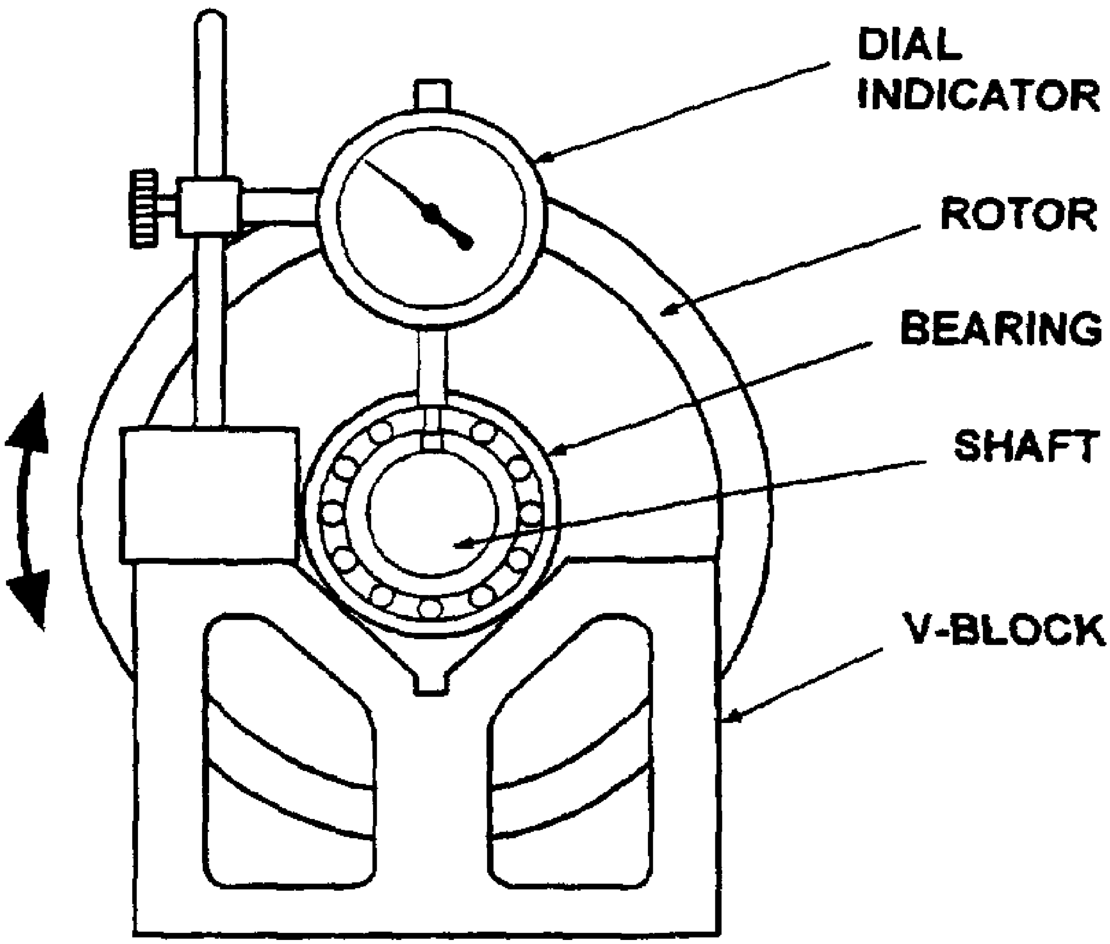


Figure 2-22 Shaft Runout Indication

a. Attach the magnetic base on the motor end bell, deck, or other suitable stationary surface.

b. Mount the dial indicator on the tool post holder.

c. Adjust the tool post holder to permit easy reading of the instrument face.

NOTE

Shaft must be clean and free of corrosion at the dial indicator contact point.

d. Bring the sensor button into contact with the surface to be measured. Tilt the adjustable sensing arm to wipe across the surface being measured. The button should contact the shaft as close to the end as possible.

e. Raise and lower the sensor button with the tool post thumbscrew to determine the full travel of the indicator.

f. With the pointer at midtravel, zero the bezel.

g. Slowly rotate the shaft. The instrument pointer should remain at zero if the shaft is straight.

NOTE

Runout should not exceed 0.002 inch total indicator reading, unless otherwise specified on equipment drawings.

If the bearings have failed, this test must be conducted with the rotor in V blocks after disassembly and bearing removal.

h. Record the measurement on the motor data sheet (mechanical) (figure 2-23).

2-56. MEASURING FACE RUNOUT OF BEARING, INNER RING.

Use the following procedure to measure face runout of bearing inner ring (figure 2-24).

a. Remove the outer bearing cap, if applicable.

b. Mount a magnetic tool holder on the end bell of the motor.

c. Mount the dial indicator on the tool post holder.

d. Bring the sensor button into contact with the bearing inner ring.

e. Raise and lower the sensor button to determine the full travel of the indicator pointer.

f. Leave the pointer at midtravel. Zero the bezel.

g. Rotate the shaft with the sensor button against the bearing inner ring.

NOTE

The maximum allowable face runout should be within 0.001 inch per inch diameter for general bearing applications and 0.0003 inch per inch diameter (maximum) for quiet (NT-4) bearings.

h. Record the measurement on the motor data sheet (mechanical) (figure 2-23).

CAUTION

Take care not to damage the dial indicator. Installed motors may not have clearance for full 360-degree rotation.

2-57. MEASURING FACE RUNOUT OF BEARING OUTER RING.

To measure face runout of bearing outer ring:

a. Use a C-clamp tool post holder to attach the dial indicator to the motor shaft.

b. Attach the dial indicator to the tool post holder.

c. Bring the sensor button into contact with bearing outer race face.

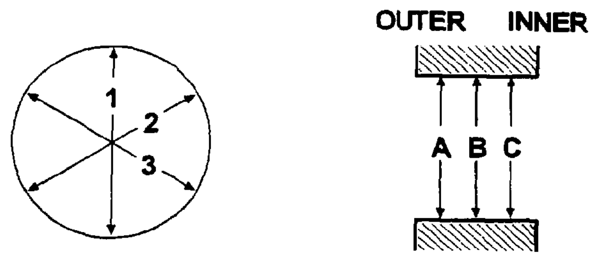
SHIP NAME & HULL NUMBER ______ DATE MONTH/DAY/YEAR

MOTOR LOCATION (I.E., NO. 2 MAIN FEED PUMP, ETC.) ______

HOUSING DIAMETERS

DRIVE END			
	A	B	C
1			
2			
3			

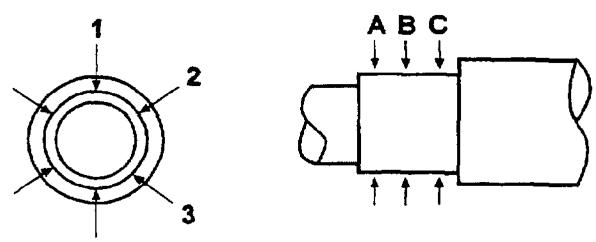
OUTER END			
	A	B	C
1			
2			
3			



SHAFT DIAMETERS*

	DRIVE END			OUTER END		
	A	B	C	A	B	C
1						
2						
3						

* FOR BEARING JOURNAL WIDTH LESS THAN 1 INCH, ONLY SIX READINGS ARE REQUIRED.



Ⓐ SHAFT RADIAL RUNOUT ______

Ⓑ FACE RUNOUT, BEARING INNER RING
DRIVE END ______
OUTER END ______

Ⓒ FACE RUNOUT, BEARING OUTER RING
DRIVE END ______
OUTER END ______

MECHANICAL CONDITION
(LOSS OF LUBE, BURNED, ETC.)
______
______
______
______
______
______

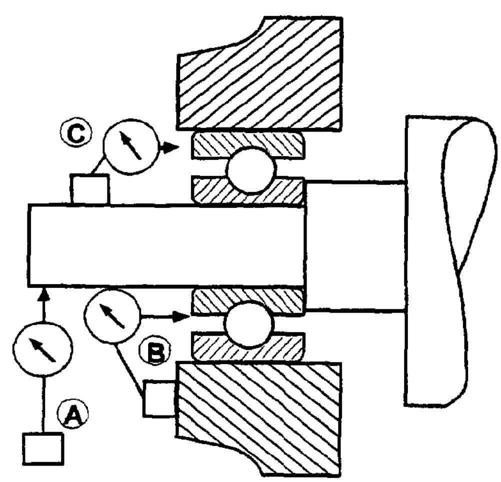


Figure 2-23 Motor Data Sheet (Mechanical)

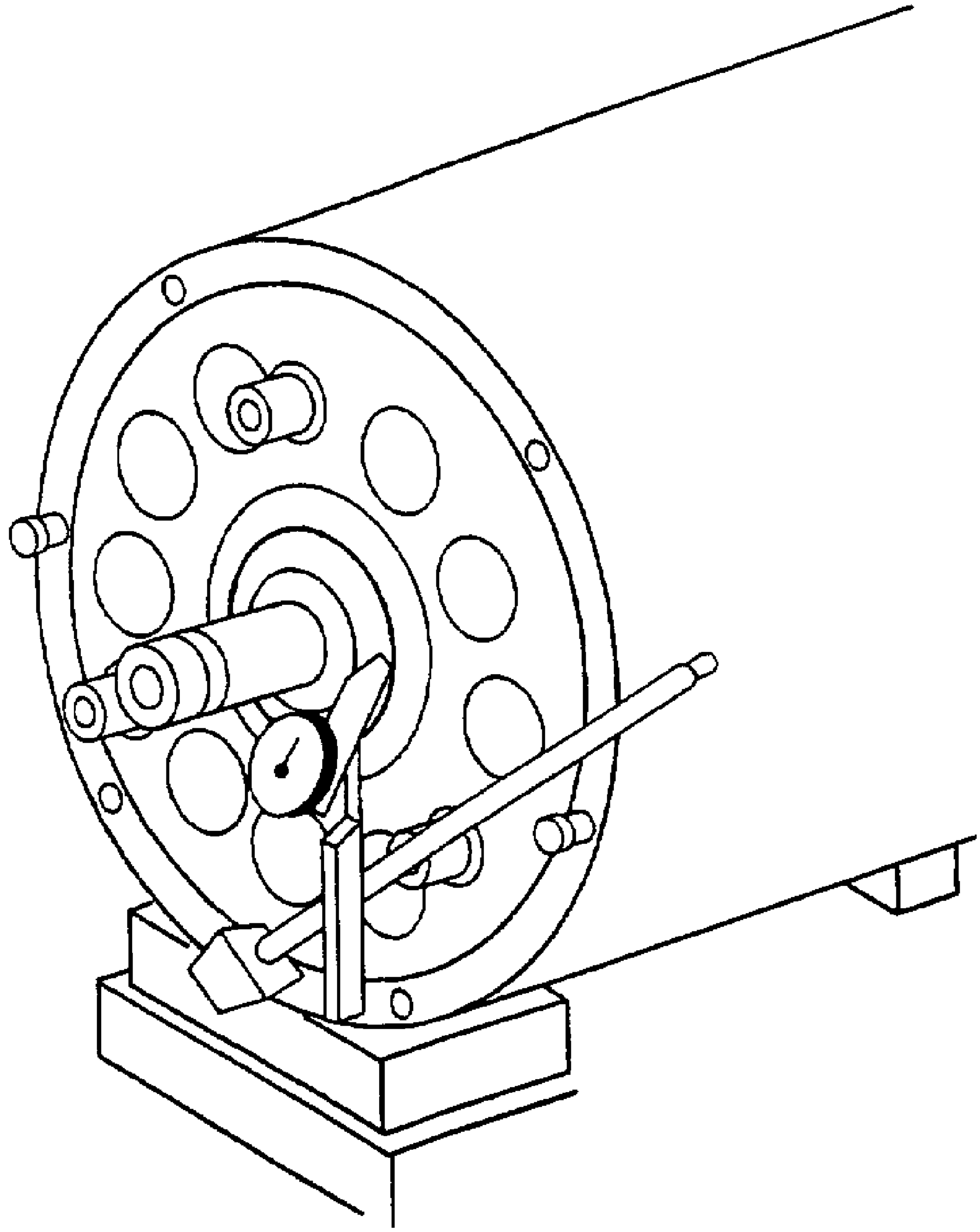


Figure 2-24 Measuring Bearing Inner Rings

d. Raise and lower the sensor button to determine the full travel of the indicator pointer.

e. Leave the pointer at mid-travel. Zero the bezel.

f. Rotate the shaft with dial indicator attached. Check the stiffness of the indicator setup at several positions. Since the gravity load may cause the indicator to shift its position, it is important that the indicator be held rigidly.

NOTE

Runout should not exceed 0.002 inch total indicator reading, unless otherwise specified on equipment drawings.

If the bearings have failed, this test must be conducted with the rotor in V blocks after disassembly and bearing removal.

g. Record the measurement on the motor data sheet (mechanical) (figure 2-23) and note the locations of the maximum and minimum readings.

2-58. TYPICAL BORE GAGE AND RING MASTER.

2-59.

The bore gage is a dial indicating instrument used to make precise measurements inside holes (i.e., bearing housings). Because it is a dial indicating instrument, it can give direct readings. Determination of proper pressure against the walls of the bore does not depend on sense of touch as it does when using a micrometer. Great skill is not required to get consistently accurate results. Figure 2-25 shows a typical bore gage. Table 2-13 describes its components.

2-60. CALIBRATION.

The bore gage indicates deviation from a standard. It must, therefore, be calibrated (zeroed) using a standard. A device called a ring master (or ring standard) is used to zero the bore gage. The ring master is a precision device, ground to the dimension stamped on it.

NOTE

The ring master must be carefully cared for to preserve its accuracy. Do not drop or scratch it. Wipe it clean of all dust, dirt, or grease before use and coat it with 2190 TEP, mineral oil, or a similar product after use to prevent corrosion.

2-61. PROCEDURE FOR USE OF A BORE GAGE.

Use the following procedure to measure a bearing housing with a bore gage:

NOTE

Allow at least 1 hour for temperature stabilization of the bore gage, standard, and housing prior to taking measurements.

a. Remove the bearing housing and clean it thoroughly.

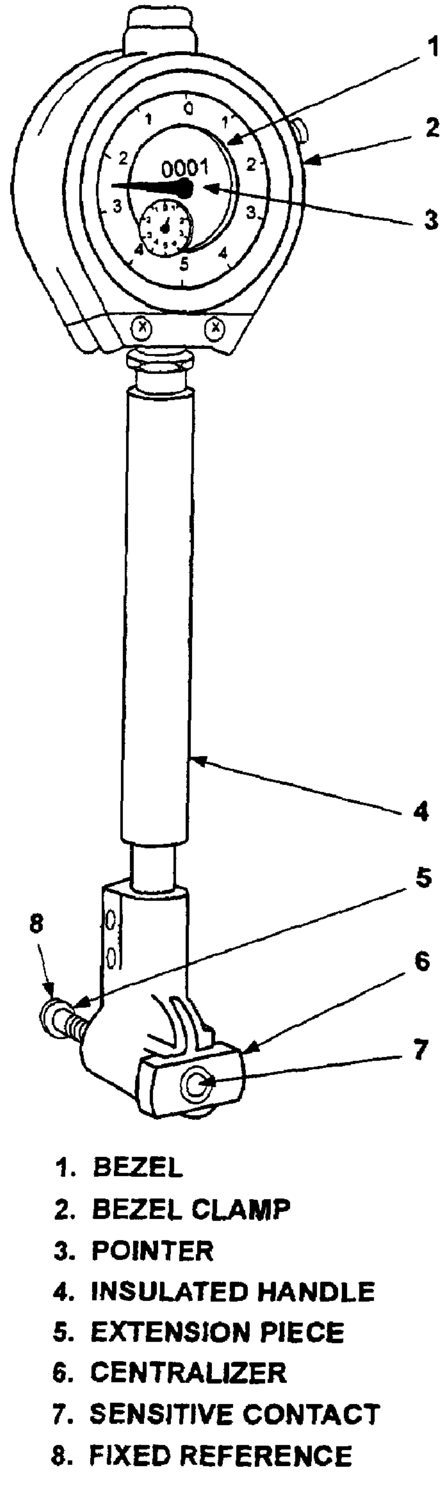


Figure 2-25 Typical Bore Gage

b. Determine the bearing size from the numbers on the bearing or from the technical manual. Consult table 2-14 to obtain the maximum and minimum dimensions of the housing for that size bearing. Record them on the motor data sheet (mechanical) (figure 2-23). For example:

Bearing	Housing Max. ID	Housing Min. ID
308	*3.5442*	*3.5433*

c. Select the ring master for that size bearing. Thoroughly clean the bore of the ring master. Check for scratches, which may cause errors in setting the bore gage. Apply a very light coat of oil to prevent scuffing the surface. Set the ring on a clean, flat surface close to the location of the bearing housing.

d. Select a bore gage of suitable range and an extension piece and locknut to fit inside the ring master. With the gage in the ring, screw the extension outward until the dial indicator pointer on the bore gage rotates one-half to three-fourths revolution. Rock the gage in the ring to check this movement. Gently tighten the locknut to hold the extension in place.

e. Loosen the bezel clamp and rotate the bezel until the zero mark is under the point of maximum travel of the pointer. Check this by rocking the gage.

NOTE

The bore gage compares the dimensions of the housing to the ring standard. If the ring standard has the dimension 3.5442 stamped on it (the maximum allowed by the specification for size 308 bearing), the housing dimensions should lie between the maximum (zero reading on the indicator) and 3.5433 (minus 0.0009 on the dial). If any readings lie outside of 0 and -9, they will be out of specification.

f. Check for ridges, dents, or localized areas which may be out of tolerance. Mark the housing at three interval points, 120 degrees apart. Number these locations. Measure the housing at three different depths at each location with the bore gage. Use a gentle rocking motion of the gage and watch the pointer for the point of maximum travel The point at which the pointer changes direction is the reading to be recorded. On seats under 1 inch wide, six readings are required. Nine readings are required on seats over 1 inch wide.

g. Heat from the operator's hand will cause the gage to drift when the bore gage is being used. Frequently check back to the standard and re-zero the gage as necessary. Add or subtract the readings from the stamped size of the ringmaster when recording the readings.

h. Recheck with the ring master after taking each set of readings. Readings can be presumed to be accurate if the bore gage remains zeroed.

i. Clean, disassemble, and stow the bore gage with a coating of oil on the extension piece. Clean the ring master with a clean cloth. Coat it with 2190 TEP oil, mineral oil, or a similar product.

Table 2-13 Typical Bore Gage Components

FIGURE 2-25 REF. NO.	NAME	FUNCTION
1	BEZEL	Marked in thousandths with 10 divisions between digits. Permits reading to one ten-thousandth of an inch. Bezel has a serrated rim to permit easy adjustment.
2	BEZEL CLAMP	Locks the bezel in place after the instrument is zeroed.
3	POINTER	Actuated by the sensitive contact and indicates the reading around the bezel.
4	INSULATED HANDLE	Since the instrument is sensitive to body heat, the insulated handle reduces the effect of heat from the operator's hand.

Table 2-13 Typical Bore Gage Components - Continued

FIGURE 2-25 REF. NO.	NAME	FUNCTION
5	EXTENSION PIECE	Adapts instrument for measuring holes of different diameters. Adjustment of extension piece automatically sets the instrument at zero. The extension piece locknut locks the extension piece.
6	CENTRALIZER	The centralizer or centering guide keeps the instrument centered in the hole.
7	SENSITIVE CONTACT	Touches the wall of the hole and transmits the readings to the dial indicator pointer.
8	FIXED REFERENCE	Polished steel insert for the extension piece.

2-62. TYPICAL SNAP GAGE.

2-63.

Proper bearing fitup is becoming increasingly important as more quiet motors are used in the fleet. A tight spot in a bearing will overheat and become noisy. A bearing not tracking properly in its races will do the same. This noise is easily detected by sonar equipment, permitting homing in on a ship or submarine that has a defective bearing. Poor journal fit (i.e., size, circularity, and taper) may also cause an otherwise good bearing to become noisy. It may also lead to early failure. The snap gage (figure 2-26) allows measurements of a journal to 0.0001 inch, and its use ensures a proper bearing fit in the journal. Do not rely on handheld micrometers for sufficient accuracy.

2-64. SETTING THE SNAP GAGE.

Use the following procedure to set the snap gage.

CAUTION

Handle standards with extreme care. Keep them on a clean, soft surface.

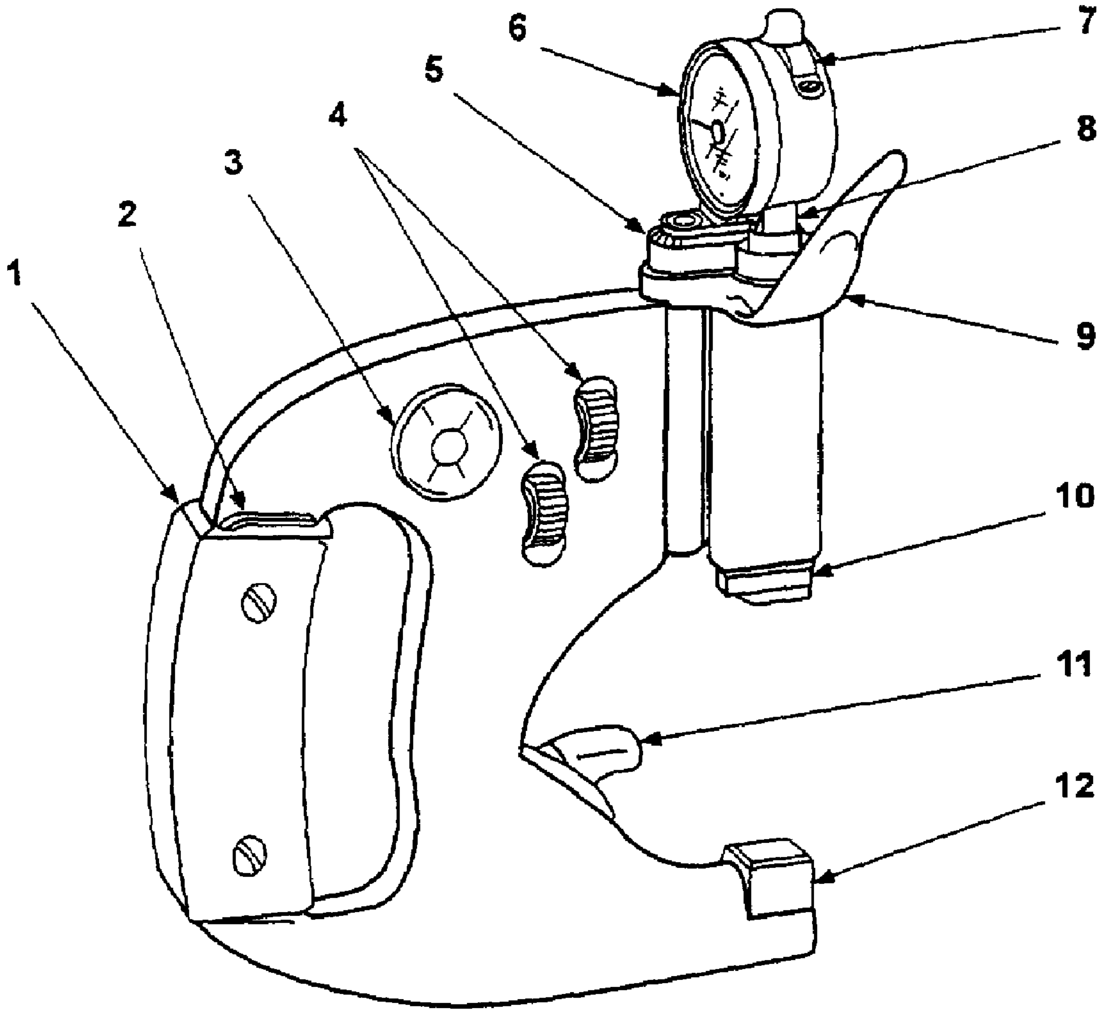
a. Select a plug standard corresponding to the size of the journal to be measured. Use table 2-14 to find correct sizes.

NOTE

Pick up the snap gage only by the insulated handle to prevent inaccuracies caused by body heat.

b. Zero the instrument to the plug size. Compare the plug size to the allowable maximum and minimum to determine acceptable dimensions. Since the instrument is zeroed to plug size, (+) readings are added to the plug standard, while (-) readings are subtracted from the plug standard.

(1) Loosen both locking wheels.



1. INSULATED HANDLE
2. HEX WRENCH
3. AGD TYPE IDENTIFICATION DISC
4. LOCKING WHEELS
5. SIZE ADJUSTMENT WHEEL
6. DIAL
7. BEZEL CLAMP
8. COLLET
9. GUARD
10. UPPER ANVIL (SENSOR)
11. BACKSTOP
12. LOWER ANVIL

Figure 2-26 Typical Snap Gage

(2) Use the size adjusting wheel to raise the upper anvil clear of the standard.

(3) Adjust the back stop to ensure that the standard centers are between the upper and lower anvils.

(4) With the standard on a level surface, bring the snap gage down until the lower anvil contacts the standard. Roll the gage forward until the upper anvil is centered on the standard.

(5) Use the size adjusting wheel to lower the upper anvil until the pointer rotates one-half to three-fourths of a revolution.

(6) Gently tighten both locking wheels.
(7) Loosen the bezel clamp. Rotate the instrument bezel until the pointer is over the zero.
(8) Tighten the bezel clamp and remove the standard.

Table 2-14 Bearing Housing Diameter Limits

	HOUSING INSIDE DIAMETER IN INCHES			
BEARING SIZES	**QUIET BEARINGS**		**STANDARD BEARINGS**	
	MAX.	**MIN.**	**MAX.**	**MIN.**
200	1.1814	1.1811	1.1816	1.1811
201	1.2601	1.2598	1.2604	1.2598
202 and 300	1.3784	1.3780	1.3786	1.3780
301	1.4571	1.4567	1.4573	1.4567
203	1.5753	1.5748	1.5754	1.5748
302	1.6541	1.6535	1.6541	1.6535
204 and 303	1.8510	1.8504	1.8510	1.8504
205 and 304	2.0479	2.0472	2.0479	2.0472
206 and 305	2.4416	2.4409	2.4416	2.4409
207 and 306	2.8353	2.8346	2.8353	2.8346
208 and 307	3.1503	3.1496	3.1503	3.1496
209	3.3473	3.3465	3.3474	3.3465
210 and 308	3.5442	3.5433	3.5442	3.5433
211 and 309	3.9379	3.9370	3.9379	3.9370
212 and 310	4.3316	4.3307	4.3316	4.3307
213 and 311	4.7253	4.7244	4.7253	4.7244
214	4.9223	4.9213	4.9223	4.9213
215 and 312	5.1191	5.1181	5.1191	5.1181
216 and 313	5.5128	5.5118	5.5128	5.5118
217 and 314	5.9065	5.9055	5.9065	5.9055
218 and 315	6.3002	6.2992	6.3002	6.2992
219 and 316	6.6939	6.6929	6.6939	6.6929
220 and 317	7.0876	7.0866	7.0876	7.0866
221 and 318	7.4814	7.4803	7.4815	7.4803
222-319	7.8751	7.8740	7.8752	7.8740
224-320	8.4657	8.4646	8.4658	8.4646
321	8.8594	8.8583	8.8595	8.8583
226	9.0562	9.0551	9.0563	9.0551
322	9.4499	9.4488	9.4500	9.4488
324	10.2373	10.2374	10.2374	10.2362

CAUTION

Use a rocking motion with the snap gage to avoid damaging the anvils.

(9) Use a rolling motion to place the standard back into the instrument. Check the zero.

NOTE

Allow at least 1 hour for temperature stabilization of snap gage, standard, and shaft prior to taking measurements.

2-65. MEASUREMENT.

Use the following procedure to measure the shaft.

a. Mark the shaft in three positions which are 120 degrees apart on the circumference.

b. Remove the instrument from the case.

c. Check the zero with the standard.

d. Using a rolling motion, place the instrument on the journal at position 1.

e. Take three measurements along the axis of the shaft at position 1.

f. Recheck the instrument on the standard.

g. Reset to zero as necessary.

h. Record the readings on the motor data sheet (mechanical) (figure 2-23).

NOTE

Housing bores and shaft seat measurements must be made at three or more locations to check for taper or barreling.

i. Use the same procedure to measure position 2 on the journal at three points along the axis of the shaft.

NOTE

Six readings are required on seats less than 1 inch wide. Nine readings are required on journals over 1 inch wide.

Always check the zero on the standard before starting a set of readings and reset as necessary.

j. Take readings at point 3.

k. Add the positive reading to the standard dimension. Subtract readings from the standard setting plug. An example of this is provided in table 2-15.

(1) In this example, the maximum deviation allowed is 0.0005 inch. No positive reading is permitted in this case. The journal is satisfactory.

(2) All bearing journals must be within the specifications of table 2-16.

NOTE

The shaft surfaces may have ridges, dents, or other localized damage which would prevent a satisfactory bearing fit-up. Use the snap gage to check for the points of maximum and minimum diameters, and for any damage. Record all pertinent information.

Table 2-15 Shaft Measurement Calculations

	MAXIMUM	MINIMUM	
308 Bearing Shaft Limits	1.5753 inch	1.5748 inch	
	A	B	C

Table 2-15 Shaft Measurement Calculations - Continued

	MAXIMUM	MINIMUM	
Snap Gage Readings	- 0.0001 inch	- 0.0002 inch	- 0.0003 inch
A Reading	1.5753 - 0.0001 = 1.5752 inch		
B Reading	1.5753 - 0.0002 = 1.5751 inch		
C Reading	1.5753 - 0.0003 = 1.5750 inch		

Table 2-16 Bearing Shaft Diameter Limits

	SHAFT OUTSIDE DIAMETER IN INCHES			
BEARING SIZES	QUIET BEARINGS		STANDARD BEARINGS	
	MAX.	MIN.	MAX.	MIN.
200 and 300	0.3939	0.3937	0.3939	0.3936
201 and 301	0.4726	0.4724	0.4726	0.4723
202 and 302	0.5908	0.5906	0.5908	0.5905
203 and 303	0.6695	0.6693	0.6695	0.6692
204 and 304	0.7878	0.7874	0.7879	0.7875
205 and 305	0.9847	0.9843	0.9848	0.9844
206 and 306	1.1815	1.1811	1.1816	1.1812
207 and 307	1.3785	1.3780	1.3785	1.3781
208 and 308	1.5753	1.5748	1.5753	1.5749
209 and 309	1.7722	1.7717	1.7722	1.7718
210 and 310	1.9690	1.9685	1.9690	1.9686
211 and 311	2.1660	2.1654	2.1660	2.1655
212 and 312	2.3628	2.3622	2.3628	2.3623
213 and 313	2.5597	2.5591	2.5597	2.5592
214 and 314	2.7565	2.7559	2.7565	2.7560
215 and 315	2.9534	2.9528	2.9534	2.9529
216 and 316	3.1502	3.1496	3.1502	3.1497
217 and 317	3.3472	3.3465	3.3472	3.3466
218 and 318	3.5440	3.5433	3.5440	3.5434
219 and 319	3.7409	3.7402	3.7409	3.7403
220 and 320	3.9377	3.9370	3.9377	3.9371
221 and 321	4.1346	4.1339	4.1346	4.1340
222 and 322	4.3314	4.3307	4.3314	4.3308
224 and 324	4.7252	4.7244	4.7251	4.7245
226	5.1189	5.1181	5.1189	5.1182

CHAPTER 3

IN-PLACE ELECTRICAL AND MECHANICAL TROUBLESHOOTING

3-1. SCOPE.

This chapter contains information for conducting in-place inspection and test procedures to determine the cause and extent of damage to electric motors after a malfunction. Topics include:

3-1.1 In-place test and inspection (paragraph 3-2).

3-1.2 Visual inspection procedures (paragraph 3-4).

3-1.3 Electrical test procedures (paragraph 3-5).

3-1.4 Mechanical inspection procedures (paragraph 3-6).

3-1.5 Bearing runout test procedures (paragraph 3-9).

3-1.6 Operational test procedures (paragraph 3-10).

3-2. IN-PLACE TEST AND INSPECTION.

In-place tests and inspections are performed to determine the actions required to restore a motor to reliable working order and to determine whether the actions will occur in place or in a motor repair shop. The actions required to restore the motor are determined by the cause of failure. In-place tests and inspections should be carried out to the extent necessary to identify the cause of failure. In-place adjustment or repair frequently restores motor operation and eliminates unnecessary disassembly and removal. Whenever possible, motors should be restored or adjusted in place. Table 3-1 provides examples of in-place corrective action.

Table 3-1 Electric Motor Failure Symptoms and In-Place Corrective Action

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
Grounds	Excessive moisture	Dry out insulation if the motor has been exposed to excessive moisture, splashed with water, or been shut down for a long period.
Grounds/Poor operation	Dirt	Clean the motor if it has been exposed to excessive dust or dirt.
Poor operation	Physical damage causing abnormal measurements	Perform tests to determine precise faults and/or abnormal operation.

3-3. MOTOR DATA SHEET.

A motor data sheet (electrical) (figure 3-1) is used to keep a permanent record of important electrical facts about a motor. Record the general condition of the motor during in-place test and inspection.

SECTION 1. NAMEPLATE DATA

EQUIPMENT ____________ USS ____________
MFGR. ____________ TYPE ____________ FRAME ____________
HP ________ INSULATION CLASS ________ TEMP. RISE ________ °C/°F ________
VOLTS ________ AMPS ________ CYO ________ R/M ________ PHASE ________
SERIAL NO. ____________ ADDITIONAL DATA ____________

SECTION 2. INPLACE INSPECTION

CAUTION: OBSERVE APPLICABLE SAFETY PROCEDURES.

SATISFACTORY		UNSATISFACTORY
______	INSULATION RESISTANCE IN MEGOHMS (REFER TO TABLE 3-2)	______
	POLARIZATION INDEX TEST 1 MIN ______ 10 MIN ______ RATIO ______	
______	MECHANICAL CONDITION (REFER TO PARAGRAPH 3-6)	______
______	CONTINUITY OF WINDINGS (REFER TO PARAGRAPH 3-5.1)	______
______	CURRENT BALANCE (USE LIMITS PRESCRIBED IN PARAGRAPH 3-10)	______
______	CONDITION OF BRUSHES AND COMMUTATOR	______
______	CONDITION OF CABLES FROM CONTROLLER TO MOTOR	______
______	CONDITION OF CONTROLLER	______

SECTION 3. INCOMING INSPECTION (GENERAL)

SURGE TEST	1 - 2	______	SAT/UNSAT
	2 - 3	______	SAT/UNSAT
	1 - 3	______	SAT/UNSAT
INSULATION RESISTANCE TO GROUND		______	MEGOHMS
RESISTANCE BALANCE	1 - 2	______	OHMS
WITH DIGITAL OHMMETER	2 - 3	______	OHMS
	1 - 3	______	OHMS

ACTION: RECONDITION ________ REWIND ________

SECTION 4. RECONDITIONING

	AFTER STEPS OF: CLEANING	DRYING
INSULATION RESISTANCE (MEGOHMS)	______	______
PHASE RESISTANCE BALANCE TEST	______	______
SURGE TEST (SAT/UNSAT)		______
DC HIGH-POTENTIAL TEST	______	______

ACTION: VARNISH ________ REWIND ________

SECTION 5. AFTER RECONDITIONING OR REWINDING AND VARNISHING

INSULATION RESISTANCE ______ MEGOHMS
POLARIZATION INDEX TEST 1 MIN ______ 10 MIN ______ RATIO ______
RESISTANCE BALANCE WITH DIGITAL OHMMETER 1 - 2 ______ OHMS
2 - 3 ______ OHMS
1 - 3 ______ OHMS
SURGE TEST ______ SAT/UNSAT
AC HIGH-POTENTIAL TEST ______ SAT/UNSAT
INSULATION RESISTANCE AFTER AC HIGH-POTENTIAL TEST ______ MEGOHMS
NO-LOAD TEST PHASE A ______ AMPERES
PHASE B ______ AMPERES
PHASE C ______ AMPERES

Figure 3-1 Motor Data Sheet (Electrical)

3-4. VISUAL INSPECTION PROCEDURES.

Visual inspection may detect certain readily observed causes of electric motor failure or faulty operation. Note the following when performing a visual inspection:

WARNING

DANGER: Electric motors use high voltages capable of causing death. Use extreme caution when working near the power source and load components. Always use proper safety equipment to include such items as insulated matting and protective gloves. Observe correct tag-out procedures.

WARNING

Take care when using metal tools around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidentally cause a short circuit which could harm personnel or damage equipment.

a. Inspect windings and adjacent areas for mechanical damage, or discolored or burned areas visible through access or ventilation openings.

b. Rotate the motor shaft by hand, if possible. Check freedom of rotation, absence of rubbing or binding, and excessive end or side play.

c. Remove the cover of the terminal box and inspect the leads and the taped lead connections for signs of overheating or mechanical damage. Do not disassemble the taped connections unless there is evidence of damage.

NOTE

A motor winding should be rewound if obvious physical damage or a burned section is detected. It is recommended to rewind a motor when the motor winding insulation is deteriorated. The presence of excessive cracking, flaking of the varnish, or bare copper will indicate deterioration.

3-5. ELECTRICAL TEST PROCEDURES.

After a visual inspection, perform the following tests:

3-5.1 Winding Continuity and Resistance Test. Use appropriate schematic diagrams of the motor being tested to locate the proper windings and connections. Perform resistance measurements with the motor at room temperature using a digital ohmmeter (paragraph 2-15). Perform initial measurements at the motor controller. Record resistance values on a motor data sheet (electrical) (figure 3-1).

a. A resistance value considerably greater than specified limits indicates a lack of continuity and represents an open circuit or a high resistance connection. If this condition is discovered, isolate the motor and measure winding resistance at the motor. Check terminal lugs for proper attachment to motor leads. If the winding resistance remains high, the motor requires rewind.

b. For three-phase motors, conduct a phase resistance balance test. See paragraph 2-15, digital ohmmeter, for the test procedure and resistance balance acceptability criteria. Windings not meeting the balance criteria require rewind.

3-5.2 Insulation Resistance Test.

a. Remove the cover of the terminal connection box and tag the leads, if necessary, before disconnecting them.

b. Measure insulation resistance, using a 500-volt megohmmeter. See paragraph 2-4 and paragraph 2-8 for use of the megohmmeter.

NOTE

Insulation resistance is measured in megohms and is affected by several conditions. These conditions are saturation or contamination with moisture, carbon dust, dirt, or oil. Deteriorated insulation caused by age or by temperatures greater than the class of insulation used can also reduce the value of insulation resistance.

The values of insulation resistance for ac generators and motors in table 3-2 serve as a guide to determine when cleaning, drying, or overhaul is necessary. For further explanation of resistance measurement, see NAVSEA S0986-KC-STM-010/CH 300.

(1) Take resistance measurements on the components of the circuits within the machine. Measure internal leads, collector rings, etc.

(2) Clean any defective parts and recheck insulation resistance.

NOTE

The cause of low insulation resistance is often a defective lead or a deposit of dirt on exposed terminals or brush insulation.

If end bells are removed, bearings *must be replaced.*

(3) Record all measurements on a motor data sheet (electrical) (figure 3-1).

(4) Disassemble the motor, as necessary, if the insulation resistance value is lower than those shown in table 3-2. Disassembly will permit in-place cleaning or removal to the shop for thorough reconditioning. See paragraph 4-16 on moving motors.

3-5.3 Controller and Cable Insulation Resistance Test. If the motor measurements are satisfactory, ensure that cable and controller insulations are in satisfactory condition.

a. Measure the insulation resistance of the cable to ground and between phases with a megohmmeter. Check the motor and motor power cable separately.

b. Record all measurements on a motor data sheet (electrical) (figure 3-1).

Table 3-2 Insulation Resistance for Generators and Motors

AC GENERATORS AND MOTORS OTHER THAN PROPULSION				
	Insulation Resistance (megohms at 25° C) [1]			
Circuit	**Minimum for Operation**	**After Cleaning in Ship**	**After Recndtn**	**After Rewinding**
Stator circuit of generators and motors	0.2	1.0	25	200

Table 3-2 Insulation Resistance for Generators and Motors - Continued

Rotor circuit of wound rotor induction motors	0.1	0.5	25	100
Field circuit of generators or of synchronous motors	0.4	2.0	25	400
Stator circuit of motors with sealed insulation system	2.0	25	500	1000 [2] 100 [3]
DC GENERATORS AND MOTORS (EXCEPT PROPULSION AND AUXILIARY GENERATORS FOR SUBMARINES) INCLUDING EXCITERS				
	Insulation Resistance (megohms at 25° C) [1]			
Circuit	**Minimum for Operation**	**After Cleaning in Ship**	**After Recndtn**	**After Rewinding**
Complete armature circuit [2], [a]	0.1	0.5	1.0	100
Armature alone	0.2	1.0	2.0	200
Armature circuit less armature [2], [b]	0.2	1.0	2.0	200
Complete field circuit	0.5	1.5	2.5	200

[1]Values are for machines rated 500 volts or less. For machines having a rated voltage (E) greater than 500 volts, multiply all values given in the table by E/500.

[2]Minimum acceptable value with winding dry, before and after submergence test.

[3]Minimum acceptable value during 24-hour fresh water submergence test.

[1]Values are for machines rated 250 volts or less. For machines having a rated voltage (E) greater than 250 volts, multiply all values given in the table by E/250.

[2]Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and the complete field circuit may be measured without breaking this connection. If necessary, the armature can be isolated by lifting the brushes.

[a]With brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanent connected field circuit. The values given in the table for the complete armature circuit will apply.

[b]With brushes lifted, the armature circuit, less armature and the complete field circuit, will be measured. The values given in the table for armature circuit, less armature, will apply.

3-6. MECHANICAL INSPECTION PROCEDURES.

3-7.

Basic inspection procedures require three steps:

3-7.1 Perform a general mechanical test and inspection to determine what action is required to restore the motor to reliable working order. When the cause of the faulty operation is determined, correct it to prevent future problems. Visual inspection may detect certain readily observable causes of motor failure or faulty operation. On-the-spot adjustment or repair frequently solves the problem and eliminates unnecessary removal and disassembly of a motor.

3-7.2 If the problem is not easily observed, check the motor, section by section, until the fault is located.

3-7.3 Before conducting repair work, review the evidence to determine all factors that may have contributed to bearing failure. Factors may include lack of lubrication, incorrect mechanical fitup, misalignment, and contaminants. It is also necessary to determine whether defects discovered are the cause or the result of the malfunction.

WARNING

High voltages capable of causing death are used in electric motors. Use extreme caution when working near the power source and load components. Always wear proper safety equipment. Observe correct tag-out procedures.

CAUTION

Take care when using any conducting tool around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidentally cause a short circuit that could damage equipment.

NOTE

It may be necessary to have the machinist's mate or engineman disconnect the coupling of the driven unit to test the motor.

Ensure that the motor is tagged out before grabbing the shaft or removing the coupling.

3-8. VISUAL INSPECTION.

The motor data sheet (mechanical) (figure 3-2) provides a convenient method of keeping a permanent record of important mechanical facts about a motor. Record the general condition of the motor in the spaces provided during in-place test and inspection.

a. Turn the motor shaft by hand or observe coastdown to check for freedom of rotation (figure 3-3).

NOTE

The trouble may be either in the motor or the driven machine (pump, compressor, etc.) if the shaft binds.

b. Listen to the motor as it is coasting down. This is one way of directly tracing the source of vibration, particularly in the case of a large motor generator set. Actual coastdown time depends upon the motor size and its mechanical condition.

c. Cautiously touch the housings to check for excessive heating of the bearings.

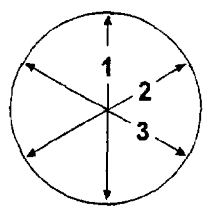
SHIP NAME & HULL NUMBER ______ DATE MONTH/DAY/YEAR

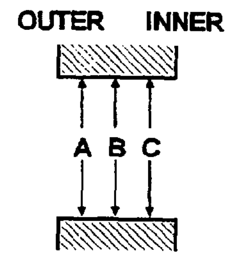
MOTOR LOCATION (I.E., NO. 2 MAIN FEED PUMP, ETC.)

HOUSING DIAMETERS

DRIVE END			
	A	B	C
1			
2			
3			

OUTER END			
	A	B	C
1			
2			
3			

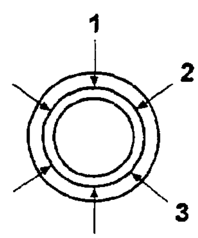


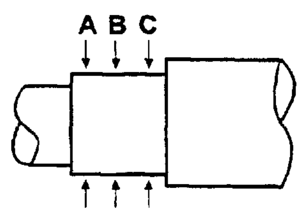


SHAFT DIAMETERS*

	DRIVE END			OUTER END		
	A	B	C	A	B	C
1						
2						
3						

* FOR BEARING JOURNAL WIDTH LESS THAN 1 INCH, ONLY SIX READINGS ARE REQUIRED.





(A) SHAFT RADIAL RUNOUT ______

(B) FACE RUNOUT, BEARING INNER RING
DRIVE END ______
OUTER END ______

(C) FACE RUNOUT, BEARING OUTER RING
DRIVE END ______
OUTER END ______

MECHANICAL CONDITION
(LOSS OF LUBE, BURNED, ETC.)

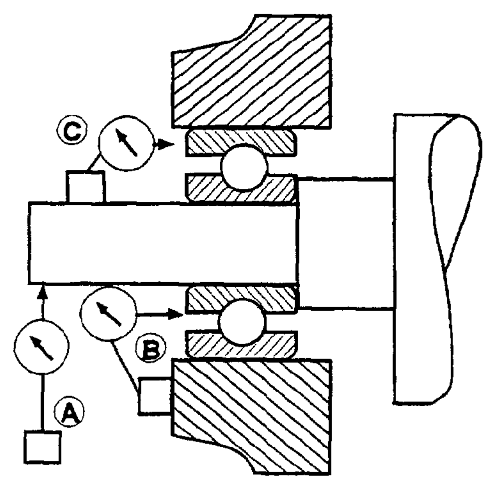


Figure 3-2 Typical Motor Data Sheet (Mechanical)

ROTATIONAL SHAFT MOVEMENT - ROTATE THE MOTOR SHAFT CLOCKWISE AND COUNTERCLOCKWISE TO DETERMINE BINDING

RADIAL SHAFT MOVEMENT - MOVE THE MOTOR SHAFT SIDE TO SIDE OR UP AND DOWN TO DETERMINE BEARING WEAR

AXIAL SHAFT MOVEMENT - MOVE THE MOTOR SHAFT BACK AND FORTH TO DETERMINE ENDPLAY

END PLATE GAP - A MOTOR SHOWING END PLATES NOT PROPERLY MOUNTED. THIS PREVENTS THE ROTOR FROM TURNING

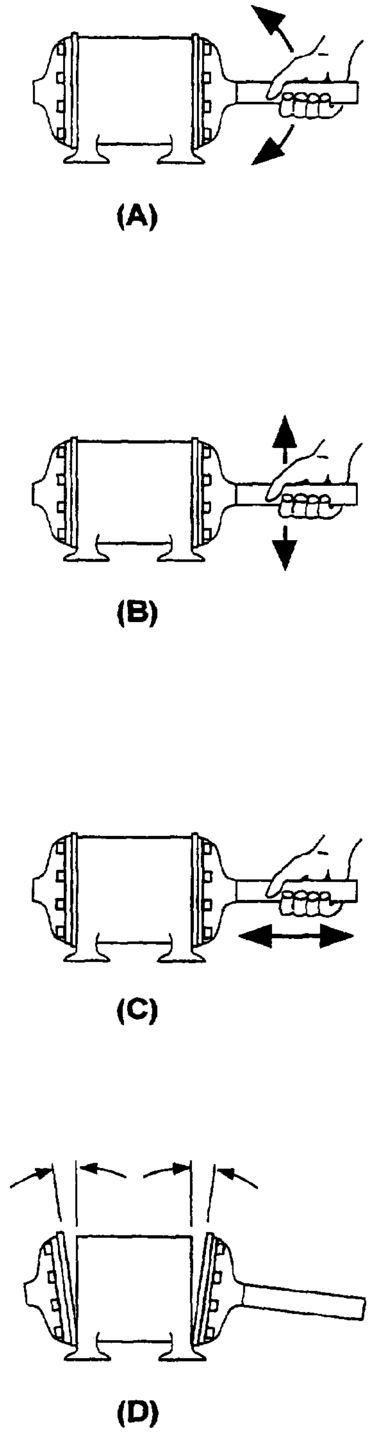


Figure 3-3 Checking Motor Shaft Movement

NOTE

Request that a trained mechanic work on the coupling connecting the motor and the driven equipment.

d. If there is a coupling, check for obvious looseness or distortion.

NOTE

A worn bearing or motor shaft is indicated if the shaft can be moved radially.

e. Check the motor shaft for radial movements (figure 3-3).

f. Check the motor frame for loose or improperly installed end plates and bearing caps.

g. Check for cracked, loose, or missing bolts or capscrews. Ensure that the balancing rings are secure.

h. Check for ″sound shorts″ on sound-mounted equipment like piping, cables, or other loosely connected equipment. Examine the condition of the mountings and holddown bolts. Check the expiration date of the mounts and check for excessive deflection.

i. Make radial and axial vibration records. Use analysis methods described in NAVSEA 0900-LP-060-2020.

NOTE

Not all motor end bells have removable bearing end caps.

3-9. BEARING RUNOUT TEST PROCEDURES.

Use the following procedures to test bearing runout:

a. Measure shaft motion axially using dial indicators. Recommended maximum axial runout is shown in table 3-3.

Table 3-3 Recommended Maximum Axial Runout for Bearing, Shaft, and Housing Assemblies Using Quiet Bearings

BEARING BORE CODE	BEARING BORE		MAXIMUM RECOMMENDED AXIAL RUNOUT OFASSEMBLY
200 & 300 Series	**Inches**	**mm**	
00 to 03	0.3937 to 0.6693	10 to 17	0.0004 inch
04 to 10	0.7874 to 1.9685	20 to 50	0.0005 inch
11 to 17	2.1654 to 3.3465	55 to 85	0.0010 inch
18 to 26	3.5433 to 5.1181	90 to 130	0.0015 inch

Source: NAVSEA S9086-HN-STM-010/CH 244, ″Bearings, Ball and Roller.″

b. Remove one or both motor bearings caps, if they are accessible. Attach a dial indicator magnetic base firmly on the motor frame. Set the contact point on the face of the bearing inner ring (figure 3-4).

c. Rotate the shaft slowly with an even turning force. Be careful that it does not move toward either end.

NOTE

Dial indicator variations in bearing runout measurements at one end of a motor will also indicate bearing misalignment at the other end. Misalignment may occur in inner or outer bearing rings at either end of the motor. The amount of axial vibration caused by misalignment depends on the type of bearing mounting used and the axial and radial loads on each bearing. Excessive runout indicates a problem which may not only cause vibration but may also severely lower the reliability of the motor.

d. Reassemble the motor bearings and caps if bearing runout is within tolerance levels.

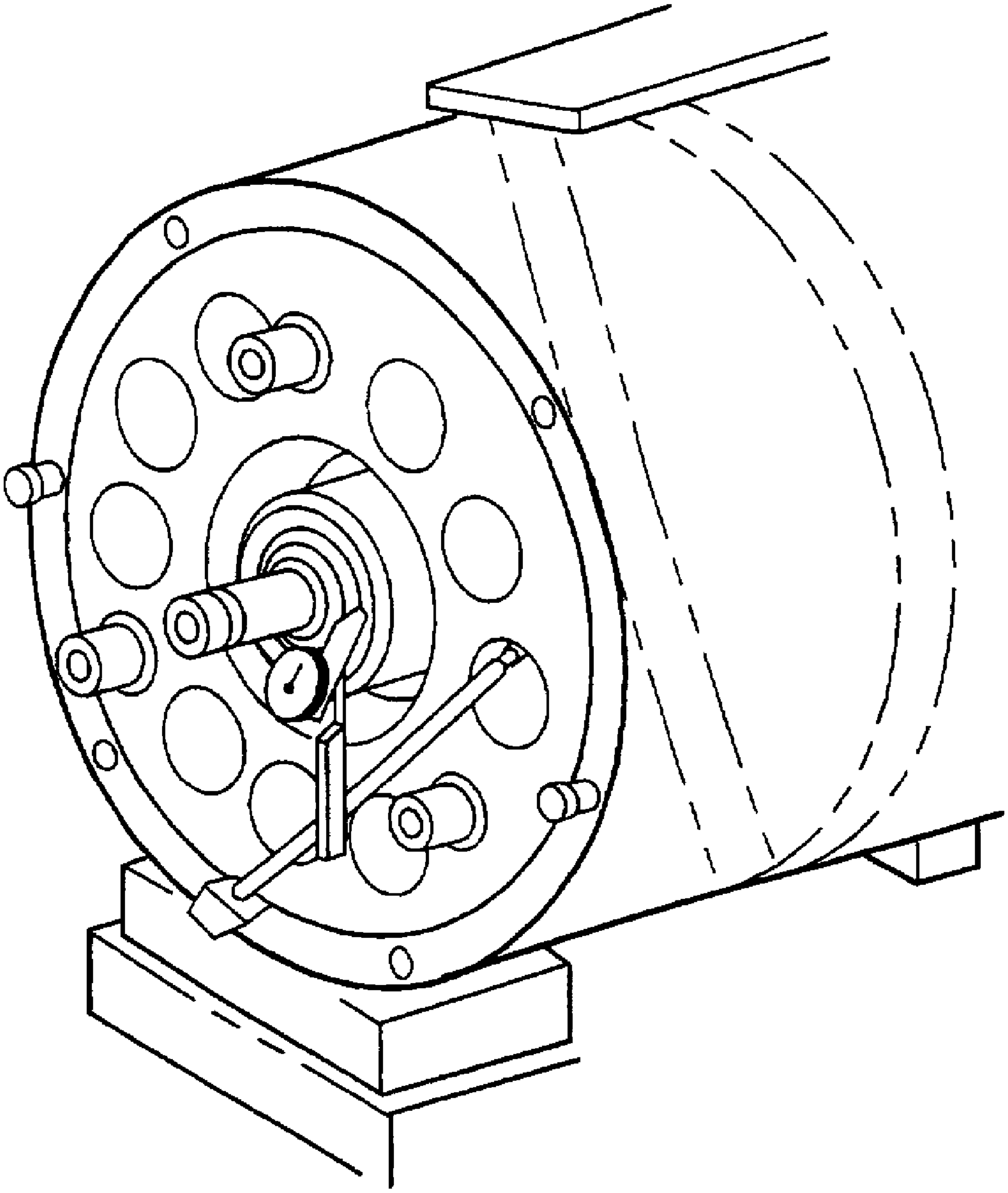


Figure 3-4 Measuring Bearing Inner Rings

NOTE

If the coupling has been removed, test the motor with no load first. Then have the machinist's mate reinstall the coupling and test it with a load.

3-10. OPERATIONAL TEST PROCEDURES.

If the rotor or armature rotates freely, perform an operational test on the reassembled motor after all leads have been connected properly and checked against the appropriate schematic diagram.

CAUTION

Make sure that equipment serviced by the motor may be safely operated before conducting an operational test.

a. Remove the safety tag and energize the circuitry.

b. Start the motor at its normally used pushbutton station.

c. Measure phase currents if the equipment is ac. Use a clamp-on ammeter (paragraph 2-25) or a clamp-on multimeter (paragraph 2-29).

NOTE

The current in any phase, at rated load, shall not differ from the arithmetic average of the maximum and minimum phase current by more than 10 percent for 1 1/2-horsepower motors or less; by more than 7 1/2 percent for 2-and 3-horsepower motors; and by more than 5 percent for motors over 3 horsepower. For submarine motors, at no load, the maximum deviation of any phase shall not exceed 3 percent of the average no-load current.

d. Record all measurements on a motor data sheet (electrical) (figure 3-1).

e. If the current imbalance is excessive, check the incoming phase voltage at the controller with the motor deenergized. Imbalanced voltage indicates improper phase balance from the motor's power source. Incoming voltage cannot vary more than ± 10 percent and must be less than ± 3 percent difference between phases.

WARNING

Electric motors use high voltages capable of causing death. Use extreme caution when working near the power source and load components. Always use proper safety equipment to include such items as insulated matting and protective gloves. Observe correct tag-out procedures.

Take care when using metal tools around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidentally cause a short circuit which could harm personnel or damage equipment.

f. Check the controller and cable for loose or high resistance connections if voltage imbalance is not causing the imbalanced phase currents. Correct any faults.

g. Measure winding resistances using a digital ohmmeter (paragraph 2-15).

h. Record all measurements on a motor data sheet (electrical) (figure 3-1).

NOTE

A motor must be rewound if unbalanced currents are drawn by the motor and they are caused by shorted, grounded, or open sections of the winding; by unequal winding resistances; or the cause is unknown.

i. Deenergize the equipment and reinstall the motor terminal box cover upon completion of the test.

j. If the motor requires repair or overhaul and the problem cannot be corrected in place, remove the motor to the shop. See Chapter 4 on rigging and transporting motors.

CHAPTER 4

RIGGING AND TRANSPORTATION

4-1. SCOPE.

This chapter contains information on the rigging and transportation of electric motors. Topics include:

4-1.1 Preparation for moving (paragraph 4-2).

4-1.2 Rigging fundamentals (paragraph 4-7).

4-1-3 Transporting the motor (paragraph 4-15).

4-2. PREPARATION FOR MOVING.

4-3.

Carefully inspect the motor, and determine the type of mounting employed. Be sure to:

a. Note the size and weight of the motor.

b. Ensure that the motor lifting eyebolts are firmly mounted and secure.

c. Check the motor mounting feet to determine if the foundation bolts are corroded.

NOTE

Only a machinist's mate should work on the coupling connecting the motor and the driven equipment. This applies to all pertinent steps in this chapter.

4-4. MOTOR LOCATION AND REMOVAL ROUTE.

Review the motor's location and nearby machinery and plant layout. Select the best route for moving the motor to the repair activity shop, as follows:

4-4.1 Look for anything that might interfere with motor removal: ladders, handrails, deck plates, etc.

4-4.2 Check headroom. Look for piping systems and overhead barriers that might interfere with movement.

4-4.3 Check the ship's blueprints and manuals and the manufacturer's manuals for information concerning the arrangement of machinery on a particular ship. Be familiar with the location of engineering equipment, and the layout of piping and electrical systems.

4-5. RIGGING INSPECTION.

Check all rigging accessories and weight-moving equipment.

4-5.1 Ensure that accessories are inspected for wear and for suitability for use. Accessories include wire rope and wire rope attachments (e.g., clamps and fittings), hooks, shackles, slings, straps, and hitches.

4-5.2 Inspect weight-holding and weight-moving equipment. Review inspection records maintained by experienced rigging personnel to ensure the safe condition of this equipment. Inspect dollies, pallets, blocks and tackles, chain hoists, comealongs, winches, cranes, and derricks.

NOTE

QA personnel are responsible for ensuring proper testing of padeyes.

4-5.3 Ensure that padeyes have been tested for the weight specified.

WARNING

High voltages capable of causing death are used in electric motors. Use extreme caution when working near the power source and load components. Always wear safety equipment. Observe correct tag-out procedures.

CAUTION

Take care when using any conducting tool around an electric motor with energized lines. Handle tools properly to avoid dropping them. Mishandling can accidently cause a short circuit that could damage equipment or injure personnel.

4-6. DISCONNECTING THE MOTOR.

To remove the motor from its mount:

WARNING

To ensure that it is working properly, use only a voltmeter that has been checked out on a known live circuit.

a. Use a voltmeter to check the motor leads before disconnecting them. Test the ″live″ side first, then the ″dead″ side. Then, retest the ″live″ side.

b. Identify and tag the motor leads before disconnecting them. Disconnect the electrical cables from the motor and controller. Tape and tie them back and out of the way.

NOTE

Dispose of oil according to the individual ship's procedure.

c. Drain all lube oil reservoirs. Close any openings.

d. Cap, mask, or cover all openings to keep out foreign matter.

NOTE

Remove the motor, shock mounts, bedplate or foundation, and auxiliary pump (if any) as a unit whenever possible.

e. Follow the appropriate manufacturers disassembly procedure to uncouple the motor shaft. Use the proper tools.

f. Discard the grid, if the coupling is a grid type.

g. Mark and store the coupling hub cover bolts.

h. Remove the motor foundation bolts. Use the proper tools.

NOTE

Drill or machine-grind badly corroded foundation bolts. Do not chisel them out.

i. Pull or drill out tapered dowel pins which are set at an angle. Remove, identify, and safely store shims from under the motor feet.

j. Place and attach a pipe extension on the shaft to protect it from damage.

k. Carefully inspect each nut and bolt or other fastening device on the whole assembly to ensure that they are properly installed and tight. Do this before handling.

NOTE

The motor is now safely disconnected. All reusable parts and components have been marked and stored. It is ready to rig and transport.

4-7. RIGGING FUNDAMENTALS.

4-8. HANDLING PROCEDURES AND PRECAUTIONS.

Observe the following procedures and precautions in rigging the motor:

NOTE

Ensure that each piece of rigging equipment is capable of holding the entire weight of the unit being rigged and transported.

4-8.1 Know the safe working load of all rigging lines, slings, and hoists. Also know the weight and size of the motor or coupled unit.

4-8.2 Handle coupled units as an assembly. Do not lift the entire weight of the unit at only one point, or by only one component.

4-8.3 Do not attach a sling or other rigging accessory which will distort, bend, or otherwise damage the equipment.

4-8.4 Never lift any component by the part which might rotate, such as the motor shaft.

4-8.5 Never lift a unit by its end bells or mounting flanges.

4-8.6 Avoid bumping and jarring the motor while handling it.

4-8.7 Ensure that supporting structures, such as A-frames, shoring, staging, or rigging, are removed before handling assembled units on a bedplate.

CAUTION

Handle low-noise electric motors carefully. Handling damage can cause high vibration levels and reduce mechanical or electrical reliability.

4-8.8 Handle components carefully to avoid damaging critical parts. Undue stress on noise-critical machinery can damage bearings or result in imbalance or misalignment.

4-9. RIGGING COMPONENTS.

Wire rope is vital in rigging. It can be used in various tackle and lever combinations to form the rigging to lift and move heavy loads. Many different attachments are used for rigging, including wire rope clamps and fittings, hooks, and shackles.

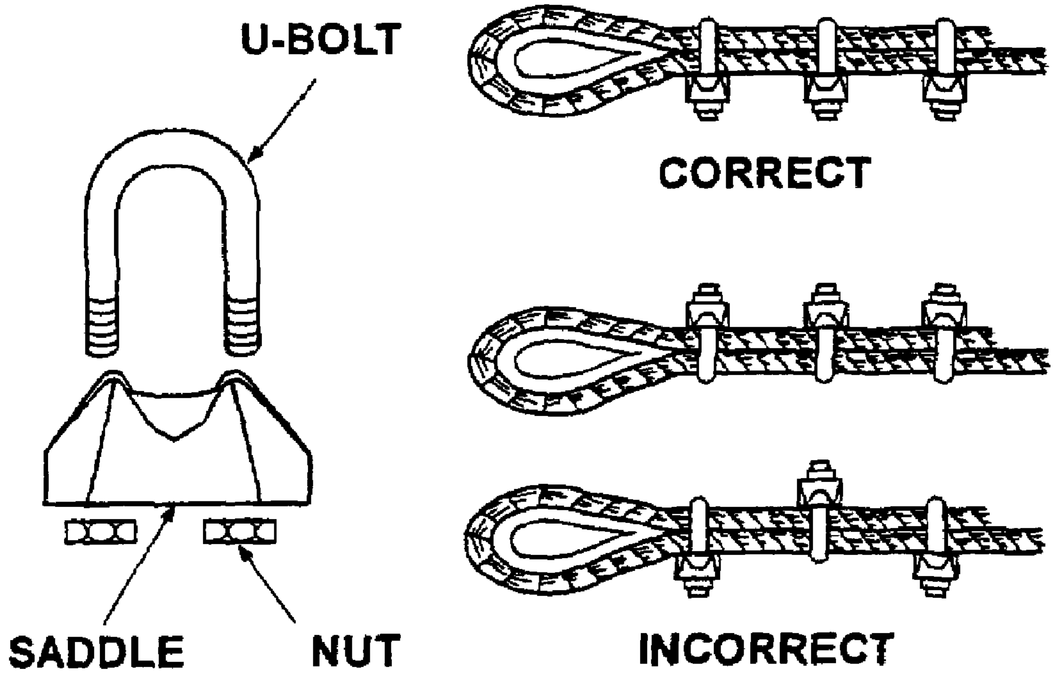
4-10. WIRE ROPE CLAMPS.

Clamps are put on a wire rope to form a loop. The loop may be attached to other wire rope fittings, such as shackles or hooks, so that the wire rope can be affixed to weight-lifting equipment (figure 4-1 and figure 4-2). The wire rope clamp forms a temporary eye splice. A single clamp consists of a U-bolt, saddle, and nuts. There is only one correct method for applying these clamps to wire rope. Follow these precautions when using rigs with wire rope clamps:

4-10.1 Ensure that all U-bolts bear against the bitter end of the rope.

4-10.2 Tighten the clamp after the rope is taut.

4-10.3 Tighten the clamps daily on operating ropes. Inspect the ropes carefully at clamped points.



Clamp Size In Inches	Minimum No. Of Clamps	Amount Of Rope to Turn Back In Inches	Torque In Foot Pounds
1/8	2	3- 1/4	-
3/16	2	3- 3/4	-
1/4	2	4- 3/4	15
5/16	2	5- 1/4	30
3/8	2	6- 1/2	45
7/16	2	7	65
1/2	3	11-1/2	65
9/16	3	12	95
5/8	3	12	95

Figure 4-1 Use of Wire Rope Clamp Fittings

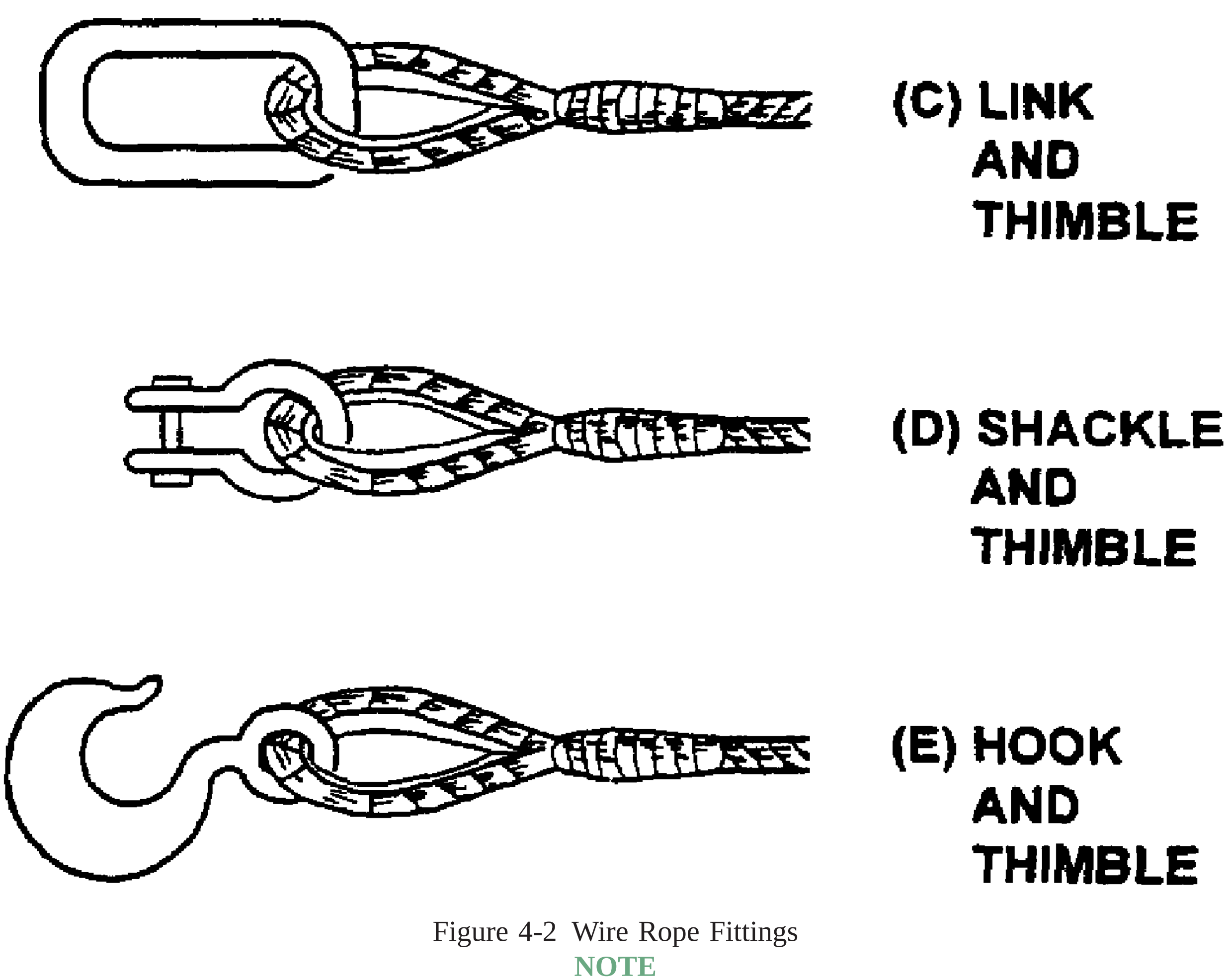


Figure 4-2 Wire Rope Fittings

NOTE

The size is stamped on the saddle between the two holes.

4-10.4 Ensure that the correct size and number of clamps are used to obtain maximum strength in the eye splice.

4-10.5 Space the clamps to provide a good hold on the wire rope.

4-11. WIRE ROPE FITTINGS.

Fittings are attached to the ends of wire rope. They permit easy connection to other wire ropes, chains, padeyes, or heavy equipment. The type of lifting to be done will determine the kinds of fittings used.

4-12. HOOKS AND SHACKLES.

Hooks and shackles are a useful means of hauling or lifting loads. They may be used without tying directly to a load by using a line, wire rope, or chain. When using hooks and shackles, follow these precautions:

CAUTION

Hooks may straighten out and drop their load when overloaded. A hook should NEVER be rebent and put back in service if it has been stretched or spread by overloading. It should be destroyed by cutting it in half with a cutting torch.

a. Shackles should be used for loads too heavy for hooks to handle.

b. Visually inspect hooks before lifting any full-rated load. To determine if a hook can lift a full load, measure the shank of the hook and refer to an appropriate chart showing hook capacity.

c. When there is danger of an open hook catching on an obstruction, use hooks that close.

NOTE

These hooks have rugged positive-action safety latches. The latch has a powerful snap spring that prevents jarring the load from the hook.

d. Use mousing to close the open section of a hook (figure 4-3A) if a safety hook is not available. This will keep slings, straps, etc., from slipping off the hook. Hooks may be moused with rope yarn or seizing wire, or a shackle (figure 4-3B). Make 8 or 10 wraps around both sides of the hook when using rope yam or wire. Make several turns with the yarn around the sides of the mousing. Tie the ends securely to finish off.

e. Mouse shackles when there is a danger of the shackle pins working loose and coming out because of vibration. To mouse a shackle, make several turns with seizing wire through the eye of the pin and around the bow of the shackle (figure 4-3C).

4-13. CHAIN HOISTS.

Chain hoists are a convenient means of hoisting heavy objects. The load can remain stationary without requiring attention when a chain hoist is used. The slow lifting travel of a chain hoist is also advantageous. It permits short movement, accurate height adjustments, and cautious handling of loads. The spur gear hoist (figure 4-4A) is best for ordinary operations which require frequent hoist use, and where a minimum number of personnel are available to operate it. The differential hoist is suitable for light loads, and when occasional use of the hoist is involved (figure 4-4B). Observe the following safety precautions when using chain hoists:

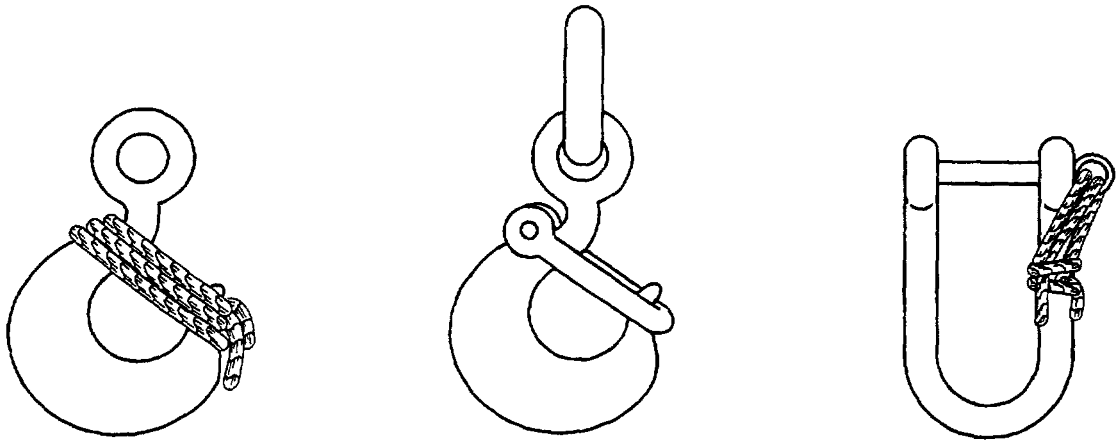


Figure 4-3 Mousing Wire Rope Fittings

CAUTION

The lower hook is usually the weakest part of a chain hoist. Spreading in the hook is a signal to the operator that the chain hoist is nearing the overloading point. Therefore, close observation by the operator is necessary to detect any sign of overloading in time to prevent damage to the hoist. Ordinarily, pull exerted by one or two people on a chain hoist is not enough to overload it.

a. Always inspect the chain hoist’s mechanisms before use to ensure safe operation.

b. Replace any hook that shows signs of spreading or excessive wear.

c. The chain hoist has probably been overloaded if the links of the chain are distorted. In such cases, do not use the hoist, and see that it is condemned and removed from service immediately.

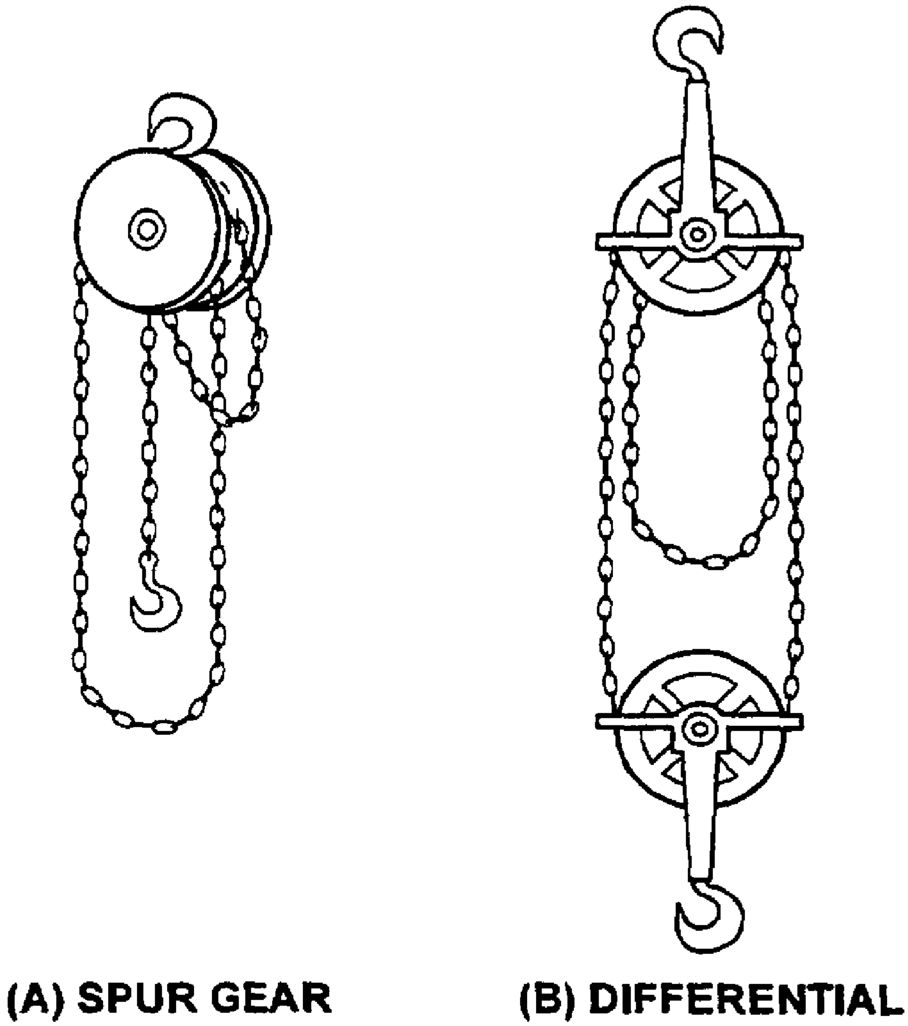


Figure 4-4 Types of Chain Hoists

4-14. WINCHES.

Winches are frequently used as a power source for hoisting rigs, particularly for heavy-duty derricks. A winch is a device for hoisting or hauling materials or objects. It has one or more drums on which line or wire rope is wound. Hand-operated and engine-driven winches are available. A single-drum, hand-operated winch is suitable for lifting light loads. Single-drum hand-operated winches are available in capacities such as 2, 5, 6 and 15 tons (figure 4-5). Hand-operated winches are generally mounted near the foot of the rig, where they can be operated efficiently.

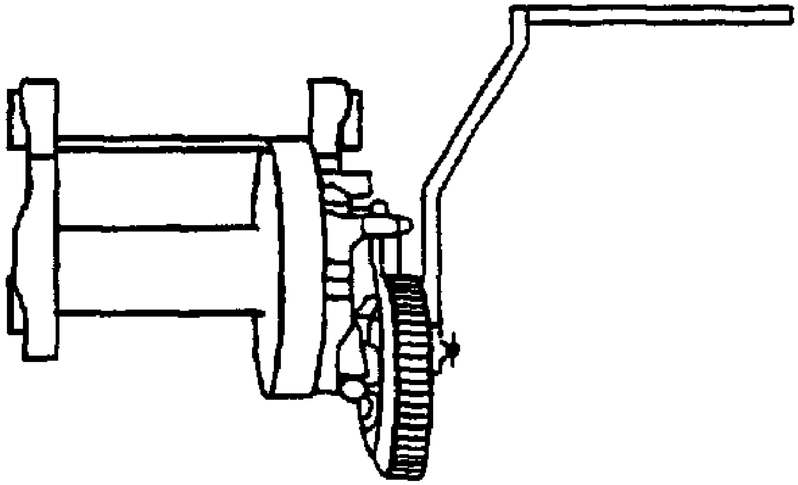


Figure 4-5 Single-Drum Hand Winch

4-15. TRANSPORTING THE MOTOR.

WARNING

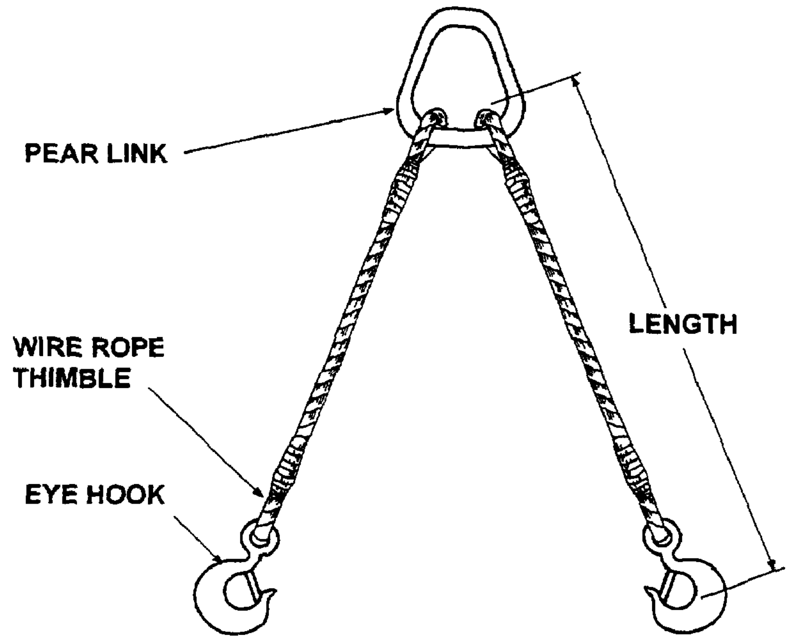
Avoid horizontal lifts which put a bending load on lifting eyes. Use extreme caution if such lifts must be made. They can be dangerous to personnel and equipment.

CAUTION

Have the equipment operator conduct a thorough inspection of all safety devices before starting a job. Hoist controls, brakes, and clutches must be inspected.

4-16. ATTACHING THE RIG.

Various types and combinations of rigs can be used to lift the motor from its foundation mounting. The two-legged bridle sling is one type (figure 4-6). Always consider the safety of the load, personnel, and the environment. Observe the following general procedure:



Dimensions		Fittings			Rated Capacity in Tons (2000 lbs)			
Diameter in Inches	Recm'd Minimum Length	Pear Link One Req'd Code No.	Eye Hooks Two Req'd Code No.	Wire Rope Thimble Two Req'd	Vertical Hitch	30°	45°	60°
1/4	2 '	L-2	23	1/4	2.0	1.7	1.4	1.0
3/4	3 '	L-3	25	3/8	3.8	3.3	2.7	1.9
1/2	3' 6"	L-5	28	1/2	6.8	5.9	4.8	3.4

Figure 4-6 Two-Legged Bridle Sling

WARNING

DO NOT use a heavily corroded eyebolt.

a. Attach a safety hook or shackle to the motor-mounted eyebolts to rig lifting gear to the disconnected motor.

NOTE

Be sure that the tag line is long enough and that it remains free of loops and knots.

b. Attach a steadying tag line to guide the load and prevent it from moving out of control.

WARNING

Before giving a hoisting signal, check to ensure that all members of the crew have removed their hands from slings, hooks, and loads. See that all personnel are clear of the lifting rig and tag lines, and that loose parts or objects are properly secured.

Know the load capacity of the rig being used. Ensure that its capacity is not exceeded.

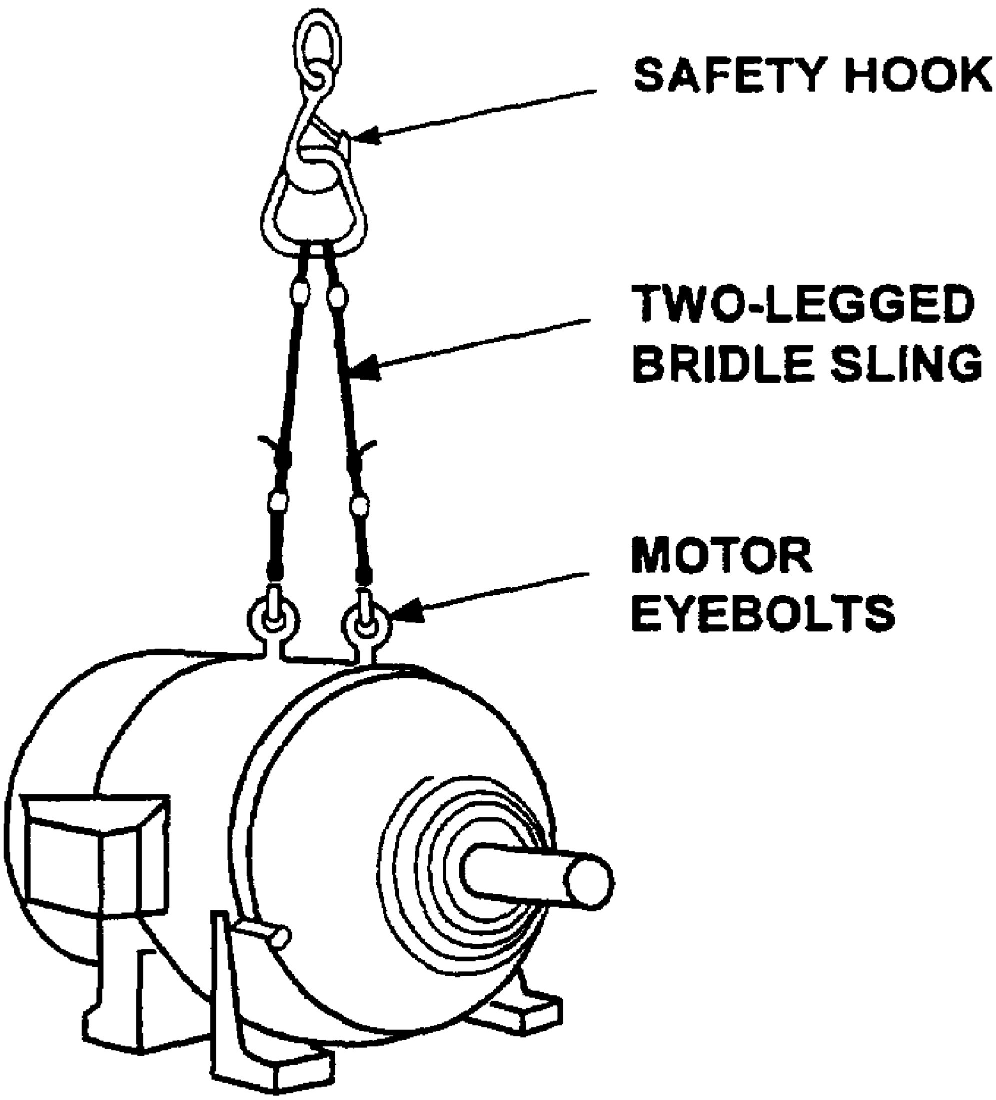


Figure 4-7 Two-Legged Bridle Sling Lifting Motor with Safety Hook

c. Ensure that the hoist equipment operator knows what is to be done.

d. Ensure that each crew member wears the proper safety apparel (e.g., hard hats, gloves, and safety boots).

4-17. HOISTING.

When hoisting, follow these procedures:

a. Raise a heavy load a few inches. Let it hang for a moment to see if the load is balanced before continuing the lift. Be sure that the brakes of the hoist function properly. Watch the load as it is hoisted (figure 4-7).

b. Gently lift the motor and recover any shims which might be under the mounting feet. Shims must be tagged, identified, and stored.

CAUTION

Do not use a hammer to remove the coupling.

c. Place pallet on the deck where the motor can be temporarily lowered for removal of the shaft coupling.

d. Stop the motor before it is completely lowered and wrap the shaft with cotton waste. Bolt a pipe extension to the shaft for protection.

4-18. TRANSPORTATION.

Various methods of transporting the motor may be used after it has been disconnected and lifted from its foundation mounting. A dolly is preferred. Other methods may be used, depending on the size and weight of the motor. Pallets and rollers make the movement of heavy loads easier. Skids with rollers may also be used. The pallet or skid can be dragged along by attaching a fiber or wire rope rig and a winch or come-along at some distant padeye. Use the following general procedures:

WARNING

Make sure that all deckplate openings have been roped off along the transportation route.

a. Use a dolly to transport the motor, if possible. Use the welded test-pulled padeyes located throughout the ship if the motor is too large.

b. A motor can be moved through the ship by ″yard and stay″ rigging when a dolly cannot be used. Two hoists are needed to yard and stay.

(1) Inspect the padeye of the motor to ensure that it is in good condition.

(2) Attach one shackle in the padeye which is capable of passing the clevis pin to two other shackles.

(3) To the shackle in the motor padeye, attach two shackles capable of receiving the hoist hooks.

(4) Rig one hoist and fall directly over the motor. This hoist is the yard hoist (figure 4-8A).

(5) Pass the hoist hook through one shackle and mouse the hook.

(6) Rig a second hoist a few feet downstream from the first. The distance from the first hoist will depend on the overhead height and length of the hoist. this is the stay hoist (figure 4-8A).

(7) Pass a second hoist hook through the second shackle and mouse the hook.

(8) Lift the load with a yard hoist (figure 4-8B).

(9) Heave in the stay hoist (figure 4-8C).

(10) Slowly slack the yard and transfer the motor to the stay as the stay hoist takes the strain.

NOTE

The stay becomes the yard for the second move when the stay has the motor weight (figure 4-8D).

(11) Move the original yard downstream from the original stay when the yard is completely slack (figure 4-8E).

(12) Continue moving the hoist until the motor is topside or in position to be lifted over the side.

NOTE

Use either nylon lifting straps or a net around the motor when the motor does not have lifting eyebolts.

c. Ensure that knots do not slip when using nylon straps. Use bowline, square, clove, and barrel hitch knots where appropriate.

d. Use a net under the load for additional safety.

e. See that all rigging gear is returned or properly stored when not in use.

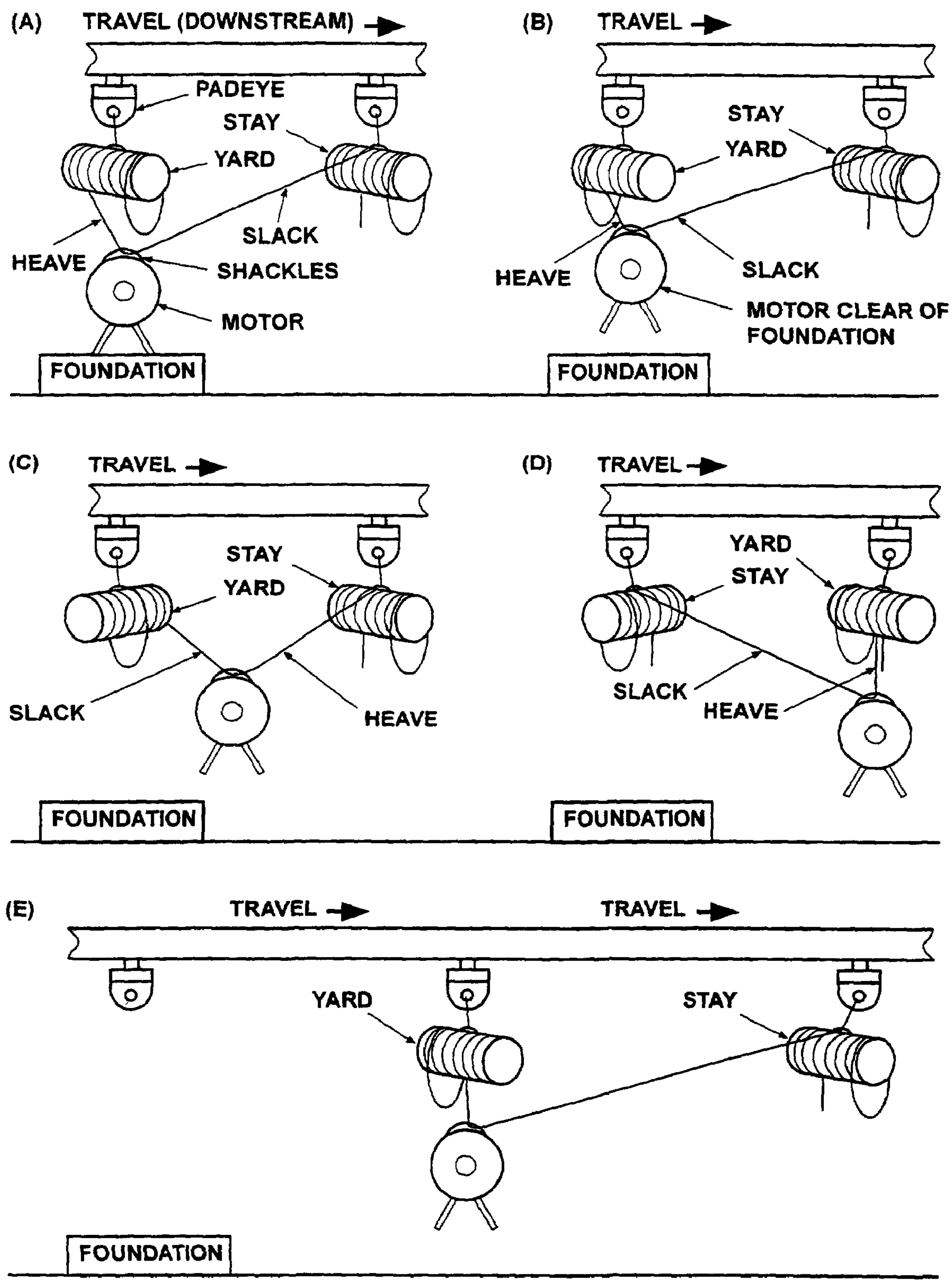


Figure 4-8 Yard and Stay Method

4-19. MOTOR ROTOR TRANSPORT.

Follow these steps when moving a motor rotor:

NOTE

Follow the safety precautions discussed in paragraph 4-8 when only the motor rotor is being transported.

4-19.1 Protect the rotor shaft with cotton waste and a pipe extension.

NOTE

Special protective fixtures for rotor shafts are constructed so they can be used on a variety of rotor shafts. A shaft protection fixture (figure 4-9) is made of a circular plate that fits flat against the motor end bell with a hole in it through which the rotor shaft would extend. An oversized piece of pipe or rigid tubing is welded to the center of the plate and perpendicular to it. Cotton waste is placed around the rotor shaft prior to placing the shaft protection fixture around the rotor shaft to protect it from burrs, nicks, and scratches.

4-19.2 Use rotor slings that have been fabricated ahead of time. The rotor sling is used to lift the shaft protection fixture.

NOTE

Properly made rotor slings will accommodate several size rotors. Figure 4-10 shows a typical rotor sling. The sling has an eye on each end and is made with either a hand or mechanical splice.

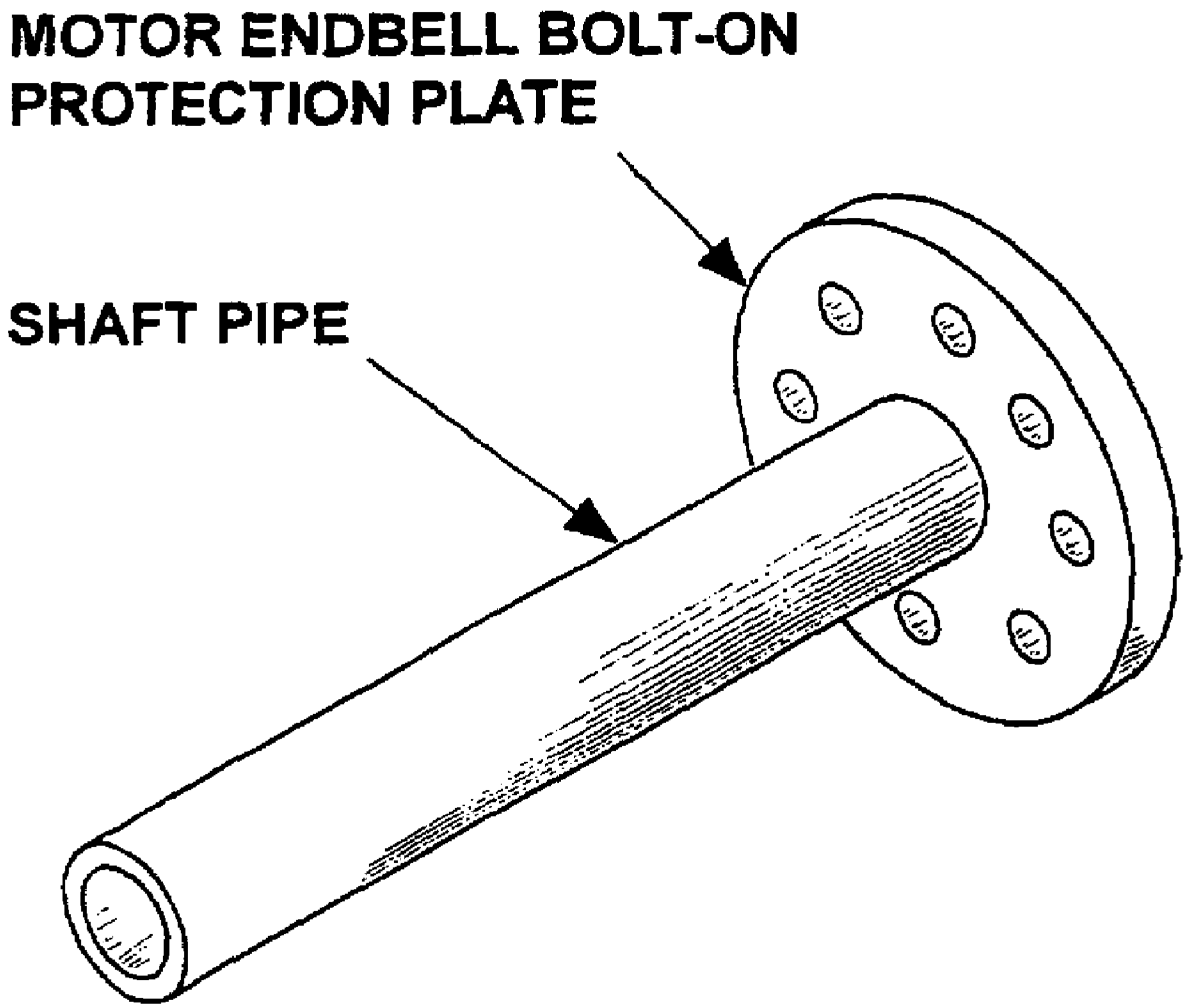


Figure 4-9 Shaft Protection Fixture

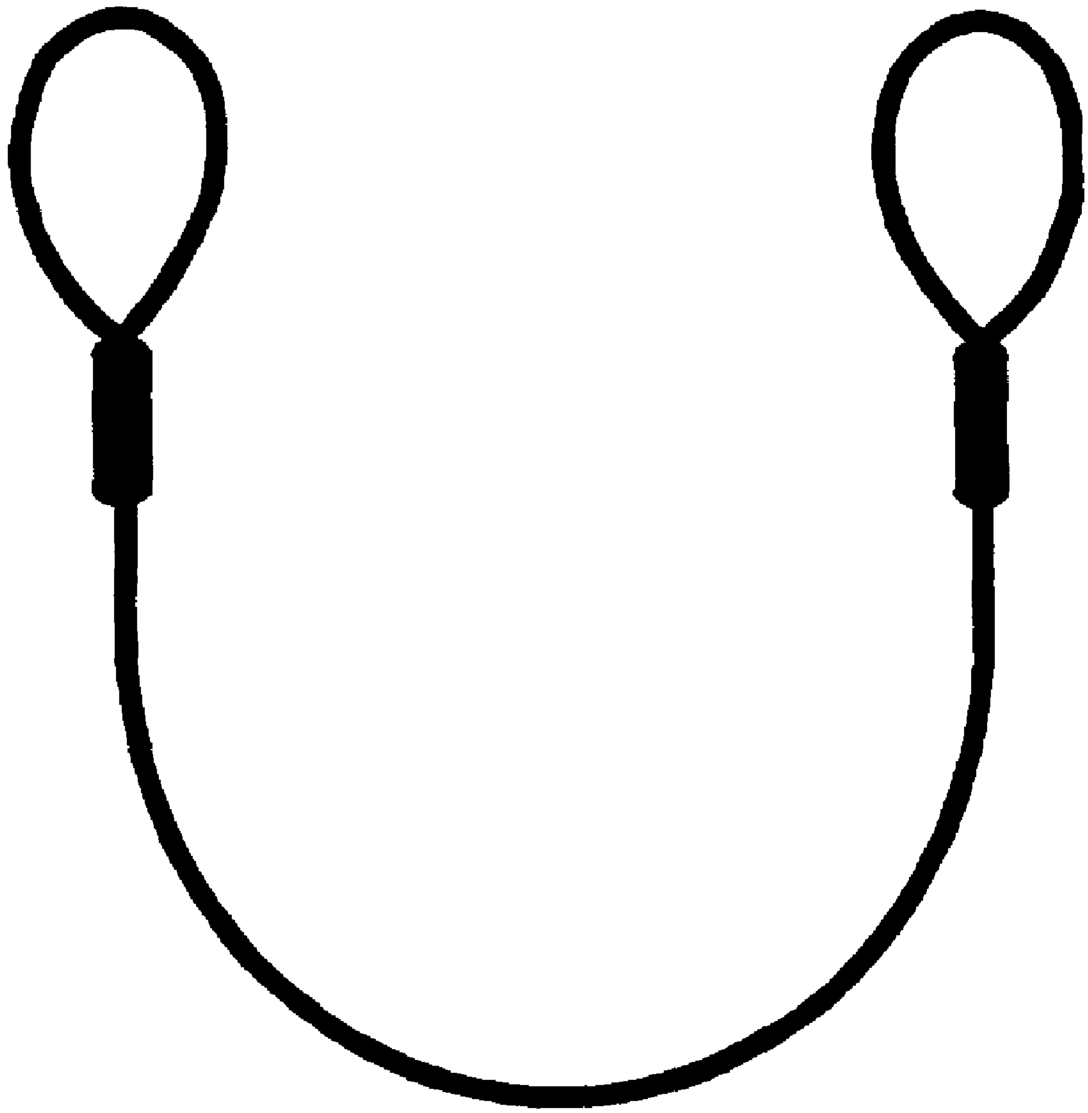


Figure 4-10 Typical Rotor Sling

CHAPTER 5

IN-SHOP ELECTRIC MOTOR INSPECTION AND DISASSEMBLY

5-1. SCOPE.

This chapter contains information on electric motor in-shop inspection and disassembly procedures. Topics include:

5-1.1 Electric shop records (paragraph 5-2).

5-1.2 Initial mechanical inspection procedures (paragraph 5-7).

5-1.3 Disassembly procedure (paragraph 5-11).

5-1.4 Electrical inspection (paragraph 5-18).

5-2. ELECTRIC SHOP RECORDS.

5-3.

The recordkeeping system in an electric motor repair shop must ensure a smooth flow of vital inspection and test information so that motors can be repaired correctly and returned to operation in minimum time. Some of the documentation required will accompany the motor in a work package; other documents must be completed in the shop.

5-4. WORK PACKAGE.

A considerable amount of documentation should accompany the motor, either as part of a work package or separately with the motor. Pertinent documents include:

5-4.1 Automated Work Request (AWR). An AWR is prepared by the tended unit. It should provide all necessary motor identification information, a description of work requested, and the name of a contact person.

5-4.2 Maintenance Planning and Estimating Form. This form, OPNAV 4790/2P, is prepared by the planning and estimating office of the IMA.

5-4.3 Formal Work Procedure (FWP). This document provides clear, concise, and technically correct instructions for performing the assigned maintenance task.

5-4.4 Quality Assurance Documents. The IMA quality assurance office will add to the work package any quality assurance documentation required in the inspection, repair, and testing of the motor.

5-4.5 In-place Mechanical and Electrical Data Sheets. If an in-place inspection (ship check) has been accomplished, the mechanical and electrical motor data sheets should accompany the work package and/or the motor. These records are used to enter the cause and extent of damage to electrical motors noted during any in-place inspection. These two motor data sheets are also used in the shop for in-shop inspections and test records, and include final (postoverhaul) inspections. The inspection determines whether the motor has been properly reconditioned and rewound and is ready for return to operational service.

5-5. WINDING DATA.

In addition to the mechanical and electrical motor data sheets and the records in the work package, the shop must use a motor repair identification sheet. This form is used to record vital winding identification data. The winding must be properly identified and recorded when it needs replacement. All pertinent information must be recorded before any connections are broken and the winding destroyed.

5-6. INSPECTIONS.

The results of the visual, mechanical, and electrical inspections are used to determine the level of effort required to restore a motor. If inspections reveal no discrepancies, the motor should be returned to the ship without restorative action. Some motors will require mechanical work such as bearing housing or shaft restoration. Other motors will require that the windings be reconditioned or rewound.

5-7. INITIAL MECHANICAL INSPECTION PROCEDURES.

5-8. VISUAL INSPECTION.

Refer to the motor data sheet (mechanical) (figure 5-1) for the results of the in-place inspection. Verify all in-place inspection items recorded by making new measurements in the shop. Fill out a motor data sheet, if the motor work package came without one. Examine the motor for the following:

a. Freedom of Rotation. Slowly turn the shaft by hand to check for freedom of rotation (figure 5-2(A)).

NOTE

A worn bearing or shaft is indicated if the shaft can be moved radially.

b. Radial Movement. Check the motor shaft for radial movements (figure 5-2(B)).

c. Axial Movement. Check the motor shaft for axial movements (figure 5-2(C)).

d. Loose End Bells. Check the motor frame for loose or improperly installed end bells/plates and bearing caps (figure 5-2(D)).

NOTE

Runout must not exceed 0.002 inch total indicated reading unless a lower limit is specified on equipment drawings. The shaft must be removed and repaired if the runout exceeds acceptable limits.

5-9. SHAFT RADIAL RUNOUT.

Use a dial indicator to determine shaft runout. See figure 5-1 for placement of the indicator.

a. Use a magnetic base holder or clamps to mount a dial indicator firmly to the motor frame, bench top, or deck.

b. Set the contact point on a smooth exposed surface of the shaft.

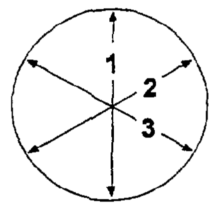
SHIP NAME & HULL NUMBER   **DATE**   **MONTH/DAY/YEAR**

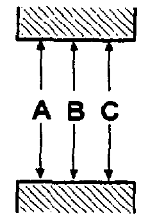
MOTOR LOCATION (I.E., NO. 2 MAIN FEED PUMP, ETC.)

HOUSING DIAMETERS

DRIVE END			
	A	B	C
1			
2			
3			

OUTER END			
	A	B	C
1			
2			
3			

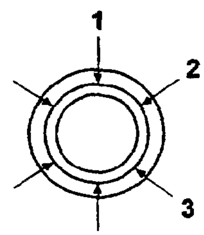


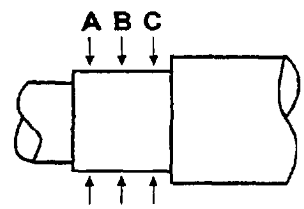


SHAFT DIAMETERS*

	DRIVE END			OUTER END		
	A	B	C	A	B	C
1						
2						
3						

* FOR BEARING JOURNAL WIDTH LESS THAN 1 INCH, ONLY SIX READINGS ARE REQUIRED.





Ⓐ SHAFT RADIAL RUNOUT ____________

Ⓑ FACE RUNOUT, BEARING INNER RING
DRIVE END ____________
OUTER END ____________

Ⓒ FACE RUNOUT, BEARING OUTER RING
DRIVE END ____________
OUTER END ____________

MECHANICAL CONDITION
(LOSS OF LUBE, BURNED, ETC.)
____
____
____
____
____
____

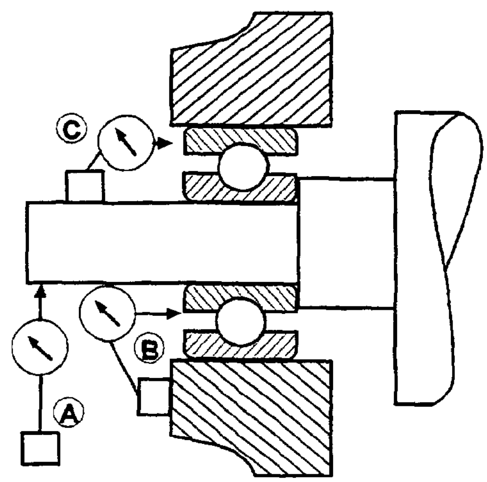


Figure 5-1 Motor Data Sheet (Mechanical)

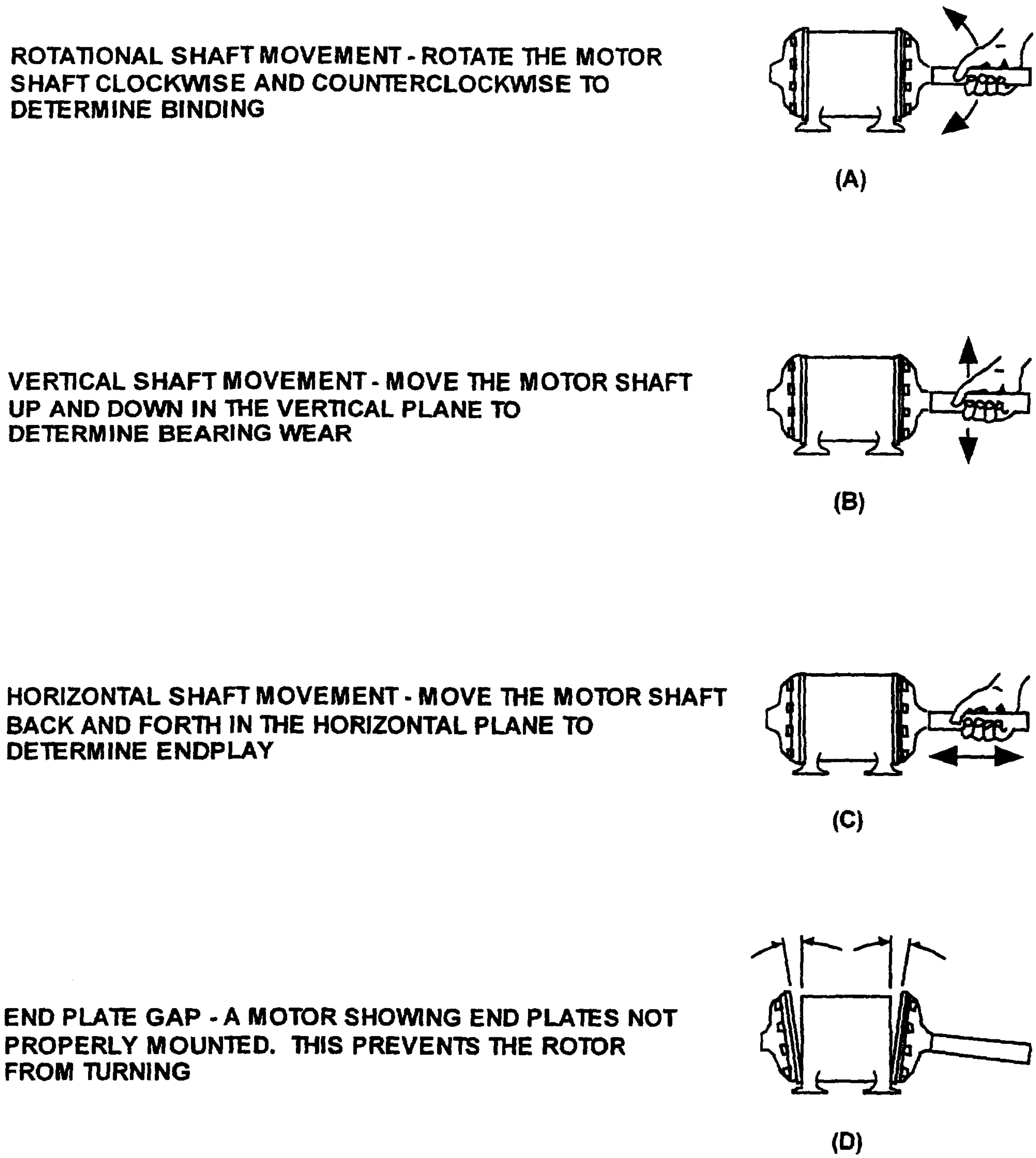


Figure 5-2 Checking Motor Shaft Movement

c. Slowly rotate the shaft 360 degrees.

d. Record the readings on the motor data sheet (mechanical) (figure 5-1).

NOTE

The face runout test may have to be done in V-blocks after motor disassembly.

5-10. BEARING INNER FACE AXIAL SQUARENESS (FACE RUNOUT).

Use a dial indicator (paragraph 2-53) to check the bearing face runout.

5-11. DISASSEMBLY PROCEDURE.

5-12. PRELIMINARY PREPARATION.

Preliminary disassembly procedure is as follows:

a. Place the motor in a solid, flat position on the workbench.

b. Use a prick punch to mark the end bells, field frame, and outer bearing caps (figure 5-3). Use existing matchmarks if possible.

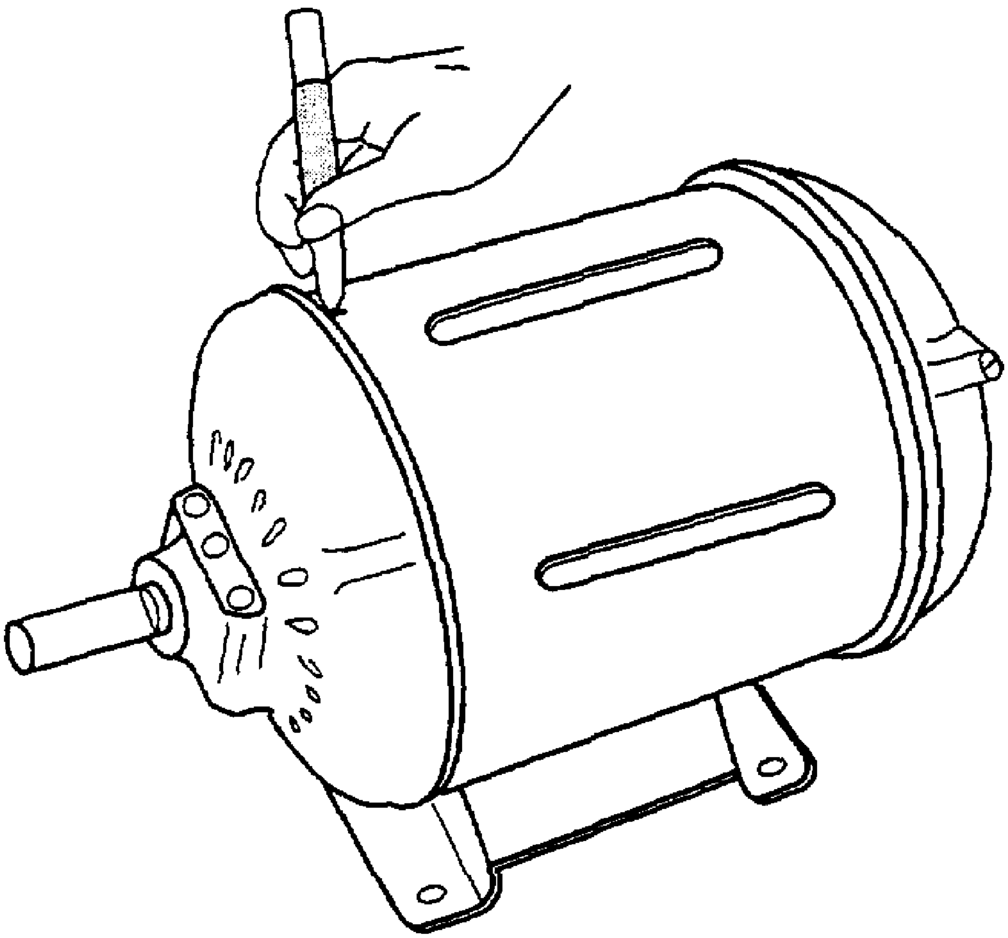


Figure 5-3 Matchmarking

NOTE

Make sure that sets of matchmarks are distinct from one another.

CAUTION

Never be hasty or careless in disassembling a generator or a motor. Handle the components with care to avoid damaging them, or causing a need for additional adjustment.

Always use extreme care in selecting tools and labeling and storing parts when disassembling a motor.

c. Make tags identifying the name of the unit and the number of the ship. Attach tags to all large pieces and to each small parts pan. Collect nuts, bolts, washers, cotter pins, etc., in plastic bags. Mark them for identification.

d. Place all parts in a tote box, parts pan, or other container to prevent them from being misplaced.

5-13. END BELL REMOVAL.

Always use the proper tools when disassembling the motor and removing parts. Label the parts as they are removed. Store them in an orderly arrangement in a safe place. Note the necessary information so that reassembly will not be a problem. If a careful job is done of breaking down a machine into its components, the process of reassembly should be simply the reverse of disassembly. Disassemble the motor as follows:

a. Balance Rings. Remove the balance rings if they are installed externally to the outer bearing caps.

CAUTION

Do not file or stone mating surfaces without expert supervision. Excessive filing can damage the flange.

b. Outer Bearing Caps. Remove the outer bearing caps. Use jacking bolts if available, or a light mallet if necessary. Inspect the mating surface of the outer caps. Carefully file or stone the mating surfaces to remove nicks or burrs as necessary.

c. Inner Bearing Caps. Remove the bolts that retain the inner bearing caps. Note any indication of loose bolts, missing parts, or items of incorrect size. When the caps are removed, remove locknuts and lock washers. Measure inner ring axial runout. Determine the cause of excessive runout if necessary.

CAUTION

Do not allow the rotor to drop down on the lamination when the motor is being disassembled. Use jacks and a pipe to support the rotor while the end bells are being removed.

NOTE

Use a mallet or wood block with a hammer when separating the end bells from the frame (figure 5-4).

d. First End Bell. Loosen the end bells with jacking screws, if provided. Slide the first end bell over the pipe. For most motors, light, thin-wall pipe of a diameter slightly larger than the shaft is satisfactory. The pipe should be long enough to fit onto the shaft and rest on a jack to keep the rotor from dropping during end bell removal. Insert packing into the clearance space. Remove the jack, pipe, and end bell after packing is inserted (figure 5-5). The bearing housings should be a sliding fit on the bearings. If excessive force is necessary to slide a housing, it is either too small or out-of-round.

e. Second End Bell. Remove the other end bell with jacking screws, if threaded holes are provided. On large motors or motor generator sets, the bearing housings may be separate from the endframe. In that case, remove the housing bolts before loosening the endframe.

f. Brushes. To prevent damage to the brushes, lift the brushes, if any, from the slip rings before removing the rotor.

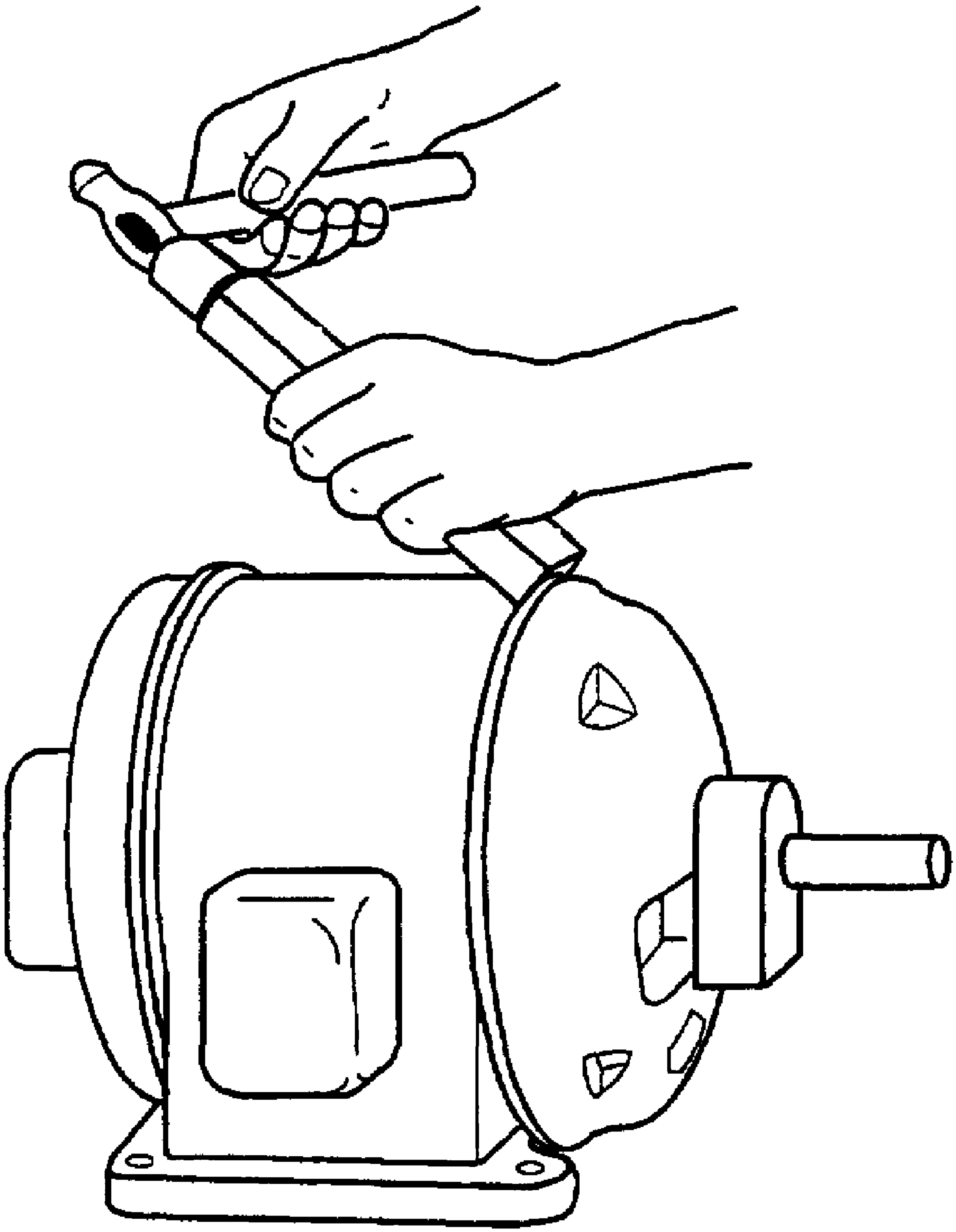


Figure 5-4 End Bell Disassembly

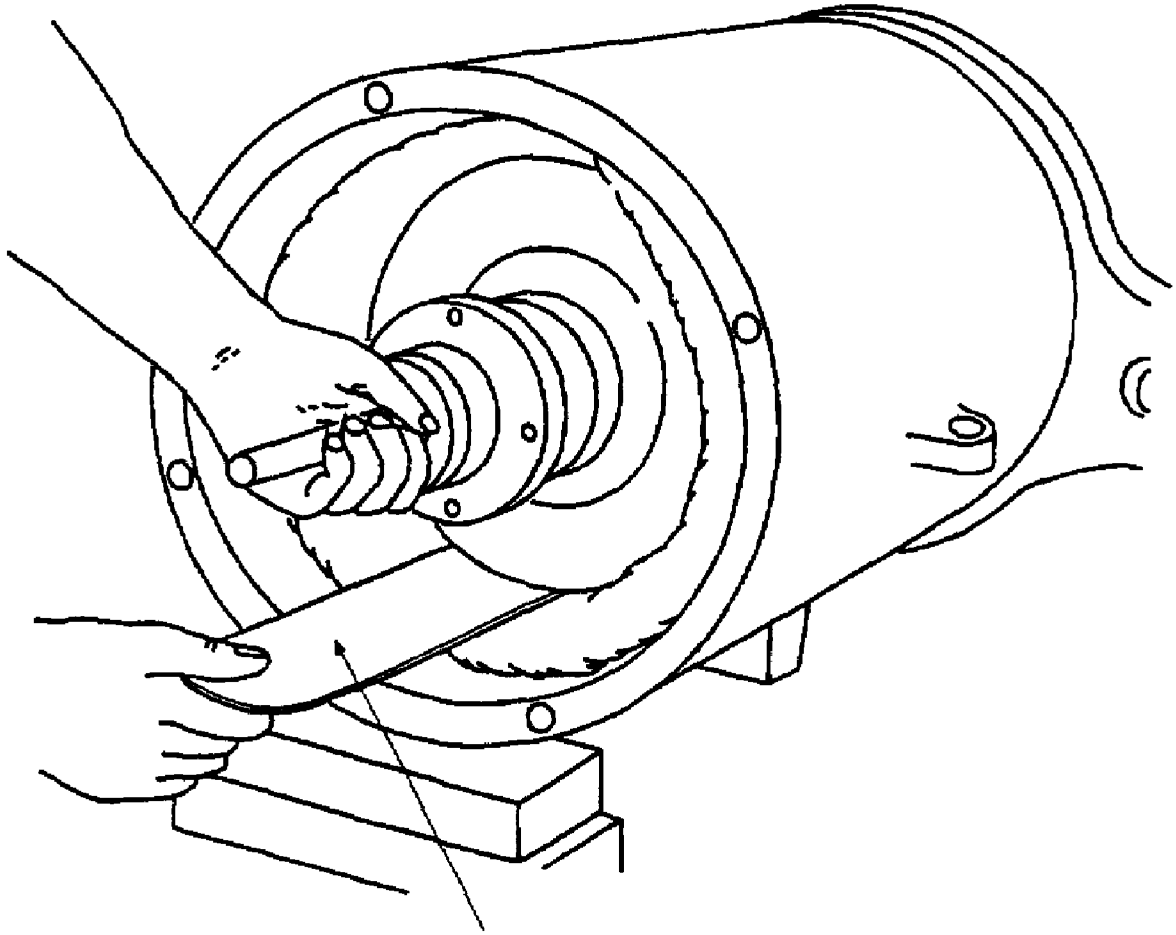


Figure 5-5 Installing Packing to Support Rotor

5-14. ROTOR REMOVAL.

Follow the removal procedures below after inserting the packing materials (see figure 5–5) into the clearance below the rotor.

CAUTION

Be careful not to let the rotor rub against the lamination or the end of the windings. Do not allow the pipe to damage bearing areas.

a. Place a suitable piece of pipe on the opposite end of the rotor shaft. Remove the rotor from the stator frame. The pipe be long enough to support the rotor while the shaft is slid completely through the bore.

b. Place the rotor on the workbench in V-blocks (figure 5-6). Secure it with a strap wrench to hold it firmly on the bench (figure 5-7).

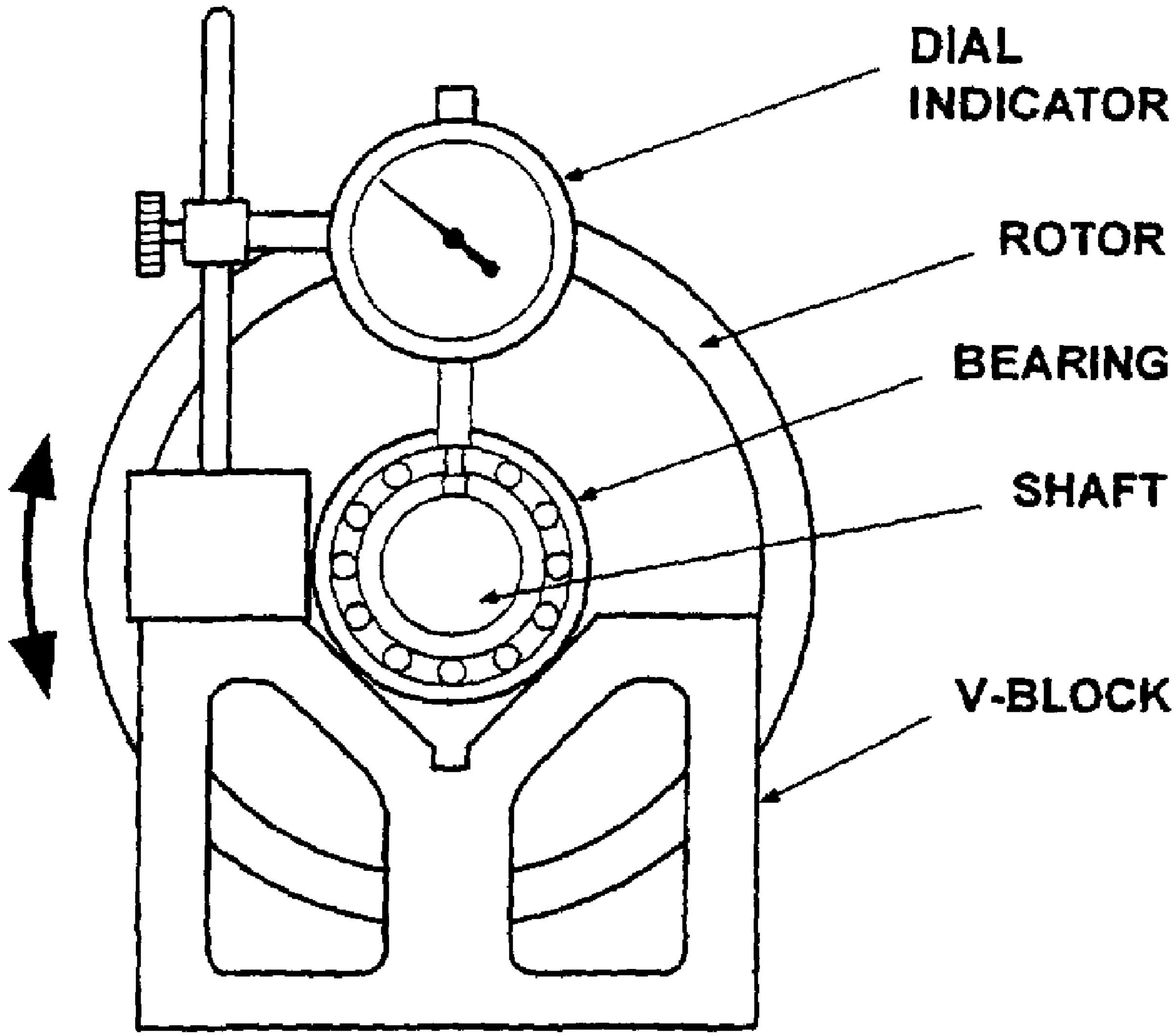


Figure 5-6 Shaft Runout Indication

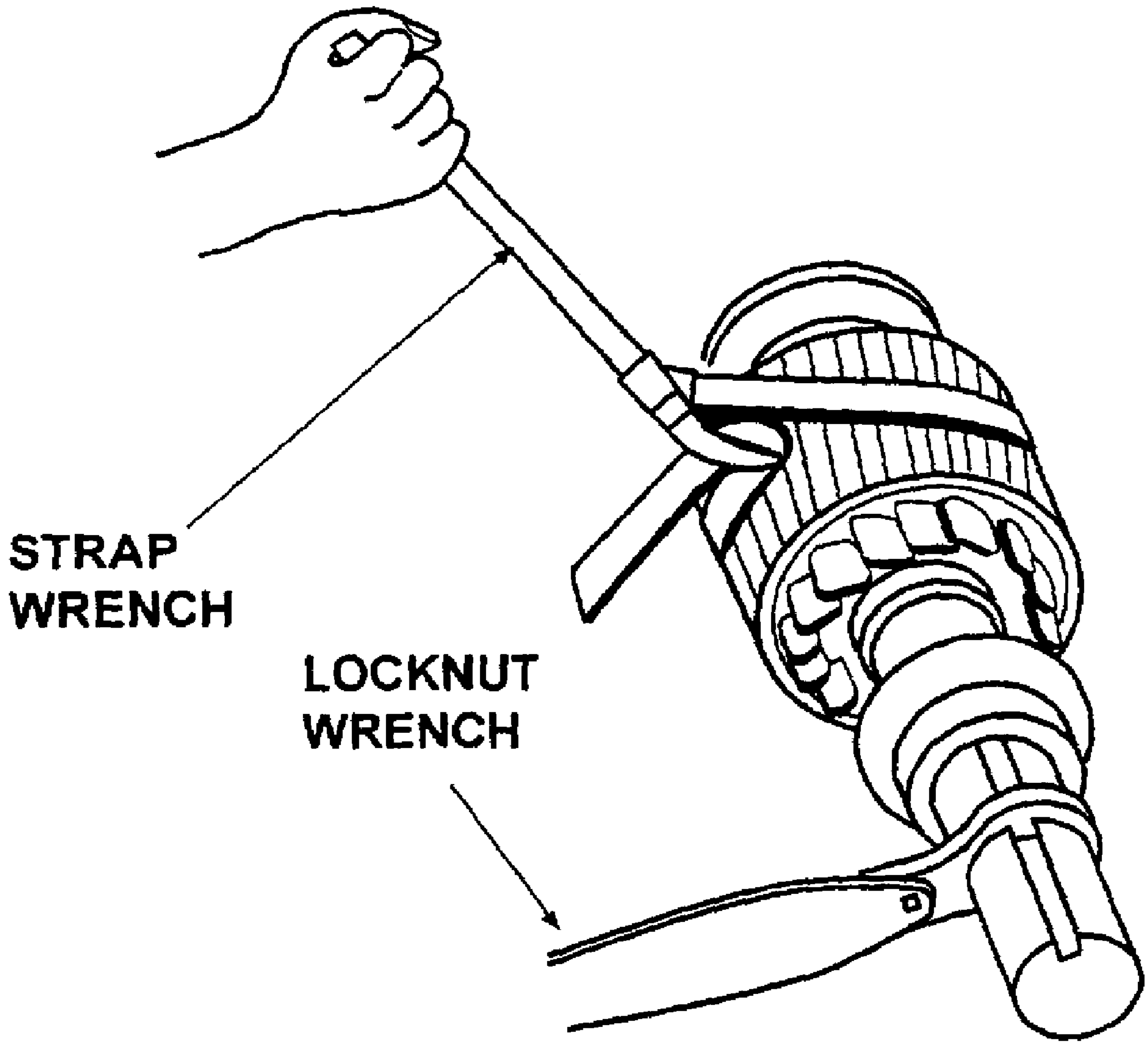


Figure 5-7 Removing Bearing Locknut

c. Free the tab washer, if present, to permit removal of the bearing locknut. Use a locknut wrench (figure 5-8). Be careful not to damage the threads.

5-15. BEARING AND END CAP INSPECTION.

Inspect the motor bearings and end caps. Examine the inner and outer end caps. Examine bearing; check for quantity and condition of lubricant as described in Chapter 7. Record the results on the motor data sheet (mechanical) (figure 5-1.)

5-16. ROTOR INSPECTION.

AC motors are either squirrel cage or wound types. Check squirrel cage rotors for evidence of: loose or cracked bars or localized overheating. Check wound rotors for obvious defects, such as:

5-16.1 Charred sections of the windings, or

5-16.2 Severe deterioration of the insulation, such as excessive cracking, flaking, or exposed bare copper.

5-17. ROTOR TEST.

Use a growler (paragraph 2-24) to test for loose bars in squirrel cage rotors which are not the die-cast type.

a. Place the rotor on the growler.

b. Hold a hacksaw blade over each bar.

NOTE

A loose bar causing an open circuit is indicated if a vibration is felt.

c. Reweld or resolder loose bars.

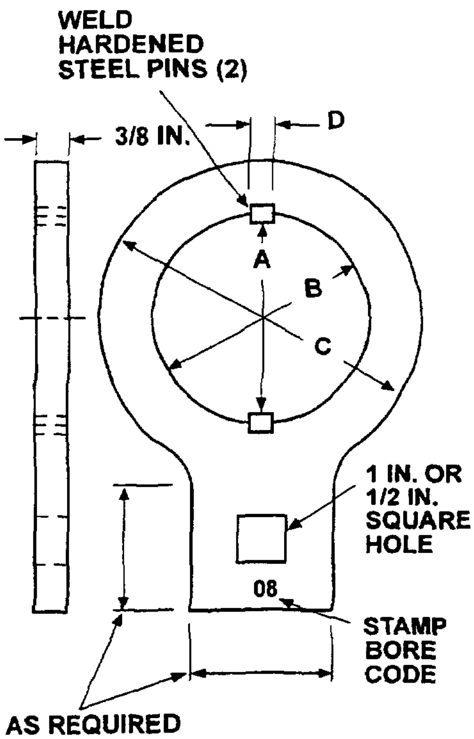
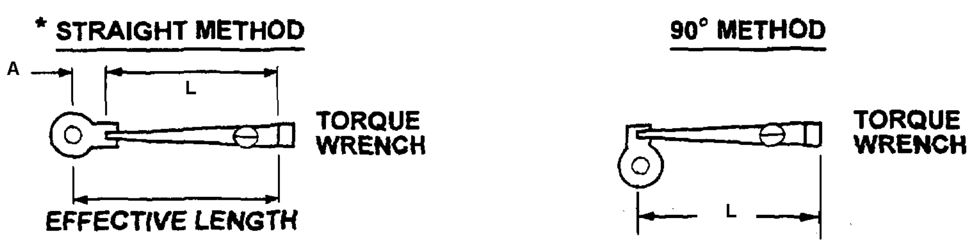


TABLE OF DIMENSIONS

Bore Code	A (Min)	B (Min)	C (Nom)	D (Max)
08	2- 3/32	2- 5/16	3- 5/16	3/16
09	2- 3/8	2- 19/32	3- 5/8	3/16
10	2- 17/32	2- 3/4	3- 3/4	3/16
11	2- 3/4	3- 1/32	4- 1/16	3/16
12	2- 15/16	3- 7/32	4- 1/4	3/16
13	3- 5/32	3- 7/16	4- 1/2	3/16
14	3- 13/32	3- 11/16	4- 3/4	3/16
15	3- 21/32	3- 15/16	5	5/16
16	3- 15/16	4- 7/32	5- 3/8	5/16
17	4- 1/8	4- 15/32	5- 3/4	5/16
18	4- 3/8	4- 23/32	6	5/16
19	4- 21/32	5	6- 1/4	5/16
20	4- 29/32	5- 1/4	6- 1/2	5/16
21	5- 3/32	5- 1/2	7	7/16
22	5- 3/8	5- 25/32	7- 1/2	7/16

MATL: HARDENED 4340 OR EQUAL

APPLICATION METHODS



* When using straight method it is necessary to compute the effective length (L+A) of the torque wrench assembly to determine actual torque applied. Use the following formula:

$$Ta = Tw \times \frac{(L+A)}{L} \quad \text{where:}$$

Ta = Actual torque exerted
Tw = Torque wrench scale reading
L = Length of torque wrench
A = Length of locknut spanner wrench (center of square hole to center of round hole)

Figure 5-8 Typical Locknut Wrench and Table of Dimensions

5-18. ELECTRICAL INSPECTION.

5-19. INSULATION RESISTANCE (IR) TEST.

Measure motor insulation resistance with a megohm bridge (paragraph 2-4 or paragraph 2-8). The measured value of IR should be temperature-corrected to 77° F (25° C) using the nomograph in figure 2-18. Refer to NSTM S9086-KC-STM-010/CH 300 for details on the use of the nomograph. The stator should be reconditioned as described in Chapter 7 of this volume if the temperature-corrected value of the IR is below the ″Minimum For Operation″ of table 7-2. Also see paragraph 5-20 for additional IR acceptance criteria. Record the results on the motor data sheet (electrical) (figure 5-9).

5-20. POLARIZATION INDEX (PI) TEST.

Used in conjunction with each other, the PI and the 1-minute value of IR are effective in identifying windings that require reconditioning.

5-20.1 The winding must be reconditioned and, if necessary, rewound, if any of the following criteria are met:

5-20.1.1 The 1-minute IR is less than the ″Minimum For Operation″ in table 7-2.

5-20.1.2 The 1-minute IR is less than five times the ″After Reconditioning″ value (table 7-2) and the PI is unacceptable.

5-20.1.3 For motors with sealed insulation only, the 1-minute IR is less than 500 megohms and the PI is unacceptable.

5-20.2 In accordance with the above, perform a PI test if the temperature-corrected value of 1-minute IR is greater than or equal to the ″Minimum For Operation″ and less than five times the applicable ″After Reconditioning″ value of table 7-2. Do not perform a PI test if the 1-minute IR is less than the ″Minimum For Operation″ since the value of 1-minute IR preempts the PI from being a determining factor. Do not perform a PI test if the 1-minute IR is greater than or equal to five times the ″After Reconditioning″ value since the 1-minute IR preempts the PI from being a determining factor. Perform the PI test using the procedures in paragraph 2-37. Record the results on the motor data sheet (electrical) (figure 5-9). Measured values of IR should be temperature-corrected to 77° F (25° C) using the nomograph in figure 2-18 before determining compliance with the minimum values in table 7-2. Refer to paragraph 2-37.2 for PI test acceptance criteria.

5-21. SURGE COMPARISON TEST.

Perform a surge comparison test (paragraph 2-19) on the winding to determine if there are shorted turns, coils, or windings. The stator must be rewound if internal short circuits or grounds are found. Proceed to the next step of testing if the winding is good. Record the results on the motor data sheet (electrical) (figure 5-9).

5-22. PHASE RESISTANCE BALANCE TEST.

Perform a phase resistance balance test (paragraph 2-15) to determine if the internal resistance of the phases is within allowable limits. For motors over 3 horsepower (hp), the resistance of each phase must be within 5 percent of the others. The stator must be rewound if the difference between the high and low readings is greater than 5 percent. Record results on the motor data sheet (electrical) (figure 5-9).

WARNING

Never conduct a high-potential test on a winding that has failed a ground insulation test.

5-23. HIGH-POTENTIAL TEST.

Perform a dc high-potential test (paragraph 2-19 or paragraph 2-45) to determine cleanliness, and the moisture content and dielectric strength of the insulation.

5-24. CORE TEST.

Perform a core test (paragraph 2-38) to determine if there is deterioration of, or damage to, the core lamination insulation (core plate) which can result in energy losses and overheating of the machine.

SECTION 1. NAMEPLATE DATA

EQUIPMENT ______________ USS ______________
MFGR. ______________ TYPE ______________ FRAME ______________
HP ________ INSULATION CLASS ________ TEMP. RISE ________ °C/°F ________
VOLTS ________ AMPS ________ CYO ________ R/M ________ PHASE ________
SERIAL NO. ______________ ADDITIONAL DATA ______________

SECTION 2. INPLACE INSPECTION

CAUTION: OBSERVE APPLICABLE SAFETY PROCEDURES.

SATISFACTORY		UNSATISFACTORY
________	INSULATION RESISTANCE IN MEGOHMS (REFER TO TABLE 3-2)	________
POLARIZATION INDEX TEST	1 MIN ________ 10 MIN ________ RATIO ________	
________	MECHANICAL CONDITION (REFER TO PARAGRAPH 3-6)	________
________	CONTINUITY OF WINDINGS (REFER TO PARAGRAPH 3-5.1)	________
________	CURRENT BALANCE (USE LIMITS PRESCRIBED IN PARAGRAPH 3-10)	________
________	CONDITION OF BRUSHES AND COMMUTATOR	________
________	CONDITION OF CABLES FROM CONTROLLER TO MOTOR	________
________	CONDITION OF CONTROLLER	________

SECTION 3. INCOMING INSPECTION (GENERAL)

SURGE TEST	1 - 2	________	SAT/UNSAT
	2 - 3	________	SAT/UNSAT
	1 - 3	________	SAT/UNSAT
INSULATION RESISTANCE TO GROUND		________	MEGOHMS
RESISTANCE BALANCE	1 - 2	________	OHMS
WITH DIGITAL OHMMETER	2 - 3	________	OHMS
	1 - 3	________	OHMS

ACTION: RECONDITION ________ REWIND ________

SECTION 4. RECONDITIONING

	AFTER STEPS OF: CLEANING	DRYING
INSULATION RESISTANCE (MEGOHMS)	________	________
PHASE RESISTANCE BALANCE TEST	________	________
SURGE TEST (SAT/UNSAT)		________
DC HIGH-POTENTIAL TEST	________	________

ACTION: VARNISH ________ REWIND ________

SECTION 5. AFTER RECONDITIONING OR REWINDING AND VARNISHING

INSULATION RESISTANCE		________	MEGOHMS
POLARIZATION INDEX TEST	1 MIN ________	10 MIN ________	RATIO ________
RESISTANCE BALANCE WITH	1 - 2	________	OHMS
DIGITAL OHMMETER	2 - 3	________	OHMS
	1 - 3	________	OHMS
SURGE TEST		________	SAT/UNSAT
AC HIGH-POTENTIAL TEST		________	SAT/UNSAT
INSULATION RESISTANCE AFTER AC HIGH-POTENTIAL TEST		________	MEGOHMS
NO-LOAD TEST	PHASE A	________	AMPERES
	PHASE B	________	AMPERES
	PHASE C	________	AMPERES

Figure 5-9 Motor Data Sheet (Electrical)

CHAPTER 6

MOTOR BEARINGS AND BEARING PROBLEMS

6-1. SCOPE.

This chapter contains information on motor bearings and the sources and causes of motor bearing failure commonly experienced in electric motors. Complete bearing information for other applications is found in NAVSEA S9086-HN-STM-010/CH 244. Topics here include:

6-1.1 Types of motor bearings (paragraph 6-2).

6-1.2 Ball bearings (paragraph 6-4).

6-1.3 Bearing identification (paragraph 6-6).

6-1.4 Bearing design (paragraph 6-7).

6-1.5 Care of unmounted bearings (paragraph 6-9).

6-1.6 Safety precautions (paragraph 6-10).

6-1.7 Care of mounted bearings (paragraph 6-11).

6-1.8 Bearing replacement (paragraph 6-17).

6-1.9 Disassembly and bearing removal (paragraph 6-21).

6-1.10 Bearing installation and assembly (paragraph 6-25).

6-1.11 Special procedures for duplex bearings (paragraph 6-30).

6-1.12 Grease pack (paragraph 6-33).

6-1.13 Postrepair inspection (paragraph 6-37).

6-2. TYPES OF MOTOR BEARINGS.

6-3. BEARING DESIGNATIONS

Since most Navy motors use *ball bearings* , they will be discussed in detail in this chapter. Type designations of ball bearings common to shipboard applications are described in table 6-1. Other types of bearings found in electrical machinery are summarized in this paragraph. The principles of failure analysis, accuracy, and clean workmanship during replacement apply to all bearing systems. Final balancing and vibration measurements also apply to all systems. Other bearing types include:

6-3.1 Rolling-Element Bearings. Rolling-element bearings are used to guide and support rotating and oscillating members. The rolling-element bearing, except for special designs, consists of two rings, a set of balls or rollers, and a cage. The cage maintains even spacing of the balls or rollers and prevents them from falling out of the bearing during handling. The rolling-element bearing has many uses in shipboard machine elements. Rolling-element bearing design is based on the principal that rolling friction is much less than sliding friction. These bearings are commonly called antifriction bearings. Reasonable changes in load, speed, and operating temperature have no effect on their satisfactory performance.

Table 6-1 Common Bearing Designs

Type	Description
Type 111	Single-row, radial, nonloading groove, both rings same width, metric
Class 1	Open
Class 2	Single-shield
Class 3	Double-shield
Class 4	Open, snap ring
Class 5	Single-shield, snap ring
Class 6	Double-shield, snap ring
Class 7	Single-seal
Class 8	Double-seal
Type 115	Single-row, radial, nonloading groove, both rings same width, inch
Class 1	Open
Class 2	Single-shield
Class 3	Double-shield
Type 120	Single-row, radial, nonloading groove, both rings same width, sealed (cartridge type without grease plug, metric bore and outer diameter (OD), inch width
Type 123	Internal self-aligning, double-row, both rings same width, metric
Type 131	Single-row, counterbore (primarily radial), self-contained, both rings same width, metric
Class 1	Single bearing
Class 2	Duplex pair, faces ground for face-to-face (DF), back-to-back (DB), or tandem (DT) mounting
Type 133	Single-row angular contact (contact angle 25°), self-contained, both rings same width, metric
Class 1	Single bearing
Class 2	Duplex pair, faces ground for DF, DB, or DT mounting
Type 143	Double-row, nonloading groove, vertex of contact angle outside of bearing, metric bore and OD, inch or metric width
Type 145	Double-row, loading groove, vertex of contact angle inside of bearing, metric bore and OD, inch, or metric width
Type 146	Double-row, loading groove, vertex of contact angle outside of bearing, metric bore and OD, inch or metric width.

NOTE

The following films are available for training: MN-10343, *Replacement of Ball Bearings for Quiet Operation* and MN-211128A. *Interpretation of Service Damage in Rolling Contact Bearings.*

6-3.2 Needle and Cylindrical Roller Bearings. These two bearing types are found in some small motors.

6-3.3 Sliding Bearings. Many types of sliding bearings are found in motors and generators of all sizes.

6-3.4 Tilting-pad Journal Bearings. Tilting-pad journal bearings are used in some main feed pump motors. They are of interest principally from a vibration-reducing viewpoint.

6-4. BALL BEARINGS.

6-5. CHARACTERISTICS OF BALL BEARINGS.

Various types and sizes of ball bearings are used in U.S. Navy motors and motor generator sets. Ball bearings accurately position the shaft and rotor and support any thrust or radial loads which may be applied by the driven equipment. Ball bearings are selected for use in electric motors because of their:

6-5.1 Small size and low weight, with high load capacity.

6-5.2 Very small internal clearance, which permits accurate balancing of rotors.

6-5.3 Long operating lives.

6-5.4 Very low lubrication requirements.

6-5.5 Small radial clearance.

6-5.6 Mass production to standard dimensions, with extremely high and uniform quality.

6-5.7 Precision. Three grades of precision are available. The standard grade of precision is grade 00 standard tolerance. This level is satisfactory for most designs and, therefore, has the widest use. Bearings having closer tolerances on dimensions are manufactured to grade 50 precision tolerances or grade 70 super-precision tolerances. Most ball bearings are purchased in accordance with FF-B-171, *Bearings, Ball, Annular (General Purpose)* . Ball bearings for Navy noise-critical applications are purchased under a special Naval Sea Systems Command (NAVSEA) specification, MIL-B-17931, *Bearings, Ball, Annular For Quiet Operation.* Dimensional tolerances for these bearings are similar to grade 50 and 70 limits. Additional strict requirements are imposed on these bearings to ensure a minimum of bearing noise and vibration. Such bearings are marked with the symbol NT followed by the number designated to the latest noise requirement in MIL-B-17931 and will be referred to throughout this manual as *quiet bearings.*

6-5.8 Limitations. Except as directed in paragraph 6-39 or as specified or approved by NAVSEA, ball bearings for shipboard use are limited to the grade, type, and class specified for the original equipment. Quiet bearings are not intended for general use and are restricted to low-noise applications.

6-6. BEARING IDENTIFICATION.

6-6.1 National Stock Numbers (NSN). In the National Supply System, rolling-element bearings are identified by National Stock Numbers (NSN). Each bearing NSN has an item description that lists the bearing design features peculiar to that NSN. This item description is used to procure new bearings from government-qualified manufacturers, ensuring interchangeability. All bearings should have the NSN marked on the outer unit package.

6-6.2 Allowance Part List (APL). In support of the National Supply System, NAVSEA has established the Coordinated Ship Allowance List (COSAL) and the Allowance Parts List (APL). The COSAL identifies specific equipment by the Component Identification Number (CID), usually the first five numbers of the APL number for hull, mechanical, and electrical (HM&E) APLs. The APL is a ready reference that lists onboard replacement parts by name and NSN for specific equipment as identified by the CIDs. Bearing NSNs should always appear on the APL as onboard replacement items. Procurement request shall specify the NSN.

6-6.3 Bearing Type. The bearing types listed in table 6-1 are in accordance with MIL-STD-102, *Anti-Friction Bearing Identification Code* . The code is descriptive and consists of 12 digits broken down into three groups. The first three digits classify the bearing type. The next five digits code the principal boundary dimensions of bore, outside diameter (OD), and width. The last four digits code variations such as precision, internal clearance, seals, shields, lubricant, cages, or preload. This numbering system has been superseded by the NSN numbering system. It is still widely used, however, on equipment drawings, in technical manuals, and by the Defense Industry Supply Center.

6-6.4 Basic Bearing Number. Each government-qualified bearing supplier has its own identification system. Manufacturers' identification numbers usually consist of a three-digit *basic bearing number* . The first digit of the basic bearing number codes the bearing OD or width series (duty) as extremely light (900), extra light (100), light (200), medium (300), heavy (400), type 120 light (500), and type 120 medium (600). The second and third digits of the basic bearing number are the *bore code* . The bore code is one-fifth of the bore dimensions in millimeters, with the exception of bore codes 00 through 03. For example, a basic bearing number of 318 tells the user that this is a medium duty bearing with a bore of 90 mm. A combination of numbers or letters is used as prefixes or suffixes to the basic bearing number to code bearing type and special features. Table 6-2 is an interchangeability list of manufacturers' basic bearing numbers (bore code 09 only) for the most commonly used shipboard machinery ball bearings. The table is provided only for guidance. Manufacturers' basic bearing numbers, as they appear stamped on ball bearings and cylindrical and spherical roller bearings, are helpful in determining bearing nominal size. This information will provide easy entry into the fitup tables in this chapter and in NAVSEA S9086-HN-STM-010/CR 244, eliminating the need to measure the bearings. Do not use bearing manufacturers' numbers for procurement, however, because:

6-6.4.1 Bearing identification is not standard. Different manufacturers use the same numbers and letters to mean different things. For example, with Koyo 7309 in an open angular-contact bearing with a large contact angle conforming to Navy type 134, but with Marling Rockwell Corporate (MRC), 7309 is an open angular-contact bearing with a small contact angle conforming to Navy type 133.

6-6.4.2 Usually, only the basic bearing number is stamped on the bearing. This number does not give information about such important features as lubricant, internal clearance, cage material, precision, preload, seals, or shields. This information, however, may be marked on the bearing package. MIL-L-HDBK-203, *Manufacturers' Symbols and Designation for Anti-Friction Bearings* , has been prepared to help translate such information.

Table 6-2 Ball Bearing Interchangeability Data for Grade 00 Bearings (Bore Code 09)

MIL-STD-102		**MRC**	**New Departure**	**Norma-Hoffman**	**NTN**	**SKF**	**Industry Series**	**Barden**	**Fafnir**	**Koyo**
Type	**Class**									
111	1	109KS	3L09	6109	6009	6009X	Extra Light	109	9109K	6009
111	1	2092	3209	209	6209	6209	Light	209	209K	6209
111	1	309S	3309	309	6309	6309	Medium		309K	6309
111	1	409S	3409	409	6409	6409	Heavy		409K	6409
111	2	209SF	7509	209P	6209Z	6209Z	Light	209S	209KD	6209Z
111	3	309SFF	77609	309PP	6309ZZ	63092Z	Medium		309KDD	6309ZZ
111	4	309SG	43309	4309	6309NR	6309NR	Medium		309KG	6309NR
111	5	309SFG	47609	4309P	6309ZNR	6309ZNR	Medium		309KDG	6309ZN
111	7	209SZ	9509	209K		6209RS	Light		209KP	6209RS
111	8	309SZZ	99609	309KK	6309LLU	63092RS	Medium		309FF	63092RS
120		309SZZC			63309LLU	462309	Medium		W309PP	N63092RS
120		309SFFC		S6309			Medium		W309KLL	
120		309SRRC		FL3609	63309LLB		Medium			

Table 6-2 Ball Bearing Interchangeability Data for Grade 00 Bearings (Bore Code 09) - Continued

MIL-STD-102		**MRC**	**New Departure**	**Norma-Hoffman**	**NTN**	**SKF**	**Industry Series**	**Barden**	**Fafnir**	**Koyo**
Type	**Class**									
131		309R	20309	L7309			Medium		7309W	
133		7309	20309	7309	7309C		Medium		7309W	
134		7309	30309		7309	7309B	Medium		7315PW *	7309

NOTE

This table is not all-inclusive. The numbers shown are for a bore code 09 bearing. For other sizes of bearings, substitute the appropriate bore code.

*Not available in 09 bore code.

6-6.4.3 Many original equipment manufacturers assign their own part number to bearings, instead of the bearing manufacturer's number. When such part numbers appear on drawings, only the original equipment manufacturer can decipher this code. Many drawings that do list bearing manufacturers' numbers list only the basic numbers.

6-6.4.4 Bearings procured outside the National Supply System may not have been subjected to quality control on a par with government standard or manufactured by a government-qualified supplier. This could result in procuring an inferior product.

6-7. BEARING DESIGN.

6-8. BEARING DESIGN FEATURES

All bearings of the same type and size are dimensionally interchangeable regardless of precision. In addition, ball, and cylindrical and spherical roller bearings manufactured to the same boundary plan dimensions in metric units are interchangeable. This does not mean that all types will perform equally well, or even work at all. In general, not more than two bearings are permitted in rigidly mounted shafts required to run in line.

6-8.1 Ball Bearings. Standard-grade ball bearings are precision-ground machine elements. Grade 00 bearings are manufactured under very close control of dimensions and finish. For example, the bore of a type 111, size 320 bearing with a diameter of 3.8370 inches must be round within 0.0009 inch. Each 1.5-inch-diameter ball in this bearing must be round within 0.000025 inch and have a surface finish between 1.5-microinch RA. Higher-precision bearings have proportionally tighter tolerances. Most ball bearings are dimensioned in the metric system. The most common ball bearing designs are discussed in paragraphs 6-8.1.1 through 6-8.1.5 and summarized in table 6-1.

6-8.1.1 Type 111 is the most versatile of bearings; it can support radial loads and two-directional thrust loads combined in any proportion. Because this bearing is not self-aligning, it requires accurate parallelism between the shaft and the housing bore.

6-8.1.2 The design of types 115 and 120 is similar to type 111 with the following exceptions:

6-8.1.2.1 Type 115 is dimensioned in inches.

6-8.1.2.2 Type 120 is termed a cartridge bearing since it is as wide as a double-row bearing but has only one row of balls. Type 120 bearings are double sealed or double shielded and lubricated for life by the bearing manufacturer.

6-8.1.3 Type 123 bearings are used mainly where housing alignment is uncertain. They will support moderate radial loads and light two-directional thrust loads. They are internally self-aligning.

6-8.1.4 Types 131, 133, and 134 are angular-contact ball bearings designed to support thrust loads in one direction, possibly in combination with radial loads.

6-8.1.4.1 In all three types, the direction of load through the balls forms an angle (the *contact angle*) with a plane perpendicular to the bearing axis. The thrust capacity increases with increasing contact angle. These bearings usually have a greater number of balls than type 111 bearings. Type 134 has a range of contact angles larger than type 133, which in turn has a range of contact angles larger than type 131.

6-8.1.4.2 Angular contact bearings are frequently made so that they can be mounted in pairs (back-to-back (DB), tandem, or face-to-face (DF)). This enables them to carry radial, thrust, or combined loads in any direction (figure 6-1b). These arrangements are called *duplex pairs* . In these arrangements bearing ring side surfaces are ground so that when the assembled bearings are clamped together, the desired internal clearance, or *preload* , is obtained. For general purpose applications duplex pairs are designed as flush-ground bearings. This means they will not have a significant preload or measurable end play. For specialized applications, varying degrees of preload, or end play, may be desired. In these cases, the bearing ring sides surfaces are ground to give the desired load condition.

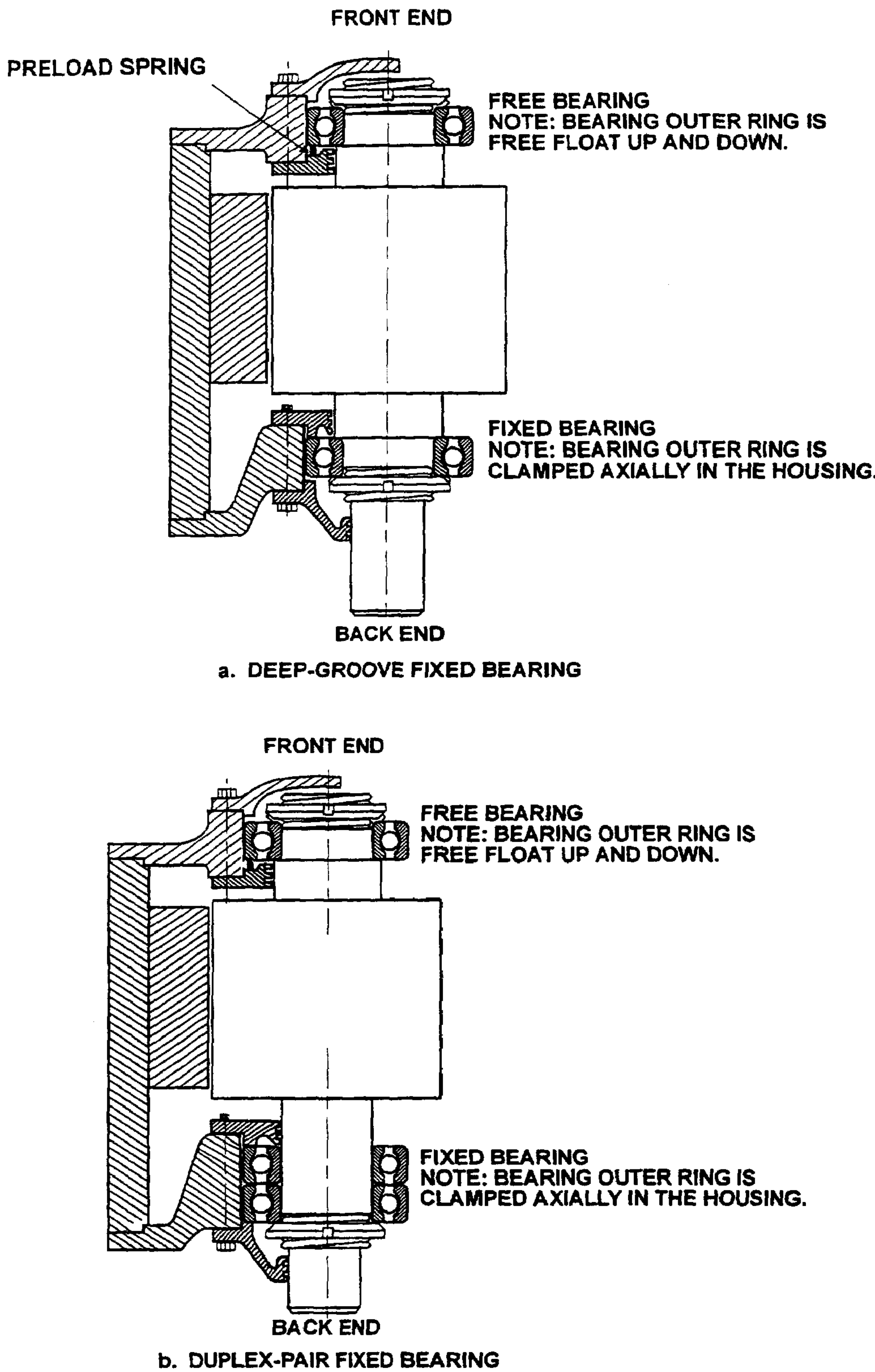


Figure 6-1 Mounting Methods for Vertically Mounted Ball Bearings

6-8.1.5 Types 143, 145, and 146 are double-row, angular-contact ball bearings. Although the two rows of balls provide greater radial load capacity than the same sizes of single-row bearings, the thrust capacity is limited to that of one row of balls since the contact angles are not parallel.

6-8.2 Bearing Cages. Cages are made to many different designs and of several different materials. The cage separates the rolling elements, spacing them evenly around the periphery and preventing them from falling out of the bearing during handling. In addition, in some roller bearing designs, the cage guides the rollers, preventing them from skewing. The cage is not designed to help carry the load. It can be subjected, however, to considerable inertial forces due to acceleration, shock due to extreme service, and centrifugal force due to high speed. Cages are either machined or stamped, usually from steel, brass, bronze, phenolic, or plastic material. The cage may pilot or ride on the balls, rollers, inner ring lands, or outer ring lands. In general shipboard applications, all cage types perform equally well. Standard cage materials of brass, bronze, phenolic, and plastic are restricted to operational temperatures below 230° F (110° C).

6-8.3 Seals and Shields. Seals and shields integral to the bearing are incorporated to prevent the entry of foreign matter and to retain lubricant. *Shields* are usually defined as circular closures affixed to one bearing ring and disposed radially toward the other ring but not in contact with it. *Seals* are similarly defined except they have rubbing contact lips or overlapping elements that form a labyrinth. It may not be outwardly possible to distinguish between a seal or shields as mounted in the bearing. Use of seals and shields has not been standardized by the bearing industry. Since many designs are available, it has been necessary to group the types that function similarly. Rubbing contact seals generate heat and so are limited by bearing size and rotational speed. In addition, all standard seal materials made of rubber, felt, or leather cannot be used at temperatures above 230° F (110° C).

6-8.4 Radial Internal Clearance. *Radial internal clearance* is the distance the inner ring can be displaced radially from one extreme position to the other in relation to the outer ring. Bearings of type 111, 115, 120, 211,212, 213, 215, 231, 232, 233, 237, 264, 764, 765, 767, and 768 are available with standard radial internal clearances. For unlisted bearing types, the internal clearances are either determined by adjustment or fitted to the manufacturer's standard practice.

6-8.4.1 Shipboard applications generally use bearings with standard clearance. Under ordinary operating conditions and with one bearing ring mounted with an interference fit, this clearance is adequate. When sealed bearings are used, a loose clearance is required. When severe operating conditions require an extra tight fit for the interference-fitted ring, when both rings must be mounted with a press fit, or when thermal expansion of the inner ring is considerably more than the outer ring, a loose clearance may be required. The degree of bearing internal clearance necessary is generally specified by the original equipment manufacturer and, if it is other than standard, this is indicated on the equipment master drawing.

6-8.4.2 Type 111 and 120 quiet ball bearings have stricter limits on radial internal clearance than those standardized by the bearing industry.

6-8.4.3 Separable-type bearings that are nonadjustable must be installed as originally matched by the manufacturer to maintain the required radial internal clearance. Mismatching these types will usually result in premature failure.

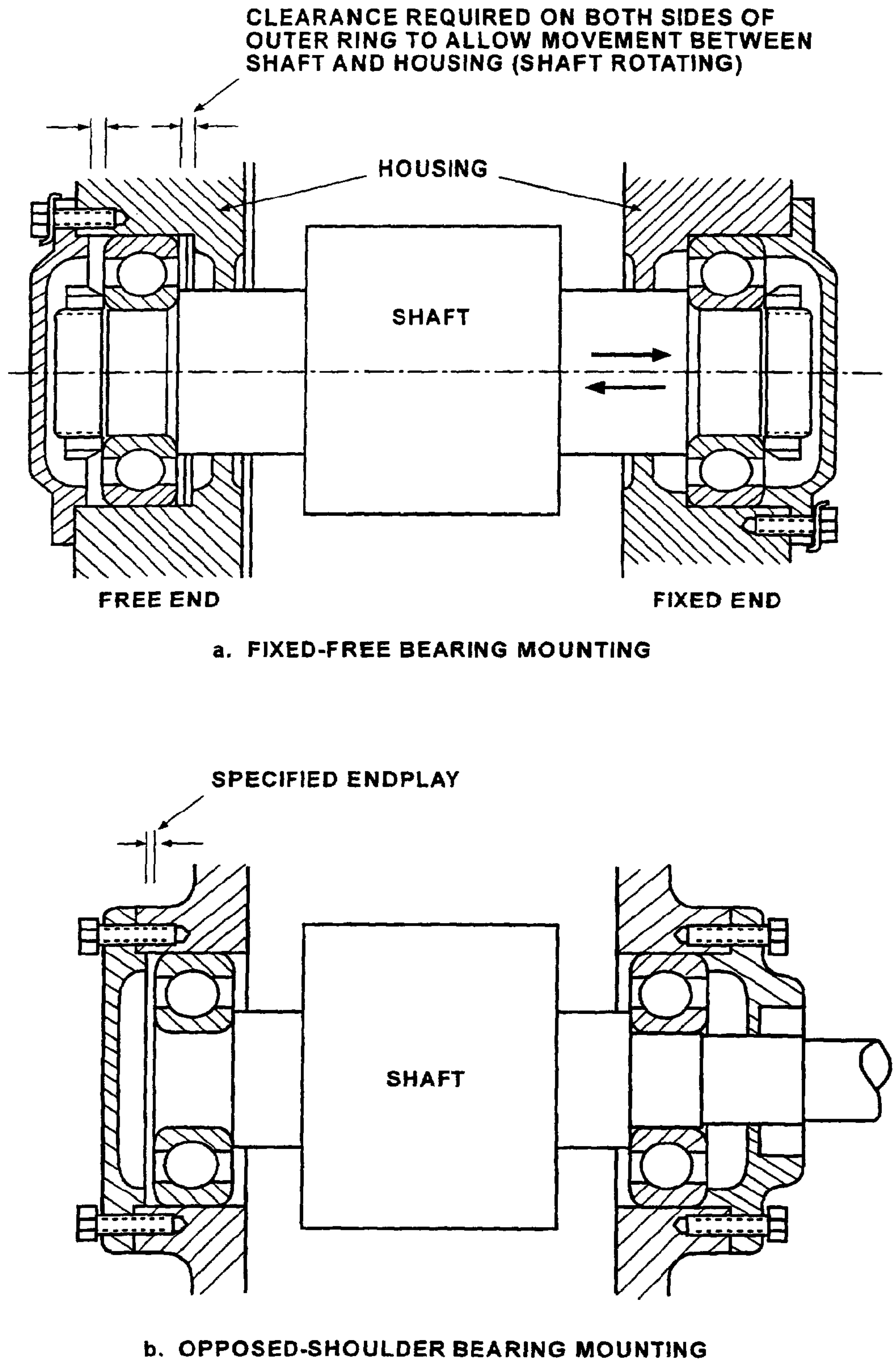


Figure 6-2 Mounting Methods for Horizontally Mounted Ball Bearings

6-8.5 Mounting Design. Bearing mounting designs are of the *fixed-free method* (figure 6-1 and figure 6-2a) or the *opposed-shoulder method* (figure 6-2b). Opposed-shoulder mounts can be designed using all types of bearings, *except* for types 211, 212, 214, 215, 251, and 252. The fixed-free method is the most popular in shipboard applications. The fixed bearing is secured on the shaft and clamped axially in the housing by end caps. The fixed bearing must be suitable for supporting radial loads and two-directional thrust loads. The floating bearings can be of any type as long as design requirements are satisfied. If the floating bearing is a cylindrical roller bearing of type 212, 214, 215, 251, or 252, the outer rings will be clamped axially and the bearing will float internally. If any other type of bearing is used, one ring will be clamped axially and the other will float. For rotating shafts, the inner ring will be clamped axially to the shaft, requiring that the outer ring have room to move axially in the housing. The clearance required depends on the bearing span, the machining tolerances affecting the span, and the shaft-to-housing temperature difference expected in service. When a bearing capable of only one-directional thrust is used as the floating bearing, thrust load output from dead weight, axial spring preload, or other loading must always be present to keep the bearing from separating. For duplex pairs, the back-to-back (DB) pair can be allowed to float in the housing. However, the face-to-face (DF) pair cannot be allowed to float in the housing, since the nonthrusted outer ring will separate from the bearing. These duplex pairs shall be installed as originally designed.

6-8.6 Shaft and Housing Design. Rolling-element bearing bores and outside diameters are held within certain defined tolerances, depending on bearing precision grade. In turn, shaft and housing diameters must be held to comparable limits also in accordance with bearing precision grade. Limits and fits are ordinarily determined by the fits best suited for the application. The shaft and housing fitups in this chapter and NAVSEA S9086-HN-STM-010/CH 244 are for use where dynamic conditions are indicated, which are characteristic of most naval shipboard applications. Shaft and housing seats and shoulder surfaces should be ground. The machining tolerances specified in table 6-3 through table 6-5 are the minimum requirements for reliable bearing life. Use these limits when other information is unavailable or when such other limits exceed the limits herein.

Table 6-3 Shaft Diameter Limits for Grade 00 and Quiet Bearings

			Shaft Diameter Limits [2] (inches)									
Bearing Bore			**Shaft Rotating**								**Shaft Stationary [1]**	
	Nominal		**Ball**		**Quiet**		**Cylindrical**		**Spherical**			
Bore Code	**MM**	**Inch**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**
4	4	0.1575	0.1576	0.1574							0.1573	0.1570
5	5	1.1969	0.1970	0.1968							0.1967	0.1964
6	6	0.2362	0.2363	0.2361							0.2360	0.2357
7	7	0.2756	0.2758	0.2755							0.2754	0.2750
8	8	0.3150	0.3152	0.3149							0.3148	0.3144
9	9	0.3543	0.3545	0.3542							0.3541	0.3537
00	10	0.3937	0.3939	0.3936	0.3940	0.3938					0.3935	0.3931
01	12	0.4724	0.4726	0.4723	0.4727	0.4725	0.4728	0.4723			0.4721	0.4717
02	15	0.5906	0.5908	0.5905	0.5909	0.5907	0.5910	0.5907			0.5903	0.5899
03	17	0.6693	0.6695	0.6692	0.6696	0.6696	0.6697	0.6694			0.6690	0.6686
04	20	0.7874	0.7879	0.7875	0.7877	0.7877	0.7879	0.7875			0.7871	0.7866
05	25	0.9843	0.9848	0.9844	0.9846	0.9846	0.9848	0.9844			0.9840	0.9835
06	30	1.1811	1.1816	1.1812	1.1814	1.1812	1.1816	1.1812			1.1808	1.1803
07	35	1.3780	1.3785	1.3781	1.3783	1.3781	1.3785	1.3781			1.3776	1.3770
08	40	1.5748	1.5753	1.5749	1.5751	1.5749	1.5753	1.5749	1.5753	1.5749	1.5744	1.5738
09	45	1.7717	1.7722	1.7718	1.7720	1.7718	1.7725	1.7721	1.7725	1.7721	1.7713	1.7707
10	50	1.9685	1.9690	1.9686	1.9688	1.9686	1.9693	1.9689	1.9693	1.9689	1.9681	1.9675
11	55	2.1654	2.1660	2.1655	2.1657	2.1655	2.1664	2.1659	2.1664	2.1659	2.1650	2.1643
12	60	2.3622	2.3628	2.3623	2.325	2.3623	2.3632	2.3627	2.3632	2.3526	2.3618	2.3611
13	65	2.5591	2.5597	2.5592	2.5594	2.5592	2.5601	2.5596	2.5601	2.5596	2.5587	2.5580
14	70	2.7559	2.7565	2.7560	2.7562	2.7560	2.7569	2.7564	2.7571	2.7564	2.7555	2.7548
15	75	2.9528	2.9534	2.9529	2.9531	2.9529	2.9538	2.9533	2.9540	2.9533	2.9524	2.9517
16	80	3.1496	3.1502	3.1497	3.1500	3.1497	3.1506	3.1501	3.1508	3.1501	3.1492	3.1485

Table 6-3 Shaft Diameter Limits for Grade 00 and Quiet Bearings - Continued

			Shaft Diameter Limits [2] (inches)									
Bearing Bore			Shaft Rotating								Shaft Stationary [1]	
	Nominal		Ball		Quiet		Cylindrical		Spherical			
Bore Code	MM	Inch	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
17	85	3.3465	3.3472	3.3466	3.3469	3.3466	3.3476	3.3470	3.3479	3.3470	2.3460	3.3451
18	90	3.5433	3.5440	3.5434	3.5437	3.5434	3.5444	3.5438	3.5447	3.5438	3.5428	3.5419
19	95	3.7402	3.7409	3.7403	3.7406	3.7403	3.7413	3.7407	3.7416	3.7407	3.7397	3.7388
20	100	3.9370	3.9377	3.9371	3.9374	3.9371	3.9381	3.9375	3.9384	3.9375	9.3965	3.9356
21	105	4.1339	4.1346	4.1340	4.1343	4.1340	4.1350	4.1344	4.1358	4.1349	4.1334	4.1325
22	110	4.3307	4.3314	4.3308	4.3321	4.3308	4.3318	4.3312	4.3326	4.3317	4.3302	4.3293
24	120	4.7244	4.7251	4.7245	4.7248	4.7245	4.7235	4.7249	4.7263	4.7234	4.7239	4.7230
26	130	5.1181	5.1189	5.1182	5.1186	5.1182	5.1194	5.1187	5.1203	5.1193	5.1175	5.1165
28	140	5.5118	5.5126	5.5119			5.5131	5.5124	5.5140	5.5130	5.5112	5.5102
30	150	5.9055	5.9063	6.2993			6.3008	5.9061	5.9083	5.9037	5.9049	5.9039
32	160	6.2992	6.3000	6.6930	6.2997	6.2993	6.6945	6.2998	6.3020	6.3010	6.2986	6.2976
34	170	6.6929	6.6937	7.0867			7.0882	6.6935	6.6957	6.6947	6.6923	6.6913
36	180	7.0866	7.0874	7.4805			7.4821	7.0872	7.0894	7.0884	7.0860	7.0850
38	190	7.4803	7.4813	7.8742			7.8758	7.4809	7.4835	7.4823	7.4797	7.4785
40	200	7.8740	7.8750					7.8746	7.8772	7.8760	7.8734	7.8722
44	220	8.6614							8.6646	8.6634	8.6608	8.6596
48	240	9.4488							9.4520	9.4508	9.4482	9.4470
52	260	10.2362							10.2396	10.2384	10.2355	10.2343
56	280	11.0236							11.0270	11.0238	11.0229	11.0277
60	300	11.8110							11.8157	11.8145	11.8103	11.8091
64	320	12.5984							12.6043	12.6029	12.5977	12.5963

[2]These tolerances apply to all points along the length of the bearing seat.

Table 6-4 Housing Bore Limits for Grade 00 and Quiet Bearings

Bearing Outside Diameter		Housing Bore Limits[5] (inches)							
		Housing Stationary			Housing Rotating			Special [4]	
Normal		All [1]	Quiet		Ball	Cylindrical Spherical		Cylindrical Spherical	
MM	Inch	Max [2]	Max	Min	Min [3]	Min	Max	Min	Max
16	0.6299	0.6303			0.6292	0.6291	0.6295	0.6295	0.6229
19	0.7480	0.7485			0.7472	0.7470	0.7475	0.7475	0.7480
22	0.8661	0.8666			0.8653	0.8651	0.8656	0.8656	0.8661
24	0.9449	0.9454			0.9441	0.9439	0.9444	0.9444	0.9449
26	1.0236	1.0241			1.0228	1.0226	1.0231	1.0231	1.0236
28	1.1024	1.1029	1.1029	1.1026	1.1016	1.1014	1.1019	1.1019	1.1024
30	1.1811	1.1816	1.1816	1.1813	1.1803	1.1801	1.1806	1.1806	1.1811
32	1.2587	1.2604			1.2588	1.2587	1.2593	1.2593	1.2599
35	1.3780	1.3786	1.3785	1.3782	1.3770	1.3769	1.3775	1.3775	1.3781
37	1.4567	1.4573	1.4572	1.4569	1.4557	1.4556	1.4562	1.4652	1.4568

Table 6-4 Housing Bore Limits for Grade 00 and Quiet Bearings - Continued

Bearing Outside Diameter		Housing Bore Limits[5] (inches)							
		Housing Stationary			Housing Rotating			Special [4]	
Normal		All [1]	Quiet		Ball	Cylindrical Spherical		Cylindrical Spherical	
MM	Inch	Max [2]	Max	Min	Min [3]	Min	Max	Min	Max
40	1.5748	1.5754	1.5753	1.5750	1.5738	1.5737	1.5743	1.5743	1.5749
42	1.6535	1.6541	1.6540	1.6537	1.6525	1.6524	1.6530	1.6530	1.6536
47	1.8504	1.8510	1.8509	1.8506	1.8494	1.8493	1.8499	1.8499	1.8505
52	2.0472	2.0479	2.0479	2.0475	2.0460	2.0459	2.0466	2.0466	2.0473
55	2.1654	2.1661			2.1642	2.1641	2.1648	2.1648	2.1655
62	2.4409	2.4416	2.4416	2.4412	2.4397	2.4396	2.4403	2.4403	2.4410
68	2.6772	2.6779			2.6760	2.6759	2.6766	2.6766	2.6773
72	2.8346	2.8353	2.8353	2.8349	2.8334	2.8333	2.8340	2.8340	2.8347
75	2.9528	2.9535	2.9535	2.9531	2.9516	2.9515	2.9522	2.9522	2.9529
80	3.1496	3.1503	3.1503	3.1499	3.1484	3.1483	3.1490	3.1490	3.1497
85	3.3465	3.3474	3.3474	3.3469	3.3451	3.3449	3.3458	3.3458	3.3467
90	3.5433	3.5442	3.5442	3.5437	3.5419	3.5417	3.5426	3.5426	3.5435
100	3.9370	3.9379	3.9379	3.9374	3.9356	3.9354	3.9363	3.9363	3.9372
110	4.3307	4.3316	4.3316	4.3311	4.3293	4.3291	4.3300	4.3300	4.3309
115	4.5276	4.5285			4.5262	4.5260	4.5269	4.5269	4.5278
120	4.7244	4.7253	4.7253	4.7248	4.7230	4.7228	4.7237	4.7237	4.7246
125	4.9213	4.9233			4.9197	4.9194	4.9204	4.9205	4.9215
130	5.1181	5.1191	5.1191	5.1186	5.1186	5.1165	5.1172	5.1173	5.1183
140	5.5118	5.5128	5.5128	5.5123	5.5102	5.5099	5.5109	5.5110	5.5120
145	5.7087	5.7097			5.7071	5.7068	5.7078	5.7079	5.7089
150	5.9055	5.9065	5.9065	5.9060	5.9639	5.9036	5.9046	5.9047	5.9057
160	6.2992	6.3002	6.3002	6.2997	6.2976	6.2973	6.2983	6.2984	6.2994
170	6.6929	6.6939	6.6938	6.6934	6.6913	6.6910	6.6920	6.6921	6.6931
180	7.0866	7.0876	7.0875	7.0871	7.0850	7.0847	7.0857	7.0858	7.0868
190	7.4803	7.4815	7.4814	7.4809	7.4758	7.4781	7.4793	7.4793	7.4805
200	7.8740	7.8752	7.8751	7.8746	7.8722	7.8718	7.8730	7.8730	7.8742
210	8.2677	8.2689			8.2659	8.2655	8.2667	8.2667	8.2679
215	8.4646	8.4658	8.4657	8.4652	8.4628	8.4624	8.4636	8.4636	8.4648
220	8.6614	8.6626			8.6596	8.6592	8.6604	8.6604	8.6616
225	8.8583	8.8595	8.8594	8.8589	8.8565	8.8561	8.8573	8.8573	8.8585
230	9.0551	9.0563			9.0533	9.0529	9.0541	9.0541	9.0553
240	9.4488	9.4500	9.4499	9.4494	9.4470	9.4466	9.4478	9.4478	9.4490
250	9.8425	9.8437			9.8407	9.8403	9.8415	9.8415	9.8427
260	10.2362	10.2374	10.2373	10.2368	10.2342	10.2339	10.2351	10.2352	10.2364
270	10.6229	10.6311			10.6279	10.6276	10.6288	10.6289	10.6301
280	11.0236	11.0248	11.0247	11.0242	11.0216	11.0213	11.0225	11.02263	11.0238
290	11.4173	11.4185	11.4184	11.4179	11.4153	11.4150	11.4162	11.4163	11.4175
300	11.8110	11.8122			11.8090	11.8087	11.8099	11.8100	11.8112
310	12.2047	12.2059			12.2027	12.2024	12.2036	12.2037	12.2049
320	12.5984	12.5998			12.5962	12.5958	125972	12.5972	12.5986
340	13.3858				13.3836	13.3832	13.3846	13.3846	13.3860
360	14.1732				14.1710	14.1706	14.1720	14.1720	14.1734
370	14.5669				14.5647	14.5643	14.5657	14.5657	14.5671

Table 6-4 Housing Bore Limits for Grade 00 and Quiet Bearings - Continued

Bearing Outside Diameter		Housing Bore Limits[5] (inches)							
		Housing Stationary			Housing Rotating			Special [4]	
Normal		All [1]	Quiet		Ball	Cylindrical Spherical		Cylindrical Spherical	
MM	Inch	Max [2]	Max	Min	Min [3]	Min	Max	Min	Max
380	14.9606				14.9584	14.9580	14.9594	14.9594	14.9608
400	15.7480				15.7458	15.7454	15.7468	15.7468	15.7482
420	16.5354				16.5329	16.5326	16.5342	16.5342	16.5358
440	17.3228				17.3203	17.3200	17.3216	17.3216	17.3232
460	18.1102				18.1077	18.1074	18.1090	18.1090	18.1106
480	18.8976				18.8951	18.8948	18.8964	18.8964	18.8980
500	19.6850				19.6825	19.6822	19.6838	19.6838	19.6854
540	21.2598				21.2571	21.2569	21.2586	21.2584	21.2601
580	22.8346				22.8319	22.8317	22.8334	22.8332	22.8349

[5]These tolerances apply to all points along the length of the bearing seat.

[4]For use in applications subject to continual vibration and shock with temporary unloading.

[1]Does not apply to quiet bearings.

[2]Minimum housing bore limit equal to bearing nominal OD.

[3]Maximum housing bore limit equal to bearing nominal OD.

Table 6-5 Repair Methods for Undersized Bearing Shaft Seats

Repair Method	Application	Reference
Electroplating (chromium)	0.0015 to 0.025 inch thick	DOD-STD-2182, *Engineering Chromium Plating (Electrodeposited) for Repair of Shafting (Metric)*
Brush Electroplating	Various thicknesses. Good for pitted or scored areas. Portable equipment	MIL-STD-2197, *Brush Electroplating on Marine Machinery*
Sleeving	Thickness limited by strength requirements of shafting or housing.	Interference of 0.001 inch per inch diameter minimum (0.001 inch minimum). Stress-relieve before installing. Pin in two places.

6-9. CARE OF UNMOUNTED BEARINGS.

6-9.1 Handling and Storage. Many bearings are made unsuitable for use by improper storage and handling. Although bearings are designed to be extremely rugged, they are very sensitive to corrosion, dirt, and abusive handling. Safe storage for any length of time requires that the storage area be dry. Do not store bearings in unheated areas, because condensate may form on cold surfaces. Likewise, avoid storing in temperatures above 120° F (49° C), as the preservative will oxidize more rapidly. Apply the first-in, first-out rule of storage. Place frequently used or heavy bearings on lower shelves. Heavy bearings requiring mechanical handling should be placed on pallets to simplify handling and to keep the bearing off the floor in case of flooding. Do not throw or drop bearings. This may scuff or dent the raceways and rolling elements, resulting in noisy operation. Keep bearings in their original packing until they are ready for installation. If a new bearing is accidentally exposed to dirt, clean it thoroughly (paragraph 6-9.3.1).

NOTE

NT4 is the latest noise requirement as of this printing.

6-9.2 Inspection. All bearings procured through the military supply system are manufactured by government-qualified firms. Boundary dimensions and tolerance grades standardized by the bearing industry and adopted by the government and material control information provide the quality control demanded by government resource inspectors. Because of the critical dimensional and vibration requirements of quiet bearings, a sample from every bearing procurement lot is checked on a continuous basis at the Carderock Division, Naval Surface Warfare Center (CDNSWC). Bearings marked with the NT symbol followed by the noise requirement number have passed the requirement for quiet bearings.

6-9.2.1 Before you use a bearing, you must inspect it also. Inspection procedures should consist of the following:

6-9.2.1.1 Inspect the bearing package date which is recorded on the individual box of every bearing or set of duplex bearings. If the package date is 10 years or older, file a Quality Deficiency Report and return the bearings to the issuer. Grease degradation in older bearings can result in reduced bearing life and early equipment failure. This procedure is applicable to both Grade 00 and noise-tested bearings.

6-9.2.1.2 Make sure that you have the correct bearing before removing the packing.

6-9.2.1.3 If the package has been broken but the bearing appears usable, clean the bearing.

6-9.2.1.4 Examine the bearing for corrosion, dirt, and dents. Do not use externally corroded bearings except in emergencies.

NOTE

Bearings packed in grease that have been on the shelf for some time may resist hand rotation at first. This resistance has resulted in the disposal of many good bearings that were reported to be defective for having dried grease or flat balls. This resistance to rotation is common and will clear up as the grease is worked. Work the bearing by hand for several minutes. Allow it to sit a short time and then check it again. If it has not cleared up, a problem may indeed exist.

6-9.2.1.5 Rotate the bearing by hand to determine freedom of rotation.

6-9.2.2 If the bearing had been preserved by grease and the application uses oil, remove the grease (paragraph 6-9.3.1).

6-9.3 Cleaning. Do not clean bearings as a routine procedure, since foreign matter can easily enter a bearing. Ordinary airborne dust, paint chips, metal filings, brush bristles, cigarette ash, and other foreign objects can severely damage a bearing. Double-seal and double-shield bearings cannot be cleaned unless manufactured with removable closures. Normal practice is to inspect these bearings and accept or reject them on the basis of rotational smoothness and appearance. Single-seal and single-shield bearings can be cleaned satisfactorily using the methods below if cleaning operations are repeated enough to ensure that all contaminant has been removed.

6-9.3.1 New Bearings. If a new bearing is exposed to any contaminant or grease must be removed, clean the bearing as follows:

a. Secure a clean, dry container and fill it with clean, filtered MIL-L-17331, *Lubricating Oil, Steam Turbine and Gear, Moderate Service, Military Symbol 2190 TEP.*
b. Heat the oil to 140° ± 10° F (60 ° ± 5° C).
c. Immerse the bearing in the oil and rotate and agitate it until all the dirt or grease is washed out. Do not use a brush.
d. Repeat step c., in a second container of clean, filtered oil.
e. When clean, remove the bearing. Cover it and allow the excess oil to drain off. Do not wipe. Do not spin. Do not use compressed air. Handle the bearing with lint-free gloves or cloths.
f. Immediately after, place the bearing in a plastic bag or wrap it in aluminum foil. If the bearing is not to be mounted, rebox, properly identify, and store it.

6-9.3.2 Used Bearings. Thoroughly consider the justification for cleaning and reusing a bearing. Such procedures are usually feasible only on larger, more expensive bearings or in emergencies. Before disassembly, determine if replacement bearings are available. When reuse of bearings is considered, dismounting procedures demand a high level of care to avoid bearing damage.

6-10. SAFETY PRECAUTIONS.

Observe the following precautions when working with rolling-element bearings:

6-10.1 Unless absolutely necessary, never use a piece of machinery if the bearings are known to be in poor condition.

6-10.2 Since good bearing performance depends on proper lubrication, never start a piece of machinery until all bearings are known to be properly supplied with lubricant, both in quality and in quantity.

6-10.3 Determine the normal running temperature of each bearing under all conditions of load and speed, and investigate immediately any changes.

6-10.4 The rapid heating of a bearing is a danger sign. A bearing temperature uncomfortably hot to the touch is not necessarily running overheated. If the bearing has taken an hour or more to reach that temperature, it is probably safe. If that same temperature is reached in a few minutes, expect serious trouble.

6-10.5 Watch the performance of newly installed bearings carefully when first starting a piece of machinery until it is known that they have reached and are operated at a safe running temperature.

6-10.6 If possible, give newly installed bearings a run-in period applying no load.

6-10.7 Do not use waste cloths to clean bearings or journals. Use only lint-free cloths.

6-10.8 When renewing rolling-element bearings be sure to use the type and grade designed on the machinery drawings and as specified by allowance parts list and the technical manual.

6-10.9 Never try to repair damaged rolling-element bearings by replacing balls or rollers.

6-10.10 Do not remove a rolling-element bearing from its original container and wrapping until every preparation has been made to install it.

6-10.11 When installing rolling-element bearings, be sure that the inner race is seated tightly against the shaft shoulder.

6-10.12 Avoid excessive lubricant in rolling-element bearings. Very little lubricant is required. Excessive lubricant fills the spaces between elements. This impedes free movement and causes early failure.

6-10.13 Be particularly careful to seal housings of rolling contact bearings against the entry of foreign matter.

6-11. CARE OF MOUNTED BEARINGS.

6-12. HANDLING, MAINTENANCE AND LUBRICATION OF MOUNTED BEARINGS

The greatest threats to mounted bearings are brinelling of the races caused by poor handling, false brinelling of the races caused by wearing away of material due to vibratory motion during storage or transport, and corrosion due to a lack of preservative compound on bearing surfaces. All these conditions can be avoided with correct care.

6-12.1 Handling and Storage. Abusive handling and improper storage of assembled machinery can negate all pervious precautions taken to prevent premature bearing failure.

6-12.1.1 If partial assemblies with mounted bearings (such as rotors) are stored, coat the bearings with a preservative and securely wrap with plastic or foil. Do not use cloth wrapping.

6-12.1.2 When handling heavy assembled machinery, always use mechanical lifting equipment. Fasten suspension lines only to the lifting lugs provided. Any other attached point may distort the housing or bend the shaft, resulting in bearing misalignment. Never attach a suspension line to the shaft extension.

NOTE

Perform shipboard maintenance in accordance with the Maintenance Requirement Cards (MRC) where installed.

6-12.2 Maintenance. Bearings are an integral part of the assembly, making it impossible to observe their operation. Do not routinely disassemble machinery just to inspect the bearings or lubricant. The following methods have been established to help assess mounted bearing condition.

6-12.2.1 Preoperational Inspection. A considerable amount of time can be saved by performing the following preoperational checks:

a. Review the unit's history. For grease-lubricated relubricable bearings: if the unit has been shut down or in storage for over 1 year, remove the end caps to check the grease. If the end caps cannot be removed without major disassembly and, if available records indicate that the bearings have not been lubricated in the past year, lubricate the unit (paragraph 6-12.3.4). In units with shafts installed or stowed vertically and using other than sealed bearings, the grease may move to a point below the bearing and will not provide lubrication on startup.

b. Rotate the shaft by hand. The shaft shall turn freely without binding. Locate and eliminate the cause of any abnormal resistance to rotation.

c. On units with shaft extensions, use a dial indicator (paragraph 2-53) to check the shaft total indicated runout (FIR) at the extreme end.

d. Check the overall appearance of the unit for indications of bumping or dropping. Severe bearing misalignment can result from abusive handling.

e. Ensure that all hardware is tight.

f. When possible, dynamically balance rotating parts in accordance with the applicable specification or technical manual. An inplace balance of the assembled unit may be required.

6-12.2.2 In-Service Inspection. The length of the run-in period of new bearings may vary considerably, but 24 hours is usually long enough. Major difficulties will almost always appear during this period. Monitor the bearing temperature, noise, and vibration. When the load can be varied, run the unit under minimum load for several hours and then gradually increase to full load at hourly increments. Rolling-element bearings will normally have an extremely long service life if properly designed for the application, correctly installed, and maintained as required. Because of this, the actual date of bearing installation is not usually known unless accurate records are maintained. Periodic casual inspection of bearing performance is, therefore, desirable. A daily casual inspection for noise, vibration, and temperature will tend to reduce unexpected failures.

6-12.2.3 Temperature. All bearings generate heat during operation. Bearing temperature is a function of load, speed, lubricant, motor losses, and ambient temperature. Military specifications for motors limit bearing operating temperature by limiting the temperature of the outer bearing ring to either 194° F (90° C) or 230° F (110° C), depending upon which specification revision was in effect when the motor was procured. Bearing operating temperature at rated load is measured with a temperature sensor on the outer ring of the bearing by the motor manufacturer during qualification resting. These test results are shown on the motor master drawing, in the Heat Run section. The motor master drawing is normally located in the technical manual for the driven auxiliary or motor. Properly designed bearing systems operate at steady temperature levels. Small temperature changes within the safe operating range are normal as the grease alternately lumps into the races and channels again, or as the load changes. On the other hand, sharp unexpected temperature increases usually indicate trouble, possibly impending failure. Bearing temperature can be routinely checked by placing a hand on the housing. If the surface feels too hot to touch, examination is necessary. Do not, however, insert a liquid-in-glass thermometer into the bearing housing, either against the bearing or in the grease or oil reservoir. Take measurements on the housing close to the bearing. Self-indicating bimetallic and gas thermometers common to shipboard use require a significant immersion length and will not accurately record surface temperature. Instruments for measuring surface temperature are commercially available and are usually supplied with tip-sensitive pencil probes. These are ideal for accurately measuring remote bearing temperature. A thermometer with the bulb embedded in a mound of clay or putty and securely fastened on the external housing surface close to the bearing will usually provide satisfactory temperature measurement. Commercially available temperature-sensitive crayons (such as Tempilstiks or Thermomelt) or tape (such as Temp-Plate) can satisfactorily indicate temperature. If the normal operating temperatures on the exterior of the motor housing in the vicinity of the bearings are known from experience, excessive bearing temperature can be identified by measuring these surface temperatures on the motor housing. If the normal operating temperatures are not known, an uncertainty results when determining bearing overtemperature this way since the outer ring is from 41° F to 59° F (5° C to 15° C) hotter than the exterior housing. The temperature measurement made on the housing must be compared to that in the motor master drawing. Be sure to adjust the housing measurements for differences in ambient temperature associated with the drawing measurement. The value on the drawing is also measured at rated load. The load on the ship is often less than the rated load. Therefore, the value measured on the housing will be less than that on the drawing due to the loading difference and due to the 41°F to 59°F (5°C to 15°C) differential mentioned above. If the bearing temperature is unexpectedly high in relation to past experience or if the temperature exceeds the maximum design limit, further examination is necessary. Bearing overheating may result from many sources. The most common ones are as follows:

6-12.2.3.1 If the temperature rises immediately after startup in a grease-bearing application, it is probably because the grease has slumped into the races. Stopping the unit and allowing the grease to cool in the channeled state will usually cure this condition.

6-12.2.3.2 If the temperature rises immediately after startup in an oil lubrication application, stop the unit and immediately check that the oil level is in accordance with the instruction. If the level is satisfactory, the circulating system may be clogged or inoperative.

6-12.2.3.3 If the temperature rise occurs immediately after the bearing has been lubricated with grease, the cause may be too much grease or the wrong type of grease. To avoid this condition, follow the correct lubrication procedure for both quantity and type. If the bearing is overgreased, remove the drain plug and allow the excess to drain. If the grease is the wrong type, disassemble and clean the bearing.

6-12.2.3.4 Excessive loading of the bearing. This can be caused by excessive bearing preload, excessive shaft or housing interference, or external bearing overload. These are usually caused by mounting or assembly errors.

6-12.2.3.5 Error in alignment during mounting.

6-12.2.3.6 Tight-fitting seals.

6-12.2.4 Noise and Vibration. In shipboard applications, noise is structureborne, airborne, and fluidboure. Noise is caused by vibration. All rolling-element bearings generate vibration. In rotating machinery, the amplitude of bearing vibration is a function of bearing quality, seat geometry, and fitup. Electronic equipment can measure the structure-borne noise of rotating equipment in noise critical applications. Quiet bearings are usually used in noise-critical applications because they generate low levels of vibration. Instruction manuals on the use of this type of electronic equipment and the analysis of results have been issued to participating ships and should be consulted. In non-noise-critical applications, a rough vibration check can be made by placing a hand on the machine frame. If a mechanic's stethoscope is not available, use a metal tool to listen for unusual noises. Hold the ear to one end of the tool, rod, or pipe and hold the other end to the machine frame as close to the bearing as possible. Only a soft purring sound should be heard. Learn to recognize this sound by practicing on bearings known to be in good condition. Some typical sounds and their causes listed below:

NOTE

> The listening method of detecting trouble is comparative. It should not be the basis for tearing down a piece of equipment unless the operator has considerable experience.

6-12.2.4.1 Squeaking noise. Inadequate lubrication or insufficient load (preload).

6-12.2.4.2 Metallic Tone. Insufficient internal bearing clearance caused by excessive shaft or housing interferences, or axial preloading caused by improper adjustment or inadequate lubrication.

6-12.2.4.3 Smooth, Clear Tone. Marks in the stationary raceway caused by brinelling. When the sound intensity varies regularly with each revolution, the rotating ring has been brinelled.

6-12.2.4.4 Intermittent Noise. Usually unique to ball bearings and indicates a damaged ball.

6-12.2.4.5 Crunching Noise. Presence of dirt. Clean the bearing immediately.

6-12.3 Lubrication. The bearing lubricant is chosen during equipment design, and an equivalent type must be used during maintenance. As a rule, all rolling-element bearings may be lubricated with oil. They are grease-lubricated in most electric motor applications. The use of grease, though, is limited by operating speeds, loads, and temperature.

6-12.3.1 Rolling-element bearing lubrication serves the following primary functions:

6-12.3.1.1 Prevents metal-to-metal contact between the races and rolling elements that is not true rolling.

6-12.3.1.2 Lubricates the sliding contact that exists between the cage and other bearing parts.

6-12.3.1.3 Lubricates the sliding contact between the rollers and guiding elements in roller bearings.

6-12.3.1.4 Protects the highly finished surfaces of rolling elements and races from corrosion.

6-12.3.1.5 In grease applications, helps seal against the entry of foreign matter.

6-12.3.1.6 In oil applications, provides cooling by dissipating heat.

6-12.3.2 Characteristics of Grease. Grease is a mixture of a lubricating oil, a metallic-base soap, and a thickener. The soap and thickener hold the oil. Oil separates from the soap under pressure or agitation. The grease acts somewhat like an oil sponge.

6-12.3.2.1 A ball bearing will sling nearly all the grease away from the ball train during normal operation. Only a small amount of oil is retained on the balls and raceways. Excess oil is pressured out as grease slumps down into the ball train. The oil is then reabsorbed into the grease. This permits a small amount of oil to provide adequate lubrication for long periods.

6-12.3.2.2 As grease repeatedly slumps into a bearing which is operated for a long time, some of the grease is thrown clear and may become mixed with air. It will have a milky appearance, but it will not become less effective as a lubricant. Some of the soap may have part of its oil drawn out during long periods of operation. This will leave hard lumps of pure soap, which serve no lubrication purpose. They will not reduce the reliability of the bearings, though, as long as there is an adequate supply of oil-rich grease to work its way into the bearings.

6-12.3.3 Grease Lubrication. For applications involving moderate speeds and temperatures, the simplicity and reliability of grease lubrication is desirable. Open, single-shield, and single-seal bearings as mounted usually require the periodic addition of grease and are termed *relubricable* bearings. Double-shield and double-seal bearings are permanently lubricated at the factory and require no further grease. Such bearings are *prelubricated* bearings. The service life of prelubricated bearings is limited to the effective life of the original grease charge. Prelubricated bearings are usually restricted to applications with favorable grease life characteristics. Electric motors with prelubricated bearings can be recognized by the absence of grease fittings or provision for attaching grease fittings and by attached warning plates stating **DO NOT LUBRICATE.** Relubricable bearings in new machines are packed with grease when they leave the factory. The frequency with which grease must be added depends on the service of the machine and the tightness of the housing seals. Avoid using too much grease because it results in an excessive and rapid temperature increase. Add grease only when required.

6-12.3.4 Grease Addition. A bearing is lubricated only by the grease that is immediately next to and in contact with it. The grease in this location may gradually stop lubricating because the oil is depleted, leaving just the thickener. The grease farther away from the bearing may still be in good condition. Therefore, it is a good idea to add a small amount of grease close to the bearing at specified intervals. The preferred method of adding grease is to open the housing so that the bearing and old grease can be examined and new grease can be placed directly in and next to the bearing. For Navy equipment where extensive disassembly would be required to repack the bearing with grease, the bearings are designed so that fresh grease can be added to the bearing housing by a grease cup, without the need for disassembly. Housing designs vary considerably, making relubrication with a grease cup something of an art. Be careful not to overgrease the bearings. The following procedure is recommended:

NOTE

Never lubricate electrical machinery with a grease gun. If grease gun fittings are found on electrical machinery, remove them and install a suitable grease cup fitting and pipe plug.

a. Select the proper grease cup and clean it thoroughly. Select the correct grease and, using a clean spatula, fill the cup. Screw the cup together, and squeeze out a ribbon of grease until clean grease emerges.

b. Secure the machine. Tag it **OUT OF SERVICE** . Disassemble it as required. Wipe all dirt from the outside of the grease fill-and-vent plugs.

c. Remove the vent plug and make sure that the passage is open by probing it with a clean screwdriver, stiff wire, or similar item. Old grease may be forced out the vent. Note the condition of the displaced grease. Dark grease indicates either the onset of oxidation or the presence of dirt. Grease containing metallic particles and dirt indicates trouble. Rub a little grease between the fingers. If water is present, it will form droplets. Particles will be felt easily. When contaminants are present, corrective action is necessary.

d. Remove the pipe plug from the grease supply passage. Observe the condition of the grease in the pipe. If acceptable, proceed. If unacceptable, remove the grease pipe, if so designed, clean it, pack it full of the correct grease, and reinstall it. If the pipe is empty, remove it, clean it, fill it with the correct grease, and reinstall it. If the grease in the supply passage is unacceptable and the pipe is not removable, remove the bearing end cap or end bell and hand-pack the bearing.

e. Mount the grease cup on the equipment. Fill the grease cup.

f. Screw down on the grease cup as far as it will go. If grease is drawn into the cup as the cap is unscrewed, the preferred action is as follows:

   (1) Screw the cap back into the cup as far as it will go to force the grease back into the lubrication supply passage.

   (2) Remove the cup from the equipment.

   (3) If relubrication is complete, install the supply passage pipe plug and operate the equipment as recommended.

   (4) If relubrication is not complete, remove the cap from the cup and reinstall the cup on the equipment.

   (5) Load the cup with grease and screw down on the cap as far as it will go, as previously recommended.

   (6) Repeat these steps as required until relubrication is complete.

g. Remove the grease cup and install the supply passage pipe plug. Start the machine and allow it to run for 30 minutes. Replace the vent pipe plug.

An alternate procedure to the above is to drill a small hole in the cap after the cup is removed from the equipment. The hole diameter should not be larger than 1/16th inch. The cap must be removed from the cup prior to drilling. The cap must be thoroughly cleaned after drilling to remove all metal chips. Any burrs around the drilled hole must be removed prior to cleaning. The operator must hold a finger over the hole to prevent grease from escaping while screwing the cap.

6-12.3.5 Grease Replacement. Replace all old grease in the bearing housings when the machinery is disassembled for any reason. Remove the bearing caps or covers that permit observation of bearing and lubricant. Depending on the conditions found, one of the following actions may be necessary.

6-12.3.5.1 If the grease in the bearing is still good, replace only the grease in the housing where possible.

a. Wrap the bearing in clean, lint-free material.

b. Scrape the old grease from all accessible portions of the housing. Be careful not to introduce dirt into the housing or the bearing. Do not wipe.

NOTE

Do not flush the bearing cap with oil if the oil could leak into the windings of electrical machinery. It may be impractical to flush out the complete housing without removing the bearing.

c. Flush out the bearing cap or cover it with clean, warm 2190 TEP oil. Apply a light coat of grease to the unpainted bearing housing surfaces.

d. Drain well.

e. In horizontal applications with an open bearing, pack the housing on both sides of the bearing half full of grease.

f. In horizontal applications with a single-seal or single-shield bearing, pack the housing opposite the seal or shield half full.

g. In vertical applications with an open bearing, or a single-seal or single-shield on top, pack the housing below the bearing three-quarters full.

h. In vertical applications with a single-seal or single-shield on the bottom of the bearing, the amount of grease above the bearing is critical. Limit the housing pack above the bearing to an amount that will lie on the stationary bearing ring (one-third to one-half full). Do not overpack or allow grease to slump into bearing. The grease will bleed into the bearing during normal operation.

i. In all cases lightly coat the bearing with grease.

j. Pack the entire length of the grease inlet passage and inlet pipe with clean grease.

k. Reassemble the bearing housing.

6-12.3.5.2 If the grease in the bearing is sticky or rancid, contains dirt or foreign matter, or is generally deteriorated, wash out the bearing (paragraph 6-9.3.1). If the bearing shows excessive wear or if any parts are damaged, replace the bearing. Otherwise, pack the bearing with clean grease (paragraph 6-12.3.5). Prepare the bearing housing and pack the grease in the housing (paragraph 6-12.3.5.1). Observe proper replacement procedures.

6-12.3.6 Preferred Navy bearing greases for shipboard auxiliary machinery are as follows:

NOTE

Other sizes of containers may be available under other NSNs. If a specified grease is obsolete, consult NAVSEA S9086-H7-STM-010/CH 262, ″Lubricating Oils, Greases, Hydraulic Fluids, and Lubricating Systems,″ for an approved substitute.

6-12.3.6.1 Bearings operating below 230° F (100° C) in non-noise-critical applications use DOD-G-24508, *Grease, High Performance, Multipurpose* , available in 1-pound cans, NSN 9150-00-149-1593.

6-12.3.6.2 Bearings operating above 230° F (100° C) in non-noise-critical applications, except electric motor bearings, use MIL-L-15719, *Lubricating Grease (High-Temperature, Electric Motor, Ball and Roller Bearings)* , available in 8-ounce tubes, NSN 9150-00-256-5358.

6-12.3.6.3 Quiet bearings for noise-critical applications use DOD-G-24508, grease available in 1-pound cans, NSN 9150-00-149-1593.

6-12.3.6.4 Where specifically approved for the application, use MIL-G-81322, *Grease, Aircraft, General Purpose, Wide Temperature Range,* or DOD-G-24508 available in the following:

6-12.3.6.4.1 MIL-G-81322, 8-ounce tube, NSN 9150-00-181-7724.

6-12.3.6.4.2 DOD-G-24508, 8-ounce tube, NSN-9150-00-149-1592.

6-12.3.6.5 Roller bearings in surface ship control surface systems use MIL-G-24139, *Grease, Multipurpose, Water Resistant* , available in 5-pound cans, NSN 9150-00-180-6382.

6-12.3.7 Oil Lubrication. For oil-lubricated bearings, refer to NAVSEA S9086-HN-STM-010/CH 244.

6-13. NOISE-TESTED BEARINGS.

The present noise-tested (NT-3 and NT-4) bearings are manufactured to very precise specifications for dimensions, geometrics, and quality of finish. For example, a size 313 bearing, with a 65mm (2.5591 inches) bore and eight balls of 15/16 inch diameter, has 0.0002 inch maximum tolerances on the inner and outer diameters. It can be expected to have taper and circularity of the rings held to within 0.00005 inch. The raceways are ground, lapped, and honed to curvature and waviness tolerances within 0.00001 inch. The maximum ball-to-ball variation in size will be about 0.000005 inch. The circularity of each ball will vary less than 0.000001 inch.

6-13.1 Raw Steel Stock. This degree of quality control extends to the raw steel stock. The processes of pouring, cooling, and forging of the steel are designed to provide optimum durability of the finished bearing. Cutting, machining, and various heat treatments are also designed to provide maximum durability.

6-14. MECHANICAL DAMAGE.

Mechanical damage to bearings may occur during installation or during operation of the motor. Mechanical damage is usually shown by damaged shields, damaged retainers, or chipped and scratched raceways.

6-15. CORROSION.

Corrosion appears in many forms. Although corrosion is undesirable, it does not always reduce the reliability of a bearing. It does not necessarily require a bearing change.

6-15.1 Rust. Rust on a new bearing or on a bearing already in a motor may be caused by moisture or corrosive gases in the air. If rust appears on the outside, there is probably rust on the raceways and balls. The bearing must be suspected to be unfit unless there is assurance that there is no internal rust.

6-15.2 Reactions. Reactions within a lubricant may frequently cause staining of the bearing rings or retainer. Dark blue, green, or brown stains which are not due to excessive heat are usually harmless. They do not require replacement of a bearing. Metal shields or retainers occasionally have tinned surfaces. They become dark blue or black under the action of some lubricants. This is also harmless.

6-15.3 Fretting. Fretting corrosion results from a combination of chemical and mechanical attack. It occurs between steel surfaces subjected to repeated mechanical loading. Fretting corrosion consists of the pitting of the steel surfaces and the formation of a brown corrosion product which is often found on the inner ring or on the outer diameter of a bearing. It is harmful only if it appreciably damages surfaces, or if pitting threatens to destroy proper bearing fitup. Fretting corrosion in a bearing bore warns that the shaft may be slightly undersized. The shaft may then have to be built up and reground to proper size. The same is true in the case of the outer ring and its housing.

6-16. ELECTRIC ARCING.

Electric arcing rarely causes bearing damage, but it occasionally occurs in motor-generator sets. It first appears as a light ″frosting″ or roughening of the ball or raceway surfaces. It causes the grease to turn black.

Electric arcing will occur in the zone of thinnest oil films; therefore, it will usually be concentrated in the loaded portions of the ball tracks on each ring. It is possible for all arcing to occur at only one part of the motor rotation. This will cause all of the marking to appear over a short arc on the inner raceway and in the leaded zone of the outer raceway. Under a microscope, electrical damage looks different than dirt damage. The arcing produces pitting with a more irregular outline. Heavy arcing appears as a blasted area. There is evidence of the melting of the steel in the bottom of the pits.

6-17. BEARING REPLACEMENT.

6-17.1 Preliminary Inspection. When equipment using rolling-element bearings requires repair, conduct an in-place inspection. The nature of the casualty can frequently be determined, and this may eliminate unnecessary disassembly. Check for the following:

6-17.1.1 Freedom of rotation. If binding occurs, check close running clearances for noncontact. In coupled units remove the coupling and rotate each unit independently.

6-17.1.2 Excessive heating of the bearings. Eliminate other heat sources.

6-17.1.3 Excessive bearing noise. Eliminate other noise sources.

6-17.1.4 Lose or broken bolts or parts. Check the foundation.

6-17.1.5 Distorted bearing supports, cracked or bent bearing caps, and loose balance rings.

6-17.1.6 Loose or inaccurate coupling alignment, if used.

6-17.1.7 Coastdown time. Compare with previous experience. Short times indicate high torque. Listen to the unit during coastdown. It may pass through resonances that may pinpoint a faulty component.

6-18. WORK AREA AND TOOLS.

The average shop fails to realize the necessity for the highest degree of cleanliness to prevent bearing contamination. An indication of the conditions required of the bearing manufacturer to ensure the cleanliness of packaged bearings is as follows:

6-18.1 The air entering the processing space shall be filtered and air conditioned.

6-18.2 The floor, walls, and ceiling shall be dust-free.

6-18.3 Entry to the are shall be restricted by double doors.

6-18.4 The air in the room shall contain no more than 100 particles, 5 microns (0.0002 inch) or larger, per cubic foot of air.

6-18.5 All personnel shall wear lint-free coats, head and shoe covers, and lint-free gloves.

6-18.6 Nothing extraneous to the operation (food, drink, cigarettes) shall be brought into the area.

6-19. CLEANLINESS.

Positive cleanliness control shall be exercised. Although establishing surgically clean white room facilities may be unfeasible, the following conditions should be adhered to:

6-19.1 In any work area make cleanliness the rule, orderliness a habit.

6-19.2 Handle rolling-element bearings in a clean, dry location.

6-19.3 Avoid areas in which turning, grinding, sandblasting, or blowing is carried on.

6-19.4 The work area shall be away from any machines that create dust-laden air or disturbing vibrations.

6-19.5 A clean workbench with a smooth metal top should be available - dirt and small metal chips cling easily to wooden bench tops.

6-19.6 When it is impossible to move the assembled equipment to a shop, remove the partial assembly that requires bearing work to a suitable location.

6-19.7 If even this is impossible, sweep out and vacuum the assembly area in the machinery space before beginning reassembly.

6-19.8 Ready all components and tools so that assembly can proceed without delay.

6-19.9 Redirect the airflow from the ventilation ducts and shut down unneeded equipment that will circulate dirt and dust.

6-20. TOOLS.

The tools that will be needed are largely determined by the size of the job and should be assembled before beginning work. Measuring instruments shall be stabilized at the same temperature as the parts requiring measurement. The following basic tools and equipment are recommended for bearing replacement work:

6-20.1 Arbor Press. This should large enough to accommodate the assemblies with which you are working. It should be kept clean and in good repair. The face of the ram shall be smooth and perfectly square with its axis. The press should operate smoothly and with accurate control.

6-20.2 Hand Tools. Hammers and drifts should not be of soft, flaky material such as brass, bronze, or aluminum. A weighted-head hammer with composition or leather ends and a soft, cold-rolled steel drift are preferred. Bearing locknut spanner wrenches are standard for smaller sizes. An efficient locknut spanner (figure 6-3) can be manufactured in any shop.

6-20.3 Bearing Pullers. Pullers should conform to GGG-P-781, *Puller, Mechanical Puller Attachment, Mechanical, and Puller Set, Mechanical.* Every ship has such pullers.

6-20.4 Torque Wrenches. Use torque wrenches corresponding to GGG-W-686, *Wrench, Torque* , to properly torque bolts on end bells, end caps, and bearing locknuts.

6-20.5 Convection Oven. Bearings still in their original intimate wrap are placed on a shelf in an oven thermostatically controlled to a nominal 203° F ± 10° F (95° C ± 5° C). Depending on bearing size, a soak period of 1/2 to 1 hour is usually enough. When several bearings are heated simultaneously, they should not be stacked, but placed side by side. Many shops have manufactured ovens using light bulbs mounted in a box lined with foil. In such apparatus, temperature should be controlled by a thermostat rather than by the less reliable method of controlling lamp size and the size of the enclosure. Do not use a convection oven when both inner and outer rings are to be fitted at the size time, since reducing interference on one ring will only increase it on the other.

6-20.6 Bore Heater. A light bulb or electric heating element is inserted in the bearing bore. An advantage of this method is that the inner ring is heated while the outer ring remains relatively cool. This permits easy handling during mounting. In this method heating is controlled by ensuring that the heating element is centered in the bearing bore. Ring temperature should not exceed 203° F (95° C). Cover the bearing to avoid contamination.

6-20.7 Induction Heater. The induction heater is basically a transformer in which the bearing ring acts as a short-circuited second winding. A high current is induced in the bearing ring, resulting in an extremely rapid heating rate. This heater is not approved for ring expansion of quiet bearings. When using for other bearings, use a contact pyrometer or other reliable method to limit ring temperature to 203° F (95° C). The bearing shall never be left unattended in this heater. Disconnect the heater power cord when installing or removing the bearing. Cover the bearing to avoid contamination and demagnetize it before mounting.

6-20.8 Oil Bath. The hot oil bath method consists of heating bearings in oil at a temperature below 203° F (95° C): Do not use this with quiet bearings.

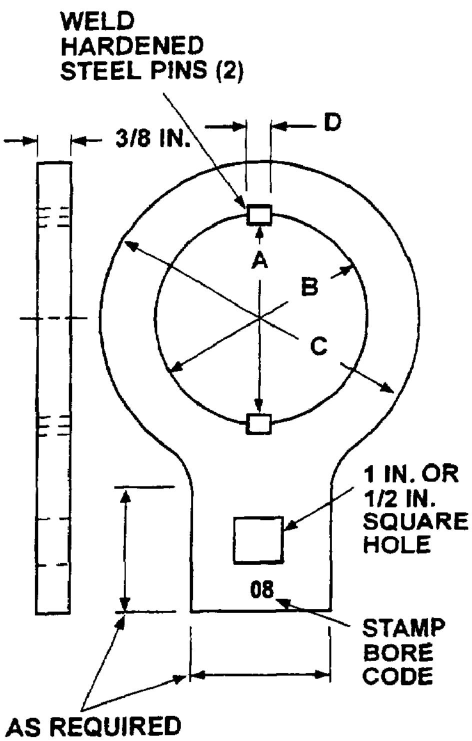
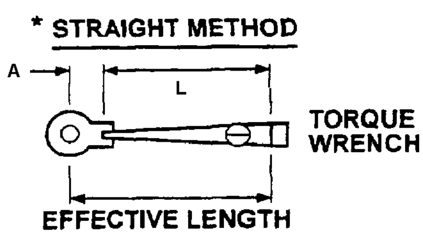


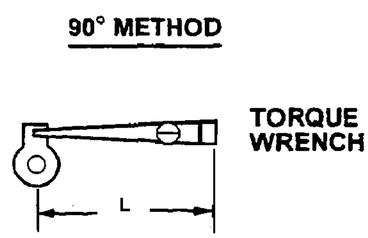
TABLE OF DIMENSIONS

Bore Code	A (Min)	B (Min)	C (Nom)	D (Max)
08	2- 3/32	2- 5/16	3- 5/16	3/16
09	2- 3/8	2- 19/32	3- 5/8	3/16
10	2- 17/32	2- 3/4	3- 3/4	3/16
11	2- 3/4	3- 1/32	4- 1/16	3/16
12	2- 15/16	3- 7/32	4- 1/4	3/16
13	3- 5/32	3- 7/16	4- 1/2	3/16
14	3- 13/32	3- 11/16	4- 3/4	3/16
15	3- 21/32	3- 15/16	5	5/16
16	3- 15/16	4- 7/32	5- 3/8	5/16
17	4- 1/8	4- 15/32	5- 3/4	5/16
18	4- 3/8	4- 23/32	6	5/16
19	4- 21/32	5	6- 1/4	5/16
20	4- 29/32	5- 1/4	6- 1/2	5/16
21	5- 3/32	5- 1/2	7	7/16
22	5- 3/8	5- 25/32	7- 1/2	7/16

MATL: HARDENED 4340 OR EQUAL

APPLICATION METHODS





* When using straight method it is necessary to compute the effective length (L+A) of the torque wrench assembly to determine actual torque applied. Use the following formula:

$$Ta = Tw \times \frac{(L+A)}{L} \text{ where:}$$

Ta = Actual torque exerted
Tw = Torque wrench scale reading
L = Length of torque wrench
A = Length of locknut spanner wrench (center of square hole to center of round hole)

Figure 6-3 Typical Locknut Wrench and Table of Dimensions

6-20.9 Wiping and Handling Materials. Lint-free, clean cloths for covering partial assemblies and for wiping grease and dirt from shafts, housings, and hands should be on hand in ample quantities. Do not use waste, burlap, or cheesecloth. Use clean, insulated gloves when handling bearings. Wear clean clothes when mounting bearings.

6-20.10 Grease. Keep limited stocks of grease at hand. Small containers are preferred as a measure to avoid contamination. Apply grease with a clean metallic or plastic spatula.

6-20.11 Measuring Instruments. For installing quiet bearings, dial-indicating comparative bore and snap gage readings in units of 1/1,000 (0.0001) inch are preferred. Such gages measure the difference between the measured object and a standard of known dimensions. Standards are provided for each shaft and housing size corresponding to a particular bearing size. (Repair ships and yards should have these instruments. They are desirable but not always practical for shipboard.). All ships should have carefully calibrated inside and outside micrometers reading to 0.0001 inch, a dial indicator reading to 0.0001 inch, and master precision gage blocks for checking.

6-21. DISASSEMBLY AND BEARING REMOVAL.

6-22. GENERAL INFORMATION.

Care in removing a bearing is as important as the care in installing a new bearing. Do not destroy any evidence of why a bearing failed, as this information may lead to the solution of the trouble. In an emergency, and if a replacement is unavailable, it may be necessary to reinstall the bearing (paragraph 6-9.3.1). If the machine is dismantled for reasons other than bearing replacement, bearings should not usually be removed. In such instances, the bearing shall be tightly wrapped in a lint-free covering while other work is performed.

6-22.1 Consider the complexity of the job and the experience of the personnel with the fundamentals of bearing handling. Obtain drawings and study the bearing scheme carefully. Read all available repair instructions thoroughly and completely before taking any action. Discuss the entire repair procedure so that each person knows what to do.

6-22.2 Use proper tools, and use them for their intended purpose. Chiseling, prying, and needless hammering are definitely discouraged. Before disassembly, matchmark all adjacent parts including end bells, stator feet, cartridge covers, end caps, coupling halves, and so forth so that they are remounted in their exact original position. When removing parts over the shaft, be careful not to damage the shaft surface or threading. As small parts are removed, place them in a tote pan. Tag large parts for identification.

6-23. BEARING REMOVAL.

Dismount bearings by one of the methods below. Pressure for removal (and installation) of a bearing shall be applied directly to the interference-fitted ring (figure 6-4). In most applications, the inner ring is tight on the shaft. In a few cases the outer ring is tight in the housing. In a very limited number of applications both rings will be tight. The technical manual or applicable ship or equipment drawing should provide the fitup limits. If it is impossible to apply the force directly to the interference-fitted ring, the bearing will undoubtedly be unfit for further service.

CAUTION

Never use a naked flame to heat a shaft, bearing, or housing. This can significantly distort the components.

6-23.1 Arbor Press Method. If possible, place the bearings to be removed and the shaft or housing on which they are mounted into an arbor press. This is one of the best methods of removing bearings; use it whenever possible. When working with a shaft assembly, place the bearing inner rings against a pair of flat blocks of the same thickness. Take care to keep the shaft straight to prevent damage from cocking. Use a firm, steady pressure and force the shaft out (figure 6-5.a). When working with housing, support the housing against a pair of flat blocks of equal thickness. Using a sleeve, push against the outer ring, or both rings, and force the bearing out (figure 6-5b).

6-23.2 Puller Method. If an arbor press is unavailable, use pullers that conform to GGG-P-781. The puller attachment (type XII in the specification), which can be inserted behind the bearing inner ring, should be used in conjunction with puller types I or VII. Puller jaws (type I) should be set so that they will pull straight and not slip. An uneven pressure in pulling may cock the bearing, so exert an even pressure with a straight pull (figure 6-6). Always use shaft center protectors of type XIII, class 3 or class 4, conforming to (GGG-P-781. When enough space is unavailable for installing the type XII attachment behind the bearing, it may be possible to remove the bearing by pulling on the inner cap or cartridge. This should be done by manufacturing a split spacer that, when filled between the bearing inner ring and the housing cap or cartridge, will prevent loading of the bearing outer ring (figure 6-7).

6-23.3 Seized Bearing. Remove a seized bearing as follows:

CAUTION

Never use a torch to loosen a bearing. A torch may cause shaft distortion.

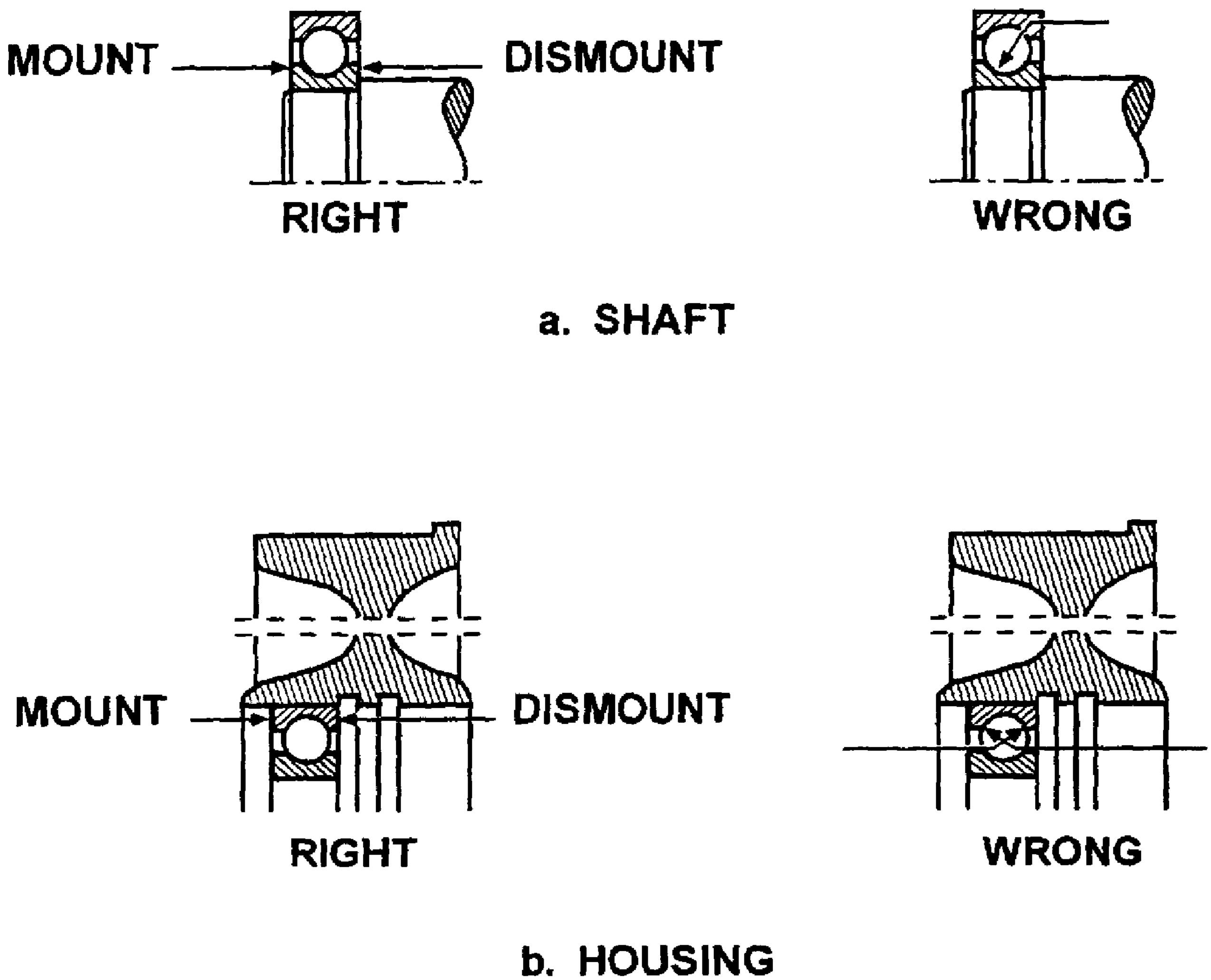


Figure 6-4 Application of Mounting and Dismounting Forces to Tightly Fitted Bearing Rings

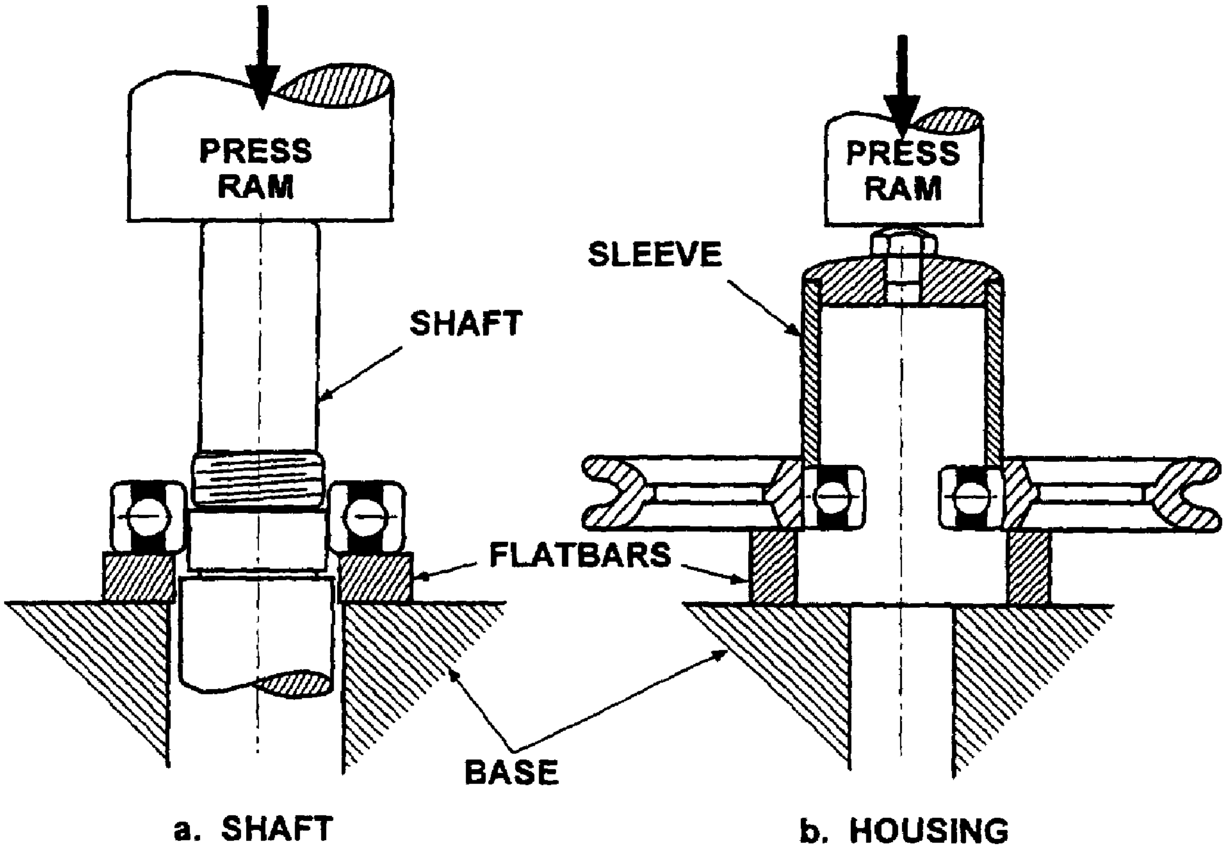


Figure 6-5 Arbor Press Method of Removing Bearings

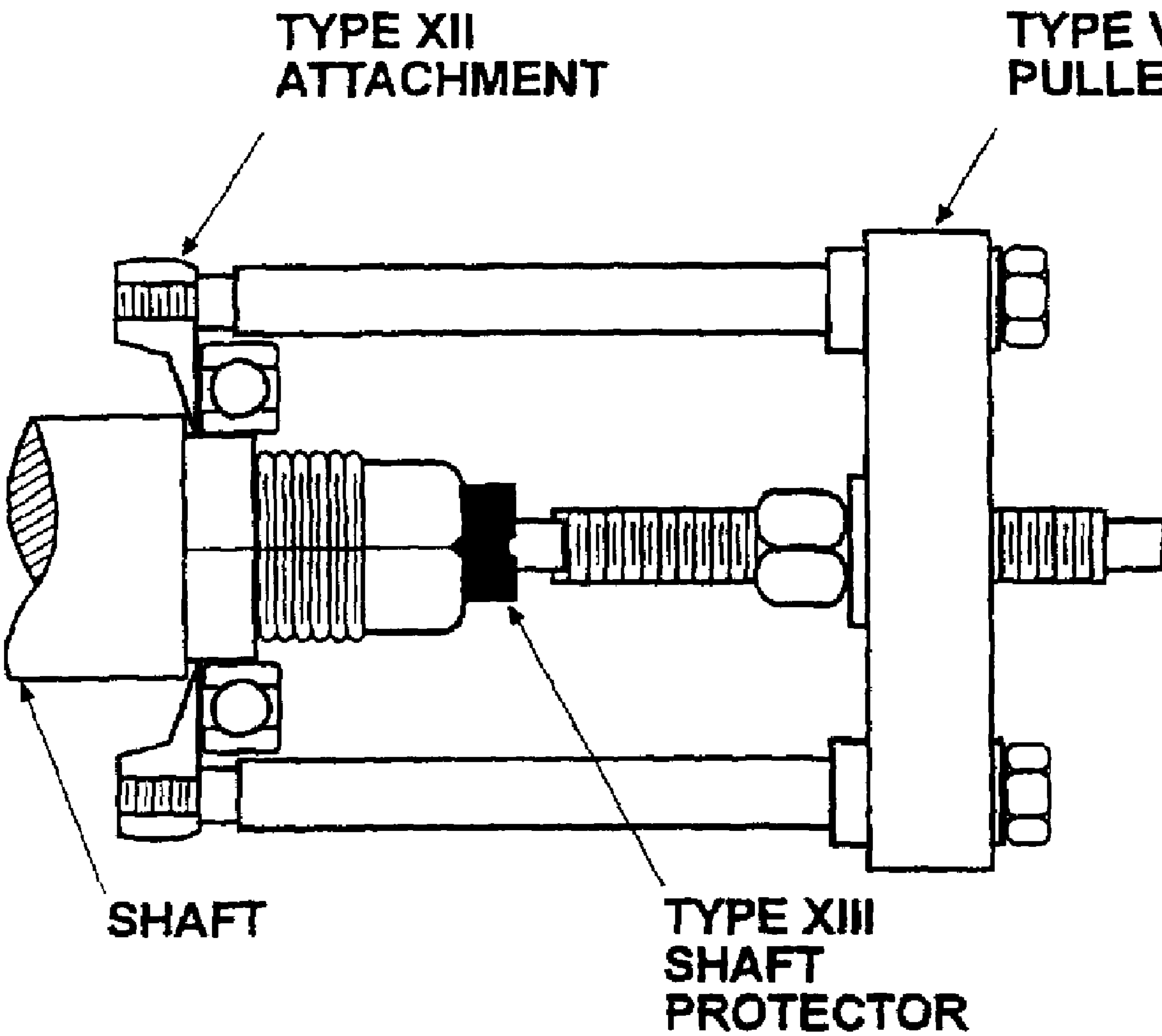


Figure 6-6 Bearing Puller Removal Using Split Puller Attachment and Shaft Protector

CAUTION

Never use a torch to loosen a bearing. A torch may cause shaft distortion.

a. If the bearing does not move after using a bearing puller set with moderate pressure, the bearing is seized on the shaft. Use a high-speed grinder to remove the bearing.

WARNING

Wear safety eyeglasses or goggles when grinding.

NOTE

While using the high-speed grinder, use rags to protect the rest of the motor from metal particles.

b. Use a high-speed grinder to cut the outer race completely through in two places diametrically opposite each other and parallel to the shaft (figure 6-8).

c. Cut the ball cage in two places at diametric opposites. Remove the cage and balls.

d. Cut the inner race at two diametrically opposite points parallel to the shaft. Do NOT cut into the shaft or the journal shoulder (figure 6-9a).

e. Holding the grinder at a 45-degree angle, make two cuts at right angles to the first two cuts (figure 6-9b).

f. Start the cuts 1/8 to 1/2 inch from the journal shoulder. This cut reduces the thickness of the metal at the journal shoulder.

CAUTION

Use the chisel to split the bearing race only. Do not try to cut the race with a chisel.

g. Use a cold chisel and a ball peen hammer to split the inner race off the shaft. Place the point of the chisel directly into the groove cut by the grinder (figure 6-10).

h. Regardless of which bearing removal method is used, visually inspect and clean the shaft bearing journal.

NOTE

Always suspect shaft damage when a bearing is seized on a shaft.

i. Take a reading with a snap gage and record the reading on the motor data sheet (mechanical) (figure 6-11).

j. Route to the machine shop if journal repairs are required.

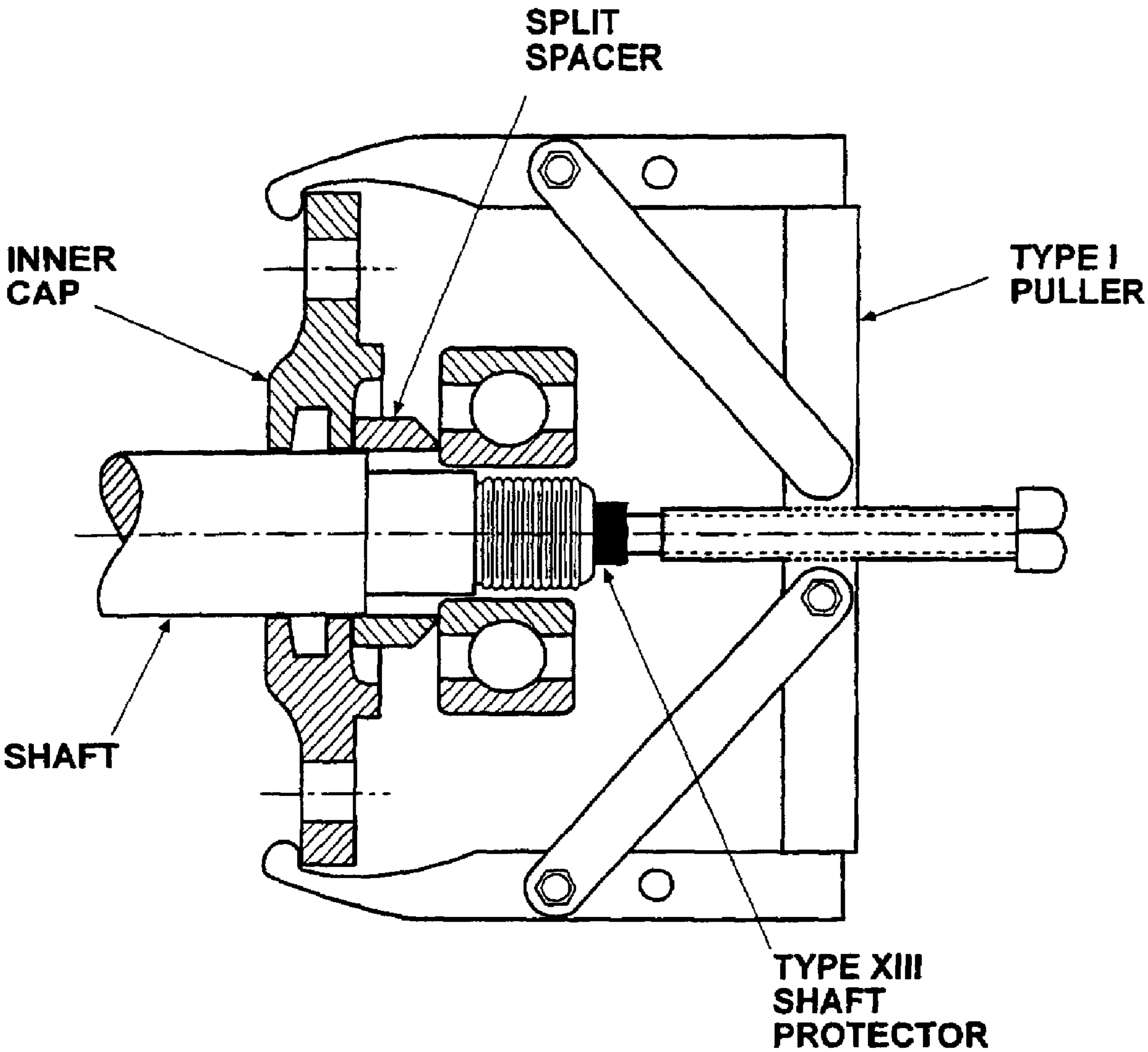


Figure 6-7 Split Spacer Allows Use of Cover to Remove Inner Ring

6-24. COMPONENT INSPECTION AND REPAIR.

If the shaft was damaged during bearing removal, restore it before measuring or reworking the surfaces. Inspect and repair the components as follows:

a. Inspect the end bells, cartridges, or other bearing-carrying parts for splits and cracks. If any are found, repair or replace the piece.

b. Examine the shaft and housing seats for damage, wear, or other deterioration. If there is no evidence of such deterioration or wear and if the seats are not suspect, the bearing seats need not be measured or reworked before installing new bearings during shipboard bearing replacements. Bearing seats shall be inspected during all other bearing replacements, even if there is no evidence of wear or deterioration. The original dimensions are usually adequate and should nor be changed merely to conform to some other limits.

c. If there is evidence of seat damage, or wear, inspect the bearing seats for conformance to the dimensions and tolerance limits in NAVSEA S9086-HN-STM-010/CH 244. Because bearing tolerances require measuring accuracies of 0.0001 inch, using a dial-indicating, comparative snap gage (paragraph 2-62) for measuring shaft diameters and a dial-indicating bore gage for measuring housing diameters and a dial-indicating bore gage (paragraph 2-58) for measuring housing diameters. Standard hand-held micrometers are inadequate for inspecting bearings. If the seat roundness one-half diameter tolerance limit is greater than 0.0004 inch, a dial indicator (paragraph 2-53) with 0.0001 graduations may be used to inspect seat roundness. As measurements are being made, frequently check the gage back to the gage block, and correct any variations.

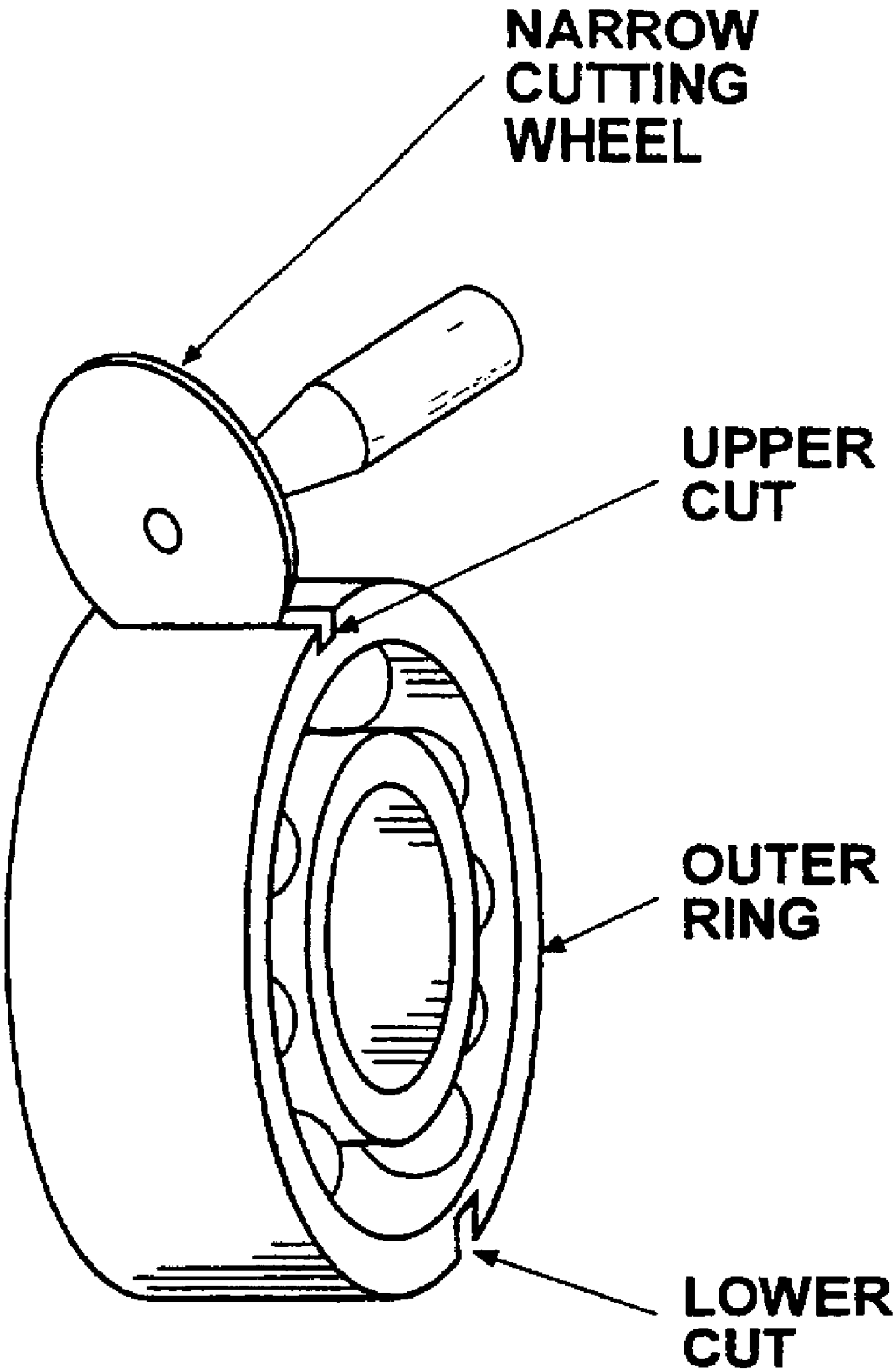


Figure 6-8 Using a High-Speed Grinder to Cut Outer Ring

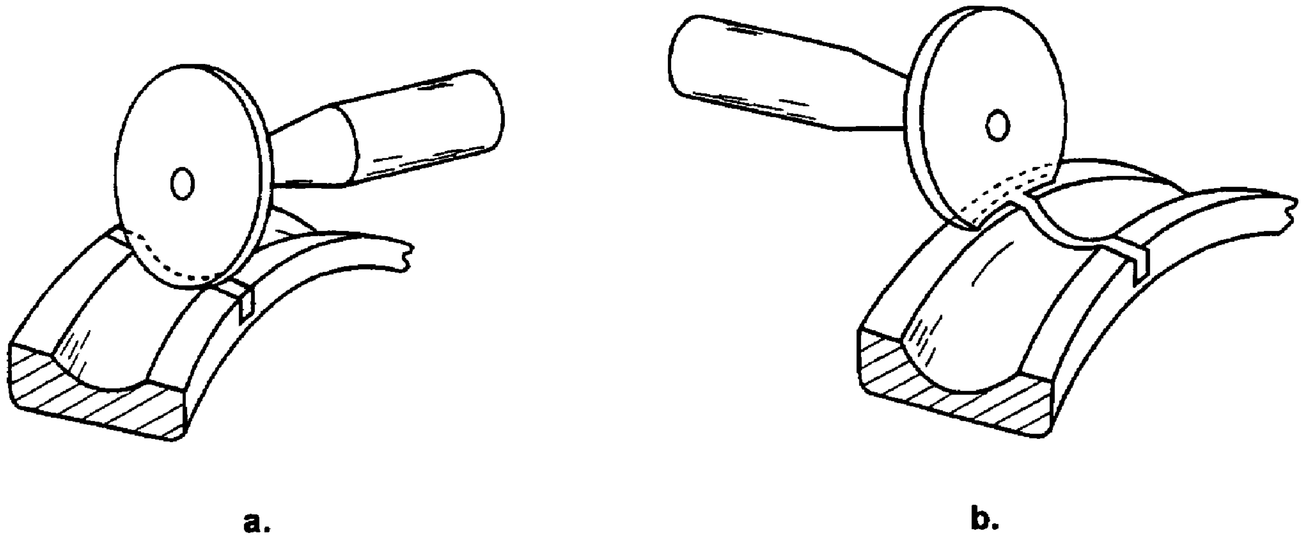


Figure 6-9 Cutting Inner Ring with High-Speed Grinder

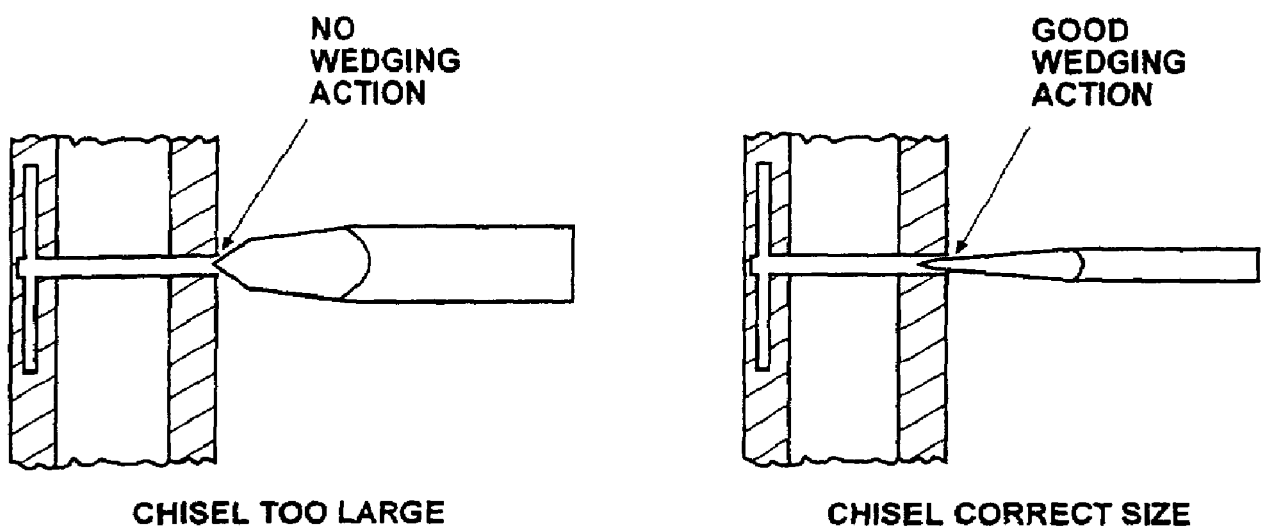


Figure 6-10 Using Chisel to Remove Inner Ring

NOTE

The measurements and repairs in step d., step e., and step f., below must be performed by a qualified machinery repairman (MR).

d. If components are damaged or worn, measure the shaft shoulders (figure 6-12) for runout to be sure that the face of the shoulder is perpendicular to the axis of the shaft. Shoulders should be square as specified in NAVSEA S9086-HN-STM-010/CH 244. If there is no undercut on the shaft, check the manufacturer's drawing and modify the shaft accordingly.

e. Repair undersized shaft seats using the methods presented in table 6-5. Reduce oversized seats by machining. Perform final machining by grinding. Inspect the seats after final machining.

f. Stone all burrs and sharp edges.

g. Check bearing locknuts, lockwashers, and preload springs. If springs were subjected to high temperatures, they may have lost their stiffness. Nuts and lockwashers should be free of burrs and their faces should be square.

Self-locking nuts that still function may be reused. Abutting faces of spacers, slingers, and sleeves shall be square and parallel and shall retain a good finish in accordance with NAVSEA S9086-HN-STM-010/CH 244.

h. Clean all components thoroughly, using approved methods and solvents or detergents as dictated by safety regulations. Once cleaned, store parts in a clean, dust-free area until needed for assembly.

6-25. BEARING INSTALLATION AND ASSEMBLY.

6-25.1 Nearly all rolling-element bearing applications require an interference fit on at least one of the bearing rings. Therefore, all mounting methods are based on obtaining the necessary interference without undue effort and with no risk of damage to the bearing. The most important rule when mounting and dismounting bearings is that the mounting pressure shall never be applied in such a way that it is transmitted through the rolling elements. Apply the mounting force directly against the interference-fitted ring (figure 6-13). Bearings shall remain packaged until they are required for installation and shall not be cleaned routinely. All unnecessary handling of bearings is definitely discouraged. Observe the conditions described in paragraph 6-9.1 to ensure cleanliness and to avoid bearing contamination. The same personnel who disassembled the machinery should also assemble it.

6-25.2 Ring expansion will simplify the mounting of interference-fitted bearing rings. Expand the rings by one of the methods described in paragraphs 6-20.5 through 6-20.8. Each method requires care, because bearing damage invisible to the eye can result. The convection oven method is preferred in most cases and should always be used for installing quiet bearings. The other methods listed are less desirable and should be used only by a skilled mechanic who has the expertise to avoid bearing damage. All methods except the convection oven require removal of the bearing intimate wrap. With the wrap removed, take care during ring expansion to avoid contamination. When the bearing outer ring is mounted with an interference fit in the housing, the housing, depending on size, can also be expanded by these methods. Do not freeze the bearing or shaft because corrosion may result from condensation.

CAUTION

Never use a naked flame to heat a shaft, bearing, or housing. This can significantly distort the components.

SHIP NAME & HULL NUMBER ______ DATE ______ MONTH/DAY/YEAR

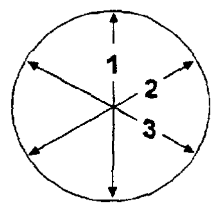
______

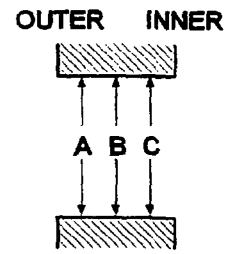
MOTOR LOCATION (I.E., NO. 2 MAIN FEED PUMP, ETC.)

HOUSING DIAMETERS

DRIVE END			
	A	B	C
1			
2			
3			

OUTER END			
	A	B	C
1			
2			
3			

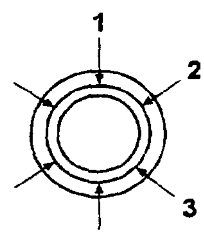


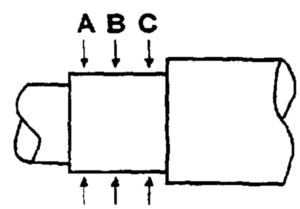


SHAFT DIAMETERS*

	DRIVE END			OUTER END		
	A	B	C	A	B	C
1						
2						
3						

* FOR BEARING JOURNAL WIDTH LESS THAN 1 INCH, ONLY SIX READINGS ARE REQUIRED.





Ⓐ SHAFT RADIAL RUNOUT ______

Ⓑ FACE RUNOUT, BEARING INNER RING
DRIVE END ______
OUTER END ______

Ⓒ FACE RUNOUT, BEARING OUTER RING
DRIVE END ______
OUTER END ______

MECHANICAL CONDITION
(LOSS OF LUBE, BURNED, ETC.)
______
______
______
______
______
______

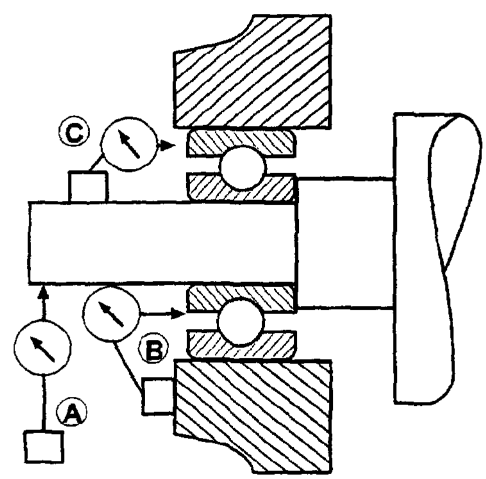


Figure 6-11 Motor Data Sheet (Mechanical)

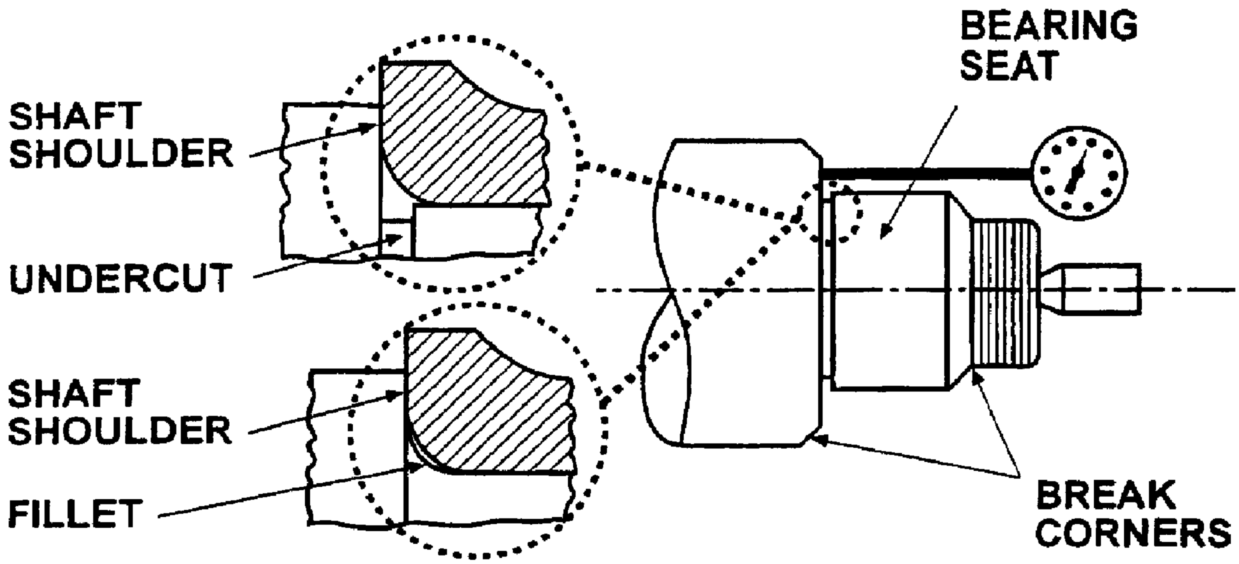


Figure 6-12 Measuring Shaft Shoulder Runout

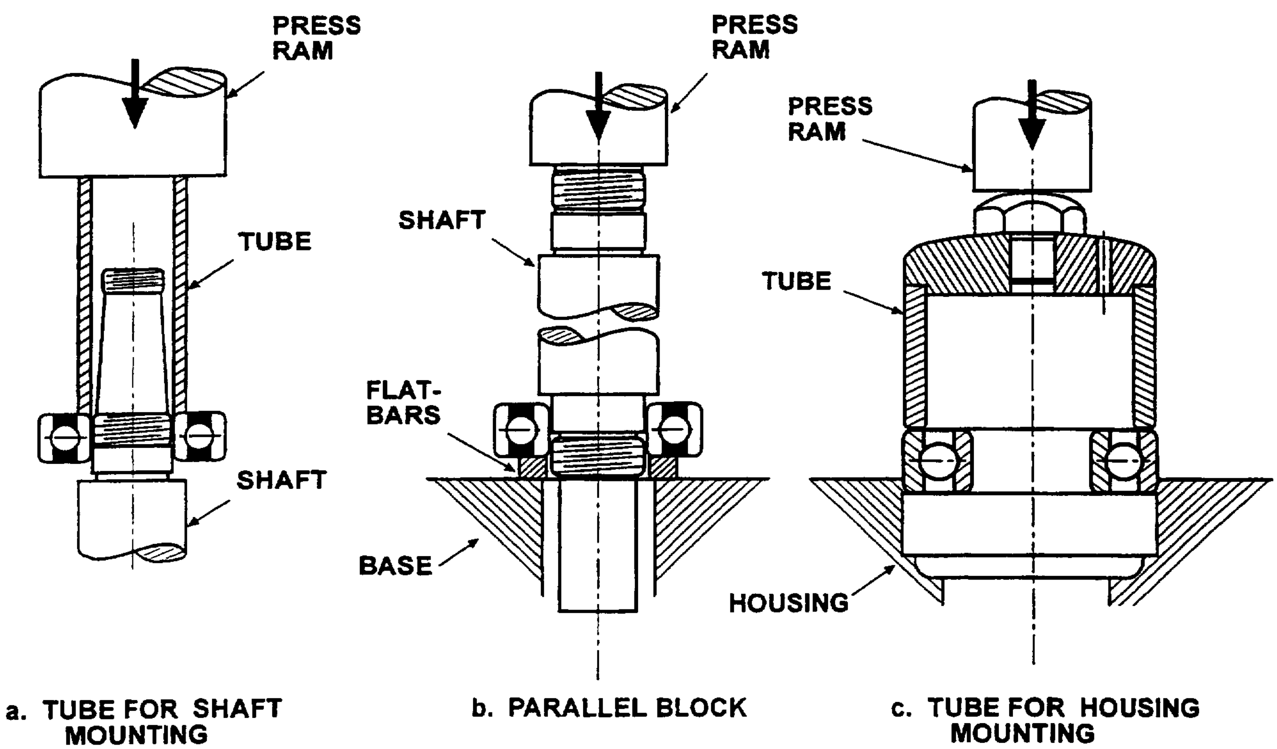


Figure 6-13 Pressing Bearings on Shaft with an Arbor Press

6-25.3 Obtain drawings and study the bearing scheme carefully. Read all available repair instructions thoroughly and completely before taking any action. Discuss the entire assembly procedure so that each person knows what to do. Use extreme care in assembling all parts. Be careful not to damage mating surfaces or shaft threading. Avoid undue force.

6-25.4 Mount bearings by one of the methods below. The entire shaft or housing including keyways, threads, splines, grooves, and so on, shall be thoroughly clean, since foreign matter or dirt between the inner ring and shoulder can cause misalignment (figure 6-14). Bearings will not seat firmly against the shaft shoulder unless the shoulder is clean. Apply a thin coat of clean oil to the bearing seats before assembly. Before mounting bearings on the shaft or in the housing, ensure the correct bearing orientation to avoid unnecessary disassembly. Draw a line through the bearing and compare sides. If the bearing is exactly the same on both sides, either side can be mounted first. When the sides are different, the bearing must be mounted only one way. If you mount a bearing backwards, you will find out later because the machine cannot be assembled or because it fails rapidly. A seal or shield that is on the wrong side may interfere with bearing lubrication or may permit contaminants to enter the bearing. Special instructions for mounting duplex bearings are in paragraph 6-30.

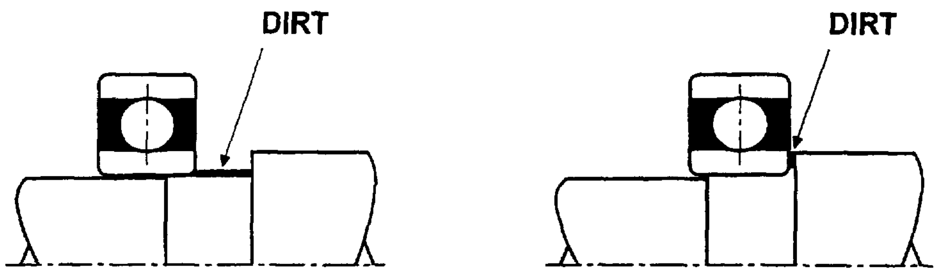


Figure 6-14 Effect of Dirt in Mounting Bearings

6-25.5 Bearing Locknuts. Bearing locknuts ensure that the bearing mounts hold the bearings correctly.

6-25.5.1 A conventional locknut and lockwasher are shown in figure 6-15.

6-25.5.2 Self-locking locknuts (figure 6-16), sometimes referred to as *prevailing torque retaining nuts* , are essentially the same size and material as the conventional locknuts. They are equipped with a nylon compression collar, however, that has a temperature limit of 300° F (149° C). The collar eliminates the need for a lockwasher. Self-locking locknuts permit convenient assembly and disassembly. The resilient collar follows the metal threads in engagement during assembly. This develops compression of the collar, with the metal threads of the shaft eliminating the space between the shaft threads and the collar. This compression develops tension between the mating parts, providing better locking and more protection against loosening, especially from vibration. Locknuts must be installed using a bearing locknut spanner wrench (figure 6-3) and torque wrench. For conventional locknuts with lockwashers (figure 6-15), use torque values in table 6-6. For self-locking locknuts (figure 6-16), use torque values in table 6-7.

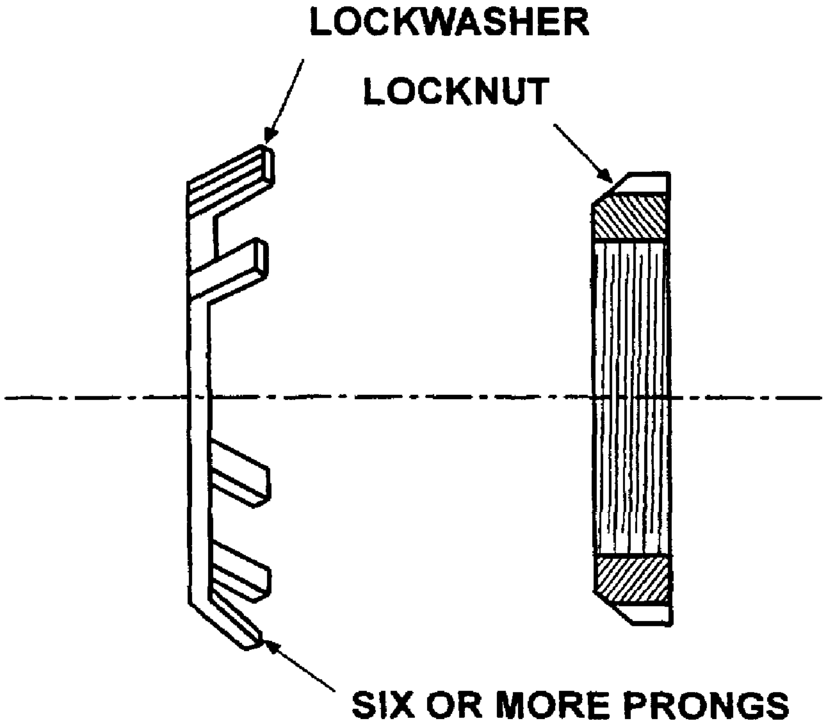


Figure 6-15 Conventional Locknut and Lockwasher

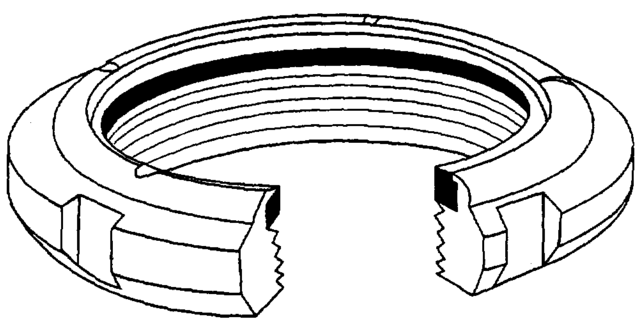


Figure 6-16 Self-Locking Locknut

6-25.6 Assemble the unit in accordance with the equipment technical manual. All parts should go together easily without undue force. When outboard parts are tightly fitted, apply steady, even pressures and avoid hammering. Ensure correct location of mating parts by aligning matchmarks. Tighten all bolts holding end bells and end caps by diagonal sequencing. Finally, tighten with a torque wrench to the specified values or, as a minimum, to the appropriate values of table 6-8.

WARNING

DANGER: Wear lint-free insulated gloves or use clean cloths when handling hot bearings.

6-26. HEAT SOURCE METHOD.

a. For short interference-fitted rings, the preferred method of mounting is to use a heat source to expand the inner ring (paragraphs 6-20.5 through 6-20.7).

b. A 100° F (38° C) difference between the parts to be fitted should be enough for the bearing to slide all the way to the shoulder. Any difficulty may indicate the shaft is oversized.

c. Install the locknut while the bearing is hot, and torque to the value specified in table 6-8.

d. Cover the assembly while left to cool to protect it from atmospheric dirt. Loosen the locknut and retorque after the assembly cools.

6-27. ARBOR PRESS METHOD.

If a heat source is unavailable, the next best method is to use an arbor press and a piece of tubing.

a. Remove any burrs, sharp corners, and so on from the shaft or housing, and carefully center the bearing at the beginning of the seat-the seat corner radius of the bearing will help.

b. Place the tube on the appropriate ring face, and apply pressure with the arbor press ram (figure 6-13a and 6-13c). With uniform pressure, the bearing should go on smoothly all the way. If it sticks or requires extra force at any point, stop the pressure. Look for cocking burrs on the seat or a tapered seat.

6-28. PARALLEL BLOCK METHOD.

For shaft interference-fitted rings, another way of using the arbor press is to use parallel blocks under the bearing inner ring and press the shaft into the bearing (figure 6-13b).

Table 6-6 Torque Values for Bearing Locknuts (Dry Threads)

Bearing Bore Code	Torque Value (ft-lb)
00	10-20
01	10-20
02	10-20
03	10-20
04	12-35
05	23-50
06	32-60
07	39-70
08	50-80
09	64-90
10	67-100
11	82-125
12	99-150
13	131-175
14	152-200
15	173-250
16	197-275
17	222-325
18	248-375
19	277-425
20	345-475
21	380-550
22	380-550
24	380-550
26	380-550

Table 6-6 Torque Values for Bearing Locknuts (Dry Threads) - Continued

Bearing Bore Code	Torque Value (ft-lb)
32	380-550

6-29. EMERGENCY METHOD.

a. In extreme emergency only, when none of the above apparatus is available, small bearings can be mounted by holding a sleeve against the interference-fitted ring and hammering alternately at opposite points on the sleeve.

b. Use light blows, and work around the sleeve to avoid cocking (figure 6-17).

6-30. SPECIAL PROCEDURES FOR DUPLEX BEARINGS.

6-31.

Duplex bearings consist of two angular-contact ball bearings mounted so that they can control the rigidity and precision of the shaft location. They are usually mounted either back-to-back (DB) or face-to-face (DF) (figure 6-18). As the figure shows, the distinguishing features of each duplex mounting is the relative position of the thick and thin faces of each bearing outer ring. The thin face is referred to as the *counterbored face* , or simply, the *face* . The thick face is referred to as the *back face* , or simply the *back* . Some angular-contact bearings are manufactured with a counterbored inner ring face. This is not important in achieving the correct mounting and should be disregarded. In the DB mount, the back faces of the outer rings are abutted. In the DF mount, the counterbored faces of the outer rings are abutted.

Table 6-7 Recommended Prevailing Torque Values, Locknut Reuse

	BONE FIBER (FT/LB)		NYLON (FT/LB)	
BORE SIZE	INITIAL	REPEATED	INITIAL	REPEATED
00	3	1	3	2
01	3	1	3	2
02	6	3	4	3
03	8	4	6	4
04	11	5	8	5
05	15	7	11	7
06	16	8	12	8
065	17	8	12	8
07	19	9	13	9
08	25	12	17	12
09	30	15	20	15
10	40	17	25	17
11	40	18	28	18
12	45	19	29	19
13	45	20	30	20
14	50	20	31	20
15	50	25	35	25
16	54	25	36	25
17	59	25	38	25
18	63	25	38	25

Table 6-7 Recommended Prevailing Torque Values, Locknut Reuse - Continued

	BONE FIBER (FT/LB)		NYLON (FT/LB)	
BORE SIZE	**INITIAL**	**REPEATED**	**INITIAL**	**REPEATED**
19	65	30	40	30
20	68	30	40	30
21	71	30	41	30
22	74	30	42	30
24	79	30	44	30
26	81	30	45	30
28	83	35	46	35
30	86	35	48	35
32	88	35	50	35
34	91	35	53	35
36	95	40	56	40
38	98	40	60	40
40	102	40	63	40

6-31.1 Duplex pairs are either flush ground or modified for preload or end play. All single angular-contact bearings that are flush ground can be duplexed. Where preload or end play is specified, however, only single bearings from a single manufacturer, with the same contact angle and with faces ground for the same modified condition, should be duplexed. To avoid complications in selecting single bearings for duplexing, use only bearings furnished as duplex pairs. For precision pairs such as quiet bearings, both bores and outside diameters are selected to match closely on tolerance. Also, the high point of radial runout of each ring is marked on one face of both the inner and the outer rings of each bearing. Depending on the manufacturer, the radial runout mark could be a burnished spot, a circle, or an arrow. During installation these marks must be lined up at the same angular position so that the high points of runout of both bearings coincide (figure 6-19). These bearings must be procured under the proper stock number for the specified application because a preloaded bearing will not operate satisfactorily in an application where a bearing with a loose internal setup is required, and vice versa. An early failure would result in either case.

Table 6-8 Recommended Torque (in Foot-Pounds) for Bolts, Nuts, and Studs on End Caps and End Bells

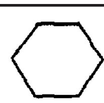
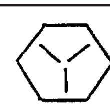
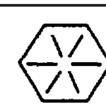
	Hexagon Head Bolt Grades 1 and 2	**Hexagon Head Bolt Grade 5**	**Hexagon Head Bolt Grade 8**
			
Bolt, Nut, Stud Size (Inch)	**No Marking Carbon Steel Corrosion-Resistant Steel**	**Marking Carbon Steel Alloy Steel**	**Marking Carbon Alloy Steel**
1/4	2-4	6-8	9-12
5/16	4-8	13-17	18-25
3/8	6-12	23-30	35-45
7/16	10-20	35-50	55-70
1/2	15-30	55-75	80-110
9/16	23-45	80-110	110-150

Table 6-8 Recommended Torque (in Foot-Pounds) for Bolts, Nuts, and Studs on End Caps and End Bells - Continued

5/8	30-60	110-150	170-220
3/4	50-100	200-260	280-380
7/8	80-160	300-400	460-600
1	123-245	440-580	680-900
1-1/8	195-390	600-800	690-1280
1-1/4	273-545	840-1120	1360-1820
1-3/8	365-730	1100-1460	1780-2380
1-1/2	437-875	1460-1940	2360-3160

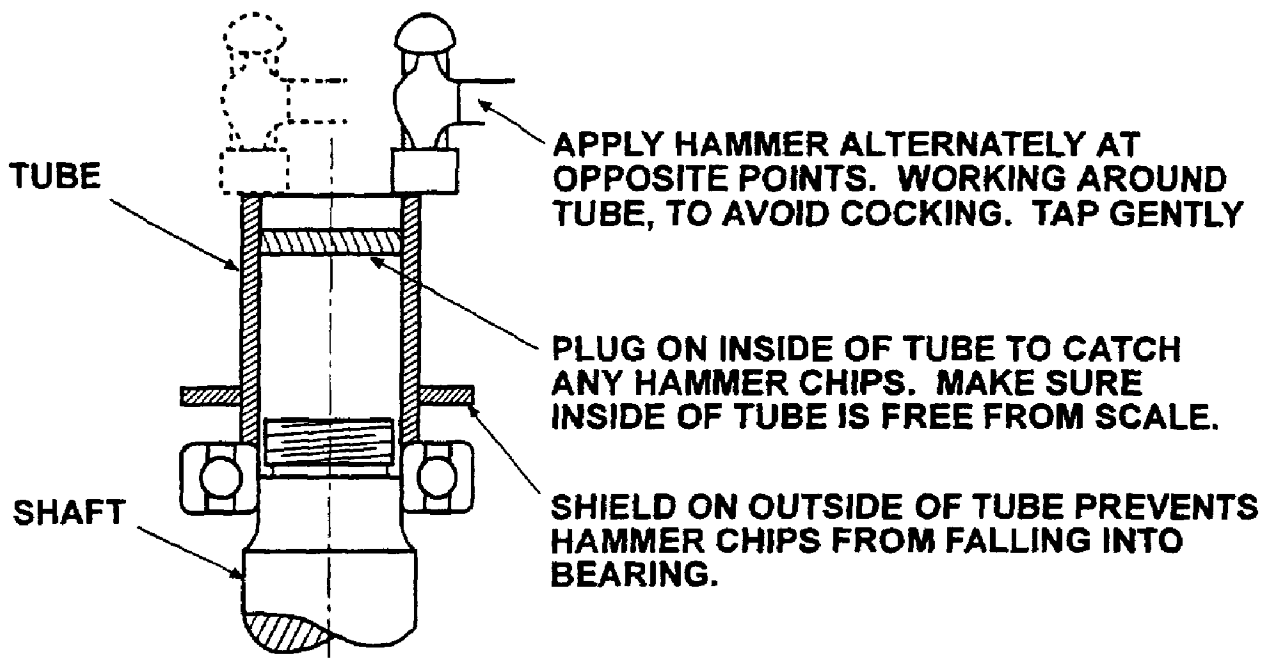


Figure 6-17 Hammer Mounting (Use in Emergencies Only)

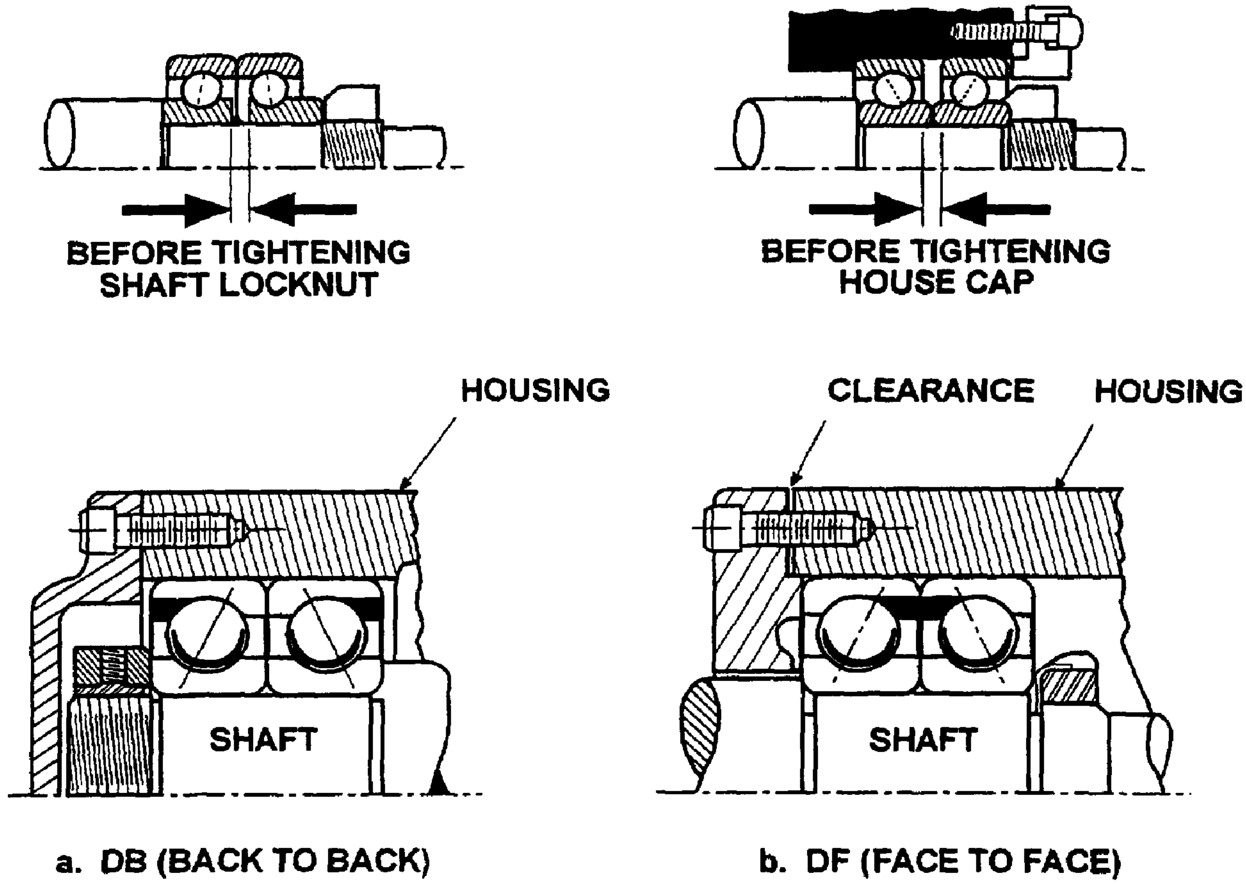


Figure 6-18 Duplex Bearing Arrangements Showing Relation of the Outer Ring Faces

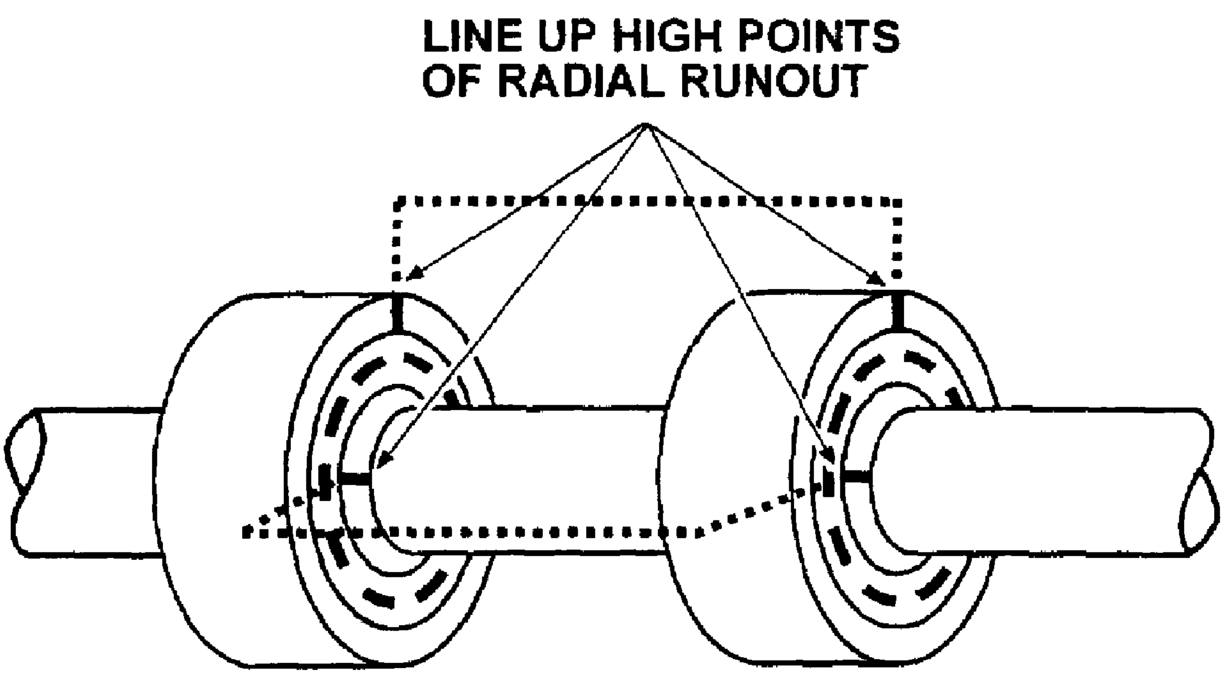


Figure 6-19 Bearing Ring Radial Runout Alignment of Precision Bearing Pairs

6-31.2 Assuming that the bearings are heated as indicated in paragraphs 6-20.5 through 6-20.7, duplex bearings shall be installed one at a time.

a. After orienting the inner beating to achieve the correct duplex mount, press it firmly into contact with the shaft shoulder, or in a few cases, a backing sleeve or oil impeller.

b. The bearing should be held against the shaft shoulder by the locknut and a sleeve. The sleeve should have parallel faces and be at least as wide as the outer bearing (figure 6-20). (Disassemble the old bearing, increase the bore diameter, and use as the spacer.)

c. Do not remove the holding device until the entire assembly is at room temperature. Cover the bearing while it cools.

6-31.3 Install the outer bearing in a similar manner.

a. Before installing the outer bearing, orient it to achieve the correct duplex mounting. If so marked, align the points of maximum radial runout so that these marks are aligned in the same angular position as those on the inner bearing.

b. Bearing rigidity with the DB mount is achieved by the clamping action of the beating locknut through the inner rings. It is therefore desirable to rotate the bearing outer rings by hand while tightening the locknut. This allows the rolling elements to seat and avoid brinelling the races.

c. Do not loosen the locknut once it is installed. Install any sleeve or hub of an adjacent part that is clamped between or in conjunction with the bearings before tightening the locknut. With the DF mount, the bearings rigidity is achieved by clamping action of the cap and housing shoulders through the bearing outer rings.

d. Rotate the shaft by hand during final assembly while tightening the housing end cap bolts in a diagonal sequence to allow the rolling elements to seat and to avoid brinelling the races.

e. After final tightening of the bolts with a torque wrench, enough clearance must exist between the end cap and the housing to ensure actual clamping of the rings (figure 6-18b).

6-31.4 If heat is not used for installing duplex bearings, use an arbor press. Be certain the bearings seat firmly against the shaft shoulder and each other. With the DB mount, press the second bearing on far enough so that the locknut threads can be fully engaged and then use the locknut to force the bearings together and fully clamp them.

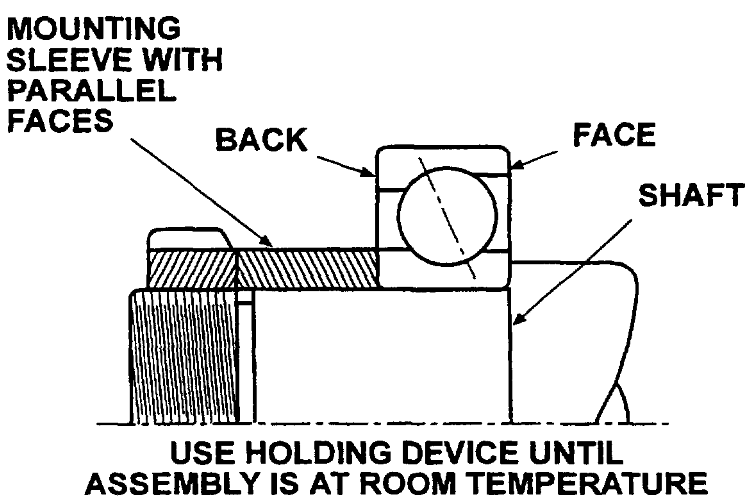


Figure 6-20 Mounting of Duplex Bearing (DB Mount Shown)

6-32. BEARING LOCKNUT TORQUES.

Unless otherwise specified, torque all bearing locknuts to the appropriate value specified in table 6-6.

6-33. GREASE PACK.

6-33.1 At installation, pack the bearing with grease. Quiet bearings are supplied with the correct amount and type of operational lubricant. With all other grades of bearings, double-shield, double-seal, and single-seal bearings are shipped with the correct amount and type of operational lubricant. Single-shield and open bearings, however, are shipped with a preservation slush. Only open and single-shield bearings, therefore, excluding quiet bearings of these types, will require grease to be placed into the bearing at installation. Pack grease in a bearing from one side until the grease just begins to come past the balls on the opposite side. Distribute this grease uniformly within the bearing air space. Apply a light coat of grease to any remaining ungreased surfaces of the bearing.

6-33.2 With all relubricable bearings, fill the bearing housing cavity 20 to 50 percent full. The lower limit applies to vertical applications, the higher limit to horizontal applications (paragraph 6-12.3.4). Bearing operational greases for shipboard machinery should conform to those indicated (paragraphs 6-12.3.6.1 through 6-12.3.6.5), depending on service application. The grease should be applied with a clean metallic or plastic spatula. Apply a light coat of grease to all unpainted bearing housing surfaces. With prelubricated bearings (double-sealed or double-shielded), do not add grease to the bearing housing cavity.

6-33.3 For motors with relubricable bearings, if the grease inlet passage and inlet pipe have not had old grease cleaned out, clean it out. Then pack the entire length of the passage and pipe with new grease to prevent corrosion.

6-34. PRELOAD SPRINGS.

Preload springs are used to reduce ball skidding, thereby reducing noise and increasing bearing life. It is important that such springs be installed correctly during assembly. Various types of springs are used for this purpose. In most applications one spring or a series of springs is clamped between the bearing outer race and the inner or outer bearing cover. Check the drawing to determine the correct orientation.

6-35. AXIAL RUNOUT.

Where quiet bearings are used, the maximum axial runout should not exceed the values listed in table 6-9. Bearing axial runout is the sum of the runout of the bearing outer ring face with reference to the shaft and the inner ring face with reference to the housing. This measurement is made during the final stages of assembly on units where the design allows making the measurements (figure 6-21: add measurements B and C). Values obtained for measurement A on figure 6-21 indicate shaft radial runout. Large values of radial runout indicate bent shafting that may cause excessive radial vibration and should be minimized.

6-35.1 Alignment. When assembling two or more machinery components such as pumps, compressors, blowers, or motors, it is essential that some degree of alignment be maintained between respective shafting. The most common method of specifying alignment of close-coupled and rigid-couplet units is to list face and rim runout requirements. The face reading indicates angular misalignment between two flanges. The rim reading measures axial misalignment between the shafts (figure 6-22). Acceptable limits should be as specified on the drawing or in the technical manual. If face runouts are unlisted, use the appropriate value from table 6-9 applicable to housings. Rim runouts should not exceed 0.0005 inch and are normally less, as specified.

6-36. OIL LUBRICATION.

In oil-lubricated bearing applications, be sure to add the lubricant to the correct level before operating the machinery.

Table 6-9 Recommended Maximum Axial Runout for Bearing, Shaft, and Housing Assemblies Using Quiet Bearings

Bearing Bore Code 200 and 300 Series	Bearing Bore		Maximum Recommended Axial Runout of Assembly (inch)
	(Inch)	(MM)	
00 to 03	0.3937	10	0.0004
	to	to	
	0.6693	17	
04 to 10	0.7874	20	0.0005
	to	to	
	1.9685	50	
11 to 17	2.1654	55	0.0010
	to	to	
	3.3465	85	
18 to 26	3.5433	90	0.0015
	to	to	
	5.1181	130	

6-37. POSTREPAIR INSPECTION.

6-38.

To ensure correct operation after bearings have been installed, check rotating machinery for torque, noise, and temperature when possible while it is still in the shop.

6-38.1 Torque. Any indication of high torque, binding, or drag means trouble. The completely assembled machine should turn freely without binding. High torque can be caused by excessive axial preload, pressure from an improperly located cover plate, or misalignment of the shaft housing.

6-38.2 Noise. Bearings should operate at low noise levels. Any unusual operating nose after installation shall be carefully analyzed before the bearings are considered to be the cause.

6-38.3 Temperature. Noise and excessive torque will usually be accomplished by a rise in temperature. A noticeable rise also may be caused by excess grease.

6-38.4 Recordkeeping. Maintain documentation on as-released measurements and shop test performance until the component performs satisfactorily aboard ship. Such a record can be of great value if the application exhibits operating trouble after installation.

6-38.5 Reinstallation Tests. Follow the inspection procedures described in Chapter 12.

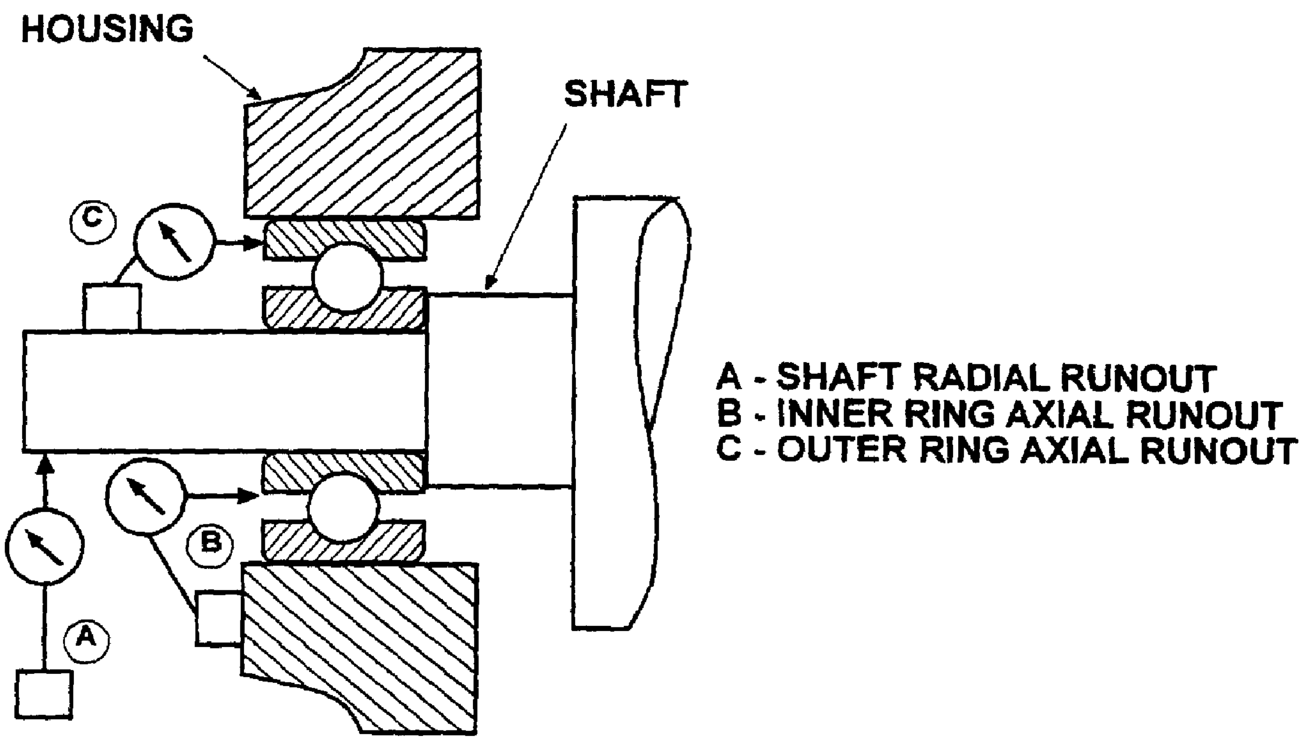


Figure 6-21 Measurement Location for Determining Bearing Axial Runout and Shaft Radial Runout

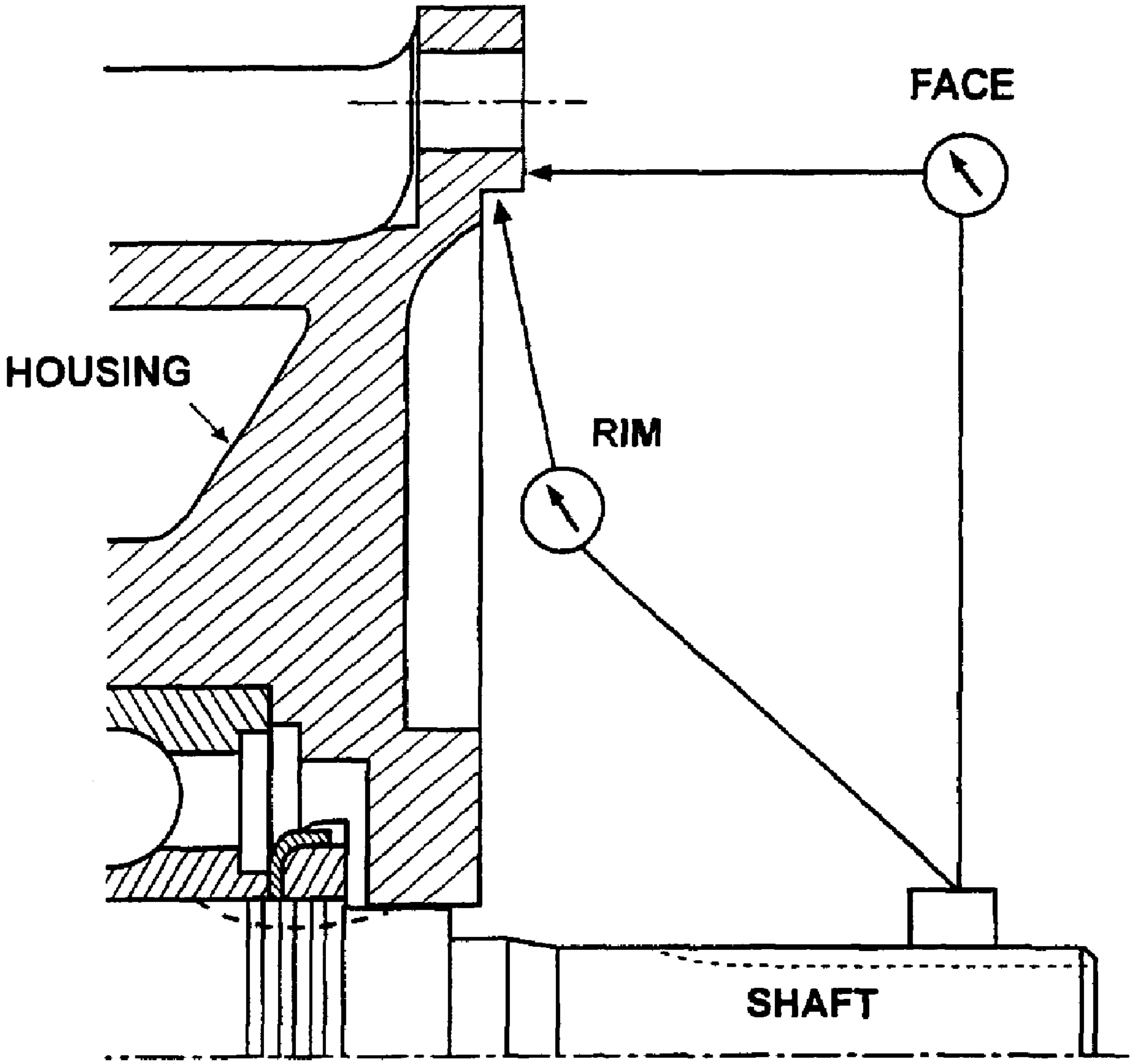


Figure 6-22 Measurement Location for Determining Face and Rim Runouts

6-39. MOTOR BEARING CONVERSION: EXTENDED-LIFE DOUBLE SEAL BALL BEARINGS

6-39.1 To reduce motor maintenance and repair costs, the following actions have been taken to implement the proper use of EXTENDED-LIFE double seal (ELDS) bearings.

1. Limits of applicability for ELDS bearings have been developed that will ensure acceptable bearing life in Navy motors, see paragraph 6-39.2.
2. APLs for motors meeting the applicability requirements have been modified to identify ELDS bearings. If ELDS bearings are not indicated in an APL, applicability may be reviewed using paragraph 6-39.2.
3. NSNs for the ELDS bearings have been developed and are indicated in table 6-10.

6-39.2 Applicability. Motors NOT under the cognizance of NAVSEA 08, that meet all of the motor criteria of paragraph 6-39.3, should be repaired using ELDS bearings.

6-39.3 Motor Criteria.

1. Motor must be installed on a surface ship.
2. Motor must NOT be under the cognizance of NAVSEA 08.
3. Commercial motors are not eligible. Motors must have been furnished to the Navy in accordance with MIL-M-17060, MIL-M-17413 or MIL-M-17059.
4. Motors using one or more noise-quiet bearings per MIL-B-17931 are not eligible.
5. Bearings originally furnished with the motor must both be type 111 bearings per FF-B-171.
6. The use of ELDS bearings is limited to motors where the full load speed and the size of both bearings are as follows:
   a. Maximum bearing size 306 or 206 and full load rpm between 1,801 and 3,600 rpm.
   b. Maximum bearing size 313 or 213 and full load rpm between 1,201 and 1,800 rpm.
   c. Maximum bearing size 318 or 218 and full load rpm less than 1,200 rpm.

6-39.4 In addition to the requirements of this technical manual for bearing care, installation and removal, the repair process using ELDS bearings includes the following requirements:

1. Only ELDS bearings can be used. Other double seal bearings will not provide an acceptable bearing life.
2. Both bearings of each converted motor must be ELDS bearings.
3. A label plate must be permanently attached to the motor indicating, ″Do Not Lubricate″.
4. Grease fills and drains, if present, must be fitted with a pipe plug, securely fastened. Fittings to accommodate grease guns must be replaced with pipe plugs.
5. After repair, the shipboard databases affecting maintenance requirements such as the Equipment Guidance List (EGL) must be updated to reflect the change in maintenance requirements for the converted motor. The installing activity must advise the scheduling activity to submit a change to the EGL and other databases as appropriate.
6. Where APL changes are initiated to convert to ELDS bearings, a COSAL feedback report should be submitted, providing the NSN and part number for the ELDS bearing. Only the ELDS bearing should be indicated on the APL.

Table 6-10 ELDS Bearings NSNs and Part Numbers

SIZE	P/N	NSN
201	6201-2RS1C3/GHY	3110-01-492-0221
202	6202-2RS1C3/GHY	3110-01-491-0233
203	6203-2RS1C3/GHY	3110-01-491-0234
204	6204-2RS1C3/GHY	3110-01-491-6636
205	6205-2RS1C3/GHY	3110-01-451-9166

Table 6-10 ELDS Bearings NSNs and Part Numbers - Continued

SIZE	P/N	NSN
206	6206-2RS1C3/GHY	3110-01-451-9165
207	6207-2RS1C3/GHY	3110-01-451-9164
208	6208-2RS1C3/GHY	3110-01-451-9170
209	6209-2RS1C3/GHY	3110-01-451-9252
210	6210-2RS1C3/GHY	3110-01-492-1831
211	6211-2RS1C3/GHY	3110-01-518-0937
303	6303-2RS1C3/GHY	3110-01-493-3750
304	6304-2RS1C3/GHY	3110-01-451-9153
305	6305-2RS1C3/GHY	3110-01-451-9158
306	6306-2RS1C3/GHY	3110-01-451-9159
607	6307-2RS1C3/GHY	3110-01-451-9161
308	6308-2RS1C3/GHY	3110-01-451-9167
309	6309-2RS1C3/GHY	3110-01-451-9168
310	6310-2RS1C3/GHY	3110-01-490-6683
311	6311-2RS1C3/GHY	3110-01-492-0223
312	6312-2RS1C3/GHY	3110-01-490-6848
313	6313-2RS1C3/GHY	3110-01-492-0191
314	6314-2RS1C3GHY	3110-01-492-0226
315	6315-2RS1C3/GHY	3110-01-494-0993
316	6316-2RS1C3/GHY	3110-01-492-0188
317	6317-2RS1C3/GHY	3110-01-492-0219
318	6318-2RS1C3/GHY	3110-01-493-3749

CHAPTER 7

PREPARATION FOR MOTOR RECONDITIONING

7-1. SCOPE.

This chapter contains information on the six preliminary procedures to be followed when a motor arrives at the electric motor repair shop for reconditioning and repair. A reconditioned motor is one that has been disassembled for cleaning or other repairs but is not to be rewound. Topics include:

7-1.1 Cleaning the motor (paragraph 7-2).

7-1.2 Drying the motor (paragraph 7-10).

7-1.3 Testing (paragraph 7-16).

7-1.4 Cleaning electrical equipment after seawater damage (paragraph 7-18).

7-2. CLEANING THE MOTOR.

7-3. METHODS OF CLEANING.

It is sometimes possible to recondition an electric motor without rewinding. Initial electrical tests (see Chapter 5) may indicate that rewinding is unnecessary. However, there may be contaminants such as dirt, oil, grease, or other foreign material in the motor. In such cases, the motor must be cleaned. Only approved methods should be used to do this. Approved methods are:

7-3.1 Suction,

7-3.2 Wiping,

7-3.3 Air pressure,

7-3.4 Water washing with compounds, and

7-3.5 Steam spraying with compounds (Steam jenny).

CAUTION

Be certain that the tube or nozzle, if used, has no sharp edges which might scrape insulation.

7-4. SUCTION.

Vacuum suction is the preferred method of removing dry materials like dust, chips, and dirt. A small nonconductive nozzle or tube may have to be connected to the vacuum cleaner to allow better access to the surface and narrow openings. Use a soft brush to remove any foreign matter sticking to the winding. Hold the vacuum nozzle close while brushing lightly with the soft brush. The vacuum will pick up material loosened by the brush.

CAUTION

Take care when removing the material. Chips or other rough matter adhering to the cloth may scratch or remove insulation.

Foreign matter may be pushed or pressed into an inaccessible opening if the material to be removed is close to such an opening. This will create more serious problems.

7-5. WIPING.

Use a dry lint-free cloth to wipe over the exposed surfaces to remove loose foreign material. Use a clean cloth to avoid carrying dirt or grit from one part of a surface to another. This method will remove loose dirt.

WARNING

Improper or playful use of the high-pressure hose may cause severe injury to internal organs and eardrums. Never allow compressed air to contact or enter any persons body. Always use proper safety equipment such as face masks and goggles.

CAUTION

Ensure that any accumulation of moisture in the air lines has been removed. Remove any moisture by operating the air away from the stator to be cleaned long enough to blow moisture out of the line.

Ensure that foreign material is actually being removed by blowing it from the stator. Ensure that material is not deposited deeper into inaccessible crevices.

Air pressure must not exceed 30 pounds per square inch.

Ensure the removal of dirt-laden air whenever compressed air is used to remove foreign material. Ensure that there is suction on the opening at the end opposite the air jet.

Use compressed air with caution. Abrasive particles may puncture insulation and be forced under insulating tape.

7-6. CLEANING WITH AIR PRESSURE.

Air pressure is the least acceptable method of removing loose foreign material. This method is used to remove dry loose dust and foreign particles from inaccessible locations.

7-7. CLEANING WITH COMPOUNDS AND HOT WATER.

Cleaning with compounds and water requires great care when windings are contaminated with dirt and oil.

7-7.1 Types of Compounds. Three types of cleaning compounds are authorized for use in the reconditioning of stators by NAVSEA S9086-KC-STM-010/CH 300:

7-7.1.1 Cleaning compound P-D-220 (NSN 7930-00-249-8036) or a nonionic-type detergent according to MIL-D-16791 (NSN 7930-01-055-6121 [quantity 1 gallon] or NSN 7930-00-282-9700 [quantity 55 gallons]). Both should be mixed in a proportion of 1 pound to 2 1/4 gallons of water. The formula for gallons of water in a rank is:

7.48 gallons of water = 1 ft ^{3}

Number of gallons = Number of cubic feet x 7.48

Number of pounds of compound = Number of gallons/2.25

7-7.1.2 Powdered Salt Water Soap. Powdered salt water soap (synthetic detergent) MIL-D-12182 (NSN 7930-00-252-6797) may be used in either soft or hard water. It should be mixed in a proportion of 1 pound to 50 gallons of water. This compound has the advantage of being neutral. It is neither acidic nor alkaline. The formula is:

Pounds of compound = Gallons/50

7-7.1.3 Removal of Grease, Oil, and Carbon Dust. Cantol Tech 736 and Formula 409 are water-based alkaline cleaners approved for removal of contaminants by either brushing or wiping. Wear safety glasses and rubber gloves and provide adequate ventilation when using either cleaner. Minimize exposure to vapor mist when using a pressure sprayer. Rinse the motor with clean water.

7-7.1.4 Steam Cleaning Compound. Steam cleaning compound and butyl alcohol are added to water in the proportions of 15 to 20 pounds of compound and 1 quart of butyl alcohol per 1,000 gallons of water. Steam cleaning compound is available in 25-pound drums (NSN 6850-00-965-2087) or 400-pound drums (NSN 6850-00-965-2329).

7-7.2 Compound Tank. The tank holding any of these compounds must be large enough to allow sufficient compound to cover the stator or armature and to allow agitation of the liquid.

7-7.2.1 Air or steam may be used to agitate the liquid. Temperature of the liquid should be maintained at 194°F (90°C) by use of steam or electric heaters.

7-7.2.2 Mechanical agitation can be done with air cylinders. Use air cylinders to raise and lower an expanded metal tray into and out of the solution in the wash tank.

7-7.2.3 The stator should be immersed so that the bore is vertical. This will allow thorough flushing and washing of the windings.

WARNING

Insulated gloves should be worn when steam cleaning to protect the operator from being burned or scalded.

CAUTION

Take care to keep live steam from impinging directly on the windings. The temperature of the solutions at the windings should not exceed 194° F (90° C). The pressure should not exceed 30 psi.

NOTE

The motor must be thoroughly flushed with fresh water upon completion of any liquid or steam method of cleaning. Flushing will remove all of the cleaning agents prior to drying and testing.

7-8. CLEANING WITH COMPOUNDS USING A STEAM SPRAY MACHINE (STEAM JENNY).

Prepare the cleaning solution in a separate container before starting the Steam Jenny. An old oil drum or grease drum that has been thoroughly cleaned may be used for this purpose. Mix the compound with water according to the manufacturer's directions for the particular compound being used.

7-8.1 Starting the Unit. To start a fuel-type steam spray unit, refer to the manufacturer's manual for proper operating instructions. If not available, take the following steps:

a. Fill the fuel tank with number 2 fuel oil, diesel fuel, or kerosene.

b. Connect the water hose to the machine. Turn the water on full.

c. Ensure that the oil burner fuel valve is shut off. Plug the electric cord into a proper voltage outlet for the machine.

d. Fully open the fuel valve when the water is flowing freely. The fire will light automatically.

7-8.2 Introducing the Cleaning Compound. To introduce cleaning compound:

a. Mix and heat the compound solution by immersing the steam gun in the solution for a few minutes.

b. Place the end of the siphon hose in the compound solution tank.

c. Regulate the flow of cleaning compound solution with the valve provided on the gun.

7-9. STEAM SPRAYING WITH COMPOUNDS.

The same compounds used with water washing are used with this method. There are, however, two differences in the method. A steam boiler is used, and a hose with a nozzle directs the cleaning compound through the windings.

7-10. DRYING THE MOTOR.

7-11.

It is necessary to dry the stator after water and compound or steam cleaning. The five types of drying are:

7-11.1 Oven drying,

7-11.2 Vacuum,

7-11.3 Electric heater,

7-11.4 Circulating current, or

7-11.5 Infrared ray.

7-12. OVEN DRYING.

Oven drying is the most common and practical method of drying small motors. There are three important points to remember when drying insulation in an oven. These are:

7-12.1 The oven air temperature must not be so high that it causes the formation of steam in voids in the insulation and results in rupture and permanent damage. The danger from this, however, is not as great as might be expected, because heat is applied from the outside and a large amount of heat is absorbed by water before it turns to steam. With a reasonable amount of ventilation, heat will be carried off before excessive pressures are developed in the insulation.

7-12.2 The oven air temperature should not exceed 300° F (149° C) when drying any class of insulation. The oven air temperature should be maintained at 300° F - 20° F (149° C - 11° C) until the winding reaches a temperature of 220° F + 10° F (104° C + 6° C). The oven air temperature should then be adjusted to maintain the winding temperature at 220° +10° F (104° C +6° C) until the winding is dry, as indicated by no abrupt changes in insulation resistance, and 65 percent increase in insulation resistance over a 10-hour period, or a polarization index greater than 3.0. In an emergency, equipment may be urgently needed, and there is a strong temptation to obtain quicker results by using higher temperatures. In certain cases, higher temperatures have been used, and the insulation successfully restored to service. However, as temperature is allowed to go up, the risk of permanently damaging insulation also increases.

7-12.3 Provisions must be made for removing moisture from the oven. This may be done by providing openings which allow circulation of air by convection. More thorough removal of moisture can be accomplished by forced ventilation by means of fans or blowers. The fresh, dry air which enters the enclosure should first pass over the heaters to become heated, and should then circulate over the insulation that is being dried.

CAUTION

Always consult and follow the manufacturer's instructions before operating vacuum drying machinery.

7-13. VACUUM DRYING.

It is not always easy to remove moisture from fibrous material insulation, even at 212° F (100° C). The quickest and most effective method is to use a combination of heat and vacuum. Use this method if a heated vacuum tank/chamber is available. The following points should be taken into consideration:

7-13.1 Temperature-Pressure Relation. The boiling point of water decreases as vacuum is increased. Therefore, moisture can be removed in a vacuum at temperatures significantly lower than atmospheric pressure. Temperatures less than 212° F (100° C) allow very rapid evaporation of moisture and thorough drying in a moderate vacuum.

7-13.2 Temperature Limits. Internal pressure may be created if the temperature is raised above the boiling point. This may damage the insulation, so it is important that the temperature be raised slowly and be carefully controlled. It is recommended that the temperature of the insulation should not be more than 10° F (-12° C) above the boiling point for a given vacuum. Table 7-1 shows the values that can be determined from vapor pressure of water tables.

7-13.3 Accelerating Drying. Drying in a vacuum may be accelerated by breaking the vacuum at intervals and allowing clean dry air to enter the oven/heating chamber. In this way, the dry air permeates the winding, absorbs moisture, and is removed.

7-13.4 Procedure. Increase the vacuum when no further moisture appears at a given temperature/vacuum. An increased vacuum will result in more moisture being given off. The temperature will decrease due to increased evaporation of moisture.

a. Continue drying at the maximum vacuum obtainable until no further moisture is apparent.

b. Reduce the vacuum gradually. Increase the temperature correspondingly until the unit is back to atmospheric pressure.

c. If insulation tests and measurements indicated that no further drying is necessary, continue the reconditioning process.

7-14. DRYING WITH ELECTRIC HEATERS.

Some motors are too large to be put into an oven for drying. A dryer may be built using electric heaters if sufficient power is available. The capacity required in the heaters will vary with the size of the motor, degree of enclosure, location of equipment, and amount of ventilation. It is, therefore, not practical to state a rigid rule for the exact size heater required to dry the equipment. Make an estimate as follows:

NOTE

This calculation assumes that no heat is lost by radiation, forced or natural convection, or ventilation. Measure the temperature at regular intervals. Increase the capacity of the heater 500 watts at a time if the required temperature is not attained. For example, kilowatts might be increased from 3.5 to 4.0 to allow for natural heat loss. It may be possible to raise the temperatures to 200° F (93° C) with 2.4 kilowatts. To do so, precautions would have to be taken to protect against heat loss. The admission of fresh air to the machine must be limited. This procedure would require more time.

Table 7-1 Vapor Pressure of Water at Different Temperatures

Temperature		Vapor Pressure	Temperature		Vapor Pressure
(°C)	(°F)	(mm. of Hg)	(°C)	(°F)	(mm. of Hg)
0	32	4.58	29	84.2	30.04
5	41	6.54	30	86	31.82
10	50	9.21	31	87.8	33.70
11	51.8	9.84	32	89.6	35.66
12	53.6	10.52	33	91.4	37.73
13	55.4	11.23	34	93.2	39.90
14	57.2	11.99	35	95	42.18
15	59	12.79	40	104	55.32
16	60.8	13.63	45	113	71.88
17	62.6	14.53	50	122	92.51
18	64.4	15.48	55	131	118.04
19	66.2	16.48	60	140	149.38
20	68	17.54	65	149	187.54
21	69.8	18.65	70	158	233.7
22	71.6	19.83	75	167	289.1
23	73.4	21.07	80	176	355.1
24	75.2	22.38	85	185	433.6
25	77	23.76	90	497	525.8
26	78.8	25.21	95	203	633.9
27	80.6	26.74	100	212	760.0
28	82.4	28.35	150	302	3570.5

7-14.1 Estimate the weight of the motor to be dried. Calculate on the assumption that the motor consists entirely of steel weighing 485 pounds per cubic foot.

7-14.2 Use the following formula to find the quantity of energy required to increase the temperature of a material:

Kilowatt hours = 3.5 x weight in pounds x °F rise/100,000

7-14.3 Use this formula to determine the time required to raise the temperature:

T (time in hours) = Desired temperature rise/7

The formula is implemented in the example on the next page.

7-15. DRYING WITH CIRCULATING CURRENTS.

This method should be used only in an extreme case. See NAVSEA S9086-KC-STM-010/CH 300 if this method is used. It is sometimes difficult to satisfactorily dry large machines with only external heating. As much moisture as possible should be removed by the external heating method. Drying may then be hastened by circulating current from an external source through the windings.

EXAMPLE	
Given:	The rate of temperature increase should not exceed 7° F per hour. Calculations are being made for a 10,000-pound motor. The temperature must be raised to 200° F from a current temperature of 75° F.
Then:	To find the kilowatt hours required, multiply 3.5 by 10,000 by 125° F. Divide by a constant of 100,000.
	Kilowatt hours = 3.5 x 10,000 x 125/100,000 = 43.8 approx
And:	*T = 125° F/7° F = 18 hours*
Then:	To find the kilowatts required, divide the kilowatt hours by the time required, or *43.8/18 = 2.4*
So:	2.4 kilowatts are required to raise the temperature of a 10,000-pound motor to 200° F from

7-15.1 The source of the current must have a means of adjusting the voltage to permit limiting the current going through the windings.

7-15.2 Exciter sets or voltage arc welding sets are suitable sources of current.

7-15.3 If the windings to be dried are of equal resistance and current carrying capacity, they may be grouped in series or parallel depending on which is best suited to the voltage and current available.

7-16. TESTING.

7-17.

Measure the winding insulation resistance with a megohmmeter when drying is complete. Use the procedures outlined in paragraphs 2-4 through 2-14. Also, perform the following tests: phase resistance balance (paragraph 2-15.), surge comparison (paragraph 2-19), and dc high potential (hipot) (paragraph 2-23 or paragraph 2-50). Record the readings on the motor data sheet (electrical). Compare with the readings taken before cleaning.

7-17.1 If the insulation resistance has increased to the ″after reconditioning″ measurement shown in table 7-2, it may be assumed that the low value before cleaning was due to leakage across the winding to ground caused by the presence of dirt, grease, oil, salt deposits, or other foreign matter. Reconditioning may now be completed and the motor returned to service.

7-17.2 If insulation resistance has not increased to the ″after reconditioning″ measurement shown in table 7-2, repeat the cleaning and drying processes in this chapter and retest. This sequence may be repeated a maximum of three times. If insulation resistance has not increased to the ″after reconditioning″ measurement in table 7-2 after the third clean and dry sequence, the motor must be rewound. Use the procedure outlined in the following chapters.

NOTE

For dipping and baking, refer to Chapter 10, and for final electrical testing, refer to Chapter 11.

7-18. CLEANING ELECTRICAL EQUIPMENT AFTER SEAWATER DAMAGE.

7-19. IMPORTANCE OF THOROUGH CLEANING.

Electrical equipment may be damaged by being submerged in or splashed with seawater. Reliability is imperative in electrical equipment. Therefore, such equipment must be restored as nearly as possible to new condition.

NOTE

Sodium chloride is the principle salt found in seawater. Magnesium chloride and calcium chloride are also present, but in lesser amounts. All salts have a corrosive effect on metals. It is important, therefore, that all traces of seawater and salt deposits be thoroughly removed before equipment is returned to service.

Table 7-2 Insulation Resistance for Generators and Motors

AC GENERATORS AND MOTORS OTHER THAN PROPULSION				
	Insulation Resistance (megohms at 25°C) [1]			
Circuit	Minimum for Operation	**After Cleaning in Ship**	**After Recndtn**	**After Rewinding**
Stator circuit of generators and motors	0.2	1.0	25	200
Rotor circuit of wound rotor induction motors	0.1	0.5	25	100
Field circuit of generators or of synchronous motors	0.4	2.0	25	400
Stator circuit of motors with sealed insulation system	0.2	25	500	1000 [2] 100 [3]
DC GENERATORS AND MOTORS (EXCEPT PROPULSION AND AUXILIARY GENERATORS FOR SUBMARINES) INCLUDING EXCITERS				
	Insulation Resistance (megohms at 25° C) [1]			
Circuit	**Minimum for Operation**	**After Cleaning in Ship**	**After Recndtn**	**After Rewinding**
Complete armature circuit [2], [a]	0.1	0.5	1.0	100
Armature alone	0.2	1.0	2.0	200
Armature circuit less armature [2], [b]	0.2	1.0	2.0	200
Complete field circuit	0.5	1.5	2.5	200

[1]Values are for machines rated 500 volts or less. For machines having a rated voltage (E) greater than 500 volts, multiply all values given in the table by E/500.

[2]Minimum acceptable value with winding dry, before and after submergence test.

[3]Minimum acceptable value during 24-hour fresh water submergence test.

[1]Values are for machines rated 250 volts or less. For machines having a rated voltage (E) greater than 250 volts, multiply all values given in the table by E/250.

[2]Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and the complete field circuit may be measured without breaking this connection. If necessary, the armature can be isolated by lifting the brushes.

[a]With brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanent connected field circuit. The values given in the table for the complete armature circuit will apply.

[b]With brushes lifted, the armature circuit, less armature and the complete field circuit, will be measured. The values given in the table for armature circuit, less armature, will apply.

7-20. CLEANING.

Follow these steps in cleaning equipment after seawater exposure.

a. Thoroughly flush all salt deposits from the windings. Use the methods presented in paragraph 7-7 or paragraph 7-8.

b. As the washing progresses, collect drippings. Test these drippings by one of the following means:

   (1) Obtain competent technical assistance to perform the standard salinity test, or

   (2) Take 2 ounces of drip test water. Add 2 to 3 drops dilute nitric acid and 2 drops of silver nitrate. If the solution becomes clouded, the amount of clouding indicates the amount of salts still present.

c. Continue washing and flushing for 1 hour after test water runs clear. This ensures thorough cleaning.

d. For drying after cleaning, use the methods described in paragraphs 7-10 through 7-15.

e. If time and conditions permit, use the following method to assure reliability of the equipment:

   (1) Measure the insulation resistance while the unit is still hot from the drying process. Continue to measure at frequent intervals as it cools to room temperature.

   (2) Allow the unit to stand for 2 days or longer after cooling. Keep the humidity as high as possible, using pans of water placed on heating coils if necessary.

   (3) Measure the insulation resistance frequently. If possible, let a reconditioned motor that has not been subjected to salt water stand in the same area. Compare the insulation readings.

   (4) Insulation readings should not fall rapidly under these conditions. Readings should not be significantly lower than those of the other motor. If they do fall, or are lower, the salt has not been completely removed. The motor should be washed and dried again before proceeding further.

WARNING

Rust preventive compound may produce dizziness if adequate ventilation is not provided.

CAUTION

This product may have a corrosive effect on paint, varnish, and insulation. Keep it clear of windings and fabric insulation.

f. Rust prevention measures must be taken as soon as possible on all components. Apply rust preventive after all metal parts have been thoroughly washed and dried. Use a suitable compound such as MIL-C-16173, compound, rust preventive, grade 3, thin film (Polar type) (NSN 8030-00-244-1296, 1 gallon; 8030-00-244-1293, 5 gallons; 8030-00-244-1294, 55 gallons). Apply it to all metallic parts which are subject to corrosion. This compound displaces water and prevents rust.

7-21.

If the previous cleaning methods failed to correct the problem, the following actions must be taken:

7-21.1 In order to obtain maximum reliability, all coils and windings should be replaced if electrical equipment has been submerged in seawater.

7-21.2 All laminated steel magnet core structures should be replaced. Complete salt removal from these components is practically impossible.

7-22. CLEANING MOTORS WITH SOLVENTS.

WARNING

Solvents must be used with extreme care while following all applicable safety precautions for the type of solvent used. Most solvents are toxic and can be harmful to personnel if vapors are breathed or if the liquid comes into contact with the skin. Solvents should not be used where contact with open flame or extremely hot surfaces might occur because of the danger of fire or the generation of toxic fumes. Proper personnel protective equipment must be worn and adequate ventilation provided whenever solvents are used. Refer to NAVSEA S9086-KC-STM-010/CH 300 for the names of approved solvents, methods of use, and safety precautions required.

7-23.

Avoid the use of solvents for motor cleaning if possible. Use solvent cleaning only when other cleaning methods will not do.

7-24. DRY CLEANING SOLVENT, TYPE II.

WARNING

This solvent is highly flammable. Its use requires the strictest observance of all safety precautions pertaining to open flames, smoking, or spark producing activity.

CAUTION

Dry cleaning solvent type II, P-D-680 (NSN 6850-00-274-5421), may be damaging to some types of insulation. A test should be made to a small spot before using.

7-24.1 The cleaning efficiency as well as the ill effects to personnel are less than the chlorinated solvents.

a. Apply solvent to a small area of stator windings by use of a moistened, lint-free cloth. Examine area to if any adverse effects have occurred.

b. Continue to wipe the windings if no adverse effects are noted. Wipe dry with a clean, lint-free cloth.

c. Repeat wiping and drying steps as necessary.

CHAPTER 8

BURNOUT AND STRIPPING PROCEDURES

8-1. SCOPE.

This chapter outlines the procedures used to burn out, strip, and prepare a stator for rewinding. Topics include:

8-1.1 Winding identification and data collection (paragraph 8-2).

8-1.2 Oven burnout and stripping (paragraph 8-12).

8-1.3 Stripping a stator by warming and pulling (paragraph 8-16).

8-1.4 Stator cleanup (paragraph 8-22).

8-1.5 Stator sealing or varnishing (paragraph 8-30).

8-2. WINDING IDENTIFICATION AND DATA COLLECTION.

8-3.

A motor winding must be correctly identified before replacement. All pertinent information must be recorded before any connections are broken and the winding destroyed. The repaired motor cannot function properly if the winding has been changed or modified.

8-4. DATA COLLECTION FROM MASTER DRAWINGS.

The master drawing of the stator to be rewound is the primary source of rewind data. The master drawing includes all information necessary to rewind the stator. The winding information contained in the master drawing should be verified. If the information in the master drawing does not match the existing winding, proper winding data can be verified by contacting the Naval Sea Systems Command, Code 03Z71.

8-5. DATA COLLECTION FROM OLD WINDINGS.

Information can be obtained from the old winding if the master drawing is not available. If the winding is not encapsulated (see Appendix E for identification of encapsulated windings), it may be possible to obtain most of the required information as described in paragraphs 8-6 through 8-11.

8-6. NECESSARY INFORMATION.

The characteristics of the following are required for rewinding the stator:

8-6.1 Coil winding,

8-6.2 Pole phase groups,

8-6.3 Coil sides per slot, and

8-6.4 Lead wires and connectors.

8-7. MOTOR REPAIR IDENTIFICATION SHEET.

All winding information should be recorded on the motor repair identification sheet (figure 8-1). The top and nameplate sections of the sheet are self-explanatory. Paragraphs 8-8 through 8-11 refer to the winding section. Take as much data as possible before the winding is cut.

8-8. COIL WINDING.

The following information is necessary to determine the coil winding:

8-8.1 Coil Shape. The coil will usually be round-nosed, flat-nosed, or diamond shaped. Determine the shape by visual inspection. See figure 9-1 in Chapter 9.

8-8.2 Coil Span. Coil span or pitch corresponds to the number of slots separating the sides of a coil. The span includes the slots in which the coil lies. These data are taken when the coils are being stripped out of the motor.

NOTE

Insulation must be stripped from the wire before it is measured.

8-8.3 Wire Size. Pull out the lead wire, Cut it below the soldered connection. Measure the magnet wire with a wire gage. Conductor size is determined by the area of the copper conductor used to wind the stator. The conductor may be round, rectangular, or square. Most conductors used in random-wound U.S. Navy motors are round. In order to fully utilize the slot area, there may be more than one conductor in a coil. In that case, there are parallel paths or conductors in parallel in the coil. More than one size of conductor may also be used in a coil.

8-8.4 Number of Wires in Hand. Determine the number of wires in hand (conductors in parallel) by counting the wires in one group going to a lead wire. When more than one group connects to a lead wire, be sure to pick up the leads of only one group.

8-8.5 Turns per Coil. Determine the number of turns per coil by counting the conductors in a complete coil. Divide the conductors by the number of wires in hand (conductors in parallel) to determine turns per coil. Recover at least one complete coil so that the turns can be counted. Record the number of turns on the motor repair identification sheet (figure 8-1).

8-8.6 End Room. End room is the distance the coils protrude beyond the ends of the slots. Use a rule to measure the distance from the end of the laminations to the end of the winding.

USS ______________ JSN ______________ DATE ____________

APPLICATION ______________ DATA TAKER ______________

NAMEPLATE DATA

VOLTS ________ AMPS ______ Ø _____ HZ ______ R/M ______ HP ______

TYPE ______ FRAME _____ CLASS _______ DUTY ______ TEMP RISE ____

MFG ______________ SERIAL # ______________ BEARING F ____________

NAVY/MFG DWG # ______________ BEARING B ____________

STANDARD WINDING		WINDING DIA.
COIL SHAPE		
NO. POLES		
NO. SLOTS		
NO. COILS		
COIL SIDES/SLOT		
CONNECTION		
NO. GROUPS		
COILS/GROUP		
COIL SPAN (PITCH)	R S	
WIRE SIZE	R S	
TURNS/COIL	R S	
NO. IN HAND		
END ROOM	F B	
LEAD WIRE SIZE		
LEAD WIRE LENGTH		

Figure 8-1 Motor Repair Identification Sheet

8-9. POLE PHASE GROUPS.

The following information is necessary to determine pole phase groups:

8-9.1 Number of Poles. The number of poles and the frequency of the motor will determine the speed of rotation of the motor rotor. Repair personnel must determine the number of poles in a motor to be able to complete the motor repair identification sheet (figure 8-1). The number of poles in a motor will be some number times two (north and south poles). The number of poles in a motor can be determined by the following formula:

P = 7200/N, where P = poles and N = motor speed

Example: P = 7200/N = 7200/3550 = 2.03 pole motor

There cannot be a fraction of a pole. Drop the decimal 0.03 and the motor is a two-pole motor. After gaining some experience, repair personnel will be able to recognize the speeds of various pole combinations without performing calculations. See table 8-1 for determining motor speed by comparison.

8-9.2 Pole Phase Groups. Use the number of poles determined in paragraph 8-9.1 to determine the number of pole phase groups in the motor. The number of phases for which the motor is designed will be on the nameplate of the motor.

PPG = P x Ø, where

PPG = Pole phase groups

P = Number of poles determined using paragraph 8-9.1.

Ø = Phases for which the motor is designed

The number of pole phase groups calculated in this manner determines the number of groups of coils needed to wind a motor. Repair personnel will also need the number of pole phase groups to determine the coils to be wound in a group or to determine the coils to be connected together to make a pole phase group.

Table 8-1 Motor Speed Table

Operating Speed	Synchronous Speed	Poles
3450 - 3575	3600	2
1725 - 1775	1800	4
1150 - 1175	1200	6
825 - 875	900	8
675 - 690	720	10
500 - 575	600	12

8-9.3 Number of Coils per Group. Individual coils are wound together or connected to form a pole phase group. To determine the number of coils in one pole phase group for a distributed winding (two coil sides per slot in a single winding):

$$\text{Coils per group} = \frac{\text{Total active coils}}{(\text{Number of phases}) \times (\text{Number of poles})}$$

An active coil is a coil that is electrically connected in the stator circuit *(Total active coils = Active coils per phase x Number of phases).*

8-10. COIL SIDES PER SLOT.

The following information is necessary to determine coil sides per slot:

8-10.1 Number of Slots. Count the number of slots in the stator.

8-10.2 Coil Sides per Slot. Examine the stator and determine the number of coil sides per slot. Basket windings (concentric windings) will usually have only one coil side per slot for each winding, as shown in figure 8-2(A). Some variations of this winding may have two coil sides per slot. When winding a basket winding, both sides of each coil are put into the slots of the stator at the same time. Do this from the beginning of the winding (bottom to bottom or top to top). The winding appears as a basket weave when viewed from the top. Distributed windings, also called whole coil or lap windings, have the winding laid in with one coil side in the bottom of one slot and the other coil side in the top of a slot. The end of the winding has a smooth or distributed appearance when viewed from the top. The coils appear to lay in each other on the ends (figure 8-2(B)).

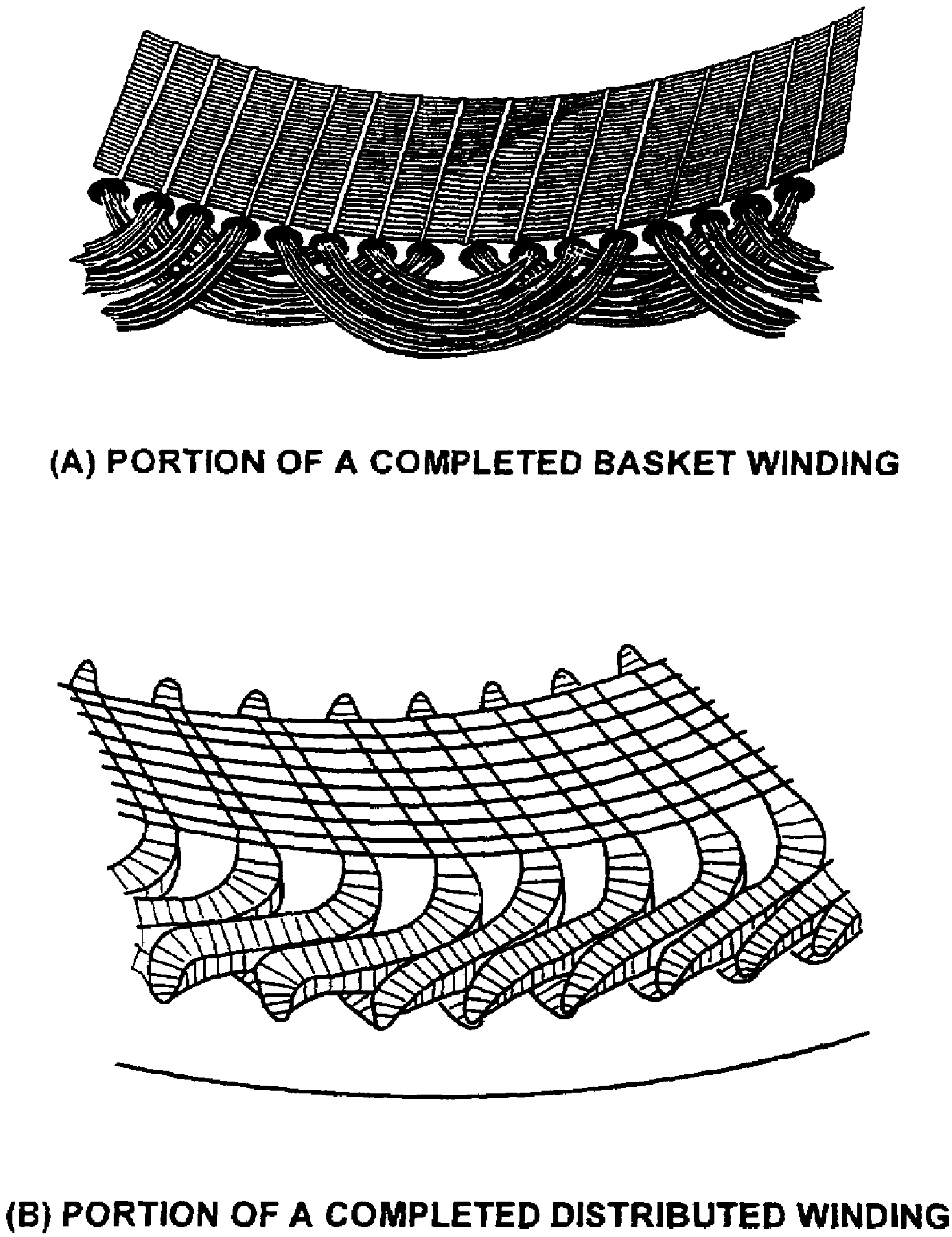


Figure 8-2 Portions of Distributed and Basket Windings

8-11. LEAD WIRES AND CONNECTIONS.

The following information is necessary to determine lead wires and connections:

8-11.1 Lead Wire Size. Measure the lead wire. The lead wire size may be checked against a lead wire table to ensure that the proper size is being used (table 8-2).

8-11.2 Type of Connection. There are basically two types of connections: delta and wye. In both cases, the type of connection is determined by examining how the leads are connected together. In the wye connection, three of the beginning or ending leads will be connected at a single neutral point in the form of the letter *Y* . In the delta connection, there will be three connecting points, each with two leads, each point being in the form of a δ. (See Appendix D, paragraph D-17, for further details and illustrations.) Use the steps below in determining the type of connection:

Table 8-2 Lead Wire Table for Motors

H.P.	**Wye**		**Delta**				
	220 V	**440 V**	**220 V**	**440 V**			
	3 Lead	**3 or 9 Lead**	**3 Lead**	**3 or 9 Lead**		**2300 V**	**4160 V**
				1-2-3	**4-5-6-7-8-9**		
	1	16	16	16	16		
2	16	16	16	16	16		
3	16	16	16	16	16		
5	14	14	14	14	14		
7.5	12	14	12	14	14		
10	10	12	10	12	12		
15	10	12	10	12	12		
20	8	10	8	10	10		
25	6	10	6	10	10		
30	6	8	6	10	10		
40	4	8	4	8	10		
50	2	6	2	6	10		
60	2	6	2	6	8	Up to	Up to
75	0	4	0	4	6		
100	2/0	2	2/0	2	4		
125	3/0	2	4/0	2	4		
150	2#1	0	2#1	0	2		
200	2#2/0	2/0	2#2/0	2/0	1		
250	2#3/0	3/0	2#3/0	3/0	2/0	#8	
300		2#1		2#1		#3	
350		2#2/0		2#2/0		#3	
400		2#2/0		2#2/0		#3	
450		2#3/0		2#3/0		#3	
500		2#3/0		2#3/0		#3	#8

NOTE

Lead wire connections can also be examined to determine whether the connection is a delta or wye connection. A wye connection would be designated as a single coil connected to the lead wire. A delta connection is determined if two coils connect to the lead wire.

a. Cut the tie cords on the connection end.

b. Separate the cross connections so that one connecting point can be isolated.

c. Count the number of wires connected together. If two, it is a delta connection; if three, a wye connection (table 8-3).

8-12. OVEN BURNOUT AND STRIPPING.

8-13.

To be able to properly remove windings and later rewind a motor, certain data must be collected before burnout or stripping. To obtain the data, refer to the master drawing or use the procedures in paragraphs 8-5 through 8-11 and Appendix E.

Table 8-3 Wire Table Standard Annealed Solid Copper Wire (American Wire Gage - B&S)

	Cross section			Ohms per 1,000 ft		Ohms per mile	
Gage Number	Diameter Mils	Circular Mils	Square Inches	25° C (77° F)	65° C (149° F)	25° C (77° F)	Pounds per 1,000 ft
0000	460.0	212,000.0	0.166	0.500	0.0577	0.264	641.0
000	410.0	168,000.0	0.132	0.0630	0.0727	0.333	508.0
00	365.0	133,000.0	0.105	0.0795	0.0917	0.420	403.0
0	325.0	106,000.0	0.0829	0.100	0.116	0.528	319.0
1	289.0	83,700.0	0.0657	0.126	0.146	0.665	253.0
2	258.0	66,400.0	0.0521	0.159	0.184	0.839	201.0
3	229.0	52,600.0	0.0413	0.201	0.232	1.061	159.0
4	204.0	41,700.0	0.0328	0.253	0.292	1.335	126.0
5	182.0	33,100.0	0.0260	0.319	0.369	1.685	100.0
6	162.0	26,300.0	0.0206	0.403	0.465	2.13	79.5
7	144.0	20,800.0	0.0164	0.508	0.586	2.68	63.0
8	128.0	16,500.0	0.0130	0.641	0.739	3.38	50.0
9	114.0	13,100.0	0.0103	0.808	0.932	4.27	39.6
10	102.0	10,400.0	0.00815	1.02	1.18	5.38	31.4
11	91.0	8,230.0	0.00647	1.28	1.48	6.75	24.9
12	81.0	6,530.0	0.00513	1.62	1.87	8.55	19.8
13	72.0	5,180.0	0.00407	2.04	2.36	10.77	15.7
14	64.0	4,110.0	0.00323	2.58	2.97	13.62	12.4
15	57.0	3,260.0	0.00256	3.25	3.75	17.16	9.86
16	51.0	2,580.0	0.00203	4.09	4.73	21.6	7.82
17	45.0	2,050.0	0.00161	5.16	5.96	27.2	6.20
18	40.0	1,620.0	0.00128	6.51	7.51	34.4	4.92
19	36.0	1,290.0	0.00101	8.21	9.48	43.3	3.90
20	32.0	1,020.0	0.000802	10.4	11.9	54.9	3.09
21	28.5	810.0	0.000636	13.1	15.1	69.1	2.45
22	25.3	642.0	0.000505	16.5	19.0	87.1	1.94
23	22.6	509.0	0.000400	20.8	24.0	109.8	1.54
24	20.1	404.0	0.000317	26.2	30.2	138.3	1.22
25	17.9	320.0	0.000252	33.0	38.1	174.1	0.970
26	15.9	254.0	0.000200	41.6	48.0	220.0	0.769
27	14.2	202.0	0.000158	52.5	60.6	277.0	0.610
28	12.6	160.0	0.000126	66.2	76.4	350.0	0.484

Table 8-3 Wire Table Standard Annealed Solid Copper Wire (American Wire Gage - B&S) - Continued

	Cross section			Ohms per 1,000 ft		Ohms per mile	
Gage Number	Diameter Mils	Circular Mils	Square Inches	25° C (77° F)	65° C (149° F)	25° C (77° F)	Pounds per 1,000 ft
29	11.3	127.0	0.0000995	83.4	96.3	440.0	0.384
30	10.0	101.0	0.0000789	105.0	121.0	554.0	0.304
31	8.9	79.7	0.0000626	133.0	153.0	702.0	0.241
32	8.0	63.2	0.0000496	167.0	193.0	882.0	0.191
33	7.1	50.1	0.0000394	211.0	243.0	1,114.0	0.152
34	6.3	39.8	0.0000312	266.0	307.0	1,404.0	0.120
35	5.6	31.5	0.0000248	335.0	387.0	1,769.0	0.0954
36	5.0	25.0	0.0000196	423.0	488.0	2,230.0	0.0757
37	4.5	19.8	0.0000156	533.0	616.0	2,810.0	0.0600
38	4.0	15.7	0.0000123	673.0	776.0	3,550.0	0.0476
39	3.5	12.5	0.0000098	848.0	979.0	4,480.0	0.0377
40	3.1	9.9	0.0000078	1,070.0	1,230.0	5,650.0	0.0299

CAUTION

Do not crack the varnish, as leads may be broken. It will then be impossible to determine connections when pulling the leads up.

Cut off the end turns of encapsulated motors to prevent uncontrolled fires in the oven. Some motors have alloy parts which may distort at 600-700° F (316-371° C). High temperatures may adversely affect iron characteristics. To avoid damage to the lamination/insulation motors, burnout should be conducted below 700° F (371° C).

NOTE

Perform a core test (paragraph 2-38) before and after burnout.

8-14. OVEN BURNOUT PROCEDURE.

The simplest, but most time consuming, method of preparing a failed winding for removal from a stator is by oven burnout. Leave the stator in a preheated, temperature-controlled burnout oven that has a forced exhaust system until all insulating materials have turned to ash and the windings can be easily removed. This will take at least 12 hours. The oven temperature during burnout should not exceed 700° F (371° C) (600° F (316° C) for T-frame and aluminum stators), measured by thermocouple on stator iron. After removing the stator from the oven, allow it to stand and cool to room temperature.

WARNING

Wear insulated gloves when removing the hot stator from the oven.

8-15. STRIPPING PROCEDURE.

Use the following procedure to strip a stator after burnout:

a. Slot Wedge Removal. Remove the slot wedges with a slot wedge removal tool or hacksaw blade. Place the blade along the length of the slot wedge and tap the blade with a hammer until the teeth are embedded in the wedge. Then tap the end of the blade with the hammer to drive the wedge in the direction in which the teeth are pointing (figure 8-3).

b. Data Verification. Stand the motor on end with the connections up. Verify the previous winding data. Check the data on the motor repair identification sheet. This is the last chance to ensure that the winding has been correctly identified.

c. Coil Removal. Lay the motor down. Cut the end turns of approximately one span of coils. Remember that the span is the number of slots separating the sides of the coil, including the slots in which the coil lies. Use pliers to pull out the cut coils. Determine the span with one coil still in the slot and both sides visible. Record this span on the motor repair identification sheet. Cut all but one of the remaining coils. Pull them out of the stator.

d. Sample Coil. Be sure to remove an uncut coil from the stator. Stow it in a safe place. It will be used later to establish the correct size for the new coils that will be wound. Count the number of conductors in the sample coil. Divide by the wires in hand (conductors in parallel) to determine the number of turns in the coil. Record this number on the motor repair identification sheet. Count the slots from one side to the other when both sides of a coil are visible. Record the span (pitch) on the motor repair identification sheet (figure 8-1).

8-16. STRIPPING A STATOR BY WARMING AND PULLING.

8-17.

Warming and pulling is the preferred method for stripping the stator. This method is to be used on motors with sealed insulation systems and can also be used with aluminum frame motors. This method uses lower temperatures, so it does not damage the laminations. The method consists of:

a. Cutting off the end turns from one end of the stator.

b. Mounting the stator on a heater ring.

c. Transmitting heat to the winding through the cut off end turns until the winding is softened.

d. Pulling the windings with a hydraulic puller.

e. Cleaning the slots with a wire brush.

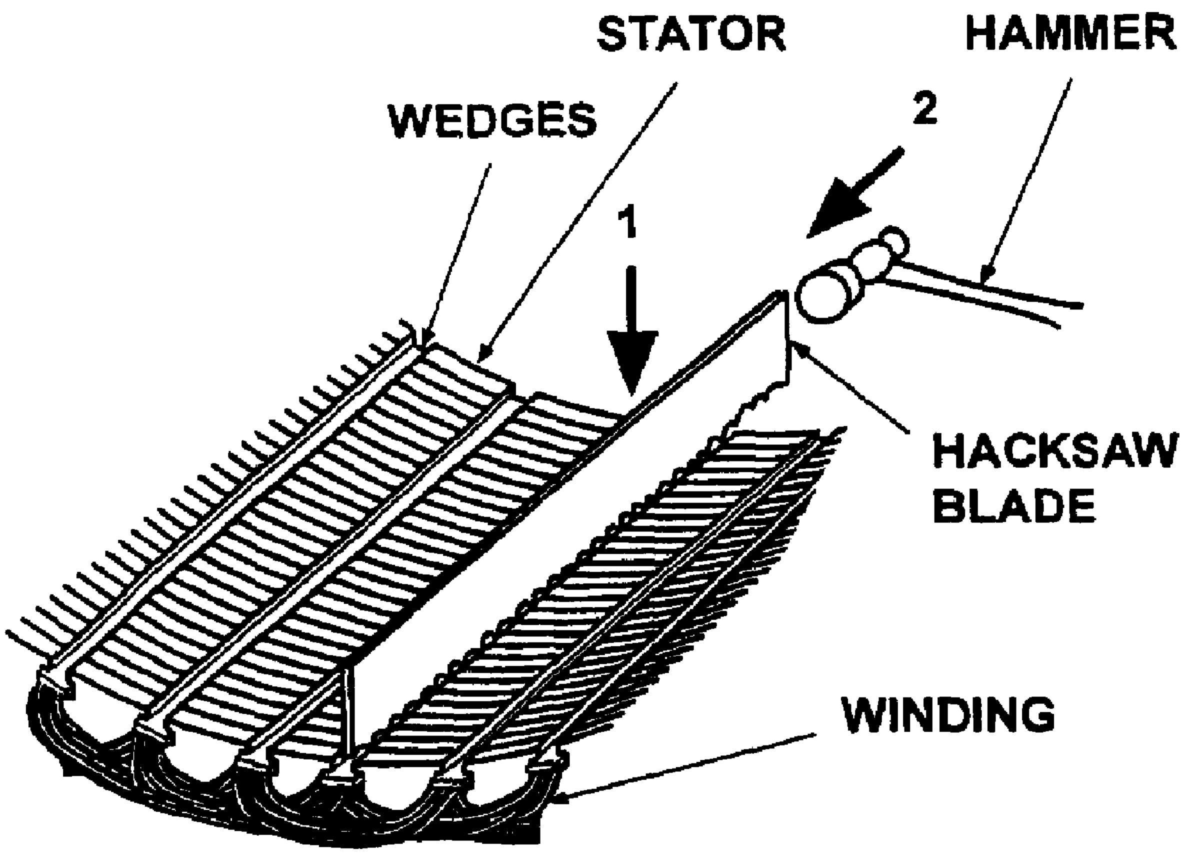


Figure 8-3 Removing Slot Wedges

8-18. END TURN CUTOFF.

Use the following procedure to strip a stator using a machine with a built-in cutoff saw and a rotating turntable (figure 8-4).

a. Secure the stator to the platform of the rotary coil cutter.

(1) Mount the stator with the connection end up.

(2) Use the clamps attached to the cutoff device to secure the stator.

b. Place the cutoff device over the center of the stator.

c. Adjust the height of the cutoff blade to cut off the end turns at the connection end. This is 1/4 inch above the stator core.

NOTE

Rotating the stator by rotating the turntable and moving the cutting wheel against the windings will provide a smooth square surface where the end turns have been cut off.

End turn cutoff devices such as Potter Rayfield ″Nibbler″ will not do a satisfactory job since they do not provide a square smooth surface. Suitable end turn cutoff devices are manufactured by Lancer of Wisconsin and Dreisilker Electric Motors, Inc., of Glen Ellyn, Illinois.

d. Cut the end turns within 1/4 inch of the stator iron.

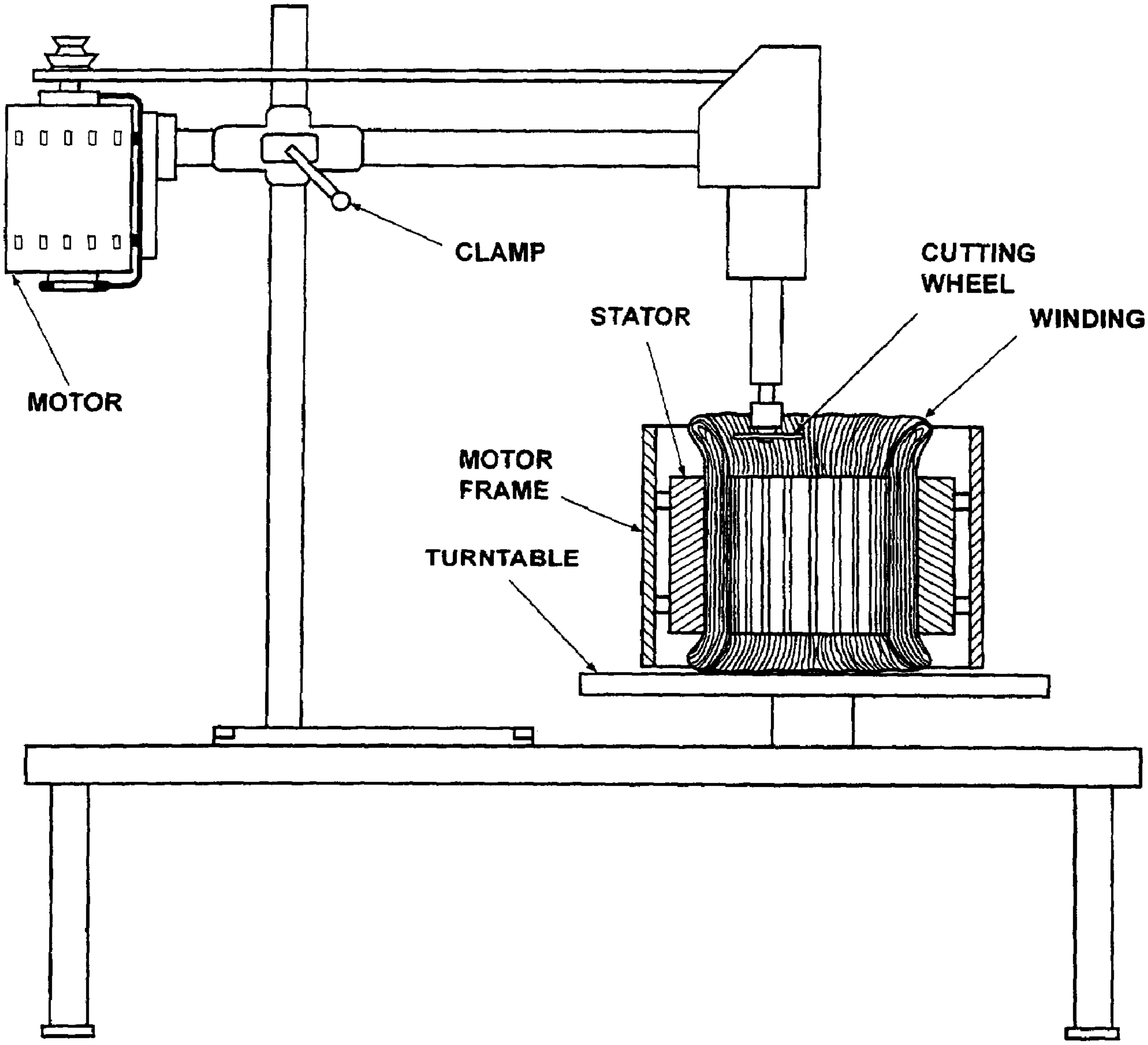


Figure 8-4 Cutting Off End Turns

8-19. FURTHER PROCEDURES FOR END TURN CUTOFF.

There are two basic procedures which can be used to cut off the end turns. They are:

NOTE

It is generally better to cut off the end turns on the side *opposite* the side where the coil connections are made. If the connection diagram is not known, the end turns where the connections were cut off can be used to determine the diagram as described in Appendix B. Ensure that safety goggles or face shield are worn. Observe standard safety precautions.

a. Procedure 1

(1) Start the saw motor.

CAUTION

Keep the saw clear of stator laminations.

(2) Bring the cutoff saw into contact with the winding end. Cut partially through the winding.

(3) Lock the saw in place.

(4) Rotate the turntable slowly to bring the remainder of the winding end under the saw blade.

(5) Unlock the saw after one complete revolution of the turntable. Carefully force the saw deeper into the winding end and relock the saw.

(6) Rotate the turntable through another revolution.

(7) Continue forcing the saw into the winding end. Rotate the turntable until the end is cut through completely.

b. Procedure 2

(1) Bring the saw into contact with the winding. Cut all the way through the winding.

(2) Back the saw out.

(3) Rotate the turntable to bring a new section of uncut winding under the saw.

(4) Cut all the way through the winding.

(5) Continue cutting through the winding, backing the saw out, rotating the turntable, and cutting a new area. Continue until the winding is completely cut off.

8-20. HEATING WINDINGS BY ELECTRICAL HEAT.

After removing the connection end turns, electrical heat is used for heating the windings in preparation for removing them from the stator core. Electrical heating offers the advantage of greater temperature control. It is important to remember that electrical heating is not a burnout procedure. It is intended only to heat the material until it is soft enough to remove with a hydraulic puller (figure 8-5). Use the following procedures for electrical heating.

NOTE

Commercial devices suitable for this operation are made by S. and W. Enterprises of Savannah, Georgia, and Dreisilker Electric Motors, Inc., of Glen Ellyn, Illinois.

a. Place the stator on the stator warmer, with the uncut coil ends up.

NOTE

The stator warmer should be equipped with heater rings of various sizes to accommodate all motor frame sizes. Select a heater ring which will fit inside the motor frame and contact the cut ends of the coil. The cut end of the coils must firmly contact the heating ring to provide for adequate heat transfer.

b. Center the stator on the heater ring.

c. Embed a thermocouple in the upper end of the uncut stator winding. The winding may be separated with a screwdriver for insertion of the thermocouple into the winding.

d. Connect the thermocouple leads to the portable pyrometer similar to a Simpson 3883L. The pyrometer scale must reach at least 500° F (260° C).

e. Energize the heating elements.

f. Watch the temperature indicator. The temperature should be maintained near 400° F (204° C) during coil removal.

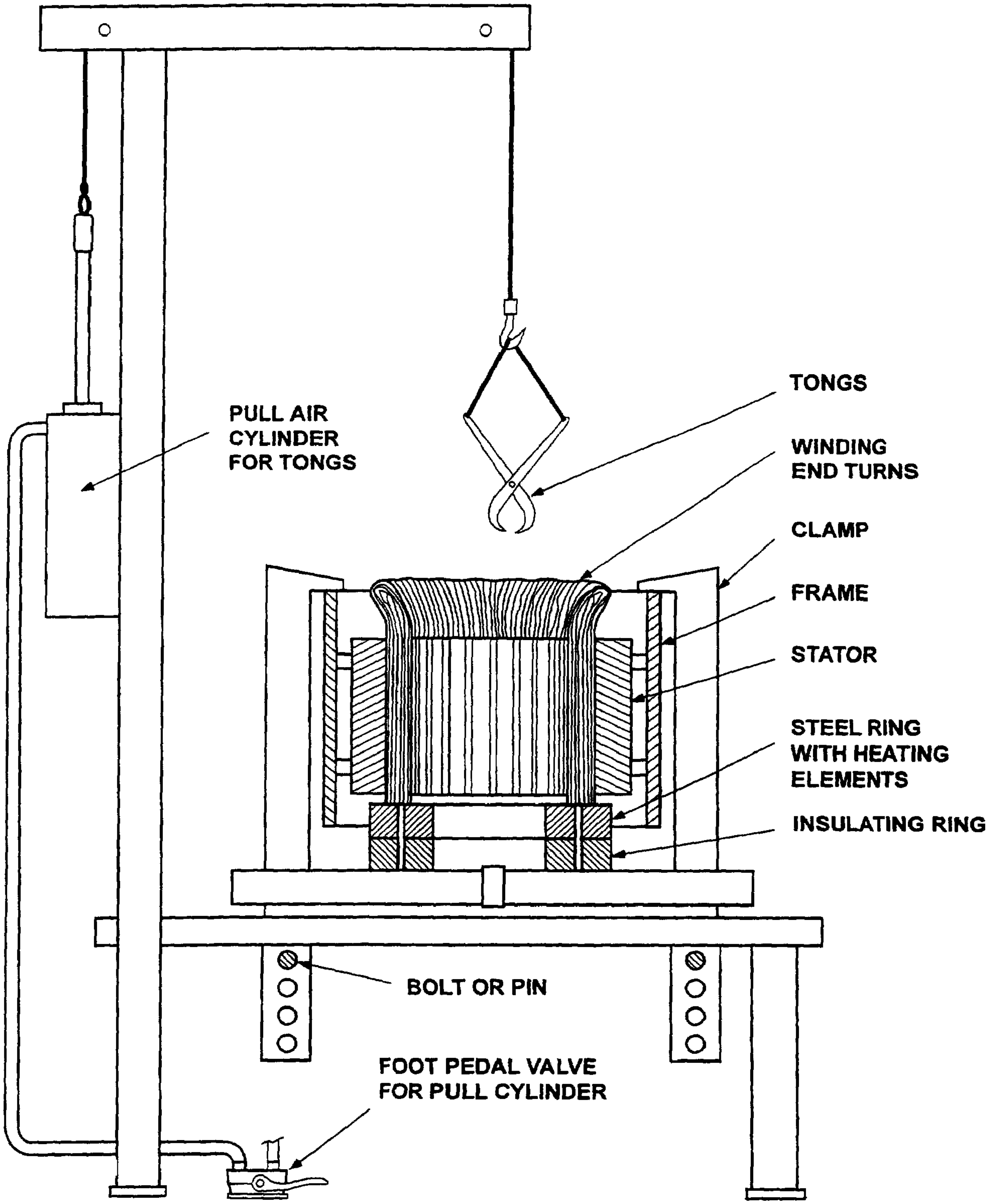


Figure 8-5 Coil Puller Setup for Electrical Heating

8-21. STATOR COIL REMOVAL.

WARNING

Use a clear plastic face mask and insulated gloves since the items being handled are hot and will not quickly cool.

CAUTION

Do not allow the heater cables to catch on obstructions while rotating the turntable. The heater leads may be pulled and shorted if leads are allowed to catch.

After the coils have reached 400° F (204° C), the coils can be removed by either a hydraulic or an air-actuated puller. The stator must be secured by clamps to resist the force from the puller. Use the following procedure to remove the coils:

WARNING

Use insulated gloves and a plastic face shield when moving the stator.

NOTE

Continue to heat the coils throughout the pulling process. Remove the winding section containing the thermocouple last.

a. Attach the tongs to the puller.

b. Force the tongs into the winding end turns.

c. Apply just enough force on the puller to barely loosen the coils.

d. Release the tongs from the winding end.

e. Slightly rotate the turntable.

f. Force the tongs into a new section of the winding end turns.

NOTE

Use a metal can to collect the extracted windings as they will initially be at a temperature of 400° F (204° C) when first removed.

Count the slots between the coil sides when both sides of one coil can be seen. Record the number on the motor identification sheet. Count the number of conductors and divide by the wires in hand to determine turns of a coil.

g. Continue until all coils are loosened. When all coils are loosened, continue around the windings, pulling each coil completely out.

8-22. STATOR CLEANUP.

8-23.

It is important to properly clean the stator after stripping and before rewind. This can mean the difference between early motor failure and long, satisfactory service. Cleaning the stator and removing burrs and sharp edges helps to protect new winding insulation.

8-24. VISUAL INSPECTION.

Make a thorough visual inspection of the stator when all the coils have been removed. Look for charred but adhering varnish, sprung laminations, sharp metal edges, and dirt in lamination slots.

CAUTION

Be careful when sandblasting to ensure that the stator laminations are not loosened.

8-25. VARNISH.

Old varnish must be removed. If not removed, it can interfere with the new winding. Varnish can be removed by chemical cleaning with an approved ultrasonic cleaner or with approved solvents, wire brushing, glass beads, or sandblasting.

8-26. SPRUNG LAMINATIONS.

Pull any sprung laminations together with heavy wire before sandblasting. Use a ball peen hammer to peen a single lamination at an angle.

8-27. SHARP EDGES.

File any sharp edges or burrs on laminations to a smooth finish. This will prevent cutting of the slot insulation material. It will also prevent damage to wire varnish during installation.

CAUTION

Do not use compressed air to clean slots. It may contaminate the stator with moisture.

8-28. DIRT IN LAMINATION SLOTS.

Brush dirt and loose material from the stator slots. Use a round, stiff brush similar to a rifle bore brush.

8-29. CORE TEST.

Perform a core test (paragraph 2-38) after stripping and cleaning to ensure that the core was not damaged during the process.

8-30. STATOR SEALING OR VARNISHING.

NOTE

When solvent-type varnish is being used, use a 20 percent varnish solution of the same varnish that will be used in varnishing the windings. Use one part varnish to four parts thinner.

8-31.

Varnishing the stator before rewinding and after cleaning seals the lamination and prevents oxidation. Inspect the stator again before starting this procedure. Ensure that the stator is clean. Insert bolts in bolt holes if the stator is in a frame.

WARNING

Always use insulated gloves when placing the stator in the oven or removing it.

8-32. BAKING.

Place the stator in an oven preheated to 300° F (149° C). Bake 2 to 4 hours. Remove the stator from the oven. Allow it to cool to approximately 104° F (40° C).

NOTE

When solvent-type varnish is being used, be sure that the varnish has a viscosity of 150 to 250 centipoises or as specified in the manufacturer's technical manual. Refer to Chapter 10 for the viscosity measurement procedure.

8-33. DIPPING AND BAKING.

Dip the stator in the varnish and bake it after determining that the varnish is within viscosity limits.

WARNING

Always use insulated gloves when dipping and baking.

a. Immerse the stator, cooled to 104° F (40° C), in varnish. Keep it immersed until all bubbling stops.

b. Drain and dry the stator for 1 hour. Rotate the stator to prevent pocketing of the varnish.

c. Wipe the metal surface of the stator bore *after* draining but *before* baking. Also, wipe the rabbet on the frame and other surfaces which should be free of varnish. Use a cloth moistened with *xylene*. For solvent less varnish, use a clean dry rag or use a release agent provided by the manufacturer. *before* dipping.

d. Bake the stator in a circulating-type forced- exhaust baking oven at 302° F (150° C). Bake 6 to 8 hours.

WARNING

Always use insulated gloves when removing a stator from an oven.

e. Remove the stator from the oven and allow it to cool.

CHAPTER 9

MOTOR REWIND

9-1. SCOPE.

This chapter contains information on rewinding and the actions needed to return a motor to service. Topics include:

9-1.1 Motor rewind equipment and machine setup (paragraph 9-2).

9-1.2 Winding sample coils and winding groups (paragraph 9–8).

9-1.3 Insulation preparation (paragraph 9-15).

9-1.4 Winding the stator (paragraph 9-21).

9-1.5 Making and testing connections (paragraph 9-26).

9-1.6 Postwinding procedures (paragraph 9-34).

9-1.7 Rewinding motors with a sealed insulation system (SIS) (paragraph 9-38).

9-2. MOTOR REWIND EQUIPMENT AND MACHINE SETUP.

WARNING

Remove jewelry from hands, remove ties or tuck ties into shins, tuck in shirttails, roll down long sleeves, and button cuffs before operating the winding machine.

9-3.

Coils are wound on coil winding machines. These machines can be used to wind either diamond or round nose coils (figure 9-1).

9-4. DIAMOND COILS.

Six sets of fingers are mounted on the winding head to form a diamond shape. Screws permit adjustment of the overall coil length, coil side length, and coil width. End strips are slotted steel plates which support the outer ends of the winding fingers. They are numbered 1, 2, etc., to indicate the fingers to which they should be attached. End strips are provided to prevent the outside coils from becoming shorter than the inside coils. They are supported by a centerpost and locked in place by a T handle. A special attachment can be used to put a knuckle in the coil end.

9-5. COIL WINDING MACHINE SETUP (DIAMOND COILS).

Use the following steps to setup the equipment:

a. Select the fingers to be used for winding.

b. Mount the fingers on the head. Follow the numbering sequences stamped on the fingers.

NOTE

The operator will have difficulty mounting the strips if the finger numbering sequence is not followed. The number 1 strip must go on the number 1 finger and to the centerpost. The number 2 strip must go to the number 2 finger and to the centerpost. The number 1 strip must be installed before the number 2 strip.

c. Attach the end strips. Lock them loosely in place with the T handle.

NOTE

If the coil length is too great, the end turns will take up too much room and interfere with the end bell.

d. Set in the overall length of the coil. The overall length must be equal to:

(1) The length of coil slot and

(2) The length of end turns at each end. This length is determined by the space inside the end bells. The end turns must not come closer to the motor frame or end bells than 1/4 inch. There must also be sufficient room for the coil connection.

NOTE

It will be difficult to lay the coils in the slots if this width is too great.

e. Set in the coil width.

f. Set in the coil side length.

9-6. ROUND NOSE COILS.

Round nose coils are wound on heads. The heads can be used to ensure continuity of phase winding. They are mounted on a holder. Head size width is selected by the coil span. Coil length is determined by the slot length.

USS ____________ JSN ____________ DATE ____________

APPLICATION ____________ DATA TAKER ____________

NAMEPLATE DATA

VOLTS ______ AMPS ______ Ø ______ HZ ______ R/M ______ HP ______

TYPE ______ FRAME ______ CLASS ______ DUTY ______ TEMP RISE ______

MFG ____________ SERIAL # ____________ BEARING F ____________

NAVY/MFG DWG # ____________ BEARING B ____________

STANDARD WINDING	WINDING DIA.
COIL SHAPE ____________	
NO. POLES ____________	
NO. SLOTS ____________	
NO. COILS ____________	
COIL SIDES/SLOT ____________	
CONNECTION ____________	
NO. GROUPS ____________	
COILS/GROUP ____________	
COIL SPAN (PITCH) ______ R ______ S ______	
WIRE SIZE ______ R ______ S ______	
TURNS/COIL ______ R ______ S ______	
NO. IN HAND ____________	
END ROOM F ______ B ______	
LEAD WIRE SIZE ____________	
LEAD WIRE LENGTH ____________	

Figure 9-1 Motor Repair Identification Sheet

9-7. COIL WINDING MACHINE SETUP (ROUND NOSE COILS).

Use the following steps to set up this equipment:

a. Mount the holder on the winding machine.

NOTE

It will be difficult to lay in the coil sides if the heads are too small. End room will be excessive if the heads are too large.

b. To select the heads for the coil, compare the coil span with the head size.

c. Place the holder in the horizontal position.

d. Mount the heads on the holder.

e. Set in the coil side length. The coil side length is the length of the stator slots plus 3/4 inch to allow for the slot cell cuff.

9-8. WINDING SAMPLE COILS AND WINDING GROUPS.

9-9. WINDING SAMPLE COILS.

Use the following procedure to wind sample coils:

a. Open the winding head and lock it open. Tighten the T handle to lock the end strips.

b. Adjust the winding machine to a safe operating speed. Check the machine manufacturers instruction book for speed adjustment.

c. Test the winding machine brake. The head should stop quickly and positively when the foot control is released. Refer to the machine manufacturer’s instruction book for instructions on brake adjustment.

d. Select the proper size and number of reels of magnet wire. Discard broken or cracked reels.

(1) Use the size wire recorded on the motor repair identification sheet (figure 9-1).

(2) There must be one reel, or bucket, of wire for each wire in hand. See the motor repair identification sheet.

NOTE

Dereeling from reels mounted on horizontal bars will result in wire spillage and waste, even at moderate speeds.

e. Mount the reels on low-inertia dereelers.

f. Use a tensioning device to lead the wire from the dereelers over the winding machine wire guide bar (figure 9-2) to the winding head.

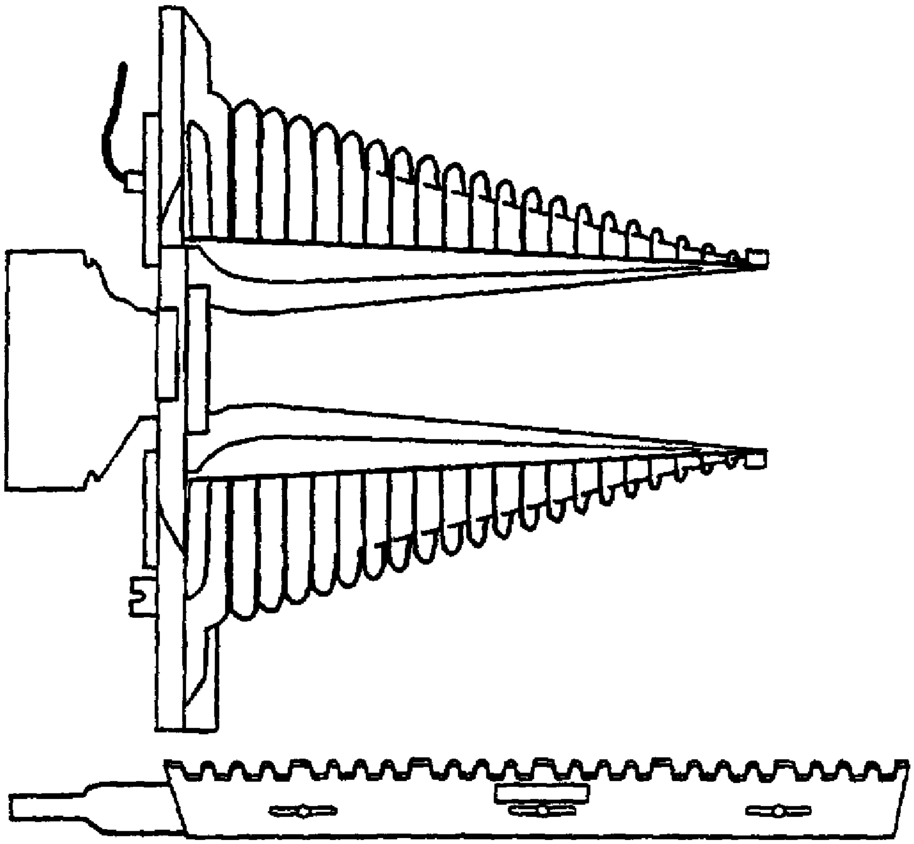


Figure 9-2 Winding Head and Wire Guides

(1) The tensioning device prevents wire crossover if properly adjusted.

(2) The wire guide bar slots should line up with the slots in the winding heads. This makes it easier to feed wire to the head and to keep it in the right slot.

(3) The bar is also a safety device that prevents the winder from being pulled against the rotating heads.

g. Hook the wire securely to the winding head.

h. Set the machine counter to zero. Set the number of turns in one coil into the control if the machine is automatic.

i. Wind a sample coil with the proper number of turns.

j. Tie the coil in the center of both coil sides (figure 9-3).

k. Cut the magnet wire at the guide bar. Loop the end which goes to the reels over the bars. Do not allow the magnet wire to fall on the deck. This will prevent damage to the wire insulating film.

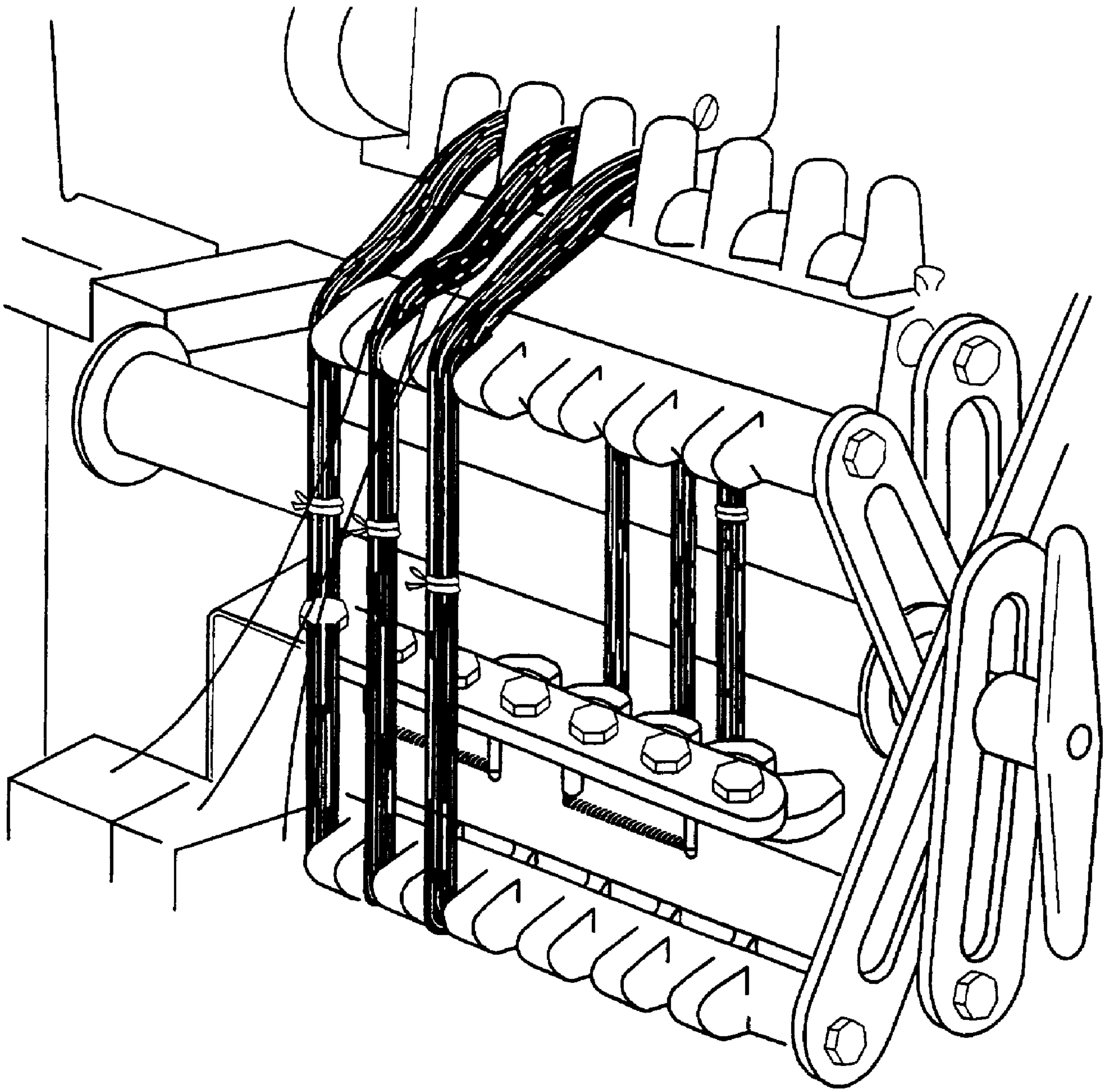


Figure 9-3 Tying of Coils on Winding Machine

l. Unlock the winding head. Loosen the T handles. Collapse the head or fingers together and remove the sample coil.

m. Lay the sample coil on the stator. Ensure that the coil is the correct width. Check the end room for proper length. The coil should reach from center to center of the slots representing the span.

n. Adjust the winding heads as necessary to get a proper fit. Wind the groups for the motor when the coil fit is correct.

9-10. WINDING GROUPS.

Calculate the stops for each coil in the group. Record the stop numbers on a piece of adhesive-backed tape. Stick the tape near the center of the winding machine. Set the turns per coil into the control on automatic counters with several group stops. For example, the coil stops are 18, 36, and 54 when the group has three coils of 18 turns.

9-11. WINDING THE FIRST COIL.

Use the following procedure for winding the first coil:

a. Position the winding head to the desired start position.

b. Open the head and lock it in the open position.

c. Secure the end of the magnet wire to the head.

d. Set the machine counter to zero. Reset the control on automatic machines and set the manual counter to zero.

e. Wind the proper number of turns for one coil. Be sure that the winding head stops in the same position in which it started. Cross the magnet wire over to the next slot in the head. The wire should enter this slot in the same way that the start wire of the first coil entered the first slot.

NOTE

The magnet wire must pass through the fingers. Stop the machine and discard the group if nicks or breaks in the insulating film can be felt.

9-12. WINDING SUBSEQUENT COILS.

Wind the second coil in the same manner as the first. Always stop the winding head in the same place. Always cross over to the slot in the same place. Continue until the group is finished. Check for nicks or breaks in the insulating film.

9-13. POSTWINDING PROCEDURE.

Use the following procedure after the last coil in the group is wound:

a. Turn off the winding machine.

b. Tie the last coil wound in the middle of the back coil side. Use cotton twine.

c. Cut the magnet wire at the wire guide bar.

d. Pull the cut end of the wire to the group straight out from the back coil side.

e. Loop the end of the wire going to the reels over the guide bar. This will prevent it from falling to the floor.

f. Tie all of the remaining coil sides in the middle. Use cotton twine.

g. Release the starting end of the group from the winding head.

h. Loosen the T handle. Collapse the winding head and remove the group.

i. Lay the group on a clean flat surface or hang it on a coil rack.

NOTE

Do not tape the coil crossovers or group leads to the coils (figure 9-4).

9-14. TAPING COILS.

Use the following procedure to tape coils:

a. Pull the group leads straight from their respective coil sides.

b. Wrap the center of the end turns of each coil with one and one-half turns of adhesive-backed glass tape, 3/4 inch to 1/2 inch wide.

c. Stow the taped coils where they cannot be damaged.

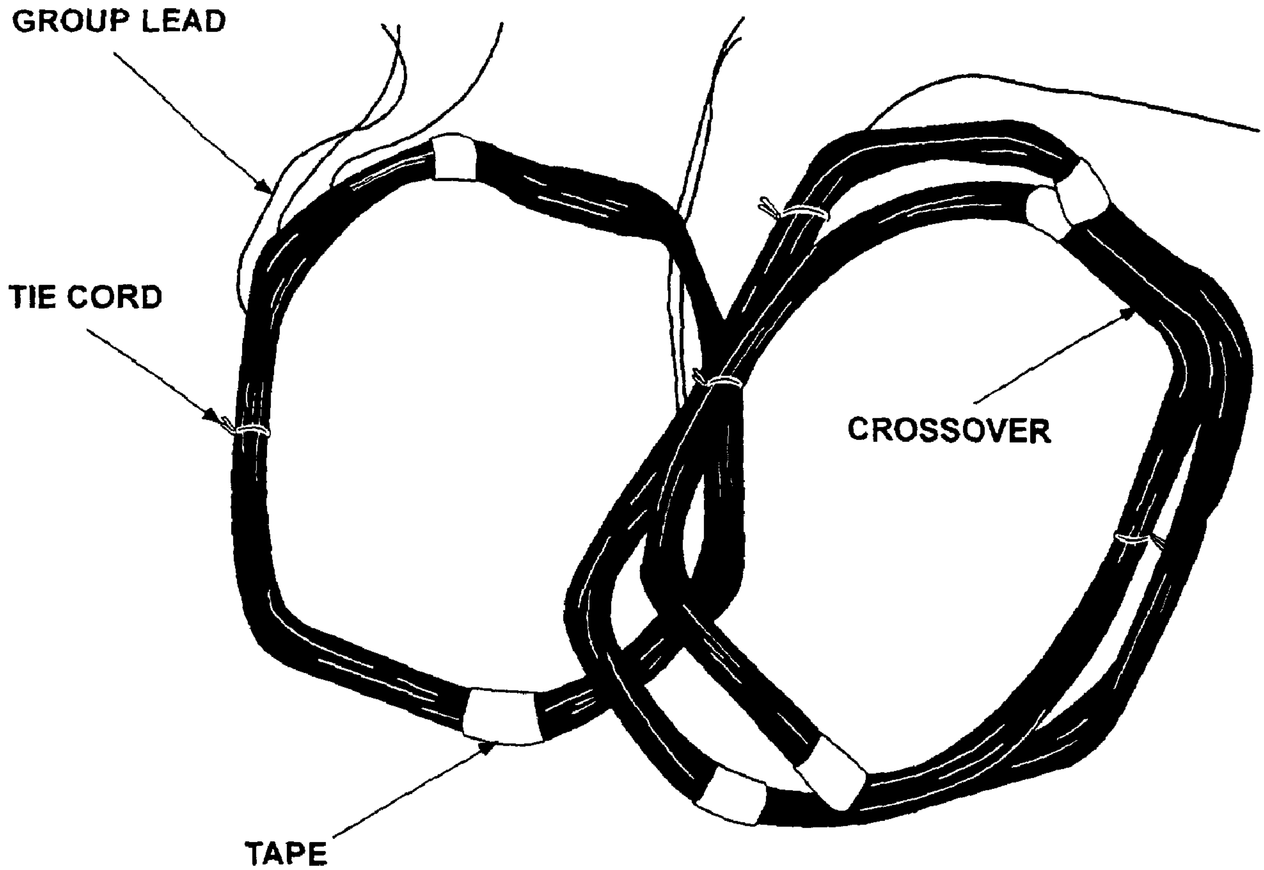


Figure 9-4 Tape Applied to Coils

9-15. INSULATION PREPARATION.

9-16.

Four types of insulation are used in winding. They are:

9-16.1 Slot insulation,

9-16.2 Coil side separators,

9-16.3 Slot wedges, and

9-16.4 Phase insulation.

NOTE

See Appendix F for a list of materials to be used in the preparation of motor insulation.

Commercially available precuffed slot cell insulation reduces the number of man-hours that are required to form the cuffs by hand.

9-17. SLOT INSULATION.

Slot or ground insulation separates the coil sides in the slot from the laminations. It is prepared from two 7-mil (0.007 inch)-thick pieces of polyamide (NOMEX) insulating material. To prepare the insulation:

a. Form enough NOMEX to make one insulator for each slot. Cut strips long enough to be 1-1/2 inches wider than twice the depth of the stator slot. To obtain that measurement, push a sample of the NOMEX into a slot. Mark 3/4-inch extensions above the slot, then measure the distance between the marks. The length of NOMEX needed will be the number of slots multiplied by the measured distance, multiplied by a factor of 1.1.

NOTE

The tear strength of NOMEX insulation is greater in one direction than the other. Cut the slot insulation so the higher tear strength is parallel to the slot. The red line on the NOMEX insulation will be circumferential to the stator bore.

b. Use the insulation forming machine to form a 3/8-inch cuff on each edge of the strip of NOMEX (figure 9-5).

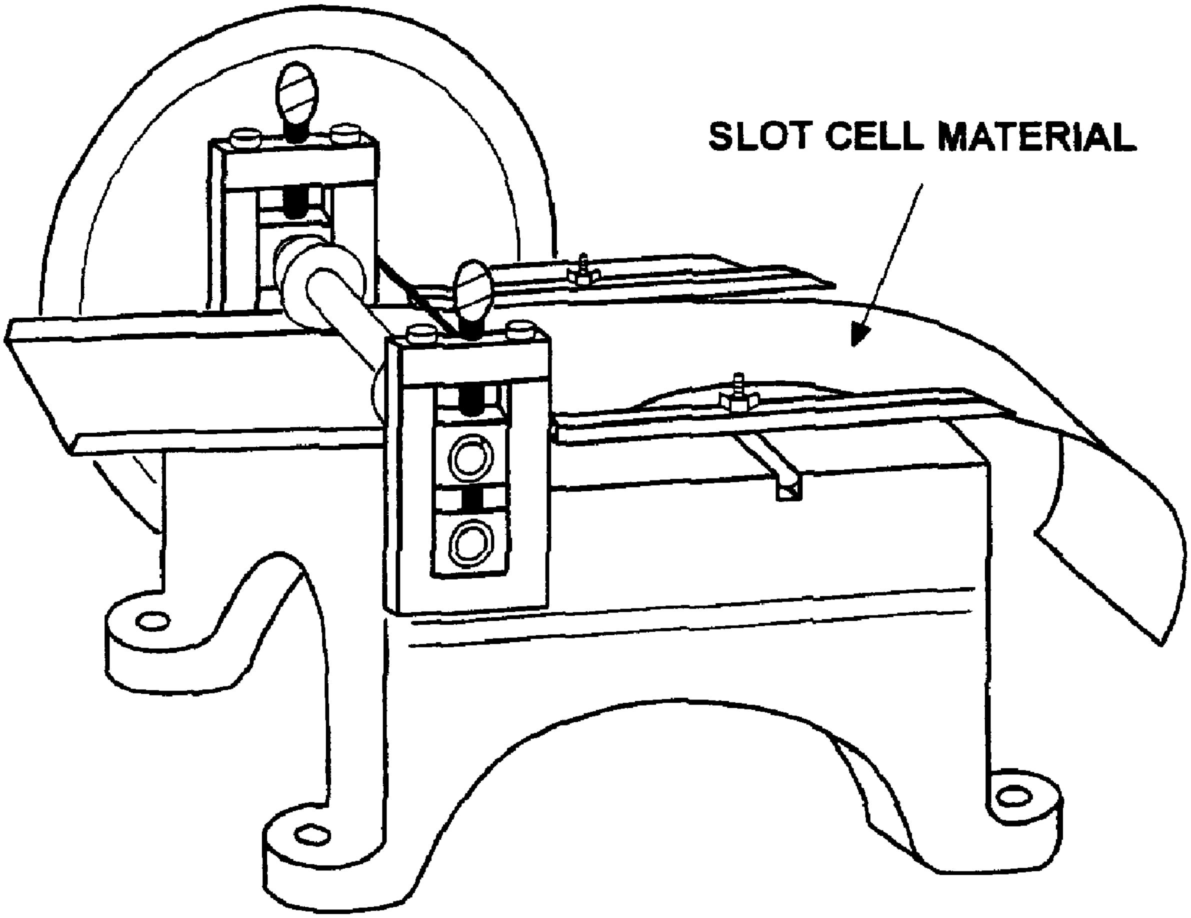


Figure 9-5 Cuffing of Slot Cell Material

NOTE

The distance between the creasing wheels on the machine is equal to the slot length plus 3/4 inch.

c. Cut the formed material into strips. Each strip should be wide enough to project 1/2 to 3/4 inch out of the stator bore when inserted into the slot. They should be closely fitted to the bottom and the sides (figure 9-6).

NOTE

To protect the windings during insertion, the slot liners should extend 3/4-inch above the slot (figure 9-6) or feeder paper (figure 9-7) should be used.

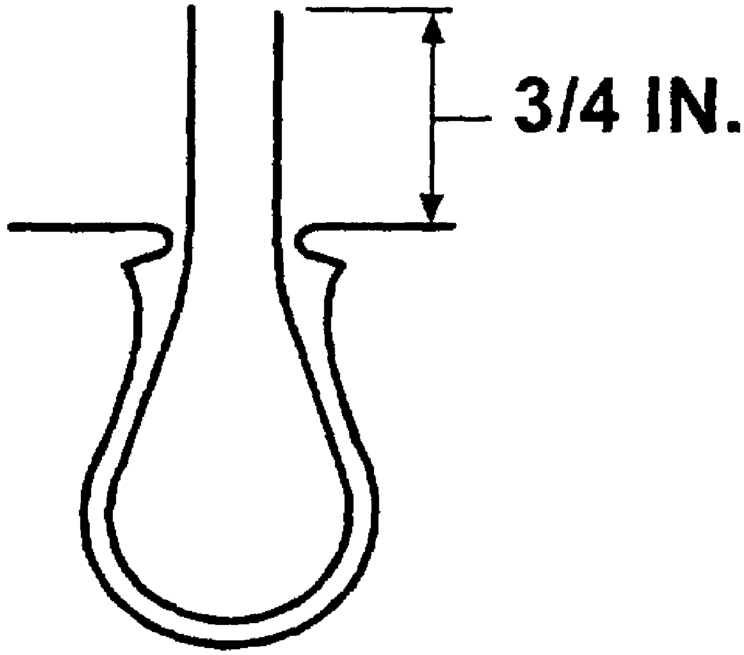


Figure 9-6 Method of Fitting Slot Insulation

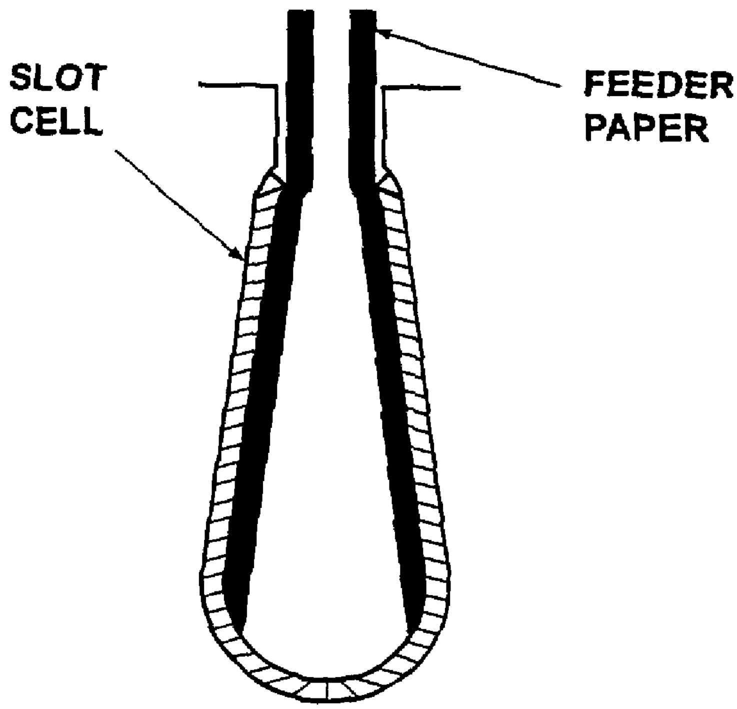


Figure 9-7 Slot Cell Width Precut with Feeder Paper

d. Cut the second piece of slot insulation in the same manner as the first. This piece of insulation should be 3/4 inch narrower than the width of the cuffed pieces (figure 9-8).

e. Fold the cuffs over the formed pieces of NOMEX (figure 9-9).

f. Insert the uncuffed piece of insulation between the cuffs (figure 9-10).

g. Prepare one slot insulator for each slot. Put them aside.

9-18. COIL SEPARATORS.

Coil separators are placed on top of coil sides as they are laid in the slots. This prevents the two coil sides in the same slot from touching. To lock in the phase paper, separators are cut 1/2 inch longer than the slot insulation. Separators may be flat silicon glass or formed NOMEX. The separator length is the length of the slot plus 1-1/2 inches. Prepare a coil side separator for each slot in a winding.

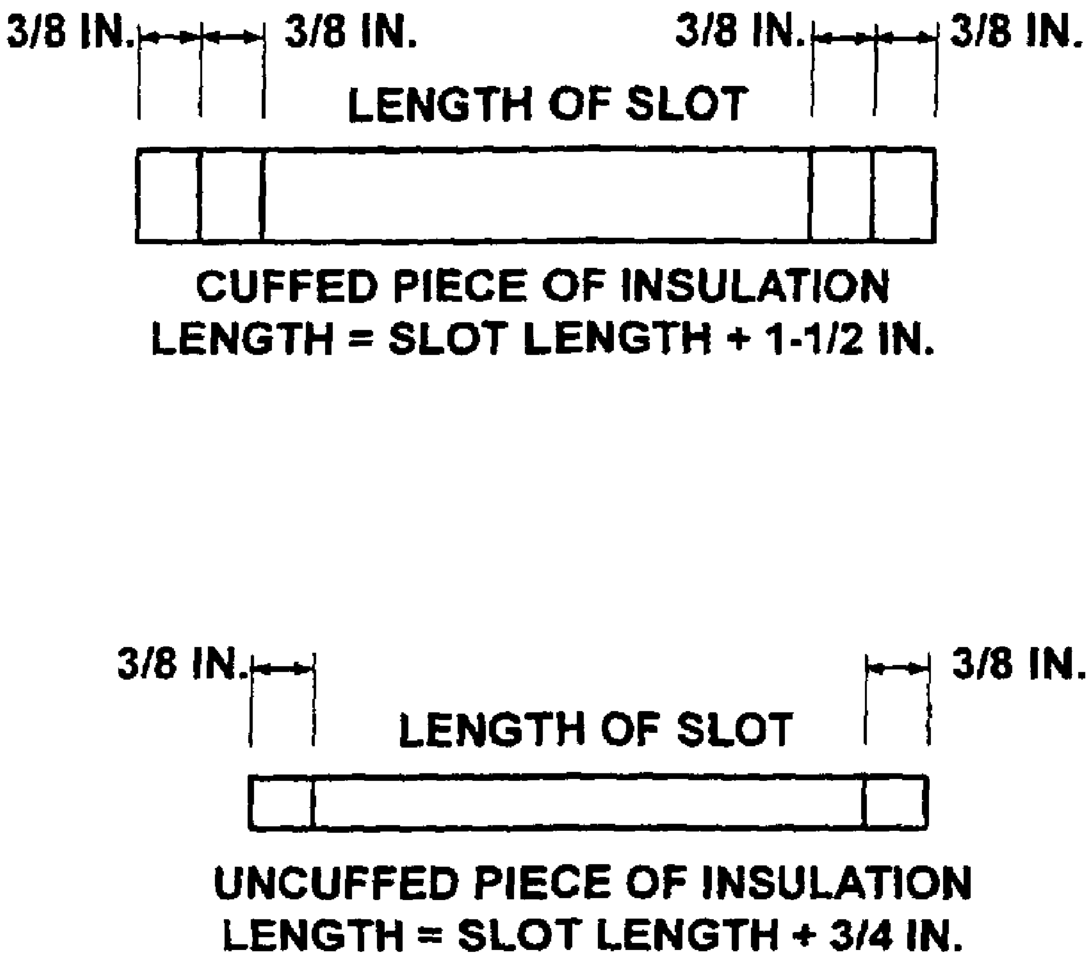


Figure 9-8 Lengths of Slot Insulator Pieces

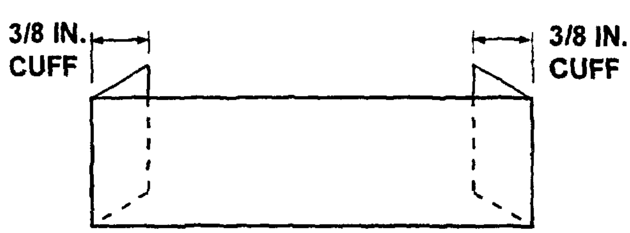


Figure 9-9 Folding Slot Insulation Cuffs

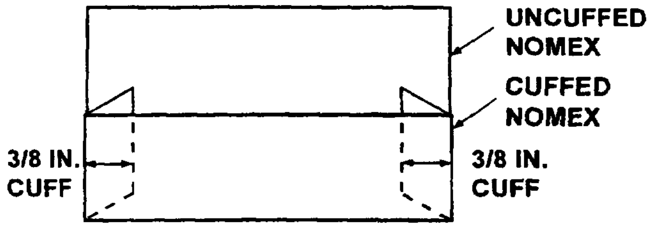


Figure 9-10 Fitting the Pieces of a Slot Insulator

CAUTION

Do not use silicone glass laminate or varnished glass-fiber cloth in a totally enclosed motor-generator set if one machine is direct current with carbon brushes. This arrangement causes excessive carbon brush wear.

9-19. WEDGES.

Wedges are used to close the slots. They should be cut from a silicon glass sheet when the insulation is prepared as shown in figure 9-11. Formed NOMEX may also be used as wedges.

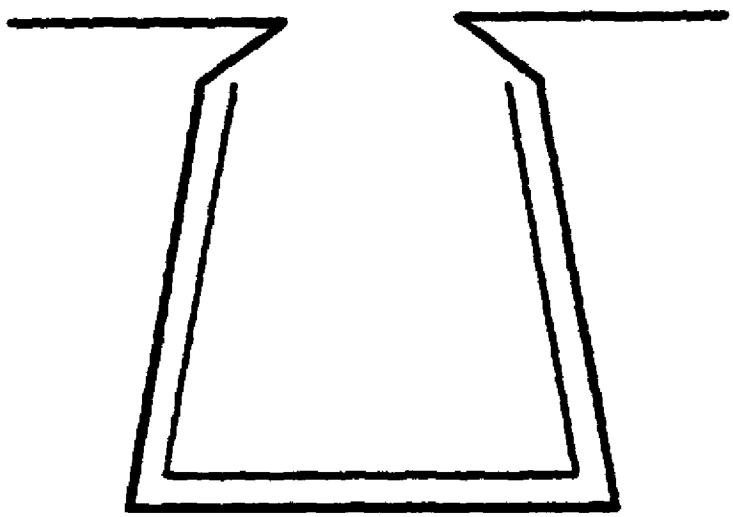


Figure 9-11 Slot Insulation Fitting for Feeder Paper

9-20. PHASE INSULATION.

Phase insulation (phase papers) prevents the ends of coils in different pole phase groups from touching. Phase insulation is prepared from NOMEX or varnished glass fiber cloth with a thickness not less than 0.007 inch. Phase insulation must butt against the ground insulation. It must be wide enough to completely separate the coils of adjacent groups. The phase insulation is prepared as a triangle. It is trimmed after it is in place. It is locked in place by coil side separators.

9-21. WINDING THE STATOR.

9-22.

Inspect the stator for lumps of varnish, sharp edges on the laminations, sprung laminations, and cleanliness. Correct any condition which may affect the winding before laying in the coils.

9-23. TOOL ASSEMBLY.

Assemble all tools necessary for winding the stator. These include scissors, wedge drivers (for flat wedges), tamping tools, wire cutters, heat sinks, coil forming tongs, and a slot insulation trimmer (figure 9-12).

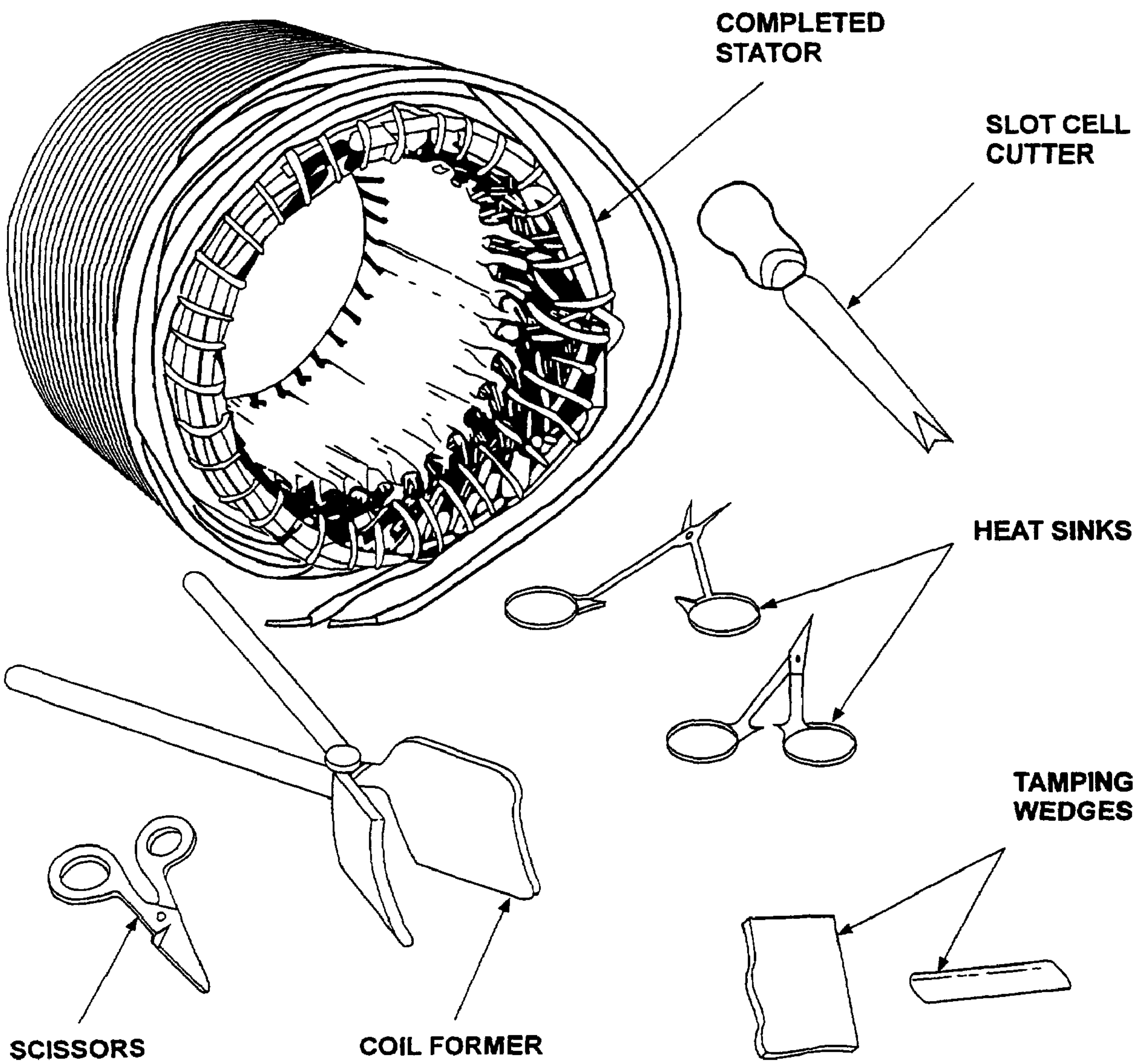


Figure 9-12 Completed Stator with Tools Used

9-24. COIL INSTALLATION.

Use the following procedure to install the coils:

a. Mount the stator in a stator holder (figure 9-13) or place it on a flat surface and carefully wedge it securely in place.

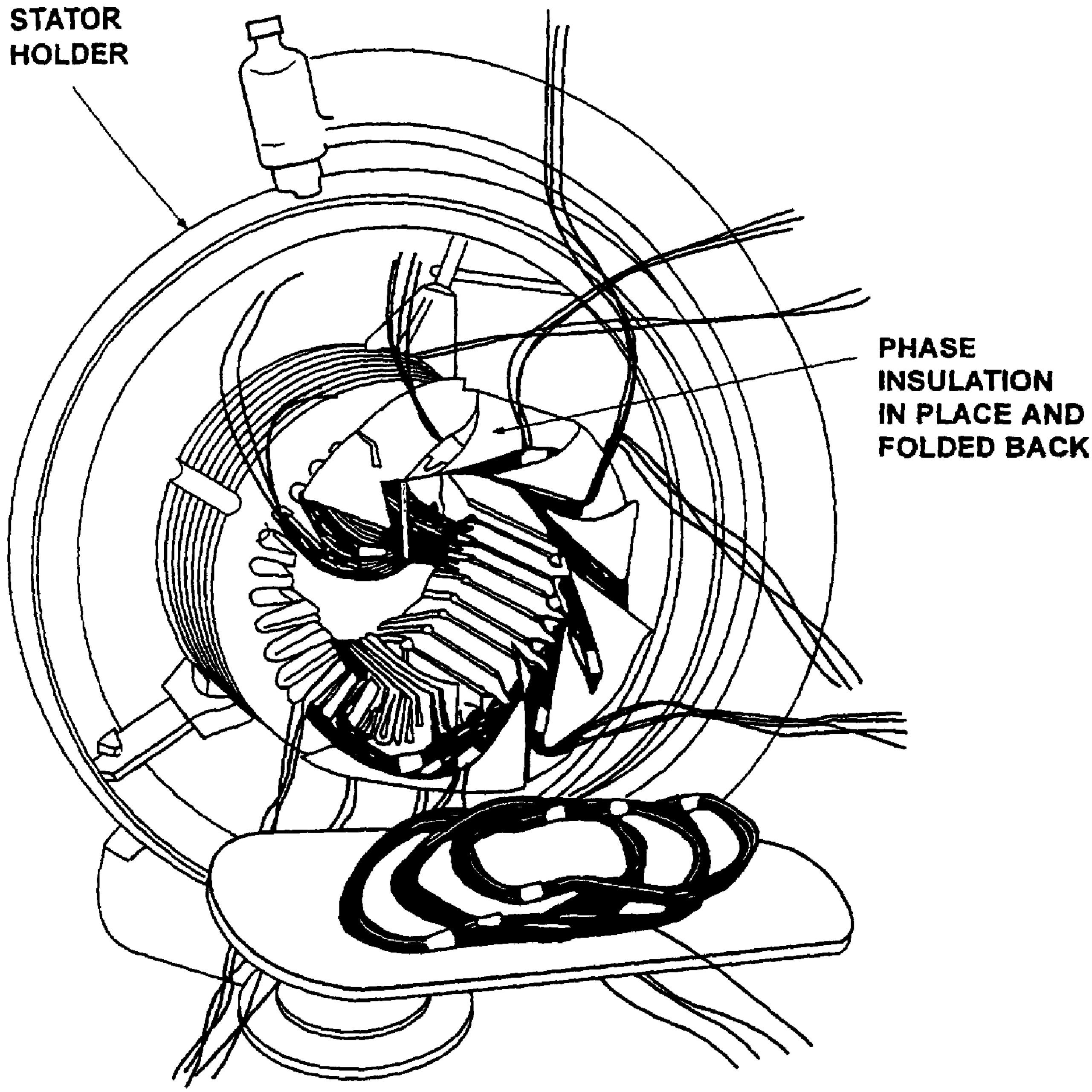


Figure 9-13 Partially Completed Stator in Stator Holder

WARNING

NOMEX insulation has a very sharp edge and can easily cut an operator's hands.

b. Lay in slot insulation in a sufficient number of slots to span the width of one coil. Set in the first coil in the first insulated slot. Then add slot insulation in each successive slot just prior to inserting the corresponding coil. It is better to lay in the slot insulation progressively, rather than putting it all in place at one time, because the projecting edges interfere with the worker's hands.

c. Check each slot insulator. Be sure that the cuffs lock the insulation securely in place and prevent it from moving during winding.

d. The slot insulation should project 1/2 to 3/4 inch into the bore if prepared as shown in figure 9-6.

e. Slot insulation, prepared as shown in figure 9-11, will require feeder paper the same length as the slot insulation. It should also be wide enough to reach from the bottom of the slot and project 3/4 inch into the bore. The feeder paper will protect the magnet wire from chafing against the laminations as it is fed into the slot (figure 9-7).

f. A piece of NOMEX should be cut about 2 inches wider than the length of the stator core. It should be long enough to fit halfway around the inner periphery of the stator core. It should be used to ensure that the stator iron will not damage the magnet wire insulation of the first few coils installed.

g. Lay one group adjacent to the connection side of the stator with the group leads and the crossovers pointing toward the stator.

h. Pick up the top coil of the group by the end which is away from the stator. Remove the tie cord on the first side to be laid into the slot.

i. Reach through the stator with one hand from the side opposite the connection side. Take the end of the coil furthest from the stator with that hand. Hold the end closest to the stator with the other hand. Pull the coil through the bore. The group lead and crossover should still be on the connection side of the stator.

j. Spread the conductors at the bottom of one straight section of the coil with gentle manual pressure. Feed the conductors between the extensions of the ground insulation which protrude into the stator bore. Slide the coil into the slot (figure 9-14).

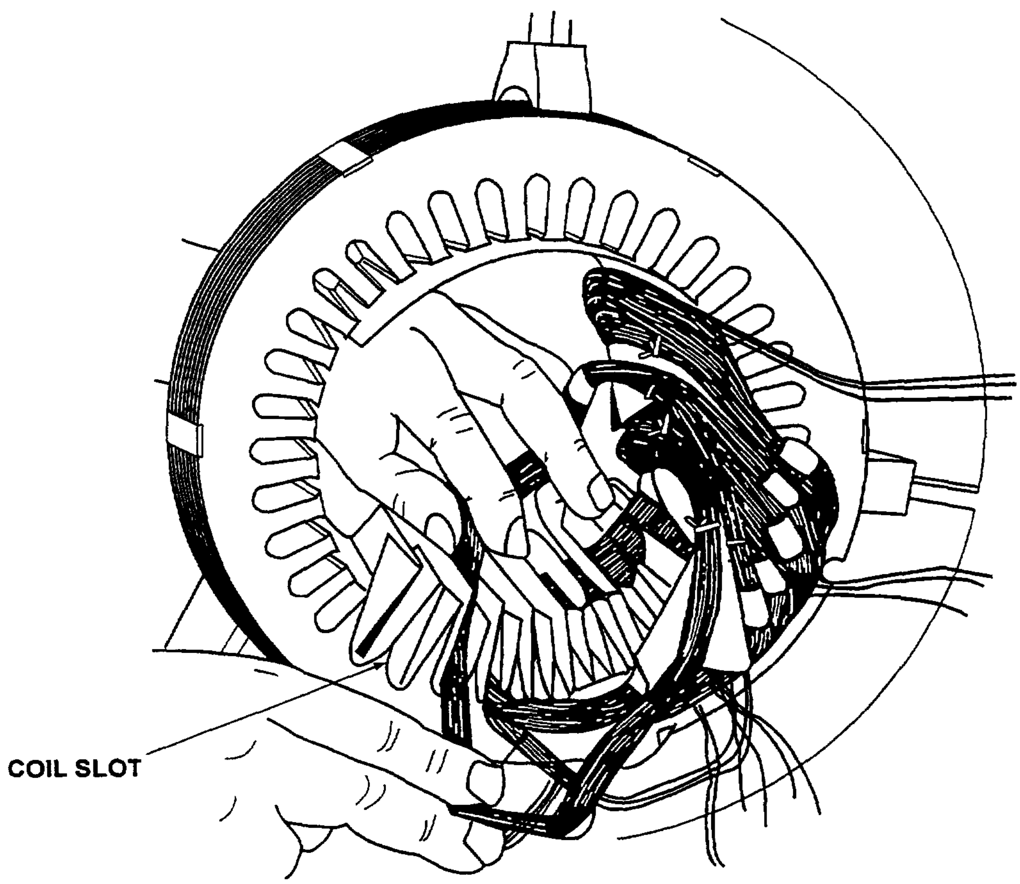


Figure 9-14 Placing of Coil Sides from Slot Edges

k. Ensure that the conductors are resting in an orderly manner in the slot. Ensure that the conductors are not crossing or crowding. When one side of the first coil span is in its proper slot, the other sides of these coils will be loose in the stator bore. They will be on top of the piece of ground insulation mentioned in the paragraph above (figure 9-15).

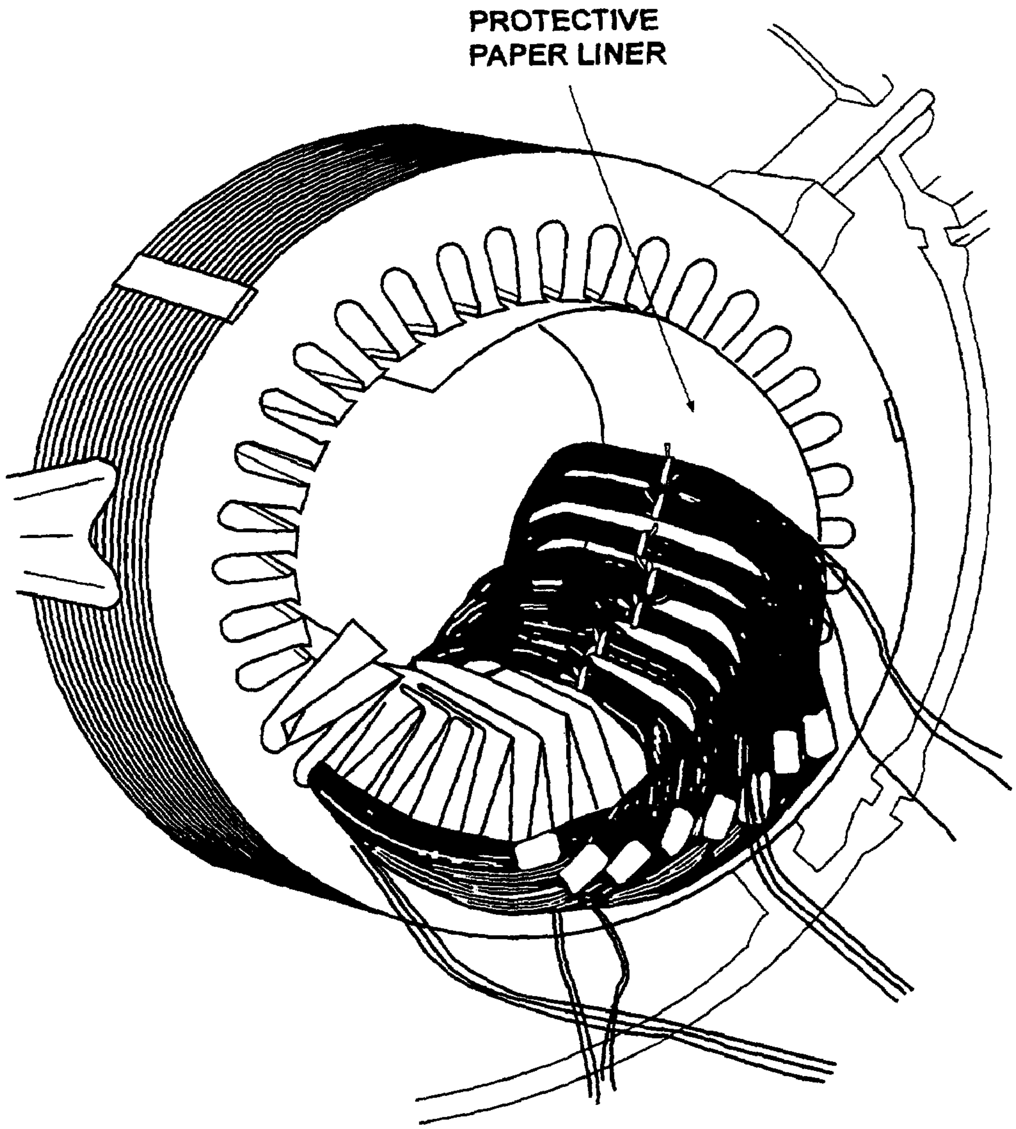


Figure 9-15 Protection of Coil Sides from Slot Edges

l. Insert a coil separator on top of the coil section in the slot. The ends of the separators should extend 1/4 inch out of each end. Continue laying in one coil side of each coil until a coil span is laid in.

m. The next coil can then be completely laid in. One half of the coil goes in the bottom half of the next empty slot. The other half goes in the top half of the slot with the coil separator. Ensure that the coil separator completely separates the conductors of one coil from those of the other coils in the slot.

n. Check the insulation of the filled slot.

9-25. PREPARATION OF SLOT FOR CLOSING.

Use the following procedure to prepare the slot for closing:

a. From each end of the winding, place two temporary wedges in the slot. The wedges should meet in the middle of the slot. This protects the coil from the insulation trimmer. The temporary wedges also hold the insulation against the sides of the slot (figure 9-16).

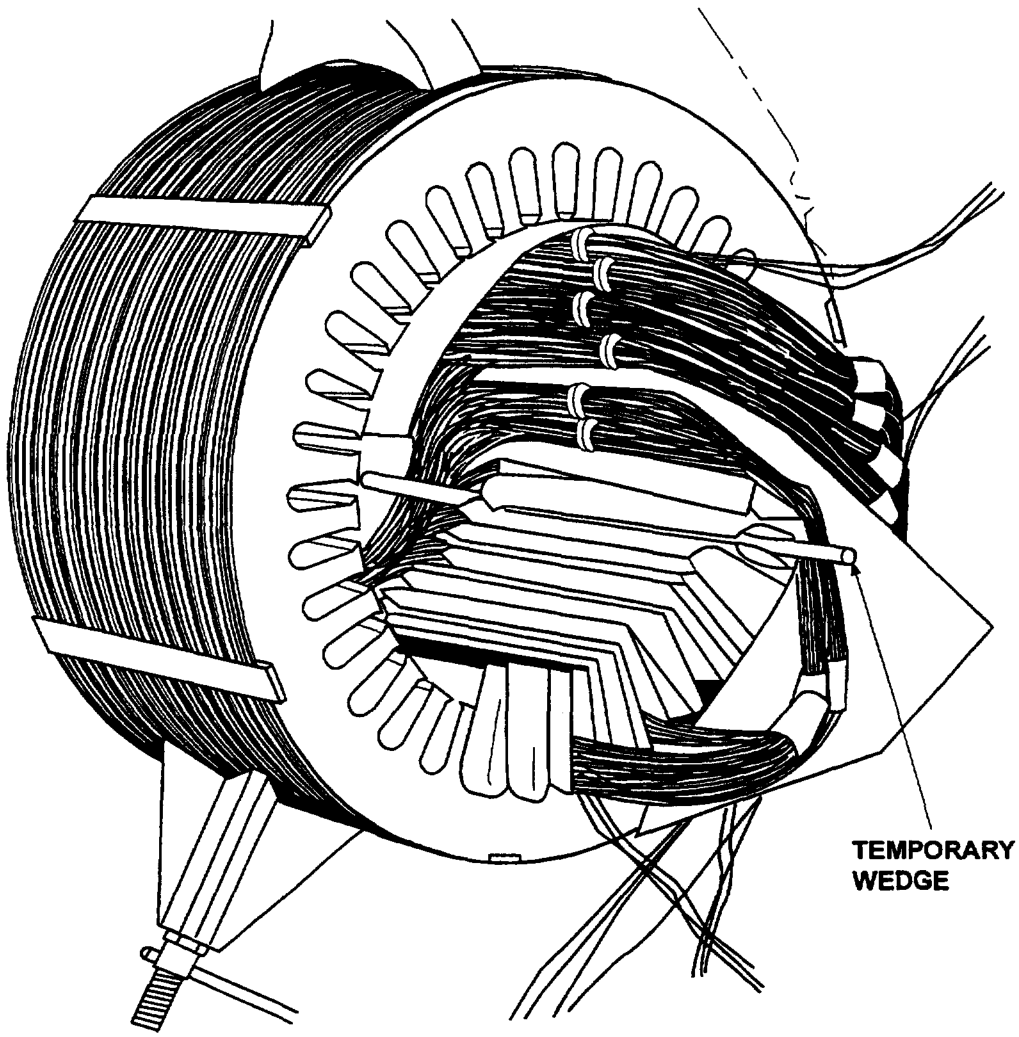


Figure 9-16 Temporary Wedge Holding Down Coil Sides

b. Cut that portion of the slot insulator projecting into the bore flush with the stator iron (figure 9-17). Use a slot cell cutter (figure 9-12).

c. Remove the temporary wedges.

d. When a flat wedge is used to close a slot, one side of the remaining ground insulation should be carefully folded into the slot on top of the coil conductors. The other side of the ground insulation should be folded over the first in a similar manner, providing a lap joint. Insert a wedge on top of lap-folded ground insulation. This will hold the material in place as shown in figure 9-18.

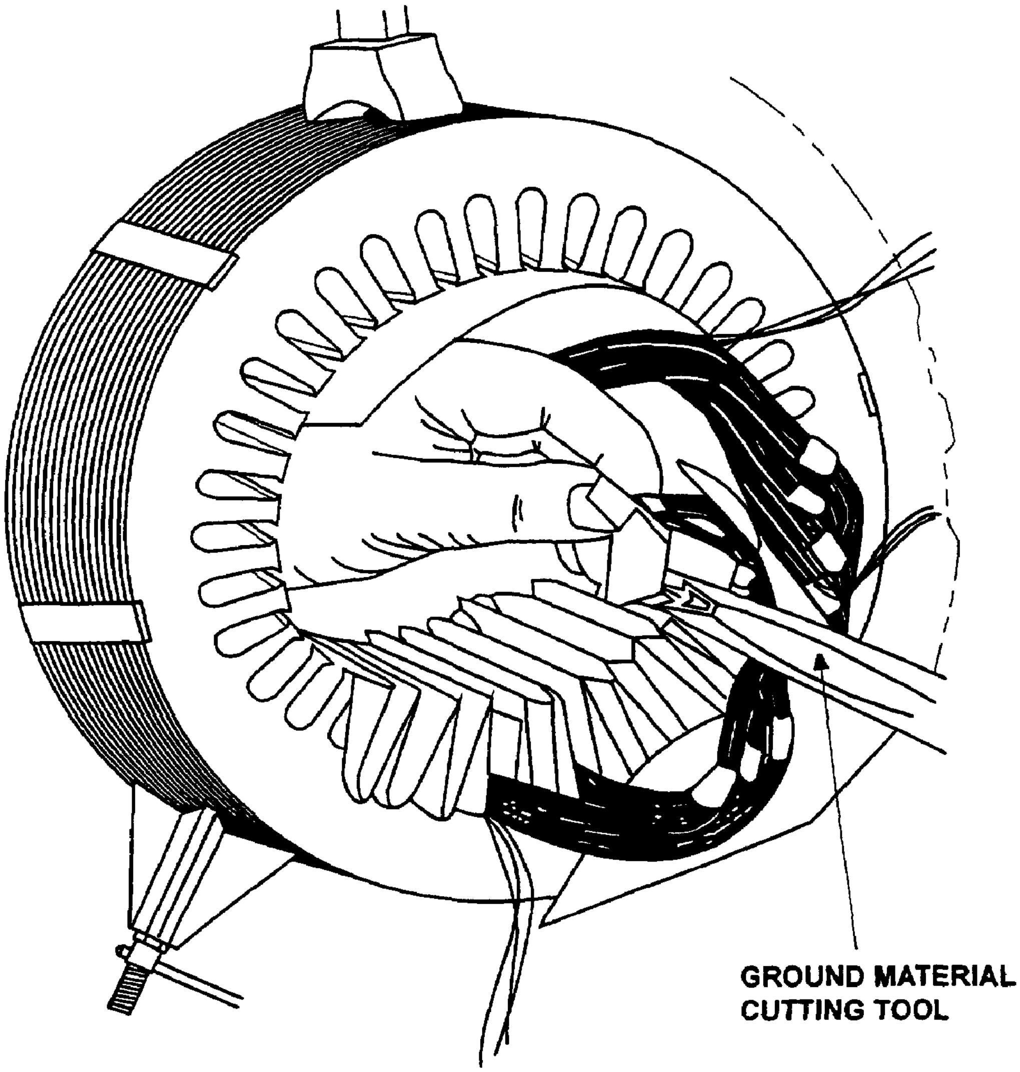


Figure 9-17 Cutting of Slot Cell Material

e. To ensure that leads to the same group can be identified, loosely twist the group ends together after all the coils of a group are laid in the slots. Keep the leads pulled back out of the bore.

NOTE

To lay in the last coils, it is necessary to remove the piece of NOMEX used to protect the first span.

f. Continue this procedure until all slots have one coil in the bottom of the slot. The top coils of the first span will not be in the tops of their slots. These coil sides may now be laid in their slots. The slots may be closed as described in step a through d above.

CAUTION

Do not allow the scissors to cut or abrade the magnet wire insulation.

g. Phase insulation should now be placed between the groups of coils, as shown in figure 9-19, if insulation was not installed as groups were laid in. The phase insulation should be butted against the slot insulation and it should lap either over or under the ends of the coil separator. Trim the excess phase insulation to within 1/8 inch of the coil ends using scissors (figure 9-20).

CAUTION

Be careful not to damage the slot cell material, wedges, or magnet wire insulation when bending the coils.

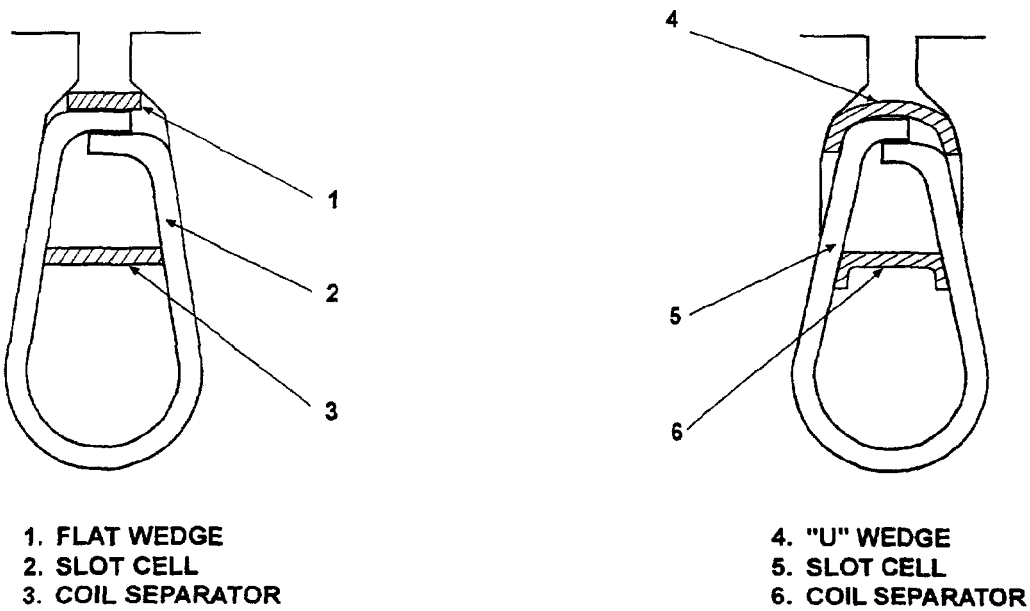


Figure 9-18 Closing Slots

h. Bend the coils 1/4 inch back from the lines of the stator bore. Use a coil-forming tong (figure 9-12).

9-26. MAKING AND TESTING CONNECTIONS.

9-27. MAKING TEMPORARY CONNECTIONS.

Use the following procedure to make temporary connections:

NOTE

If there is any doubt about which group a lead or set of leads belongs, use a continuity tester to check.

a. Pull the group leads straight out from the bore. Select any pair of leads that are twisted together. Mark both of these leads as a group with adhesive labels. Continue marking each set of leads around the stator until all leads are marked. All labels must be removed before dipping the stator.

b. Strip approximately 1 inch of film from the magnet wire of each group lead.

c. Connect the groups to form the winding indicated on the motor drawing. Use twist connections at the stripped portion of the wire. The numbered labels on the leads are used to identify groups, for connections.

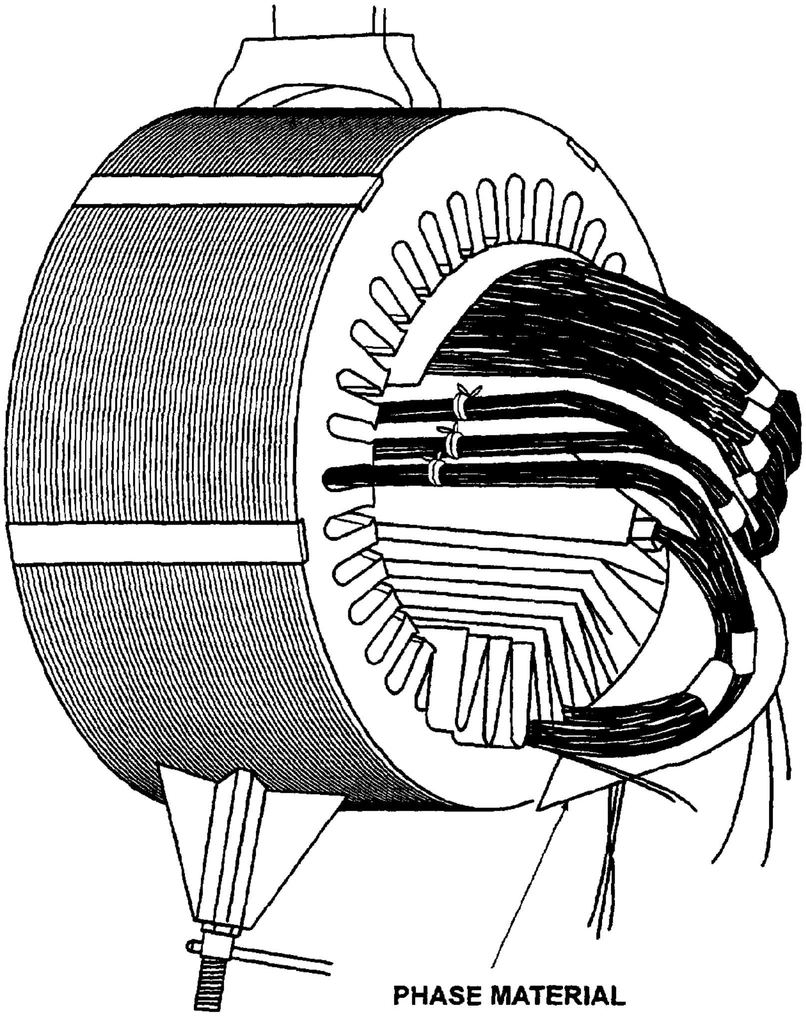


Figure 9-19 Placement of Phase Material

NOTE

This is a temporary connection used for testing the winding.

9-28. TESTING THE TEMPORARY WINDING CONNECTION.

Use the following procedure to test the temporary windings:

a. Test the winding for grounds, using a General Radio 1644A or 1863, or equivalent megohmmeter (paragraph 2-4 and paragraph 2-8).

b. Perform a phase balance test on the winding. Use a low-reading digital ohmmeter (Valhalla or equivalent). Refer to paragraph 2-15 for information on how to use the instrument.

c. Perform a surge comparison test on the winding. Use a Baker ST112E surge comparison tester (paragraph 2-19).

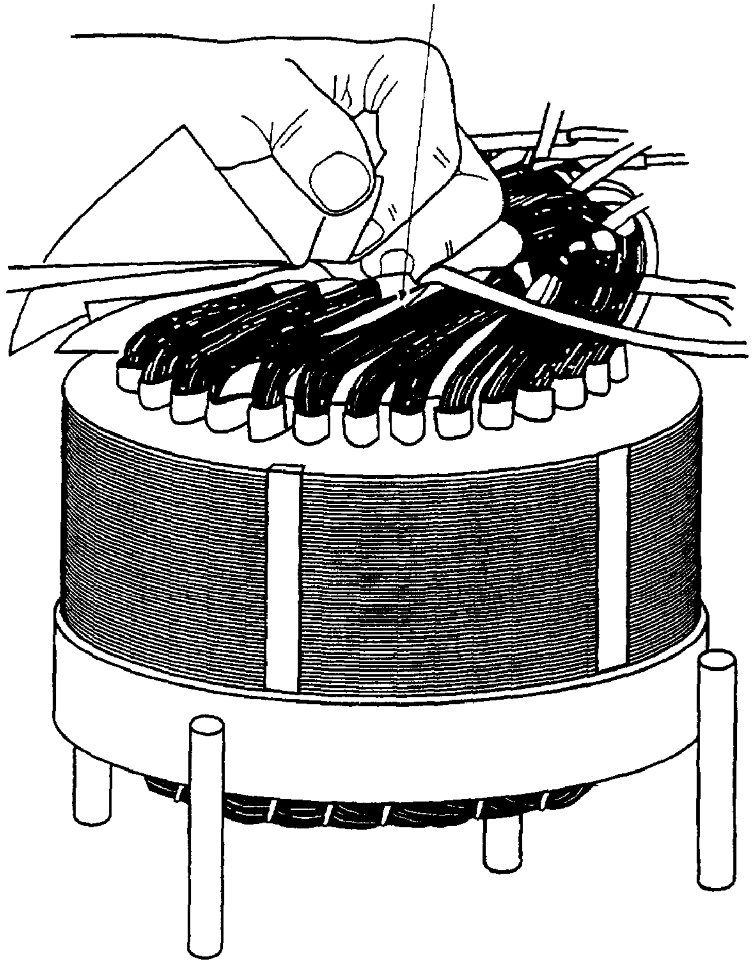


Figure 9-20 Trimming of Phase Material

d. Perform a dc high-potential test. Use a Baker ST112E surge comparison tester/high-potential tester (paragraph 2-23).

e. Correct any problems indicated by these tests before making the permanent connections.

9-29. PERMANENT GROUP CONNECTIONS.

Use the following procedure to make permanent connections:

a. Cut one of the temporary connections.

b. Dress the group leads in this connection around the end of the winding. Determine the point at which the connection will be made on the winding. Carefully dress the group and line leads around the winding end. All connections must be long enough to be laced to end turns of the winding without excess length.

c. Mark the group lead at the point of connection. Cut the lead at least 1 inch beyond this point to allow for making the connection.

d. Remove all tape or markers from the magnet wire.

e. Select a small sleeving which will fit snugly over the group lead. Cut two pieces of sleeving long enough to prevent the lead from touching any coils it will cross going to the connection.

f. Select a sleeving large enough to slip over the small sleeving and the soldered connection. Cut a piece of this sleeving long enough to project approximately 1 inch on either side of the connection.

g. Slip the piece of large sleeving over the small sleeving.

h. Strip approximately 1 inch of insulating film from the magnet wire of the group leads.

i. Twist the group leads tightly together. Pliers may be used to twist the leads to ensure a tight connection. A Western Union splice is preferred.

j. Cut the remaining temporary connections one at a time. Make up the remaining connections in the manner described above.

9-30. SOLDERING CONNECTIONS.

Use the following procedure to solder connections:

a. Pull the connections away from the winding so that solder will not fall into the winding. Slide a small piece of insulation paper between the winding and the connection to be soldered.

b. Attach heat sinks to either end of the connection to be soldered. This will protect the magnet wire film from the heat of the iron (figure 9-21).

c. Apply the soldering iron to the bottom side of the connection. Allow the heat to rise from the iron through the wire.

d. Touch the solder to the top of the connection. Allow the solder to touch only the wire and then flow down through the connection. Use only SN-10 solder, QQ-S-571, with rosin flux.

e. Solder all connections. Lay the soldered connections tightly against the group leads.

f. Slide the large sleeving over the soldered connection and small sleeving. Center the large sleeve over the connection.

NOTE

The lead lines can be given added strength by going the long way around the crown of the winding to the connection box with the line leads.

9-31. CONNECTING LEAD WIRES.

Cut lengths of lead wire long enough to reach the connection of the connection box. The wire should go the long way from the group lead connection to the connection box (figure 9-21 and figure 9-22). Allow for at least 10 inches of lead wire in the connection box.

a. Make the connections to the group lead wires in the same manner as group connections.

b. Solder the connections and cover with lengths of large sleeving material (figure 9-23).

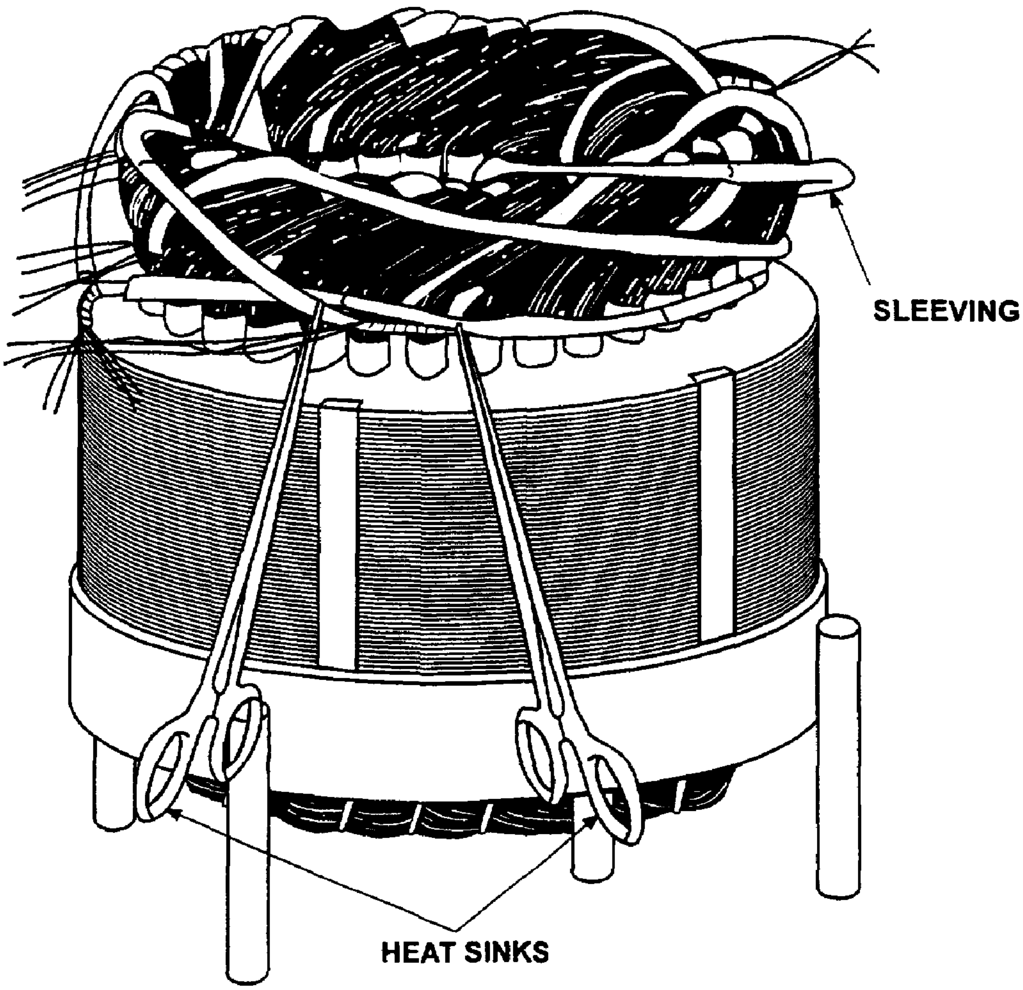


Figure 9-21 Heat Sinks in Place and Placement of Sleeving

9-32. LACING WINDING END TURNS.

Carefully inspect the windings and insulation before lacing the winding end turns. Ensure that the coil side separators and slot wedges are in place and extending uniformly from each slot. The phase insulation should be in place and lapping the ends of the coil side separators. Inspect for foreign particles or small scraps of material caught in the windings. Use Appendix C as a guide for inspecting the windings.

a. Cut 6 to 8 feet of approved lacing material. See Appendix F.

NOTE

Lacing may start at any point when lacing the end with no connections.

b. Insert the end of the lacing through the space between the coils next to the stator iron. Pull up and repeat for two turns. Pull tightly and tie with a square knot, leaving enough bitter end on the short side to secure the finishing end of the lacing (figure 9-22).

c. Insert the end of the lacing through the space next to the stator iron for the next two coils. Pull the excess lacing through. Hold the standing part of the lacing. Twist an eye and pass the loose end of the lacing through the eye. Pull it up tight to form a rolling hitch. This will keep slack out of the completed lacing. Continue lacing along the crown of the windings. Proceed as follows if the round turn is to be used to lace: Start lacing as per step b. Insert the bitter end of the lacing through the space between the coils. Continue until all spaces are laced. Go back and tighten, shape, and form the wires, winding until the entire end is secure.

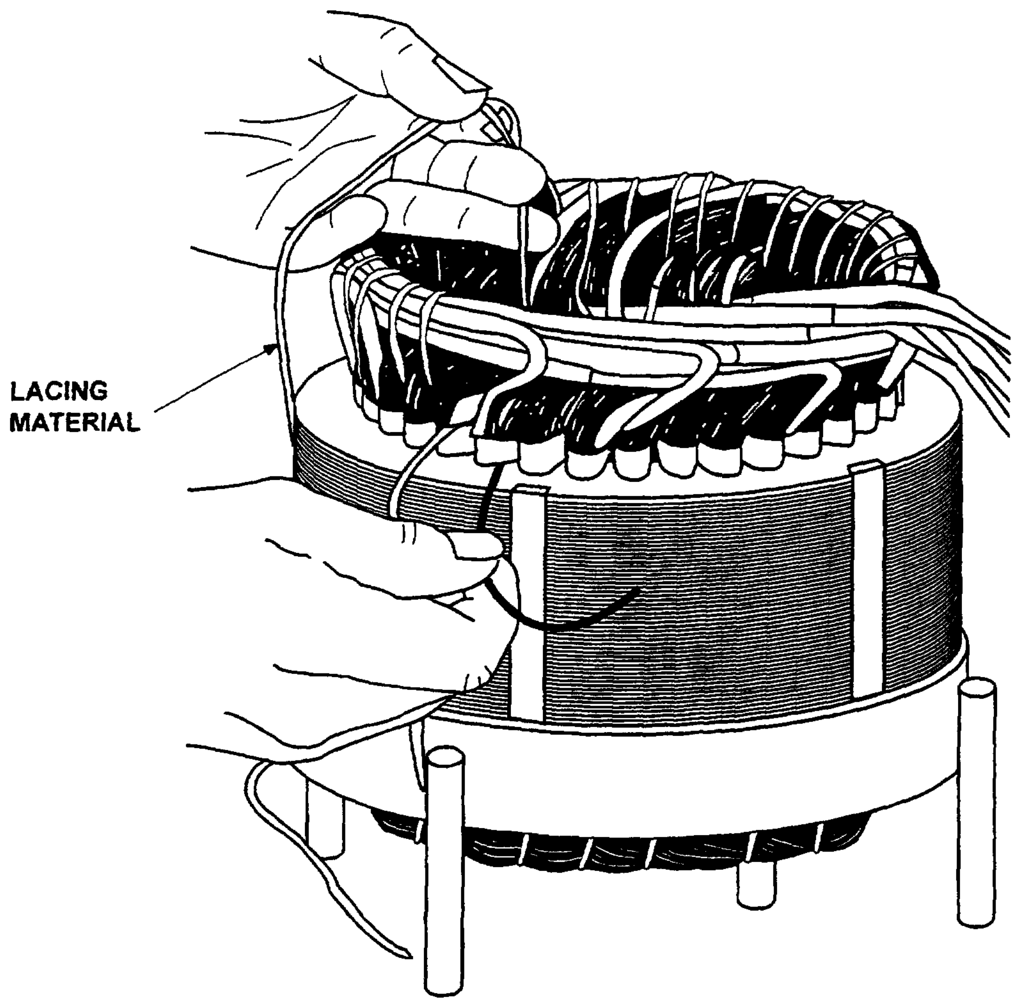


Figure 9-22 Lacing of End Turns and Coil Connections

NOTE

Ensure the windings are tight to avoid any vibrations between the end turns that could result in early failure.

d. End the lacing by securing the bitter end to the end of the short piece on the beginning knot Pull tight and secure with a square knot.

e. Start at a lead wire when lacing the connection end of the winding. Neatly form the lead wires and wye point connecting jumper along the crown of the winding as lacing proceeds.

f. Apply several turns on top of one another at the point adjacent to the connection box. This will provide additional strength.

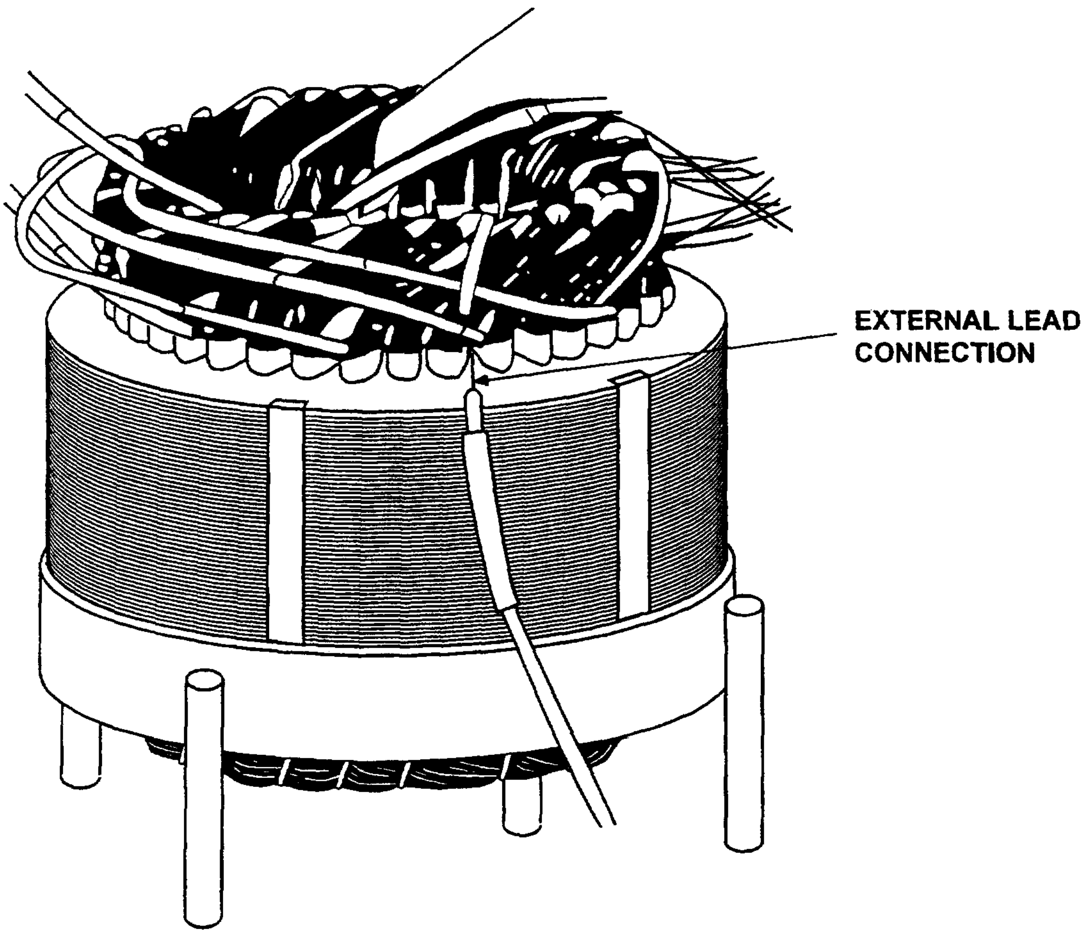


Figure 9-23 External Connection Prior to Soldering

CAUTION

The winding must not touch the end bell at any point or the motor will burn out.

9-33. FORMING ENDS OF WINDINGS.

Use forming tongs to bend the laced coil ends clear of the stator bore. Place the end bell on the stator to check the clearance of the winding.

9-34. POSTWINDING PROCEDURES.

9-35. ELECTRICAL TESTS.

Perform the following tests (refer to Chapter 2 for information on the test equipment and test procedures):

9-35.1 Measure the insulation resistance (paragraph 2-4 or paragraph 2-8) with a megohm bridge or equivalent. A rewound motor should have a minimum resistance of 200 megohms.

9-35.2 Measure the winding phase resistance with a digital ohmmeter (paragraph 2-15). Winding phase resistance readings should be within 5 percent of each other.

9-35.3 Perform a surge comparison test (paragraph 2-19) on the windings. Use a Baker surge comparison tester or equivalent. There should be no disparity of patterns displayed and the full calculated voltage should be applied.

9-35.4 Perform a dc high-potential test (paragraph 2-23) on the windings. Plot the voltage and current on graph paper and the shape of the resultant curve is used for checking the cleanliness of the winding, the moisture content of the winding tested, and the dielectric strength of the winding.

9-36. VISUAL INSPECTION.

Make a visual inspection using the checklist in Appendix C. Correct any deficiencies.

9-37. ANNEALING.

The stator should now be put in an oven at 302° F (150° C) for 4 hours. This will anneal the magnet wire and ensure that all moisture is removed from the insulating materials before varnishing.

9-38. REWINDING MOTORS WITH A SEALED INSULATION SYSTEM (SIS).

9-38.1 Motors with a sealed insulation system that require rewind should be rewound with a sealed insulation system by a facility certified by NAVSEA. If motor rewind using a sealed insulation system will result in significant impact on the ship's schedule, the motor may be rewound with a Class F nonsealed insulation system, provided formal concurrence is obtained from the cognizant planning yard or design agent. However, the information plate identifying the motor as having sealed insulation must remain on the motor.

9-38.2 Since sealed insulation provides greater reliability, the motor should eventually be rewound with sealed insulation at the discretion of the Type Commander. Fire pump and air conditioning plant compressor motors originally provided with sealed insulation that have been rewound with nonsealed insulation should be rewound at the earliest opportunity with a sealed insulation system. Motors originally provided with sealed insulation that fail after rewind with nonsealed insulation should be rewound at the earliest opportunity with a sealed insulation system. The insulation system originally provided in the motor can be determined by review of the motor drawing in the auxiliary equipment technical manual. Another means of identification is the information plate located on sealed insulated motors that indicates that the motor was previously wound with sealed insulation.

9-38.3 Sealed insulation isolates motor windings from high humidity, salt-laden atmospheres, and/or water exposure. Certified repair facilities take great care to ensure that the motor winding's sealed insulation is free of cracks or other damage; Each sealed insulated stator must pass a 24-hour submergence test prior to delivery to the ship. Care must be taken when handling these motors to prevent damaging the insulation and negating the advantages of this higher cost insulation system.

9-38.3.1 Do not pull on the motor leads when making electrical connections. Prior to rigging, ensure the motor leads are inside the terminal box.

9-38.3.2 When rigging a sealed insulation motor, handle with care. Use eyebolts and lifting eyes where available. Do not allow the motor to be dropped or exposed to other high impacts during rigging and installation.

CHAPTER 10

VARNISHING

10-1. SCOPE.

This chapter includes information on the use of varnish and procedures for varnishing new and reconditioned windings by dipping. Topics include:

10-1.1 Characteristics of varnish (paragraph 10-2).

10-1.2 Terminology used with varnish (paragraph 10-3).

10-1.3 Varnish selection criteria (paragraph 10-4).

10-1.4 Functional considerations of varnish (paragraph 10-5).

10-1.5 Construction of a varnish tank (paragraph 10-8).

10-1.6 Varnish testing (paragraph 10-19).

10-1.7 Thinning and storing varnish (paragraph 10-20).

10-1.8 Varnishing reconditioned windings (paragraph 10-23).

10-1.9 Varnishing new windings (paragraph 10-27).

10-2. CHARACTERISTICS OF VARNISH.

10-2.1 Solvent-Containing Varnish. All varnishes of this type that are received from stock for general use should be Class 155. Stock numbers for Class 155 varnish and its thinners are listed in Appendix F. Red-pigmented, alkyd-resin varnishes must not be used on bindings or coils for electrical equipment.

10-2.2 Solventless Varnish. Solventless dip varnish must be used when environmental regulations prohibit the use of solvent-containing varnishes. NAVSEA is the point of contact for information on acceptable solventless varnishes.

NOTE

Solventless varnishes Isolite 862M and Esterlite 605 are approved for use by all IMAs. Follow the manufacturer's instructions for use.

10-2.2.1 Shipboard repair activities are required to use solventless dip varnishes. Their high flash point, greater than 200° F (93° C) eliminates the fire hazard posed by solvent-containing varnishes. Solventless varnish should also be used by repair activities required to meet environmental regulations limiting the emission of volatile organic compounds (VOCs) into the atmosphere. Some solventless varnishes are not suitable for use with submarine equipment because the cured varnish emits excessive levels of undesirable chemical compounds into the atmosphere. Testing done under the auspices of the Submarine Materials Control Program has identified solventless varnishes that are suitable for use with submarine equipment. Consult NAVSEA S9086-KC-STM-010/CH 300 for the submarine-approved solventless dip varnishes. Equipment for use on surface ships may be varnished using any solventless varnish determined by the cognizant Naval Supervising Activity to be acceptable in accordance with NAVSEA S9086-KC-STM-010/CH 300.

10-2.2.2 This type of varnish typically has a greater bond strength than solvent-containing varnish; however, varnish build is often less than half of that of the solvent-containing types. Most solventless varnishes will not overcoat windings that have been previously treated with any of a wide variety of solvent-containing varnishes used by naval and commercial activities. When using solventless dip varnishes, the dipping procedure of paragraph 10-31 maybe modified by the varnish manufacturers procedure. Although solventless varnishes have not shown that multicoating is successful, three dips and bakes are recommended to ensure adequate single coat coverage. Solventless dip varnishes should not be used to overcoat windings that have been previously treated with silicone varnish. Because of their chemistry, these windings offer a poor surface for revarnishing.

CAUTION

Compatibility tests must be conducted between varnish held in the dip tank for over a month and varnish from closed containers. Do this even though manufacturer and batch numbers are the same.

10-3. TERMINOLOGY USED WITH VARNISH.

10-3.1 Solvent-Containing Varnishes. These are liquid solutions of solid, polymeric materials dissolved in a suitable solvent primarily for application by the dip and bake process. The initial solid, polymeric material is generally an alkyd or modified alkyd and the solvent most often is xylene. Some suppliers refer to the alkyd as a *polyester* and the modified alkyd as a *modified polyester* . They may also use the term *phenolic modified polyester* . These materials are actually complex mixtures of compounds of intermediate molecular weight produced by a chemical process called *polyesterification* . The solids content generally runs close to 50 percent by weight.

10-3.2 Solventless Polyesters. These resins consist of a solid resin dissolved in a liquid monomer such as vinyl toluene, or DAP (diallyl phthalate). They are referred to as *reactive or unsaturated, polyesters* . They do not contain solvent. Instead, the monomers react with the basic resin and become part of the final, cured coating. Solventless resins or varnishes are sometimes referred to as *100-percent solid materials* . Since there are no solvents to evaporate, there is less likelihood of blistering, bubbles, and cavities.

10-3.3 Solventless Epoxies. Like the solventless polyesters, these materials contain no solvents. The base material is a high-viscosity liquid epoxy. A selective amount of a diluent, which is a low-viscosity epoxy, is added to yield the final desired viscosity range. The solventless epoxies have certain properties that distinguish them from the solventless polyesters.

10-3.4 Other Liquid Polymeric Materials. This category includes materials that, for one reason or another, are not as popular as the materials covered above.

10-3.5 Polybutadienes. This class of polymeric material consists of an aliphatic hydrocarbon resin dissolved in a solvent or monomer mixture, usually consisting of naphtha, xylene, and/or vinyl toluene.

10-3.6 Silicones. These are resinous materials made from compounds, which in place of the usual carbon backbone, have a backbone of silicon and oxygen atoms. Such a structure offers excellent resistance to oxidation at elevated temperatures. Silicone resins are not to be used on enclosed rotary Navy equipment that operates with carbon brushes since certain silicone vapors can cause severe commutation problems such as excessive brush wear. Solvent solutions of these silicone polymers have been used as varnishes for many years and are recognized for their outstanding long-term thermal resistance. However, in recent years they have been replaced with specially modified polyesters which have slightly less thermal stability but offer higher bond strengths at elevated temperatures.

10-3.7 Patching Kits. These consist of polymeric materials for temporary insulation where damage to the insulation has occurred. Patching kits can be a single component polyurethane varnish, supplied in a can for brush application or in a pressurized container for spray applications. These kits can also consist of a two-component epoxy system designed for relatively quick solidification. Since this system is solventless, it may offer an advantage when toxicity and low flash point are critical.

10-3.8 Thixotropic Varnishes. These are a class of varnish materials in which the flow characteristics have been modified so that the normal build, or coating thickness, is greatly increased. *Thixotropy* , by definition, is the ability of certain colloidal gels to liquefy when agitated (as by shaking or ultrasonic vibration) and to return to the gel form when at rest. Most electrical varnishes yield a build between 0.5 and 1.2 mils after one dip or treatment. The thixotropic materials will yield 2 to 10 mils, depending on the degree of modification. This special modification is accomplished through the addition of a thixotropic agent which is normally a finely ground mineral filler. This addition is made by the manufacturer but, in some cases, slight additions have been made at the varnish treating facilities to reestablish the original degree of thixotropy. For Navy applications, thixotropic modification has been used only with the solventless type of varnishes and only with the vacuum-pressure impregnation (VPI) process. There is the possibility in the future that these materials may be used in the dip and bake process.

10-3.9 Cure. A varnish or resin must be thoroughly cured or polymerized to achieve its intended purpose. An electrical varnish is designed to provide: mechanical bonding, environmental protection, and a dielectric barrier between points of differing electrical potential. If the varnish has not been adequately polymerized, that is, chemically or thermally reacted from a liquid to a solid stare, it will not fully provide these functions.

10-4. VARNISH SELECTION CRITERIA.

10-4.1 Solvent-Containing Varnish. Solvent-containing varnish should be selected in accordance with MIL-I-24092.

10-4.2 Solventless Varnishes. They are not available as products qualified in accordance with military specifications. Therefore, repair activities are responsible for the evaluation and selection of these commercially available varnishes. The following guidance is provided to assist activities in this process.

10-4.2.1 As a minimum, the varnish manufacturer should be provided the following information at the beginning of the selection process:

1. Operating environments and types of equipment to be varnished.
2. Description of other insulating materials to be used.
3. Insulation class of equipment to be varnished.
4. Estimated average temperature of the varnish in the dip tank.
5. Estimated rate of varnish usage.

6. Local environmental and fire safety regulations.

10-4.3 Varnish characteristics such as bond strength, dielectric strength, varnish build, and others identified in MIL-I-24092 should be evaluated and compared to assist in choosing the most capable varnish.

10-4.4 Evaluation of solventless varnish must include a demonstration of compatibility between the varnish and the principle components of the insulation system, including magnet wire, slot insulation, sleeving, and insulating tapes. The varnish should provide a uniform coating, should penetrate materials as required, and should not react adversely with the insulating materials. Materials should be checked for delamination and other physical changes after soaking in varnish. The repair activity should verify that the varnish has been qualified with the repair activity's magnet wire and slot material per National Electrical Manufacturers' Association (NEMA) standard, REV 2.

10-5. FUNCTIONAL CONSIDERATIONS OF VARNISH.

10-5.1 Solventless Varnishes. These materials are used primarily when maximum bond strength is required. They yield a smooth, even coating. Since no solvent is being removed in the baking process, holes and blisters usually do not form.

10-5.2 Solventless Thixotropic Varnishes. Solventless varnishes are more effective when they are modified for thixotropy (paragraph 10-3.8). This results in a much heavier varnish build per application and effectively increases the total encapsulation. This results in a strong, unified coil structure for motors, generators, and motor generator sets.

10-5.3 Gel Time of Solventless Varnishes. The gel time of a solventless resin is a measure of the reactivity of the resin, monomer, and catalyst system. If the gel time is too long, an optimum coating will not be achieved because some of the resin ingredients may evaporate in the curing oven before polymerization occurs. It may also result in an inadequate coating thickness since the resin will stay in a liquid state for a longer period of time, and will tend to run off of vertical and inclined surfaces.

10-5.3.1 Test Method. The gel time shall be measured on three catalyzed resin specimens in accordance with ASTM D 3056, *Gel Time for Solventless Varnishes, Test for* . A bath temperature of 212, 257, or 302° F (100, 125, or 150° C) shall be employed, and shall be chosen to give gel time between 10 and 60 minutes.

10-5.3.2 Test Instrument. The usual gel time instrument is a Sunshine Gel Time Meter and the test procedure is described in the instruction manual supplied by the instrument manufacturer.

10-5.3.3 Requirements. The gel time shall meet the requirements for periodic conformance as specified in the individual specification sheets of MIL-I-24092.

10-5.3.4 Thixotropic Index. The thixotropic index measures the degree of resin retention on this equipment as it is being cured in this oven. A thixotropic solventless resin is used when heavy builds are required. The normal build for a solvent-containing varnish is on the order of 1 mil Using solventless resins that have been modified for thixotropy, the build may reach 10 to 12 mils. As the tank resin is used, and as it ages, some undesirable changes may occur. With thixotropic materials, resin retention is adversely effected and the thickness of the coating will be less than required. Thixotropy is best measured by comparing the resin viscosity measured at a low speed to the viscosity measured at a higher speed. The ratio of the low speed to the high speed viscosity yields the thixotropic index.

10-5.3.4.1 Test Method and Procedure. The viscosity shall be measured at 73° F ± 2° F (23° C ± 1° C) catalyzed resin according to method B of ASTM D 2196, *Rheological Properties of Non-Newtonian Materials, Test For* . The viscosity shall be determined at spindle speeds of 2 and 20 revolutions per minute (r/m). The resin or varnish shall be placed in a 1-quart container within 1 inch of the top. Using a water bath, adjust the sample to 73° F ± 2° F (23° C ± 1° C). After reaching the required temperature, wait 90 minutes before the first measurement is made at 2 r/m. The 20 r/m measurement shall then be made immediately after the 2 rpm measurements. Three tests at each speed shall be made to provide an average viscosity value. The thixotropic index shall be calculated as follows:

Thixotropic Index = Avg. vis. at 2 r/m / Avg. vis. at 20 r/m

10-5.3.4.2 Requirements. The thixotropic index must meet the requirements of the individual specification sheets of MIL-I-24092. The test report shall include: model number of Brookfield viscometer, speed of rotation, spindle number, average viscosity at each speed, and calculated thixotropic index.

10-5.4 Solvent-Containing Varnishes. These varnishes are the general purpose liquid insulation materials used for insulating all types of electrical apparatus for over 35 years. As the solventless materials have become more widely used, the solvent-containing varnishes are now limited to specialized applications such as the finish or top-coat varnish. They are the preferred varnish for overcoating the solventless resin since they yield a very glossy finish. After an electrical apparatus has been treated with this type of varnish, the solvent immediately begins to evaporate and, usually after less than 1 hour, depending on the temperature and local air movement, it dries to a tack-free coating. At this stage, the coating must be baked to achieve its final properties. Once this bake cycle is completed, the varnish coating has a high gloss and, although hard, is capable of absorbing the mechanical and thermal movements necessary for normal equipment performance.

10-6. VARNISH COMPATIBILITY.

All varnish received from stock should be from the same manufacturer or have the same batch number. It is sometimes necessary, however, to mix varnish from different manufacturers or with different batch numbers. In this case, compatibility of the different varnishes must be proven by testing. Varnish compatibility is essential because mixing two incompatible varnishes will produce clouding and precipitation. An incompatible mix will not produce a good, adherent surface. Use the following procedure to test varnish compatibility:

a. Draw a small sample of varnish from each manufacturer or batch. Mix the samples together thoroughly.

CAUTION

Certain varnishes not qualified under MIL-I-24092 are likely to be incompatible with varnish qualified under MIL-I-24092.

NOTE

Esterlite 862M solventless varnish has a high degree of compatibility with DAP and VT-based varnishes. However, a compatibility test is essential. Precipitation means that particles drop out and separate from the rest of the varnish.

b. Check the mix for precipitation, excessive thickening, or other signs of incompatibility.

c. Consult NAVSEA S9086-KC-STM-010/CH 300 for further information on varnish compatibility.

10-7. THINNER.

Thinners should also be tested for compatibility with varnish before use. Use the following procedure to test thinner compatibility:

a. Draw a small amount of varnish from the tank.

b. Add thinner to the varnish sample in the same ratio as the final ratio of thinner to varnish in the tank as determined by paragraph 10-13. For example, if the tank has 10 gallons of varnish and 1 gallon of thinner will be added, the sample compatibility test should be the same 10:1 ratio of varnish to thinner.

c. Thoroughly mix the varnish and thinner. Observe for signs of incompatibility, such as small gelatinous formations or clouding. This can be more easily observed by dipping a spatula or glass slide into the varnish and thinner mixture. As the mixture flows from the spatula or glass slide, watch for clouding or other irregularities.

10-8. CONSTRUCTION OF A VARNISH TANK.

WARNING

Do not permit smoking, welding, or open flames near an open tank. Varnish has a very low flashpoint.

10-9.

The electrical shop supervisor should consult a motor frame chart to determine the dimensions of the required tank. A motor frame chart should be available in the shop.

10-10. TANK DIMENSIONS.

The tank should be:

10-10.1 Long and wide enough so that the largest frame expected can be easily lowered into the tank and

10-10.2 Deep enough to allow complete submergence of the stator.

10-11. TANK EQUIPMENT.

The tank should be equipped in the following manner:

10-11.1 The tank top should have hinges that allow it to swing completely clear of the tank.

10-11.2 The top should be fitted with a gasket that will form a vapor-tight seal when lowered against the tank edge. The top is held in place by dogs when closed. The dogs will pull the top gasket tightly against the tank edge to ensure a seal.

10-11.3 A drain pipe and valve must be mounted in the bottom of the tank to allow draining and cleaning.

NOTE

The following applies ONLY to varnish tanks for solvent-containing varnish.

10-11.4 The tank must have a filter system. The filter system will consist of a valve, a positive displacement pump, a filter, and a return line.

10-11.4.1 The suction line should be near the bottom of the tank, the valve between the tank and the pump, and the filter on the pressure side of the pump. The return line for the varnish must discharge back into the tank, above the surface of the varnish.

10-11.4.2 Good circulation will be achieved by taking varnish by suction from the bottom of the tank and returning it to the top. Discharging above the surface will provide thorough mixing of the varnish during treatment.

10-11.4.3 The pump's capacity must be large enough to recirculate the tank twice an hour. Pump capacity is calculated by using the following formula:

Pump Capacity in Gallons per Minute (gal/min) = Tank Capacity in Gallons x 2/60

10-12. VARNISH TANK LOG.

A varnish tank log should be maintained for each varnish tank. The tank log should be kept in the following manner.

10-12.1 State what varnish was added to the tank, its manufacturer, and its batch number.

NOTE

The following applies ONLY to varnish tanks for solvent-containing varnish.

10-12.2 Run a weekly test (paragraph 10-13) on the varnish. The varnish tank log should state:

10-12.2.1 Date of the test,

10-12.2.2 Viscosity in centipoise,

10-12.2.3 Temperature of the varnish during the test,

10-12.2.4 Type of cup used,

10-12.2.5 Treatment necessary to correct the viscosity, and

10-12.2.6 Initials of the person conducting the test and making the correction.

NOTE

The following applies ONLY to varnish tanks for solvent-containing varnish.

10-13. VARNISH TESTING.

10-14. VISCOSITY OF SOLVENT-CONTAINING VARNISH.

Solvent-containing varnish qualified under MIL-I-24092 must be maintained at a viscosity as indicated in the varnish manufacturer's instruction sheets or product literature. Varnish is tested to determine its viscosity before use. It need not be retested more than once a week. Use the following steps to test viscosity.

a. Ensure that the varnish temperature is 77° F ±3° F (25° C ± 2° C).

b. Ensure that the recirculation pump valve is open. Start the pump. Recirculate the varnish for 1 hour before testing viscosity.

c. Dip a viscosity measuring cup (Zahn No. 2 or Demmler No. 1) into the varnish and fill it.

d. Start the stopwatch as the cup emerges from the varnish. Liquid will begin to flow through the hole in the bottom of the cup.

e. Stop the watch at the first interruption of continuous flow of the varnish. Note the time.

10-15. RECORDING VISCOSITY WITH THE ZAHN CUP.

Use the following procedure to record viscosity:

a. Locate the time in seconds on the viscosity chart for the Zahn cup No. 2 (figure 10-1) on the line marked ″Viscosity in seconds.″

b. Go up from this point to a point of intersection on the Zahn cup viscosity chart No. 2 line.

c. From this point, go left at right angles to the point of intersection with the Absolute Viscosity Line.

d. Read this point of intersection and record it in the varnish tank log as soon as the test is complete.

10-16. RECORDING VISCOSITY WITH THE DEMMLER CUP.

See figure 10-1 and use the following procedure to record viscosity:

a. Locate the time in seconds on the chart for No. 1 Demmler cup (figure 10-1) on the line marked ″VISCOSITY IN SECONDS.″

b. Go up from this point to a point of intersection of the Demmler cup No. 1 line.

c. From this intersection point, go left at a right angle to the point of intersection with the Absolute Viscosity Line.

d. Read this point of intersection and record it in the varnish tank log under ″VISCOSITY IN CENTIPOISE AT 25° F (77° C).″

10-17. APPROXIMATE VISCOSITY MEASUREMENT.

An approximate viscosity measurement can be taken in the absence of a Zahn or Demmler cup. Use the following procedure:

a. Use a small (about one-half pint) can with a small hole (not more than 1/8 inch in diameter) in the bottom.

b. Calibrate by filling the can with fresh water and observing the time it takes for the can to empty.

c. Dry the can and repeat with varnish.

NOTE

Water has a viscosity of 17 seconds by the Zahn cup No. 2 or the Demmler cup No. 1. Therefore, viscosity of a liquid can be approximated by the formula:

$17S/R = V$, *where*

R	reference value, the observed time in seconds for water,
S	observed time in seconds for varnish, and.
V	seconds viscosity, Demmler or Zahn cup.

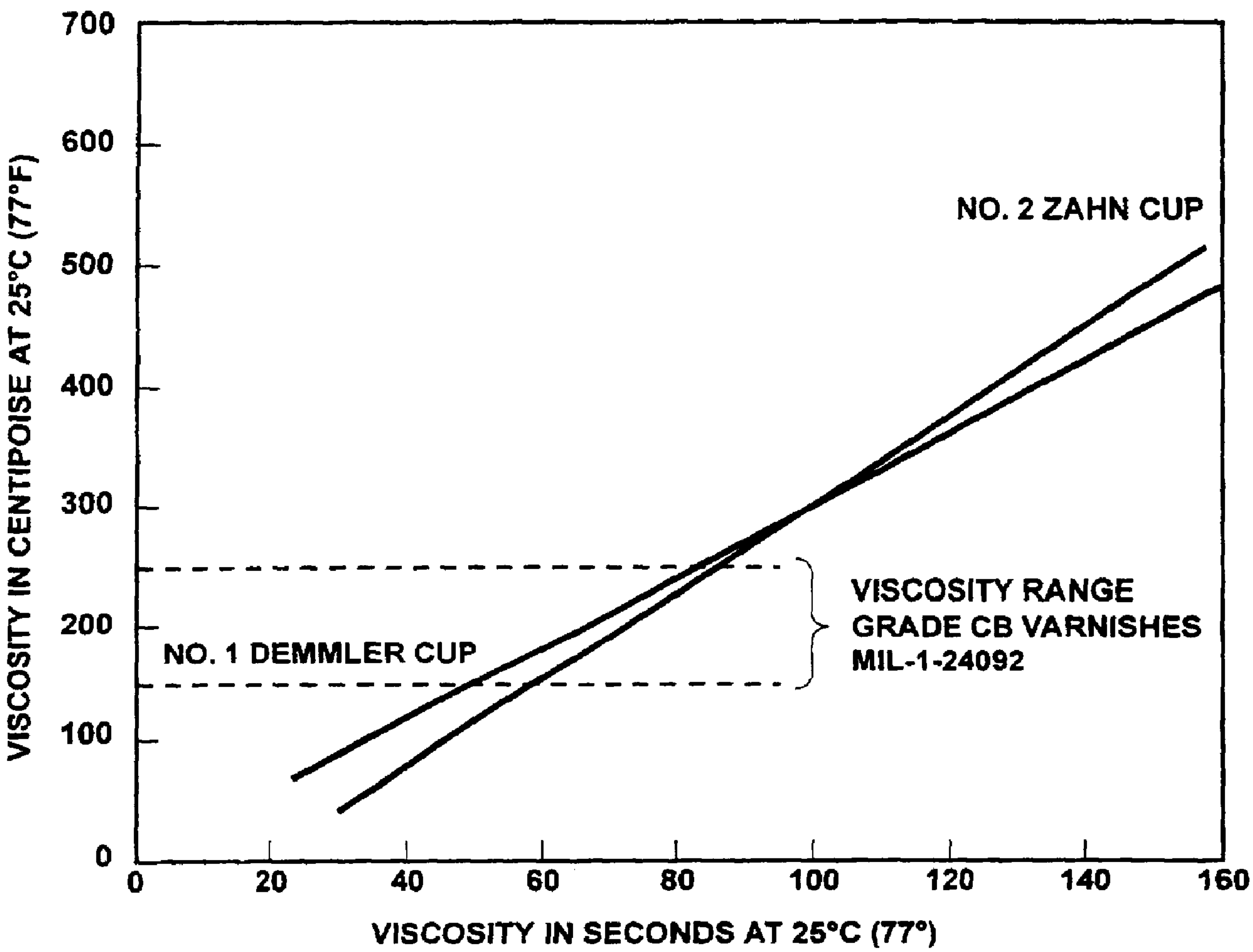


Figure 10-1 Varnish Viscosity Chart, No. 2 Zahn Cup and No. 1 Demmler Cup

10-18. SOLVENTLESS VARNISH MAINTENANCE.

In addition to viscosity, routine maintenance of solventless varnish requires evaluation of gel time. Viscosity and gel time may be out of specification due to:

10-18.1 Prolonged tank exposure to an ambient temperature in excess of the manufacturer's recommended storage temperature.

10-18.2 Equipment immersion temperature is too high.

10-18.3 Varnish usage rate is too low.

10-19. VARNISH TESTING

Gel time measurement requires specialized test equipment that is not suitable for the shipboard environment. The varnish manufacturer should be requested to perform a periodic varnish evaluation, including gel time testing, as a service to each activity using the varnish. The evaluation should be performed quarterly or more frequently if warranted. The repair activity should submit a sample of varnish to the manufacturer for evaluation. The manufacturer will submit a report to the address provided by the repair activity. The report will identify any action required by the repair activity to modify the varnish in the tank. For more information on gel time and the associated test procedures, see paragraph 10-5.3. Since its components do not separate, solventless varnish does not require circulation in the tank.

10-20. THINNING AND STORING VARNISH.

WARNING

Do not weld, smoke, or allow open flames in the vicinity of an open varnish tank. Varnish thinners have very low flashpoints.

CAUTION

Do not thin solventless varnish.

10-21. THINNING SOLVENT-CONTAINING VARNISH.

a. Determining Amount of Thinner. To determine the amount of thinner needed to return the solvent-containing varnish to its proper viscosity:
   (1) Draw a sample from the tank.
   (2) Add thinner until the sample is within specifications.
   (3) Determine the proportion of varnish to thinner.
   (4) Estimate the approximate amount of thinner needed.

b. Thinning Varnish. To thin the varnish in the tank:
   (1) Start the varnish tank recirculating pump.
   (2) Add the thinner slowly, mixing while adding.
   (3) Allow the pump to continue running for 2 hours. This will ensure thorough mixing of the varnish.
   (4) Check solvent-containing varnish viscosity in accordance with paragraph 10-14.

10-22. PRECAUTIONS IN STORAGE OF VARNISH.

The varnish tank should be closed with a properly fitting lid at all times except when equipment is being processed.

10-22.1 Solvent-Containing Varnish. If the tank contains solvent varnish, the filter system should be checked for proper operation according to the process equipment specifications. The solvent-containing varnish should be drained from the tank and the tank cleaned annually. Solvent-containing varnish, in good condition, should be put back into the tank after cleaning.

10-22.1.1 Circulate the varnish daily, using the varnish tank recirculating pump.

10-22.1.2 Circulate the varnish for 1 hour before and after using the tank when equipment is to be dipped.

10-22.1.3 Test the varnish once a week. Record the results in the varnish tank log.

10-22.1.4 Varnish should not be excessively thinned, as this will result in a baked film that will be too thin to afford electrical protection.

10-22.1.5 Varnish in the dip tank shall be maintained in accordance with NAVSEA S9086-KC-STM-010/CH 300.

10-22.2 Solventless Varnish. If the tank contains solventless varnish, the recirculating pump and filter system are not required. The varnish should be drained from the rank and the tank cleaned every 2 to 3 years.

10-23. VARNISHING RECONDITIONED WINDINGS

10-24.

Varnishing of reconditioned windings should:

10-24.1 Provide a continuous varnish film over the coils, core, and miscellaneous surfaces.

10-24.2 Provide a film which is comparatively resistant to gases, moisture, and oil.

10-24.3 Provide a smooth surface to minimize the collection of dust, dirt, and other substances on the surface of the windings.

CAUTION

Varnish should never be applied to the whole or any part of a winding, either by dipping, spraying, or brushing, until the winding has been thoroughly cleaned and dried. Varnishing a dirty or moist winding seals in dirt or moisture and makes future cleaning impossible.

NOTE

Varnish should be applied only when it will serve a useful purpose. The unnecessary and frequent application of varnish ultimately results in building up a heavy coating which interferes with heat dissipation and is likely to develop surface cracks.

10-25. PREPARING WINDINGS FOR VARNISHING.

Use the following procedure to prepare windings for varnishing:

a. Complete stator cleaning before varnishing.

b. Ensure that the winding is completely dry.

c. Ensure that the winding has an acceptable value of insulation resistance (see the After Reconditioning column in table 7-2). Ensure that all other dielectric test results were satisfactory. Ensure that the winding and leads do not have physical damage.

d. Place bolts in bolt holes to prevent the entry of varnish. This is very important, since open bolt holes will fill solidly with varnish.

e. Prepare rigging so that the position of the winding can be changed during draining. This will prevent pocketing of the varnish.

10-26. VARNISHING PROCEDURE.

When reconditioning, use table 10-1 for solvent-containing varnishes and table 10-2 for solventless varnish as described below for varnishing windings.

NOTE

One coating of varnish is usually sufficient when reconditioning windings. The winding undergoing reconditioning has several coats of varnish on it. The coat put on during reconditioning is intended to seal any minute cracks that have developed due to vibration and thermal cycling. Sometimes, solventless varnish runs off a winding during reconditioning before the varnish sets up in the oven. If this occurs, and solvent-containing varnish is not available, rewind is necessary.

a. Complete steps 1 through 4 of the appropriate table.

b. Baking should be in accordance with in step 5 of the appropriate table.

c. Steps 7 through 8 are not required.

10-27. VARNISHING NEW WINDINGS.

Tables 10-1 and 10-2 list the procedures for using solvent-containing and solventless varnishes, respectively.

10-28.

Varnishing new windings should:

10-28.1 Seal the windings from dirt, oil and moisture.

10-28.2 Bind the winding into a solid mass.

10-28.3 Provide a film over the winding. The film must be as smooth as possible, with a glossy finish to minimize the collection of dirt and dust.

10-29. PREPARING A NEW WINDING FOR VARNISHING.

Use the following procedure to prepare a new winding for varnishing.

a. Complete the checklist in Appendix C before varnishing a new winding.

b. Conduct an insulation resistance test (paragraph 2-4 and paragraph 2-8), a phase resistance balance test with a low-reading digital ohmmeter (paragraph 2-15), a dc high-potential test (paragraph 2-23), and a surge comparison test (paragraph 2-19) on the winding.

c. Correct any winding faults before varnishing.

10-30. DIP AND BAKE CONSIDERATIONS USING A SOLVENTLESS VARNISH.

Except for baking, the varnishing process is similar to that used with solvent-containing varnishes (paragraph 10-26). However, varnish build and coverage is increased if intermediate dips are baked just beyond the point where the solventless varnish is tacky. In this condition, the varnished surface allows for greater adherence of the following dip. The time to reach this point in the curing cycle varies with the mass of equipment being varnished and with the oven characteristics. Repair activities must establish guidelines for the intermediate bake times for differently sized equipment using their ovens. After the final dip, the varnish should be completely cured by baking the equipment for the duration shown in table 10-2.

Table 10-1 Varnishing Procedure: Solvent-Containing Varnish

	Processing Rebuilt Armature Coils, Stator Coils and Field Coils
Procedure	**Class A, B, F, H, and N**
STEP 1 Prebaking	Put into oven at 302° F (150° C). Hold at temperature for 2 to 4 hours depending on size of equipment. Cool to approximately 140° F (60° C) by convection. If necessary, forced air cooling may be used provided the air is filtered with a 50-micron filter.
STEP 2 Dipping	Immerse coils preheated to 140° F (60° C) in organic varnish until bubbling stops. Viscosity should be as indicated in the varnish manufacturer's instruction sheets or product literature. Dip wound rotating components with the commutator, slip ring, or connection end up.
STEP 3 Draining	Drain vertically and air-dry for 15 to 30 minutes. Periodically turn wound apparatus end for end during draining to prevent pocketing the varnish. For wound rotating components, drain with commutator, slip ring, or connection end down; do not rotate.
STEP 4 Cleaning	After draining but before baking, the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure should be cleaned by wiping with a cloth moistened with solvent.
STEP 5 Baking	Bake in a circulating type forced exhaust oven which has a minimum of six air changes per minute at 302° F (150° C) for 2 to 3 hours. Baking time begins when the equipment is at the baking temperature. For class H and N varnishes, bake at the lowest temperature recommended by the varnish manufacturer.
STEP 6 Cooling	Remove from oven and cool to approximately 140° F (60° C).
STEP 7 Second treatment	Repeat steps 2, 3, 4, 5, and 6. The duration of the immersion in step 2 should be until the bubbling stops but not less than 2 minutes. The baking time in step 7 should be 6 to 8 hours. Dip wound rotating components with the commutator, slip ring, or connection end down. Drain with the commutator, slip ring, or connection end up; do not rotate.
STEP 8 Third treatment	For wound rotating components, repeat step 7 except that dipping should be with the commutator, slip ring, or connection end up. Drain with commutator, slip ring, or connection end down; do not rotate.

10-31. SUPPLEMENTAL VARNISHING INFORMATION.

The following provides supplemental information applicable to the varnishing processes of table 10-1 and table 10-2.

a. Plug all bolt holes and screw holes with bolts and screws prior to varnishing.

b. For solvent-containing varnish, start the varnish tank recirculating pump when the stator is put in the oven.

c. Test the viscosity of solvent-containing varnish after it has been circulated for 1 hour if a weekly test has not been conducted. Enter result in the varnish tank log. Solvent-containing varnish viscosity must meet the requirement of table 10-1, step 2.

d. Verify that the solventless varnish has been evaluated by the manufacturer within the appropriate time period and the recommended corrections have been implemented (refer to paragraph 10-19).

Table 10-2 Varnishing Procedure: Solventless Varnish

	Processing Rebuilt Armature Coils, Stator Coils and Field Coils
Procedure	**Class A, B, F, H, and N**
STEP 1 Prebaking	Put into oven at 302° F (150° C). Hold at temperature for 2 to 4 hours depending on size of equipment. Cool to approximately 110° F to 120° F (43° C to 49° C) by convection. If necessary, forced air cooling may be used provided the air is filtered with a 50-micron filter.
STEP 2 Dipping	Preheat coils or wound apparatus to 110 to 120° F (43 to 49° C) and immerse in solventless varnish until bubbling stops. Viscosity and gel time should be in accordance with the varnish manufacturer's recommendation contained in the instruction sheets and product literature provided with the varnish. Dip wound rotating components with the commutator, slip ring, or connection end up.
STEP 3 Draining	Drain vertically and air-dry for 15 to 30 minutes. Periodically turn wound apparatus end for end during draining to prevent pocketing the varnish. For wound rotating components, drain with commutator, slip ring, or connection end down; do not rotate.
STEP 4 Cleaning	Before baking, if a masking compound has not been used, the metal surfaces of the armature, the stator bore, and the pole faces of the field structure should be cleaned by wiping with a cloth. If permitted by local environmental regulations, the cloth may be moistened with a solvent.
STEP 5 Baking	Bake in a circulating-type forced exhaust oven which has a minimum of six changes of air per minute at 302° F (150° C) until the varnish becomes tacky. For class H and N varnishes, bake at the lowest temperature recommended by the varnish manufacturer.
STEP 6 Cooling	Remove from oven and cool to approximately 110° F to 120° F (43° C to 49° C).
STEP 7 Second treatment	Repeat steps 2, 3, 4, 5, and 6. The duration of the immersion in step 2 should be until the bubbling stops but not less than 2 minutes. Dip wound rotating components with the commutator, slip ring, or connection end down. Drain in step 3 with the commutator, slip ring, or connection end up; do not rotate.
STEP 8 Third treatment	After the second bake, repeat steps 2, 3, 4, and 5 except that the component orientation during dipping and draining should be reversed from that in step 7 and the component should be baked for 6 to 8 hours at the temperature indicated in step 5.

CHAPTER 11

ELECTRICAL TEST, REASSEMBLY, AND FINAL INSPECTION

11-1. SCOPE.

This chapter contains information on motor testing, reassembly, and final inspection. Topics include:

11-1.1 Stator preparation (paragraph 11-2).

11-1.2 Testing the winding (paragraph 11-4).

11-1.3 Checking shaft bearing journals and bearing housing (paragraph 11-6).

11-1.4 Visual inspection of end bells (paragraph 11-8).

11-1.5 Motor assembly (paragraph 11-10).

11-1.6 Final electrical test (paragraph 11-12).

11-2. STATOR PREPARATION.

11-3.

Use the following procedure to prepare the stator for a test of the windings:

a. Remove the winding from the oven after the final bake. Allow it to cool.

b. Use a machinist's scraper to carefully remove any baked-on varnish from all machined surfaces, including the motor mounting pads. Do not remove metal. The bore should require minimal cleaning if it was wiped with a release agent before dipping.

c. Use a shop vacuum to remove all varnish particles. Do not use compressed air to blow on the windings. Air tends to drive particles into the winding.

11-4. TESTING THE WINDING.

11-5.

Use the following procedures to conduct electrical tests on the windings. Record the results on the motor data sheet (electrical) (figure 11-1).

a. Conduct the following electrical tests:
   (1) Ground insulation test (paragraph 2-4 or paragraph 2-8).
   (2) Resistance balance test with digital ohmmeter (paragraph 2-15).
   (3) Surge comparison test (paragraph 2-19).
   (4) AC high potential test (paragraph 2-39 or paragraph 2-45).
   (5) Insulation resistance after ac high-potential test (paragraph 2-4 or paragraph 2-8).

b. Enter the results of the tests in section 5 of the motor data sheet (electrical).

c. Set the winding aside after all electrical tests have been completed. Cover the winding to prevent the entry of dust and dirt.

11-6. CHECKING SHAFT BEARING JOURNALS AND BEARING HOUSINGS.

11-7.

Take the following steps to check the shaft bearing journals and housings:

11-7.1 Fill out another motor data sheet (mechanical) if machine work was necessary to return the shaft bearing areas to specification. The motor data sheet (mechanical) (figure 11-2) must show the reconditioned readings.

11-7.2 Use a snap gage (paragraph 2-62) and appropriate standards to measure the bearing journals. Record the readings on the motor data sheet (mechanical). Use bore gages (paragraph 2-58) and proper standards to measure housings. Record the readings on the motor data sheet (mechanical). In the case of bearing seats and housing measurements, the positions recorded may not necessarily include maximum and minimum readings. It is important to locate and measure high spots or low spots caused by ridges, dents, scratches, etc. Record these dimensions and their locations on the motor data sheet (mechanical). Compare the readings with the original measurements made on the incoming motor.

11-7.3 Measure the radial runout (paragraph 2-53) of the shaft. Record the readings. Return shafts that are out of specification to the machine shop for reworking, or smooth down burrs and ridges with a fine stone or polishing paper. Compare the readings with the original measurements made on the incoming motor.

11-8. VISUAL INSPECTION OF END BELLS.

11-9.

Use the following procedure to visually inspect the end bells:

a. Look at the end bell machined surfaces. Pay particular attention to the end bell rabbet and mating housing rabbet. Remove all nicks, burrs, and irregularities before the motor is assembled.

b. Examine nuts, washers, keys, locknuts, and other small hardware. Discard and replace damaged or corroded components.

SECTION 1. NAMEPLATE DATA

EQUIPMENT ______________________ USS ______________
MFGR. ____________ TYPE __________ FRAME __________
HP ________ INSULATION CLASS ______ TEMP. RISE ______ °C/°F __________
VOLTS ______ AMPS ______ CYO ________ R/M ______ PHASE ________
SERIAL NO. ______________ ADDITIONAL DATA ______________

SECTION 2. INPLACE INSPECTION

CAUTION: OBSERVE APPLICABLE SAFETY PROCEDURES.

SATISFACTORY		UNSATISFACTORY
______	INSULATION RESISTANCE IN MEGOHMS (REFER TO TABLE 3-2)	______
POLARIZATION INDEX TEST	1 MIN ______ 10 MIN ______ RATIO ______	
______	MECHANICAL CONDITION (REFER TO PARAGRAPH 3-6)	______
______	CONTINUITY OF WINDINGS (REFER TO PARAGRAPH 3-5.1)	______
______	CURRENT BALANCE (USE LIMITS PRESCRIBED IN PARAGRAPH 3-10)	______
______	CONDITION OF BRUSHES AND COMMUTATOR	______
______	CONDITION OF CABLES FROM CONTROLLER TO MOTOR	______
______	CONDITION OF CONTROLLER	______

SECTION 3. INCOMING INSPECTION (GENERAL)

SURGE TEST	1 - 2	______	SAT/UNSAT
	2 - 3	______	SAT/UNSAT
	1 - 3	______	SAT/UNSAT
INSULATION RESISTANCE TO GROUND		______	MEGOHMS
RESISTANCE BALANCE	1 - 2	______	OHMS
WITH DIGITAL OHMMETER	2 - 3	______	OHMS
	1 - 3	______	OHMS

ACTION: RECONDITION ________ REWIND ________

SECTION 4. RECONDITIONING

	AFTER STEPS OF: CLEANING	DRYING
INSULATION RESISTANCE (MEGOHMS)	______	______
PHASE RESISTANCE BALANCE TEST	______	______
SURGE TEST (SAT/UNSAT)		______
DC HIGH-POTENTIAL TEST	______	______

ACTION: VARNISH ________ REWIND ________

SECTION 5. AFTER RECONDITIONING OR REWINDING AND VARNISHING

INSULATION RESISTANCE		______	MEGOHMS
POLARIZATION INDEX TEST	1 MIN ______	10 MIN ______	RATIO ______
RESISTANCE BALANCE WITH	1 - 2	______	OHMS
DIGITAL OHMMETER	2 - 3	______	OHMS
	1 - 3	______	OHMS
SURGE TEST		______	SAT/UNSAT
AC HIGH-POTENTIAL TEST		______	SAT/UNSAT
INSULATION RESISTANCE AFTER AC HIGH-POTENTIAL TEST		______	MEGOHMS
NO-LOAD TEST	PHASE A	______	AMPERES
	PHASE B	______	AMPERES
	PHASE C	______	AMPERES

Figure 11-1 Motor Data Sheet (Electrical)

11-10. MOTOR ASSEMBLY.

11-11.

To assemble the motor:

a. Select a clean work area large enough to permit easy movement around the motor.

b. Rig chainfalls for handling heavy components. Rig slings to lift the motor.

c. Place the motor frame at a comfortable working height in the clean work area.

d. Assemble all tools and materials.

e. Line the bore of the motor stator with gasket material or with NOMEX to protect the lamination and windings.

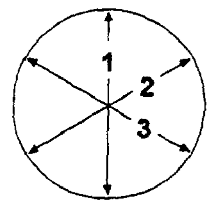
SHIP NAME & HULL NUMBER ______________________ DATE MONTH/DAY/YEAR

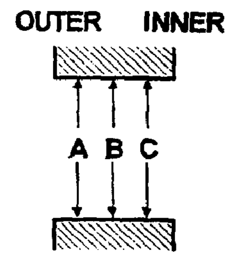
MOTOR LOCATION (I.E., NO. 2 MAIN FEED PUMP, ETC.) ______________________

HOUSING DIAMETERS

DRIVE END			
	A	B	C
1			
2			
3			

OUTER END			
	A	B	C
1			
2			
3			

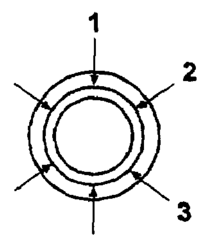


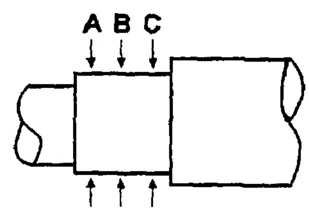


SHAFT DIAMETERS*

	DRIVE END			OUTER END		
	A	B	C	A	B	C
1						
2						
3						

* FOR BEARING JOURNAL WIDTH LESS THAN 1 INCH, ONLY SIX READINGS ARE REQUIRED.





(A) SHAFT RADIAL RUNOUT ______________

(B) FACE RUNOUT, BEARING INNER RING
DRIVE END ______________
OUTER END ______________

(C) FACE RUNOUT, BEARING OUTER RING
DRIVE END ______________
OUTER END ______________

MECHANICAL CONDITION
(LOSS OF LUBE, BURNED, ETC.)
____
____
____
____
____
____

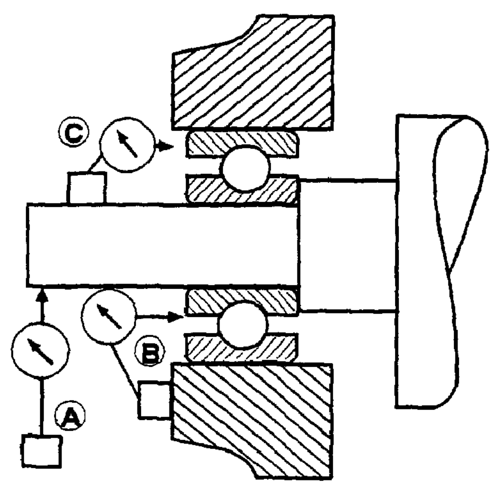


Figure 11-2 Motor Data Sheet (Mechanical)

NOTE

Ensure that the shaft is properly installed in the housing bore. Check that the matchmarks on the stator housing conform to the matchmarks on the end bell.

f. Place the rotor in the bore.

g. Place long studs in the inner bearing cap bolt holes.

h. Position one end bell on or near the shaft. This will allow the studs from the inner bearing cap to be placed through the bearing cap retainer bolt holes.

NOTE

Pack open and single-shielded bearings outer bearings caps one-third to one-half full of grease. Refill lubricated passages with clean grease.

i. Lift the end bell onto the bearing. Align matchmarks. Catch the end bell bolts. Tighten these bolts finger tight.

j. Slide the outer bearing cap into place, using the studs as a guide. Catch the inner bearing cap by installing bolts in two or more vacant holes. Remove studs. Place all bearing cap bolts into position and tighten finger tight.

k. Place studs in the inner bearing cap on the other end of the motor.

l. Place the other end bell on the motor shaft.

m. Support the motor shaft and end bell. Use a pipe slipped over the shaft and an appropriate lifting device.

n. Raise the motor shaft until the rotor is clear of the gasket material or NOMEX protecting the lamination.

o. Remove the packing material or NOMEX from between the rotor and lamination.

p. Slide the end bell toward the motor frame. Insert the inner bearing cap studs through bearing cap bolts on the end bell.

q. Align the matchmarks.

r. Slide the end bell over the motor bearing and catch the end bell bolts. Tighten them finger tight.

s. Remove the pipe and lifting device.

t. Install the outer bearing cap.

u. Pull the cap up tight. Catch the bearing cap bolts. Tighten them finger tight.

v. Remove the studs. Catch the remaining bearing cap bolts.

w. Check to ensure that the shaft turns freely.

NOTE

Do not completely tighten either end bell in one step. Turn the shaft continuously while tightening.

x. Pull the end bell bolts down in several steps. Use a crisscross pattern, shifting from one end bell to the other.

y. Torque the bolts as shown in table 11-1.

NOTE

Do not completely tighten either bearing cap in one step. Turn the shaft continuously while tightening.

z. Tighten the bearing cap bolts. Use a crisscross pattern, shifting from one bearing cap to the other.

aa. Reinstall the balance rings (if applicable).

ab. Check for free rotation of the rotor shaft by hand.

ac. Measure the radial runout of the shaft with a dial indicator. Ensure that total indicated runout is 0.002 inch or less.

11-12. FINAL ELECTRICAL TEST.

11-13.

Exercise care during motor assembly to prevent winding damage. The windings should be tested electrically after assembly and before the motor is test run. This will ensure that the windings are in good condition. Use the following procedure for final electrical testing:

a. Perform the following tests on the windings:

(1) Ground insulation test (paragraph 2-4 or paragraph 2-8).

(2) Phase resistance balance test (paragraph 2-15).

(3) Surge comparison test (paragraph 2-19).

b. Test run the motor, no load, after the winding is tested.

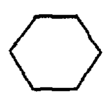
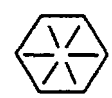
(1) Connect the motor to a line at its design voltage.

(2) Start the motor. Run it for 30 minutes.

(3) Check the line current while the motor is running (paragraph 2-25). Line currents must balance within 5 percent for surface craft and 3 percent for submarines. Determine the cause of excessive imbalance. Check the motor revolutions per minute (r/m) with a digital r/m counter. If the shaft is not accessible, use a Strobotac (paragraph 2-33). Compare r/m to the manufacturer's nameplate data. Determine the cause of low readings.

(4) Observe the bearing temperature.

Table 11-1 Recommended Torque (in Foot-Pounds) for Bolts, Nuts, and Studs on End Caps and End Bells

	Hexagon Head Bolt Grades 1 and 2	**Hexagon Head Bolt Grade 5**	**Hexagon Head Bolt Grade 8**
			
Bolt, Nut, Stud Size (Inch)	**No Marking Carbon Steel Corrosion-Resistant Steel**	**Marking Carbon Steel Alloy Steel**	**Marking Carbon Alloy Steel**
1/4	2-4	6-8	9-12
5/16	4-8	13-17	18-25
3/8	6-12	23-30	35-45
7/16	10-20	35-50	55-70
1/2	15-30	55-75	80-110
9/16	23-45	80-110	110-150
5/8	30-60	110-150	170-220
3/4	50-100	200-260	280-380
7/8	80-160	300-400	460-600
1	123-245	440-580	680-900
1-1/8	195-390	600-800	690-1280
1-1/4	273-545	840-1120	1360-1820
1-3/8	365-730	1100-1460	1780-2380
1-1/2	437-875	1460-1940	2360-3160

(5) Listen for unusual noise.

(6) Check the motor for vibration.

c. Correct all deficiencies before the motor is prepared for return to service.

CHAPTER 12

TRANSPORTATION, INSTALLATION, AND TESTING

12-1. SCOPE.

This section contains information on installing motors. Topics include:

12-1.1 Transporting motors (paragraph 12-2).

12-1.2 Mounting motor to foundation (paragraph 12-4).

12-1.3 Testing motor rotation (paragraph 12-6).

12-1.4 Testing the connection (paragraph 12-9).

12-1.5 Tag-in (paragraph 12-11).

12-1.6 Motor test preparations (paragraph 12-13).

12-1.7 Motor starting and testing (paragraph 2-15).

12-2. TRANSPORTING MOTORS.

12-3. PREVENTING DAMAGE DURING TRANSPORTATION.

Use the following procedures to prevent damage to the motor during transportation:

12-3.1 Bolt a pipe shaft protector over the shaft and to the end bell. This will prevent damage to the motor shaft.

12-3.2 Motors with mounting feet may be transported on a pallet. Inspect the pallet for weakened slats. Do not use pallets that have been weakened.

12-3.3 Cylindrical motors transported on pallets should be wedged to prevent any movement on the pallet. Nail the wedges to the pallets to prevent loosening. Band cylindrical motors to the pallet if possible.

12-3.4 All rigging and lifting devices should be positioned to strike the motor below as soon as it is on the ship. Do not leave motors on the weather decks. Refer to Chapter 4 for rigging procedures.

12-4. MOUNTING MOTOR TO FOUNDATION.

12-5.

Use the following procedure to mount a motor to the foundation:

a. Inspect to ensure that there is no:
   (1) Corrosion on the mounting bases,
   (2) Corrosion or handling damage to the motor or feet, or
   (3) Distortion of the foundation due to local welding or cutting operations.

b. It is necessary to have a level foundation in order to do a satisfactory shimming job later. This is true even if the foundation is uneven. Perform the following steps to correct an uneven motor base:

(1) Check to ensure that the motor base or feet are flat and in contact with the foundation. All points should be in contact when set on a flat surface. Hand file the surfaces if machining is not possible. Make them as smooth as possible.

(2) Place the assembly on a flat surface. Use a feeler gage to check for high points.

c. Use a flat file to smooth the area where the foundation pads of the motor will rest on the individual pads. Make the pads as flat as possible. It may not be possible to ensure that they are all the same height, but they must be flat.

d. Ensure that the shims, which were removed, marked, and stored during disassembly, are installed correctly.

NOTE

This procedure will be performed by the mechanic during alignment.

e. Set the assembly in place on the foundation. Use a feeler gage to determine the need for additional leveling. Use a file or an appropriate shimming technique when surfaces are not parallel. Good contact must be established at all fastening points.

12-6. TESTING MOTOR ROTATION.

12-7.

It is necessary to ensure that the motor will have the proper direction of rotation before connecting it to the driven unit. This should be determined any time that a motor is disconnected and/or reinstalled for any reason Determining the direction of motor rotation can normally be accomplished after the motor is set in place but before the final shimming, aligning, and tightening down has taken place. The motor is normally then connected to the controller leads, the circuit is tagged-in and the motor is ″bumped″ or ″jogged″ by the instantaneous pushing of the controller start and stop buttons. The direction of rotation can then be changed as necessary.

WARNING

Running some types of equipment in the wrong direction may injure personnel or damage the motor.

12-8.

To conduct a motor direction or rotation test, proceed as follows:

WARNING

Test the voltmeter on a known live circuit before using it to ensure that it is working properly.

a. Test the controller line (L) leads to ensure that circuit is secured.

b. Determine proper direction of rotation of motor or driven unit by consulting the manufacturers technical manual or by observing direction of rotation markings on motor or driven unit.

c. Connect motor leads and controller leads in accordance with existing lead markings if applicable. If the leads are not tagged and the motor and its power (controller) cable has only three leads, then connect any power lead to any motor lead.

NOTE

In cases of two-speed dual voltage, consequent pole motors, etc., the motor and/or power cables will have more than three leads. In such cases it will be necessary to consult the manufacturer's technical manual to determine proper connections as well as possibly identifying individual motor winding and power cable leads by means of continuity testing.

d. Insulate connections in accordance with current directives.

e. Have ship's force personnel tag-in and energize the circuit.

f. Ensure that all personnel are standing clear of the motor with exception of the person assigned to observe the direction of motor rotation, if necessary.

g. Push the controller's start button and instantly press the stop button. Observe and mark the direction of rotation with a pencil, marking pen, etc.

h. Compare the actual direction of rotation to the direction required. After ensuring that the circuit has been secured and tagged out, change direction of rotation on a single-speed motor, if necessary, by reversing any two motor leads.

i. Retest direction of rotation as previously described.

j. Have the circuit secured and tagged out when the direction of rotation, is correct.

k. Mark the motor and power cable leads at the motor. Insulate the power leads.

l. Reposition the motor as necessary in preparation for coupling installation.

12-9. TESTING THE CONNECTION.

12-10.

Conduct a ground test from the controller, using a megohmmeter (paragraph 2-4 and paragraph 2-8). The reading on the controller panel should be at least 2 megohms. Check continuity of the controller cable, motor connections, and motor windings by reading between the T leads in the controller with a digital ohmmeter (paragraph 2-15).

12-11. TAG-IN.

12-12.

Observe the following procedures for tag-in:

NOTE

See paragraphs 1-22 through 1-29 for a discussion of tag-out and tag-in procedures.

a. Tag-in Responsibility. The ship's force is responsible for tag-in. An authorized representative of the repair activity must also sign the tag-out record sheet.

WARNING

DANGER:

Closely follow the established ship procedure. High voltages used in operation of electrical equipment can cause DEATH ON CONTACT if personnel ignore safety precautions. Use extreme caution when working near the power source and load components.

b. Tag-in Procedures. Use the following tag-in procedure and the tag-in bill of the tended ship.

NOTE

See OPNAVINST 3120.32, paragraph 630.17, ″Tag-Out Bill,″ for further details on tag-in.

(1) Ensure that the motor and the equipment that it drives have been properly aligned.

(2) Identify the motor by locating it on the system diagram.

(3) Ensure that all repair work on the entire system to be energized has been completed. Also ensure that the mechanical components are completely assembled.

(4) Use a voltmeter to test the line (L) leads in the controller to ensure the circuit is secured.

(5) Notify the proper authorities that tag-in will occur.

(6) Record the tag-in on the tag-out record sheet. Both a ships force and IMA representative must initial the sheet.

(7) Remove all tags and return them to the authorizing officer for destruction.

(8) Observe as appropriate switches or breakers are placed in the energized position.

12-13. MOTOR TEST PREPARATIONS.

12-14.

Before starting the motor, ensure that:

12-14.1 Covers and guards are in place, unless the motor is started for observations requiring their absence.

12-14.2 No one is working on the motor or on the driven unit, if applicable.

WARNING

Running some types of equipment in the wrong direction may injure personnel or damage the motor.

12-14.3 The motor is connected for the proper direction of rotation.

12-14.4 The motor and driven unit are properly aligned.

12-14.5 Ship's force personnel responsible for the driven unit are standing by with the system properly aligned if applicable.

NOTE

Submarine motors shall not be connected to the driven load until after a satisfactory no-load test is completed.

12-14.6 Ship's force personnel have conducted all tag-in procedures.

12-14.7 Controller line leads are tested with a voltmeter to ensure that supply voltage is of the proper value and with no excessive unbalanced condition between phases.

NOTE

Proper voltage for a 440 volt ac installation should be 440 volts ± 22 volts (5 percent) with phase unbalance less than 13.2 volts (3 percent).

12-14.8 Cause of voltage supply malfunction has been found and eliminated before test run is conducted.

12-14.9 Appropriate range thermometers have been attached to the bearing housings.

12-15. MOTOR STARTING AND TESTING.

12-16.

Use the following procedure when starting and testing a motor:

CAUTION

Read the operating instructions carefully before starting a motor. Failure to understand the instructions may result in unnecessary delay in recognizing abnormal operation. It may also lead to permanent damage to the equipment.

a. Have ship's force personnel start the motor according to instructions in the manufacturers technical manual or those posted in the controller. Stop the motor immediately and investigate if any unusual noise, vibration, speed, or rise in temperature develops or direction of rotation is incorrect.

b. Conduct a 30-minute test run if conditions appear satisfactory.

c. Check bearing temperatures frequently. Temperatures must not exceed 180°F (68°C).

d. Check frequently to ensure that operation is quiet and vibration free.

e. Measure phase currents using a clamp-on ammeter (see paragraph 2-25).

NOTE

The current in any phase, at rated load, shall not differ from the arithmetic average of the maximum and minimum phase current by more than 10 percent for 1-1/2-horsepower (hp) motors or less; by more than 7-1/2 percent for 2- and 3-hp motors; and by more than 5 percent for motors over 3 hp. For submarine motors, at no load, the maximum deviation of any phase shall not exceed 3 percent of the average no-load current.

f. Motors that operate properly within all parameters during the test run will be considered satisfactorily repaired and installed and placed back in commission.

APPENDIX A

SUPPORT DOCUMENTATION AND SOURCES

NOTE

The documents listed in this appendix can be obtained by the command's technical librarian by using NAVSEA S8800-00-GIP-000, *NAVSEA Guidance Handbook for Intermediate Maintenance Activity Technical Library Personnel.* Always ensure that the latest edition of a document, with all changes or amendments, is being used. Be aware that many of these documents may be online or on cd-rom and that these products may no longer be available in microform.

A-1. ALLOWANCE EQUIPAGE LIST (AEL).

Listings by specific categories of allowance items of a durable nature which must be on board for the ship to perform its mission. It includes noninstalled equipage, tools, and special and common support and test equipment.

A-2. ALLOWANCE PARTS LIST (APL).

Supply document listing all the parts/data of an individual equipment or component necessary to maintain that equipment or component in operational condition.

A-3. ALTERATION.

Any change in the hull, machinery, equipment, or fittings which involves a change in design, material, number, location, or relationship of the component parts of an assembly, regardless of whether it is undertaken separately from, incident to, or in conjunction with repairs. Changes to hull configuration and permanent fittings as a result of changes in machinery, equipage, supplies, or complement are alterations.

A-4. BASIC ALTERATION CLASS DRAWINGS (BACD).

Working drawings prepared by Planning and Overhaul yards or Design Agents for installation of a specific alteration. A BACD is applicable for installation work to the first ship of a class to receive the applicable alteration and is generally applicable to all ships in that class.

A-5. BOOKLET OF GENERAL PLANS.

Normally provided to a ship at the termination of an availability period. It is a corrected copy of original drawings, showing alterations accomplished and the actual current status of, or conditions existing aboard ship. The booklet is kept by the ship being serviced.

A-6. BUREAU OF SHIPS CONSOLIDATED INDEX OF DRAWINGS, MATERIAL AND SERVICE RELATED TO CONSTRUCTION AND CONVERSION (BSCI).

Identifies drawing classification groups based on the functional segment of a ship as represented by a ship structure, systems, machinery, outfitting, etc. Groups are classified by a system of numeric groupings, or three-digit codes that prefix the seven-digit NAVSHIPS drawing numbers. An additional section lists alphabetically the noun names for a cross-reference to old BUSHIPS ″S″, groups. The listing is being superseded by the Ships Work Breakdown Structure (SWBS), limited to new ship construction at this time. (See also entry on Ships Work Breakdown Structure.)

A-7. COMPONENT IDENTIFICATION NUMBER (CID).

Identification number assigned to an equipment by the Ship Parts Control Center (SPCC). Also called the APL number.

A-8. COMPOSITE PUBLICATIONS APPLICABILITY LIST (COMPOSITE PAL).

Takes into consideration a class of ships or two or more individual ships and provides a listing of technical manuals (TMs) available to support the operation, testing, and maintenance of onboard systems, subsystems, and equipment under the technical cognizance of NAVSEA and SPAWAR (formerly NAVELEX). In addition, the Composite PAL provides a listing of the individual ships for which the equipment and documents are applicable, thereby indicating ships' equipment commonalities.

A-9. CONSTRUCTION DRAWINGS.

An engineering drawing that illustrates the design of buildings, structures, and related construction, afloat or ashore, individually or in groups; and which includes pertinent services, equipment, utilities, and any other engineering features, as required, to establish all the interrelated elements of the design. Construction drawings, in general, present design information by pictorial plans, elevations, sections, and details.

A-10. COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL).

Document prepared for an individual ship or shore activity (when it is termed a Coordinated Shore Base Allowance List, or COSBAL) which lists the equipment or components required for the ship or shore activity to perform its operational assignment; the repair parts and special tools required for the operation, overhaul, and repair of these equipments; and the miscellaneous portable items necessary for the care and upkeep of the ship or shore activity itself. The COSAL is both a technical and supply document. It is technical in that nomenclature, operating characteristics, TMs, etc., are described on APLs or AELs. It is supply in that the COSAL will provide a complete list of all parts required to operate and maintain the ship or shore activity and the equipment installed therein.

A-11. CROSS REFERENCE INDEX (CRI) OF MANUFACTURERS (VENDORS) EQUIPMENT DRAWINGS.

Relates contractor drawing numbers to an appropriate 35-mm film or reel and frame number from a microfiche index. Drawings may then be reproduced in hard copy form. The index is arranged in alphanumeric sequence listing by:

A-11.1 Vendor drawing number,

A-11.2 35-mm reel and frame numbers,

A-11.3 Aperture card reference, if applicable.

A-12. DEPARTMENT OF DEFENSE INDEX OF SPECIFICATIONS AND STANDARDS (DODISS).

Published under authority of the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics) and issued with supplements effective 1 September, 1 November, 1 January, 1 March, and 1 May. The use of this index is mandatory for all military activities. This mandatory provision requires that federal and military specifications, standards, and related standardization documents be considered in identifying items for procurement actions. Since specifications, standards, and related standardization documents are subject to change, such documents should be reviewed for applicability prior to procurement use. A cumulative alphabetic listing of specifications, standards, and related standardization documents, listed by Federal Supply Classification (FSC) Class, is also available from the Naval Publications and Forms Center. The DODISS is comprised of two separate parts: Part I, which is an alphabetic listing, and Part II, which is a numeric listing. Part II also contains:

A-12.1 Appendix. A cumulative listing of canceled documents, published three times a year. This cumulative listing of canceled documents is kept current by adding a cumulative cancellation listing of DODISS Part II Supplement and subsequent canceled listing appearing in the basic DODISS, Part II.

A-12.2 **Part II, Section ″A″** is a cumulative listing of documents, arranged numerically by document number. Section ″A″ includes the additions and changes to standardization documents listed in Section ″B.″

A-12.3 **Part II, Section ″B″** is a ready reference listing of changes, additions, and cancellations to standardization documents since the previous bimonthly supplement.

A-13. EQUIPAGE.

Specific categories of allowance items of a durable nature, which must be on board for the ship to perform its mission. It includes noninstalled equipage, tools, and special and common support and test equipment (see AEL, paragraph A-1).

A-14. JOINT FLEET MAINTENANCE MANUAL (JFMM).

The JFMM is a standardized basic set of minimum requirements to be used by all type commanders and subordinate commands as a single, unified source of maintenance requirements across all platforms: surface ships, aircraft carriers, and submarines.

A-14.1 It contains clear, concise, technical instructions to ensure that maintenance is planned, executed, completed and documented within all fleet commands. It provides for implementation of regional maintenance policies across all platforms and delivers a comprehensive set of process descriptions fur use by the Navy training community. The manual has been in effect since January 1, 1997 and replaces all other maintenance and quality assurance documents. The JFMM is maintained by the Submarine Maintenance Engineering, Planning, and Procurement (SUBMEPP) activity and all recommendations and changes should be submitted to it.

NOTE

Since Part III of Volume 5 is classified, it may not be readily available at all commands.

A-14.2 The manual is a five-volume set. The volume titles are listed below.

A-14.2.1 Volume I, New Construction,

A-14.2.2 Volume II, Integrated Fleet Maintenance,

A-14.2.3 Volume III, Deployed Maintenance,

A-14.2.4 Volume IV, Tests, Inspections, and Special Application Maintenance Programs, and

A-14.2.5 Volume V, Quality Maintenance (formerly Quality Assurance).

A-15. MULTISHEET DRAWING.

Consists of two or more sheets applicable to the same item. A multisheet drawing is not a type of drawing in the sense of a detail or assembly drawing; rather, the term describes the use of several sheets in presenting all information applicable to a single drawing of any one of several types, as opposed to the use of a single roll or flat sheet. Each sheet of a multisheet drawing must be identified by the same drawing number and a different sheet number.

A-16. NAVAL STOCK LIST OF PUBLICATIONS AND FORMS (NAVSUP PUBLICATION 2002).

Listing of all forms and publications stocked at the Naval Publications and Forms Center. It is the authority used in requisitioning material. It is divided into 15 main sections based on data types and is updated quarterly.

A-17. NAVCOMPTMAN V-2 (CHAPTER 5 (UIC)).

Listing of Unit Identification Codes (UICs) related to Navy ships, shore stations, and other unit activities. It is combined with other elements to form organizational identifiers. UICs are required for use with accounting data, Military Standard Requisitioning and Issue Procedures (MILSTRIP) usage, and contractor activities.

A-18. NAVAL SHIPS TECHNICAL MANUAL (NSTM).

Contains a comprehensive set of instructions for the operation, inspection, and maintenance of a class of equipment, and other data common to a majority of installations. Each chapter covers a specific subject and is complete in itself. Included are approximately 100 different subjects, ranging from boilers and pumps to flags and bunting.

A-19. PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS (PERA).

An engineering management organization whose mission is to act as NAVSEA's principal management agent in providing integrated planning and engineering for overhauls of its assigned ship types. Responsibilities include integrating the requirements of various Systems Commands and the Fleet. PERAs manage the planning and engineering efforts for designated ship overhauls and pertinent vital interrelated programs.

A-20. PLANNING YARD.

The Naval Shipyard or other activity designated by NAVSEA to perform the following tasks pertaining to specifically assigned ships:

A-20.1 Providing or coordinating the provision of technical and other services in design matters.

A-20.2 Preparation and availability of complete up-to-date files of BACDs, ship selected records (SSR), and working drawings.

A-20.3 Custody and maintenance of all original ship drawings and 35-mm aperture cards (Type I Class I) of drawings.

A-20.4 Providing a central repository, reproduction facility, and distribution services, or coordinating such services, from the original or master copies of working drawings, BACD, and SSR.

A-21. PUBLICATIONS APPLICABILITY LIST (PAL).

Listing of technical manuals (TMs) available to support the operation, testing, and maintenance of onboard systems, subsystems, and equipments under the technical cognizance of NAVSEA and SPAWAR. The PAL is tailored specifically to the ship indicated and is intended to serve as a tool to assist in the inventory determination of shipboard-required TMs. Since the information contained in the PAL is only as good as that provided by reporting technical activities or system users, some omissions and errors may be noted. If discrepancies are detected, marked-up pages with recent changes may be returned to the preparing activity (NSWSES Code 5700) for resolution. A revised PAL reflecting the changes will be provided within 60 days. The PAL consists of four volumes:

A-21.1 **Volume I (General)** provides a convenient listing of all nonsystem or equipment-related technical manuals (e.g., Ship Information Books, Damage Control Books, Communications Handbooks, etc.) for electronics; hull, mechanical, and electrical; and ordnance.

A-21.2 **Volume II (Electronic and Electronic Test Equipment)** contains data relating to electronic and electronic test equipment. The equipment sequence section permits checking by system and/or equipment designator (e.g., Radar Set AN/SPS-4), and provides a list of the available TMs for the system and/or equipment. A document sequence section is also included to provide a total listing of available system and equipment TMs. Equipment listed in this volume was obtained form the Ship Equipment Configuration Accounting System (SECAS I). Reported equipment discrepancies will be resolved by NAVSEA with SECAS.

A-21.3 **Volume III (Hull, Mechanical, and Electrical)** contains two sequences as described in II above. Similarly, in the equipment sequence section, a check can be made by system or equipment designator (e.g., Dishwasher Model 250 DA) to identify a list of the available TMs. Here again, the document sequence section provides a total listing of available system and equipment TMs. Equipment listed in this volume was obtained from records maintained by the Ship Technical Data Management Information System (STEDMIS) pending the implementation of SECAS III for hull, mechanical, and electrical systems and equipment.

A-21.4 **Volume IV (Ordnance)** contains the data listed in the former Publication Requirement List of TMs (Ordnance Pamphlets, Ordnance Data, Field Manuals, TMs, and Ordnance Supply Office Illustrated Parts Breakdown) required to support the operation and maintenance of onboard ordnance systems, equipments, and related items.

A-22. SELECTED RECORD DRAWINGS.

Important basic technical information and related data relative to certain shipboard arrangements, equipment, and systems under NAVSEA cognizance. It is selected for its value as a reference for consulting purposes, and for the Ship Operating Forces, Planning Yards, Overhaul Yards, and other concerned activities. The Ship Life Cycle Management Support Manual gives a listing of the types of data to be included.

A-23. SHIP WORK BREAKDOWN STRUCTURE (SWBS) (NAVSEA 0900-LP-039-9010).

Single language which can be used through the entire ship life cycle from early design through production and subsequent layup. The objective of SWBS is to combine into a single system the function formerly served by the following numbering systems:

A-23.1 Bureau of Ships Consolidated Index of Drawings (BSCI). This three-digit numeric system had been used for cost and weight estimating and reporting, progress reporting for new construction and conversion ships, and drawing numbering. This was the basic numbering system used by Naval Shipyards for work scheduling and control of ship availabilities. (See also entry on Bureau of Ships Consolidated Index of Drawings, paragraph A-6.)

A-23.2 Ship Design and Material, Group 9000 series, of the Navy Subject Identification Codes (SSIC). This four-digit numeric system was used for correspondence and filing technical document numbering sections of Ship Specifications. It was based on the former BUSHIPS ″S″ group system by changing the ″S″ to a ″9.″

A-24. SHIP CONSTRUCTION DRAWINGS (SCD).

Original drawings used for ship construction; they originate with the Planning Yard. Portions of these drawings may be maintained by an individual ship as Selected Record Drawings pertaining to specific installations. They are available in aperture card form.

A-25. SHIP DRAWING INDEX (SDI).

List of ship drawings and related design reference information which shows the actual current configuration of the ship. SDIs are required by the General Specifications for Shipbuilding for all ships over 200 feet in length. The original SDI is prepared by the shipbuilder in accordance with the Detailed Ship Specification as approved by the Supervisor of Shipbuilding (SUPSHIP).

After acceptance of the ship by the Navy, the SDI is forwarded to the selected Planning Yard which is assigned as custodian of the index. Corrections to the SDI are made by the Overhaul Yard to reflect work performed during yard periods and tender overhaul. Original SDIs are to be corrected by the Planning Yard to reflect changes reported by the ship or other activity when changes are made between regular overhauls. Information provided by the SDI includes:

A-25.1 Drawing title,

A-25.2 NAVSEA drawing number and revision, and

A-25.3 Builder's or contractor's drawing numbers of hull machinery, electrical, and electronic drawings applicable to the individual ships.

A-26. SHIP INFORMATION BOOKS (SIBs).

Part of the Selected Record Data required aboard ships. They are updated during availability periods and are in the custody of the ships being serviced. SIBs normally comprise a seven-volume set, broken down into specific systems and subsystems.

A-27. SHIP'S SYSTEM MANUALS (SSM).

Similar to SIBs, but with expanded technical information. SSMs are used on all submarines and certain surface ships in lieu of SIBs.

A-28. TECHNICAL MANUALS.

Publications and other forms of documentation containing a description of ships, boats, amphibious vehicles, systems, or equipment, with instructions for effective use, including one or more of the following sections as required: instructions covering initial preparation and installation; operating instructions; maintenance instructions; overhaul instructions; parts listing; and related technical information or procedures exclusive of those procedures of an administrative or tactical nature.

A-29. TECHNICAL REPAIR STANDARD (TRS).

Establishes requirements for the overhaul or refurbishment of a system, equipment, or component. It specifies in detail the inspections, measurements, tolerances, material, work, tests, and quality assurance operations required to restore the item to a condition that will ensure its satisfactory service for a limited period of time, during which only routine maintenance will be required.

A-30. VENDOR DRAWINGS (HULL, MECHANICAL AND ELECTRICAL).

Prepared by the manufacturer or contractor at the time of construction or original installation of equipment. In many instances, these drawings are not of sufficient detail and may not be currently updated. Drawings may be obtained for hull, mechanical, and electrical requirements. Sufficient lead time should be allowed for procurement.

A-31. VENDOR CROSS-REFERENCE INDEX (VCRI).

An index published by the Portsmouth Naval Shipyard which cross reference the drawing number of hull, mechanical, and electrical drawings to a reel and frame number for vendor drawings previous to 1965. It also indicates that a newer drawing is available on aperture cards.

APPENDIX B

SPECIFIC REFERENCES

NOTE

Ensure that the latest edition of a document is available, including any changes.

B-1. NAVY PUBLICATIONS

CINCLANTFLT/CINCPACFLTINST 4790.3	*Joint Fleet Maintenance Manual*
NAVEDTRA 10101	*Boatswain's Mate, Volume 1*
NAVSEA S8800-00-GIP-000	*NAVSEA Guidance Handbook for Intermediate Maintenance Activity Technical Library Personnel*
NAVSEA S9086-HN-STM-010/CH 244	*Naval Ships' Technical Manual*, "Bearings and Seals"
NAVSEA S9086-HT-STM-010/CH 262	*Naval Ships' Technical Manual*, "Lubricating Oils, Greases, Hydraulic Fluids, and Lubricating Systems"
NAVSEA S9086-KC-STM-010/CH 300	*Naval Ships' Technical Manual*, "Electric Plant, General"
NAVSEA S9086-KE-STM-010/CH 302	*Naval Ships' Technical Manual*, "Electric Motors and Controllers"
NAVSEA S9086-UU-STM-010/CH 613	*Naval Ships' Technical Manual*, "Rope and Rigging"
NAVSEA S9810-AA-GTP-101/IMA	*Naval Ships' Intermediate Maintenance Activity (IMA) Workcenter Requirements Manual*
OPNAVINST 3120.32	*Standard Organization and Regulations of the U.S. Navy*
OPNAVINST 4790.4C	*Ships' Maintenance Material Management (3M) Manual*

B-2. SPECIFICATIONS

DOD-STD-2182	*Engineering Chromium Plating (Electrodeposited) for Repair of Shafting (Metric)*
FF-B-171	*Bearings, Ball, Annular (General Purpose)*
J-W-1177	*Wire, Magnet, Electrical*
MIL-STD-102	*Anti-Friction Bearing Identification Code*
MIL-STD-2197	*Brush Electroplating on Marine Machinery*
MIL-B-17931	*Bearings, Ball, Annular, for Quiet Operation*
MIL-C-16173	*Corrosion Preventive Compound, Solvent Cutback, Cold-application*
MIL-D-12182	*Powdered Saltwater Soap*
MIL-D-16791	*Non-Ionic Detergent*
MIL-I-631	*Insulation, Electrical, Synthetic-resin Composition, Nonrigid*
MIL-I-695	*Insulation, Electrical, Paper (Slot Cell)*
MIL-I-3190B	*Insulation Sleeving, Electrical, Flexible, Treated*
MIL-I-003190C	*Insulation Sleeving, Electrical, Flexible, Coated, General Specification for*
MIL-I-3505	*Insulation Sheet and Tape, Electrical, Coil and Slot, High Temperature*
MIL-I-21070	*Insulation Sheet and Tape, Electrical, Reinforced Mica Paper*
MIL-I-21557	*Insulation Sleeving, Electrical, Flexible, Glass Fiber, Vinyl Treated*

MIL-I-22834	*Insulation, Electrical, Dielectric, Barrier, Laminated, Plastic Film and Synthetic Fiber Mat*
MIL-I-24092	*Insulating Varnish, Electrical, Impregnating, Solvent Containing*
MIL-L-24204	*Insulation, Electrical, High Temperature, Bonded, Synthetic Fiber Paper*
MIL-L-43435	*Tape, Lacing and Tying*
MIL-L-HDBK-203	*Manufacturers' Symbols and Designations for Anti-Friction Bearings*
MIL-P-997	*Plastic Material, Laminated, Thermosetting, Electric Insulation, Sheets, Glass Cloth, Silicone Resin.*
MIL-P-15037	*Plastic Sheet, Laminated, Thermosetting, Glass-cloth, Melamine-resin*
MIL-T-713	*Twine, Fibrous, Impregnated, Lacing and Tying*
MIL-T-15126	*Insulation Tape, Electrical, Pressure Sensitive Adhesive and Pressure Sensitive Thermosetting Adhesive*
MIL-T-19166	*Insulation Tape, Electrical, High-temperature, Glass Fiber, Pressure-sensitive*
MIL-W-16878	*Wire, Electrical Insulated, High Temperature (Navy)*
MIL-Y-1140	*Yarn, Cord, Sleeving, Cloth, and Tape-Glass*
P-D-220	*Detergent, General Purpose*
P-D-680	*Dry Cleaning Solvent*

B-3. LUBRICATING OILS AND BEARING GREASE

DOD-G-24508	*Grease, High Performance, Multipurpose*
MIL-G-24139	*Grease, Multipurpose, Water Resistant*
MIL-G-81322	*Grease, Aircraft, General Purpose, Wide Temperature Range*
MIL-L-15719	*Lubricating Grease, High Temperature, Electric Motor, Ball and Roller Bearings*
MIL-L-17331	*Lubricating Oil, Steam Turbine and Gear, Moderate Service, Military Symbol 2190 TEP*

APPENDIX C

MOTOR WINDING CHECKLIST

C-1. SCOPE.

This appendix is a checklist for use when rewinding motors.

C-2 **BEFORE WINDING.** Check to ensure that:	
	C-2.1 The stator core is clean, and that burrs are removed from slots and other areas.
	C-2.2 Correct materials are available, such as magnet wire; ground, phase, and wedge insulation; coil separators; tie cord; lead wire; sleeving; and varnish.
	C-2.3 The coils are correctly made.
	C-2.4 The coil dimensions shown in the applicable drawing are correct.
	C-2.5 The magnet wire enamel on coils has no nicks or abrasions; discard damaged coils.
C-3 **DURING WINDING.** Check to ensure that:	
	C-3.1 The proper coil span is used.
	C-3.2 The slot cell extension beyond the core is at least 3/8 inch on each side.
	C-3.3 Slot wedges are not forced into place and insulation is not damaged in the process.
	C-3.4 Slot wedges are not cocked or loose, and that they securely hold the windings.
	C-3.5 The coil ends are cleaned and tinned before soldering.
	C-3.6 The lead wire has the same current capacity as the original.
	C-3.7 End turns and connections on both ends are back clear of the line from the stator bore so that they will not interfere with installation of the rotor, and that there is no interference with end bells or air shields.
	C-3.8 The leads are properly marked and mechanically secure to prevent movement.
	C-3.9 All connections are solidly made and are of good quality.
	C-3.10 All connections are properly insulated.
	C-3.11 Tags on leads do not cut through insulation.
	C-3.12 Coil separators extend 1/4 inch beyond the slot cell to allow phase insulation to lap it.
	C-3.13 Coil separators extend the full width of the slot so that coils are separated.
	C-3.14 The phase insulation is located properly between phase groups. It must extend to the slot cell and lap either above or below the coil separator.
C-4 **AFTER WINDING AND BEFORE VARNISHING.**	
C-4.1 Observe the following guidelines:	
	a. Measure the winding resistance (paragraph 2-15) from phase to phase. Record.
	b. Measure the insulation resistance (paragraph 2-4 or paragraph 2-8) from windings to ground. Record.
	c. Conduct a dc high-potential test on the winding (paragraph 2-23 or paragraph 2-45).
	d. Ensure that the leads are properly marked.
	e. Test the winding with a surge comparison tester (paragraph 2-19).
	f. Check for reversed coil or phase, and for shorted turns or phases.
	g. Test the windings for continuity with a low-reading digital ohmmeter (paragraph 2-15).
	h. Check that wires do not overlap the phase insulation.
C-4.2 Ensure that	
	C-4.2.1 The phase insulation extends beyond end turns (approximately 1/8 inch).
	C-4.2.2 Connections are electrically sound and neat.
	C-4.2.3 Wedges are properly positioned and snug.
	C-4.2.4 The phase insulation is fully inserted to meet the slot cell.
	C-4.2.5 The slot cell extends uniformly 3/8 inch past the core.
	C-4.2.6 Tie cords are tight and secured.
	C-4.2.7 The slot cell material is not torn or damaged.
	C-4.2.8 Windings are not damaged.

	C-4.2.9 Poor workmanship (sloppy appearance) is corrected.
	C-4.2.10 Bolts have been inserted in all threaded holes.
C-5	**VARNISH, SOLVENT-CONTAINING.** Check to ensure that
	C-5.1 Viscosity and temperature are correct.
	C-5.2 Do not use varnish which has passed the expiration date in the varnish log tank unless it has been retested.
C-6	**AFTER DIPPING IN VARNISH AND BEFORE BAKING.** Ensure that:
	C-6.1 Windings are clear and smooth, with good bonding and filling.
	C-6.2 Varnish buildup is uniform over the entire winding surface.
	C-6.3 Varnish drippings are not excessive.
	C-6.4 Wedges are properly positioned.
	C-6.5 Varnish is removed from the bore of the stator and machined surfaces.
C-7	**AFTER BAKING.** Ensure that:
	C-7.1 Varnish is not cracked and there are no air bubbles.
	C-7.2 Varnish is not soft or tacky to the touch (improper varnish cure).
	C-7.3 Wires are bonded in place by varnish.
	C-7.4 Windings are not damaged.

APPENDIX D

IDENTIFICATION OF WINDINGS

D-1. SCOPE.

This appendix outlines the characteristics of single-phase and three-phase windings.

D-2. CLASSIFICATION OF AC WINDINGS AND SOME FUNDAMENTAL CONCEPTS.

D-3. COIL GROUP, COIL, TURN, CONDUCTOR, AND STRAND.

Each winding consists of a number of coils arranged in coil groups; each coil group may have one or more single coils. A coil consists of one or more turns connected in series; each turn consists of one or more individual conductors, in parallel, wrapped through 360 physical degrees.

D-4. ONE- AND THREE-PHASE WINDINGS.

AC windings are single-phase or three-phase, corresponding to the number of phases of the power source to which they are connected. In three-phase windings, the slots per pole are divided into two or three parts, one part for each phase. The number of slots per pole is determined by the total number of slots and the number of poles. The number of poles is determined by the number of cycles and the speed.

D-5. CYCLE AND FREQUENCY.

A period is the time necessary for an alternating current to change from one positive maximum to the next following positive maximum. During this time, the alternating current goes through a complete cycle, i.e., it accepts all possible positive as well as negative values. Power lines in the United States carry current at 60 cycles per second (c/s). The number of cycles per second is called *frequency* . Frequency is measured in Hertz (Hz), with 1 Hz = 1 c/s.

D-6. NUMBER OF POLES, SYNCHRONOUS SPEED.

The number of poles is determined by the following rule:

No. of Poles = 120 x Frequency/Speed (in revolutions per minute (r/m))

It follows that:

Speed (in r/m) = 120 x Frequency/No. of Poles

The speed obtained form this equation is called *synchronous speed* . A synchronous generator or motor runs at exactly synchronous speed. The actual speed of the rotor of an induction motor is somewhat below the synchronous speed.

D-7. POLE-PHASE GROUP.

The coils lying in slots that belong to one phase and that are under one pole, i.e., the coils lying in CPG (see paragraph D-8) slots, make a coil group, which is called a pole-phase group. The total number of pole-phase groups is determined by the number of poles and the number of phases. Thus:

No. of Pole-Phase Groups = No. of Poles x No. of Phases and the number of single coils per pole-phase group is equal to the CPG.

D-8. COILS PER POLE PER PHASE.

As already mentioned, the number of coils per pole for three-phase windings is divided into three parts. The number of coils per pole per phase is, therefore, equal to the number of phases or to the total number of coils divided by the number of poles and times the number of phases. The number of coils per pole per phase is an important quantity in the layout of ac windings. The symbol CPG will be used for this quantity. Thus:

CPG = Total No. of Slots/(No. of Poles) x (No. of Phases)

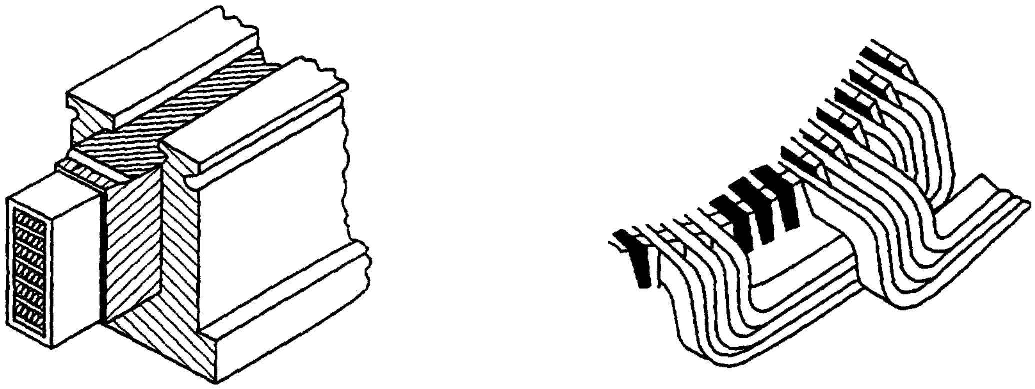
D-9. COIL PITCH.

The coil pitch, or span, is equal to the number of slots separating the sides of a coil, including the slots in which the winding lies.

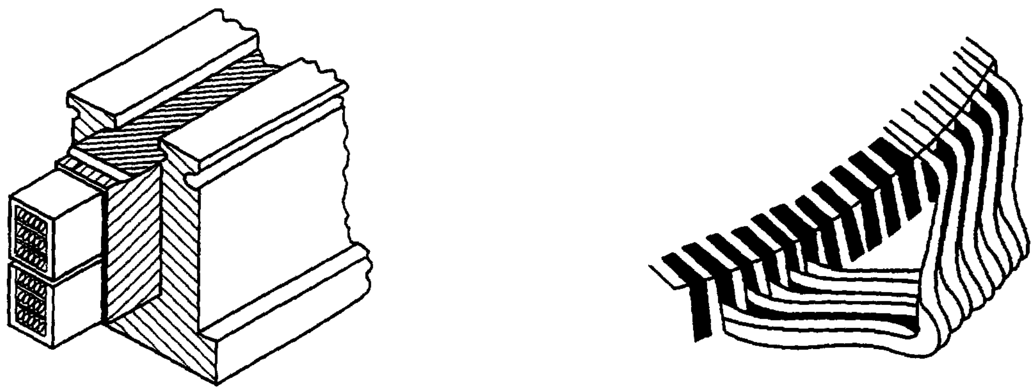
D-10. CLASSIFICATION OF AC WINDINGS.

AC windings may also be classified in several other ways:

D-10.1 Single-layer or two-layer windings (figure D-1).



SINGLE-LAYER WINDING



TWO-LAYER WINDING

Figure D-1 Single- and Two-Layer Windings

D-10.2 Semi-closed slot or open slot (figure D-2).

D-10.3 Chain or distributed (figure D-3).

D-10.4 Single phase or polyphase.

D-10.5 Round or rectangular wire section.

D-10.6 Lap or wave.

D-10.7 Star or delta.

D-10.8 Full-pitch or fractional-pitch (figure D-4).

D-10.9 Integral-slot or fractional-slot.

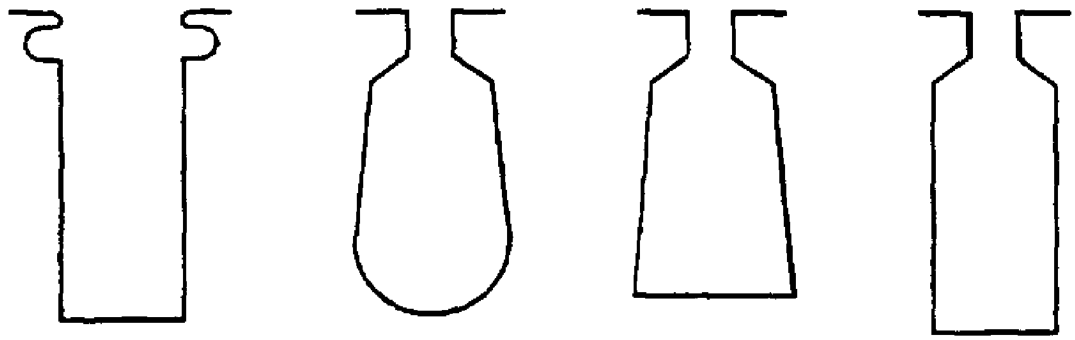


Figure D-2 Semi-Closed and Open Stator and Rotor Slots

D-11. POLYPHASE AND SYNCHRONOUS WINDINGS.

Polyphase motors usually have two-layer windings. The two coil sides of each coil lie in different planes. The smaller motors (up to a bore diameter of approximately 16 inches) have semi-closed slots with coils of round wire fed into the slots through the slot openings. The coils are usually round-end or flat-diamond. The larger motors have either round wire or rectangular wire. Normally, lap windings are used in polyphase stators. In polyphase motors the coils have equal spans. Most polyphase induction motors have integral-slot windings. In this case, all pole-phase groups of the winding have an equal number of single coils. The statements made above about the windings of polyphase motors apply also to the stator windings of synchronous motors and generators. However, synchronous motors and generators with a large number of poles usually have fractional-slot windings, i.e., the number of slots per pole per phase, CPG, is a fractional number. In this case, the number of single coils is not the same for all pole-phase groups of the windings. This is called unequal grouping.

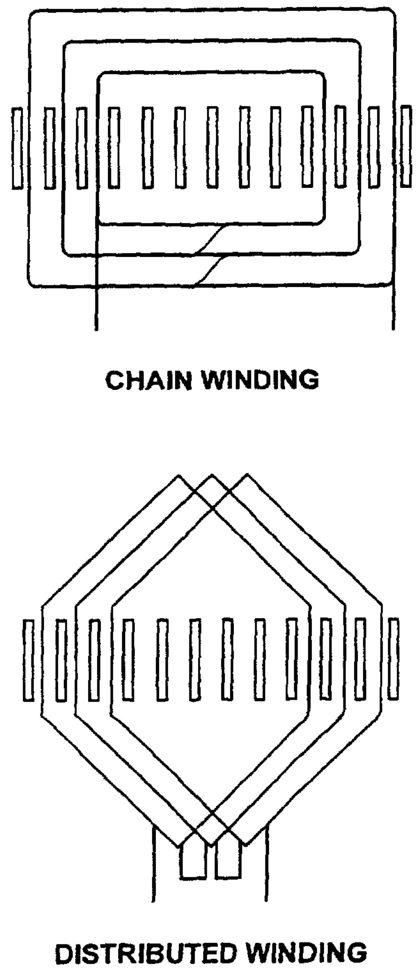


Figure D-3 Chain and Distributed Windings

D-12. INSULATION OF THE WIRE AND THE SLOTS OF THE STATOR.

Single cotton-covered enamel wire, as well as plain enamel wire, is used for the wire insulation of small single-phase motors. Where the space permits, single cotton-covered enamel wire is preferred.

D-13. LOCATION OF THE BEGINNINGS OF THE PHASES.

The beginnings of the phases lie one pole-phase group apart. They are either the starts or the finishes of two consecutive pole-phase groups. Since there are three pole-phase groups per pole, the beginnings of the phases lie in slots which are half a pole-pitch apart. The ends of the phases also lie half a pole-pitch apart. This rule is applicable for a series as well as for any kind of parallel connection.

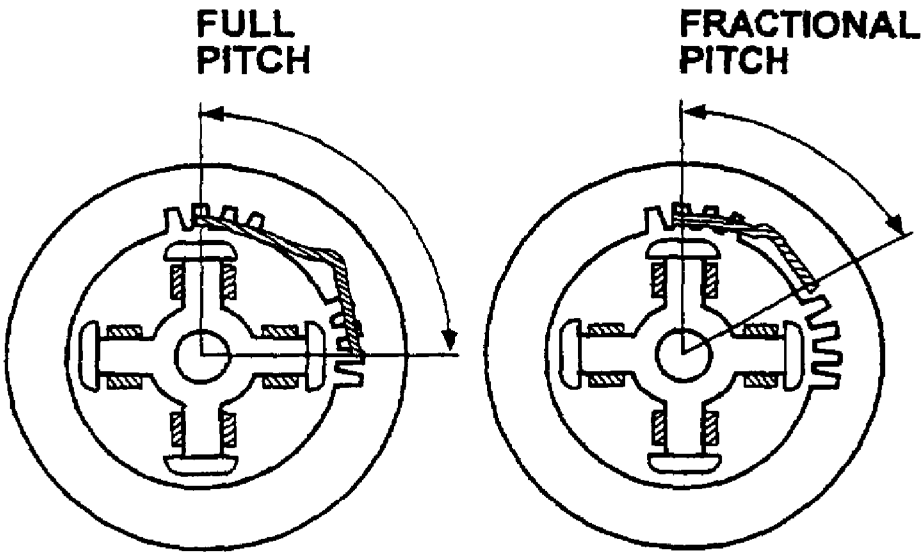


Figure D-4 Full-Pitch and Fractional Pitch Windings

D-14. DUAL-VOLTAGE CONNECTIONS.

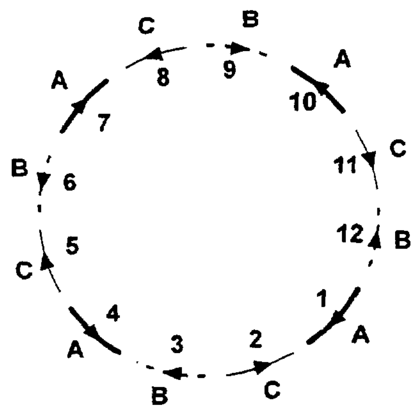
Small motors, up to approximately 15 hp, are usually designed by the manufacturer so that they may be used for two or more different voltages. For example, a winding may be laid out to have a series connection for 220 volts and a two-parallel connection for 110 volts; or a series connection for 440 volts and a four-parallel connection for 110 volts. The change from one voltage to the other is simplified when extra leads are brought out. All dual-voltage windings must have nine leads per winding.

D-15. LAYOUT OF THREE-PHASE WINDINGS.

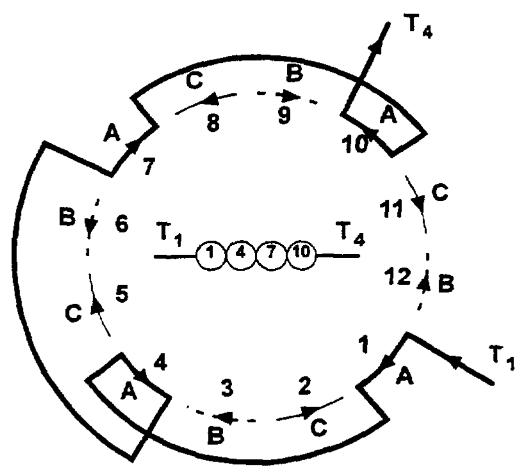
The slots belonging to one pole of a three-phase winding are divided into three parts corresponding to the number of phases; there are three pole-phase groups per pole. Two consecutive groups belonging to the same phase are two pole-phase groups apart. The number of pole-phase groups can be determined using the following equation:

No. of Pole-Phase Groups = No. of Poles x No. of Phases

Thus, in the case of a four-pole winding, the number of pole-phase groups is equal to 4 x 3 = 12. Figure D-5 shows the 12 groups. They, are numbered clockwise. Groups 1,4,7, and 10 belong to phase A; groups 2, 5, 8, and 11, to phase C; and groups 3, 6, 9, and 12, to phase B. The groups belonging to phase A are shown as heavy line, the groups belonging to phase B as dotted lines, and the groups belonging to phase C as light solid lines. Since two consecutive pole-phase groups of the same phase lie under poles of different polarity, the arrows assigned to them must have different directions. Therefore, the arrow of group 4 is opposite to the arrow of group 1, the arrow of group 7 opposite that of group 4, etc. As for the two-phase winding, the series connection of two consecutive pole-phase groups of the same phase may be accomplished by connecting either their finishes or their starts together, while for the parallel connection of these same two consecutive pole-phase groups, the start of one pole-phase group must be connected with the finish of the other pole-phase group.



(A) ARRANGEMENT OF POLE-PHASE GROUPS



(B) SERIES CONNECTION OF PHASE

Figure D-5 Three-Phase, Four-Pole Winding

D-16. CHECKING CONNECTIONS OF A THREE-PHASE WINDING.

D-17.

This and succeeding paragraphs can be used as a guide in checking the connections of a three-phase winding. Figure D-6 shows all three phases of the four-pole windings. In order to check whether the connection diagram is correct or not, assume current to flow into each one of the three leads, T_1, T_2, and T_3. Trace each phase separately through all its groups and mark on each group, by an arrow, the direction in which the pencil traced through the particular group. The connection diagram is correct if no two adjacent arrows point in the same direction, ie., if the direction alternates with each pole-phase group. This check is based upon the fact that, if direct current flows into the three phases of a properly connected winding, a compass held against the consecutive pole-phase groups will show reversed polarity for the successive groups. That direct current can be used in order to check a winding already inserted into the slots. Figure D-7 shows a wye connection and figure D-8 shows a delta connection.

D-18. WYE (″Y″) (STAR) AND DELTA CONNECTION.

The three phases of a three-phase winding can be connected in two different ways. The ends of the three phases T_4, T_5, and T_6 can be connected at a common point called the ″neutral point,″ leaving the phase beginnings as leads. This kind of connection is the wye or star connection (figure D-7). Instead of connecting the ends of the phases to the neutral, the beginnings of phases T_1 , T_2 , and T_3 can be connected together leaving the ends T_4 , T_5 , and T_6 as leads. Thus, the wye connection for the three phases is obtained, when either the beginnings or the ends of the three phases are connected together and the three phases is obtained, when either the beginnings or the ends of the three phases are connected together and the three unconnected wires are used as leads. Figure D-8 shows schematically the delta connection of the three phases. Here the end of phase A (T_4) is connected with the beginning of phase B (T_2); and the end of phase B (T_5) is connected with the beginnings of phase C (T_3). The leads are connected to the corners of the triangle. The delta connection can also be obtained if the end of phase A (T_4) is connected with the beginning of phase C (T_3); the end of phase C (T_6) is connected with the beginning of phase B (T_2); and the end of phase B (T_5) with the beginning of phase A (T_1).

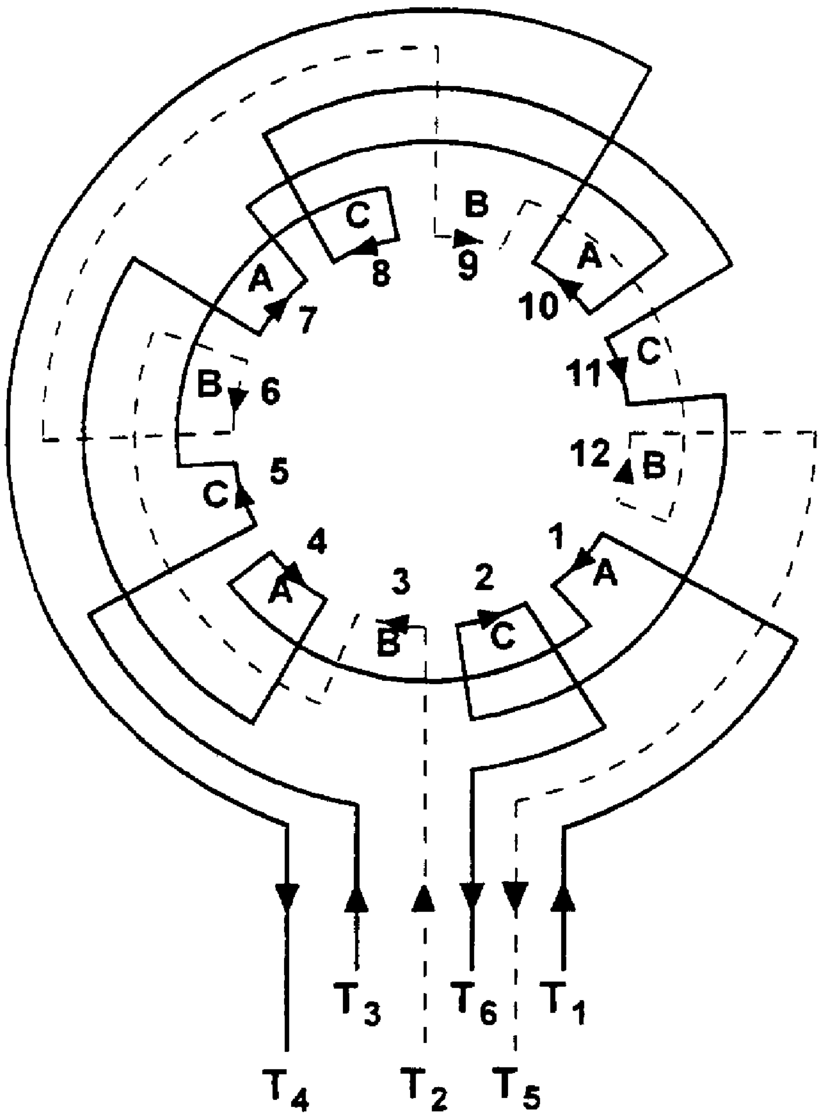


Figure D-6 Three-Phase Winding

D-19. DUAL-VOLTAGE CONNECTIONS.

Small motors are usually designed by the manufacturer to be used for different voltages; for example, for 110 and 220 volts, or for 220 and 440 volts. In this case, a series connection is used for the higher voltage, and a parallel connection for the lower voltage. The change from one voltage to the other is simplified when extra leads are brought out.

D-20. DUAL-SPEED CONNECTIONS.

When a motor must run with two or more different speeds while connected to a source of power of constant frequency, a special winding or several stator windings must be used to permit a change in the number of poles. When two synchronous speeds with the ratio 2:1 are desired, the number of poles must have the ratio of 1:2. A consequent-pole winding will have this ratio. For higher speeds, the winding must be a lap winding connected top-to-bottom by long jumpers. The N-poles and S-poles are separately connected together, making two windings per phase. The coil pitch must be as close as possible to half of the pole pitch.

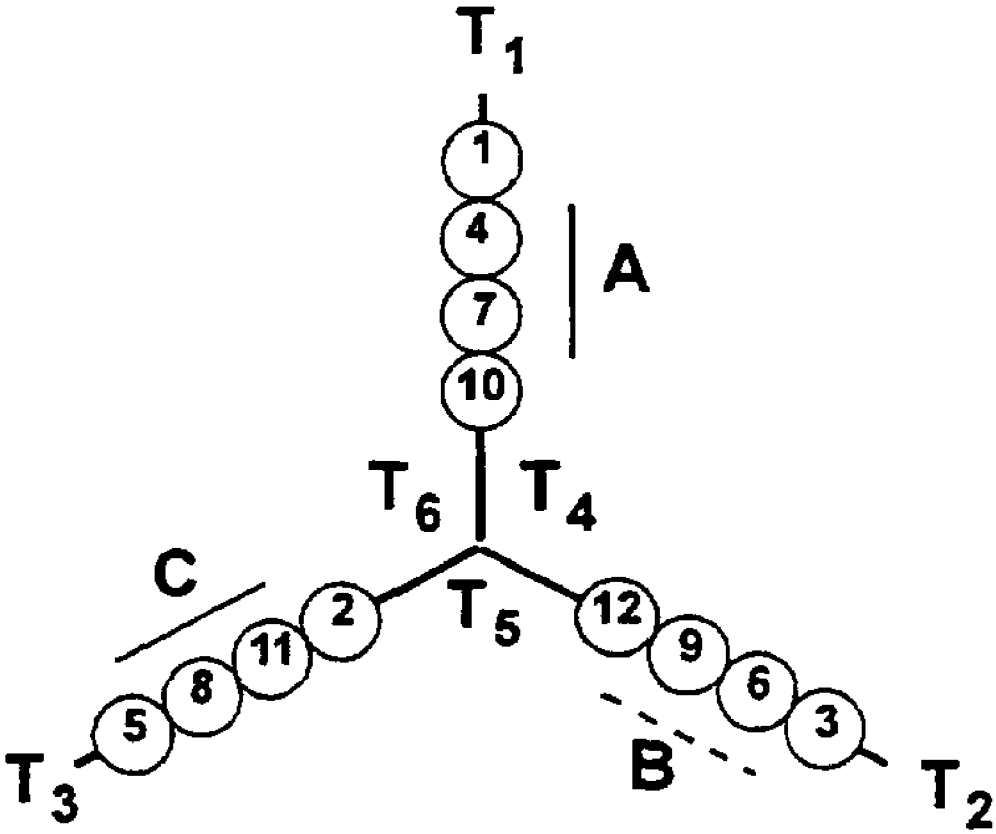


Figure D-7 Wye Connection

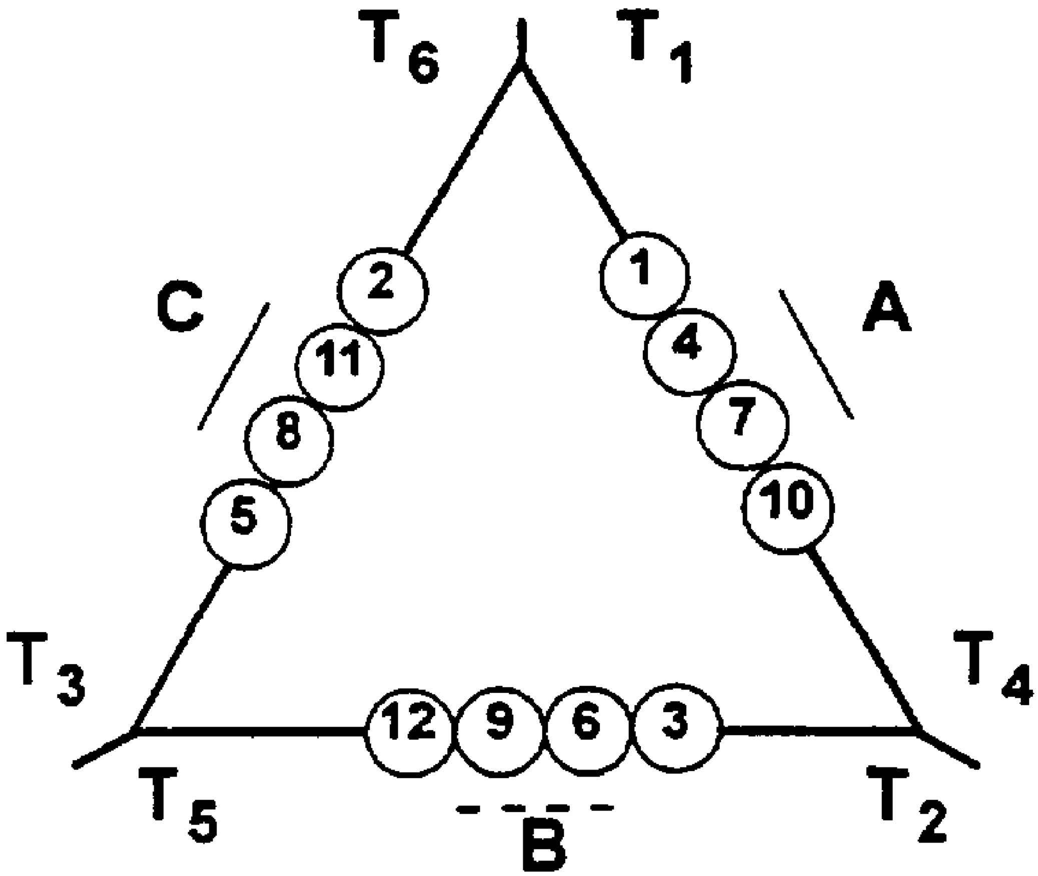


Figure D-8 Delta Connection

D-21. TABULAR TYPES.

A connection diagram for the four-pole, three-phase, series wye connection is shown in figure D-9; for the four-pole, three-phase, two parallel wye connection in figure D-10; for the four-pole, three-phase, series delta connection in figure D-11; and for the four-pole, three-phase, two-parallel delta connection in figure D-12.

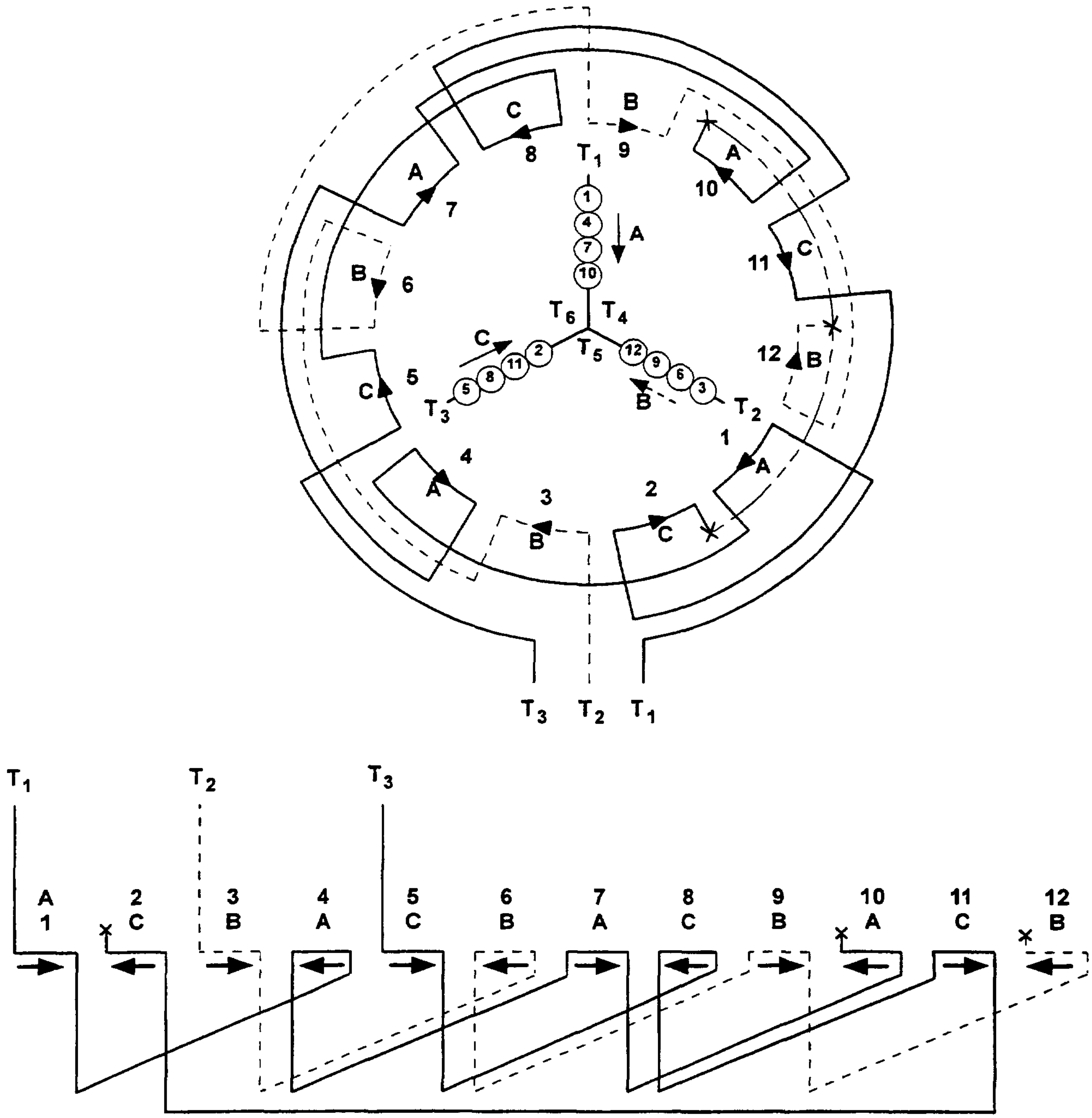


Figure D-9 Four-Pole, Three-Phase, Series Wye Connection Diagram

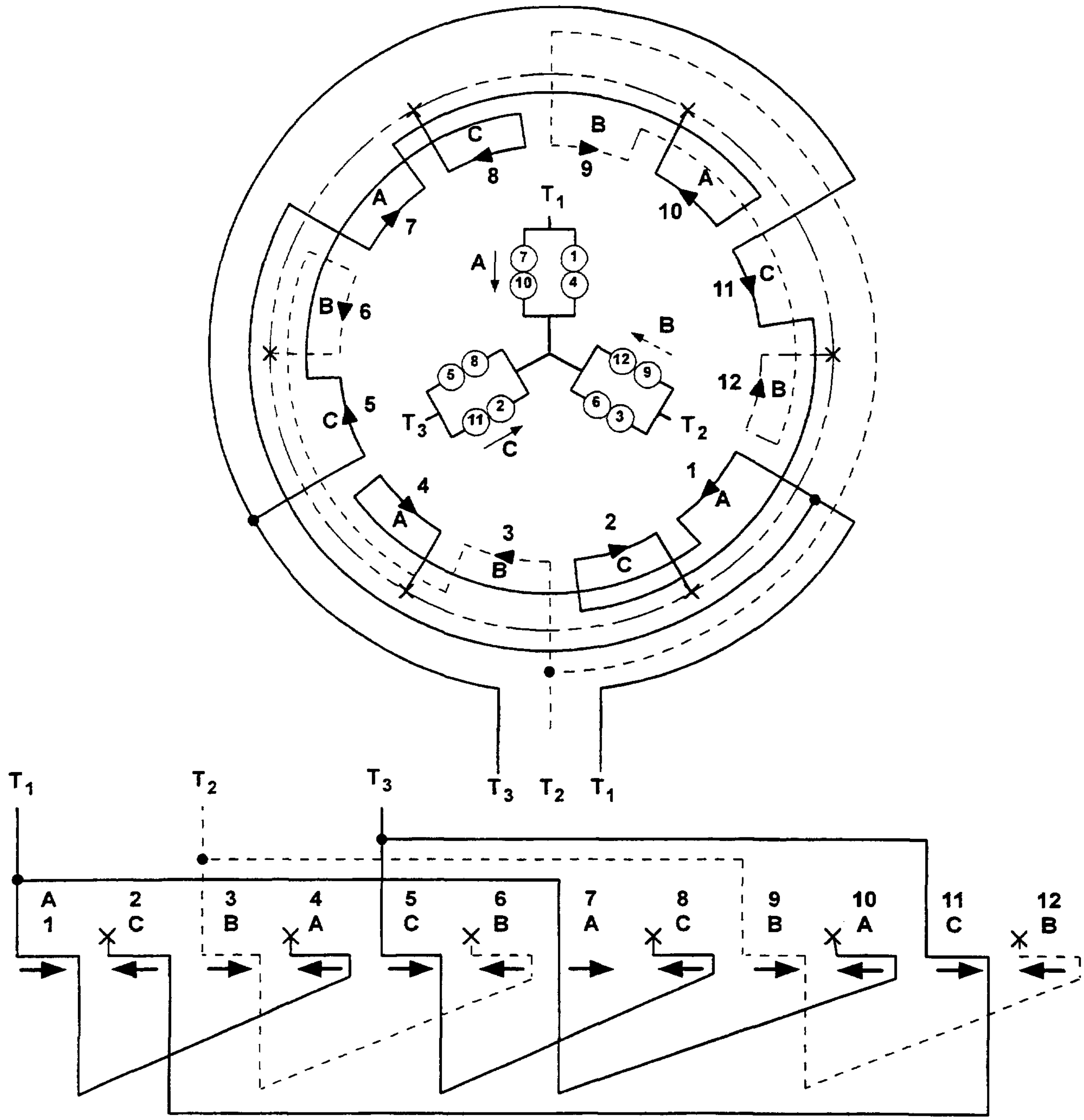


Figure D-10 Four-Pole, Three-Phase, Two-Parallel Wye Connection Diagram

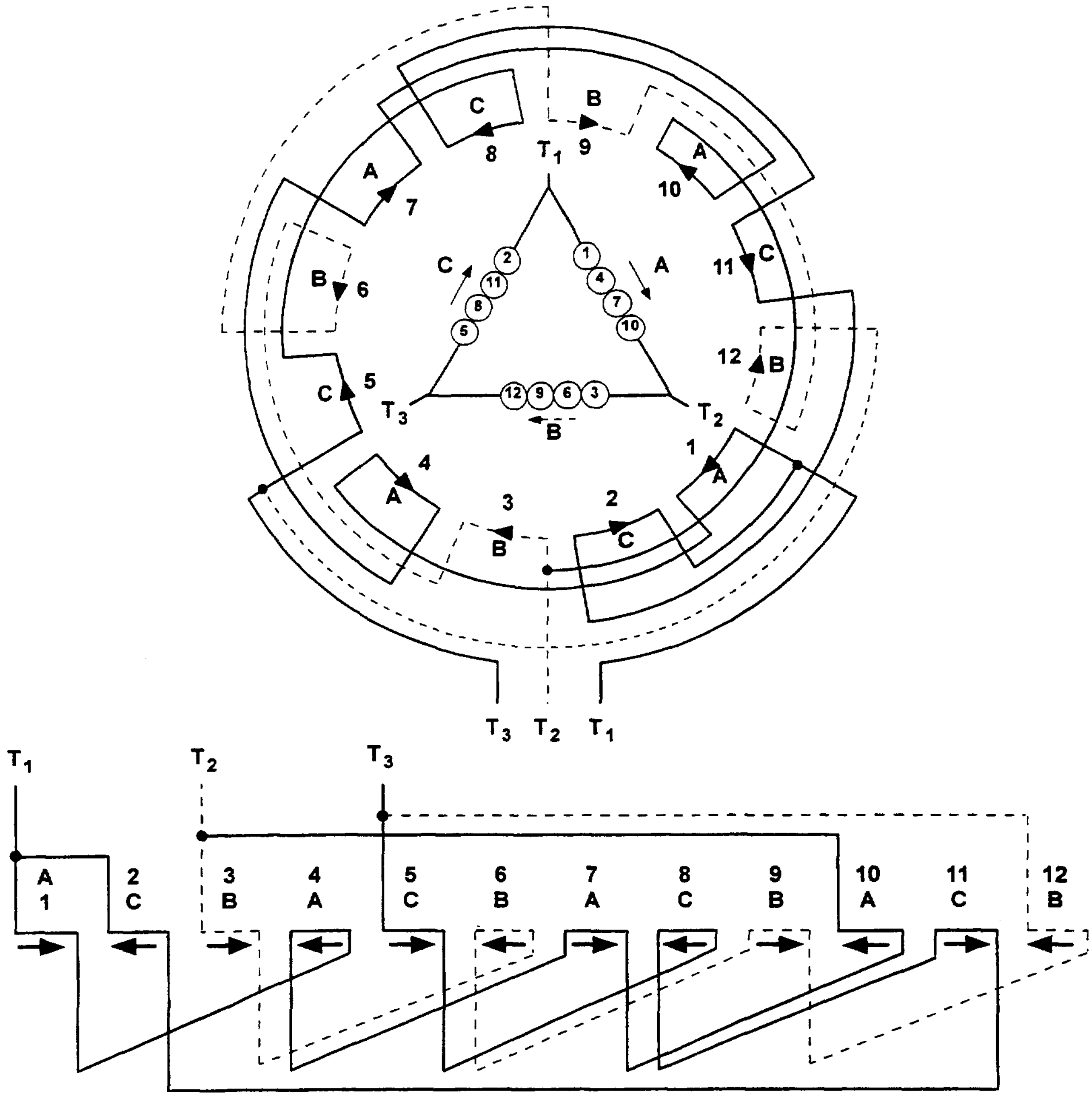


Figure D-11 Four-Pole, Three-Phase, Series Delta Connection Diagram

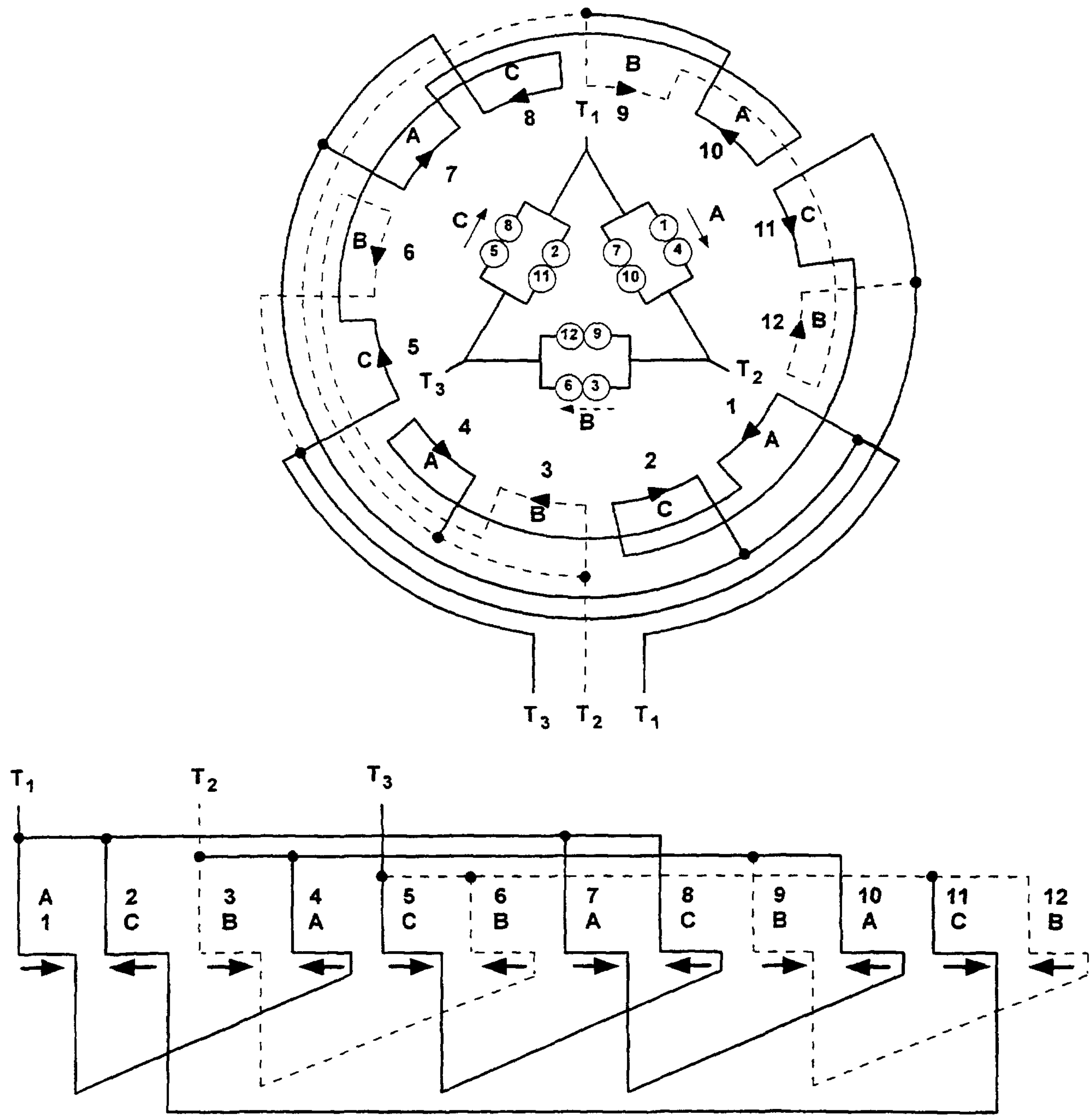


Figure D-12 Four-Pole, Three-Phase, Two-Parallel Delta Connection Diagram

APPENDIX E

PROCEDURE FOR DETERMINATION OF ELECTRIC MOTOR CONNECTIONS IN ENCAPSULATED MOTORS

NOTE

NAVSEA S9086-KC-STM-010/CH 300, Appendix B, indicates encapsulation is obsolete. Sealed Insulation System (SIS) replaces encapsulation and may only be performed by a NAVSEA-certified facility (MIL-STD-2037). Afloat facilities are not included in this program. The information provided here is provided for those few times when an existing encapsulated motor must be rewound as an interim measure.

E-1. SCOPE.

This procedure describes the method for determining the connection diagram of encapsulated motors prior to burnout Encapsulated motors may cause oven temperature runaway during burnout NAVSEA S9086-KC-STM-010/CH 300, on encapsulation of electric motors, suggests that the end turns of motors should be cut off on all motors over 10 horsepower (hp) prior to burning out the windings. This presents problems since the connection diagram of the motor is not always available. The following procedure allows a connection diagram to be developed and still limits the mass of epoxy put into the oven for burnout of the electric stator, thus preventing oven temperature runaway.

E-2. PROCEDURE.

E-3.

This procedure is based on the assumption that one lead is available and that failure has not occurred in which all three leads have been completely burned out, so that the connection may be determined by measurement. Perform the following steps to determine electric motor connection of an encapsulated motor:

a. Obtain the nameplate data from the motor.

b. Measure the length of the encapsulated winding.

c. Cut off the end turn at the connection end within 1/4 inch of the stator laminations by mounting the stator on a lathe and using a cutting speed of 150 revolutions per minute (r/m).

NOTE

The connection end is the end where the leads leave the encapsulating envelope.

d. Determine the coil throw by measuring with an ohmmeter on the stator end turn (not removed). Record the coil throw.

e. Count the number of slots in the stator and record this number.

f. Count the number of coil sides in the slot and record the number.

NOTE

There are usually two coil sides with a single-speed motor. A multiple-speed winding may have four coil sides per slot.

g. Determine the number of coil sides per group, using the following formula:

Coil sides per group = No. of Slots/(No. of phases) x (No. of poles)

Number of poles = 3600 x 2 in/r/m

(Round off to the nearest even number.)

h. Using the end turn that has been cut off, put one lead of the ohmmeter on one of the motor leads.

i. Probe the coil side copper until a continuous circuit is found.

j. Mark this coil side with a scribe on the epoxy surrounding the coil side.

k. Determine the number of wires in hand in the coil by probing the adjacent wires of the coil that is connected to the lead.

NOTE

If only one wire makes a complete circuit, the coil is one in hand. Two wires means two in hand, etc.

l. Determine whether the machine is wound progressively or retrogressively. Using the lead as the beginning of a coil group, move over one coil span, remembering that the start of a coil is in the bottom of a slot and the other side of the coil would be in the top of a slot.

NOTE

For this probing, fit a pad of cotton cloth on the probes. The pad should be approximately the size of a coil side and saturated with salt water.

m. Mark the coil connected to the lead as number 1.

n. Find the other side of the coil, one coil span away, and mark this one.

o. Check each coil in the group, marking the coils by scribing the epoxy.

p. Using one of the other leads, find the coil to which it is connected.

q. Check this coil for the number of turns in hand (see step k).

r. Lay off the second phase (see step l) and mark it number 2.

s. Repeat the procedure for the third lead, marking the coil number 3.

NOTE

The complete grouping of the coils can be completed around the cutoff end turn.

t. Determine if the winding is connected wye or delta.

NOTE

If the winding is connected wye, there will be three coils common from each of leads 1, 2, and 3. If the winding is connected delta, then there are two coils that are common to leads 1, 2, and 3. If the winding is parallel wye, then six leads will be common. A parallel delta will have four coils common to each of leads 1, 2, and 3.

u. Cut off the other end turn one-fourth inch from the stator laminations.

v. Place the stator in the burnout oven. Burn it our at 600° F for the required length of time.

w. Remove the wires from the slots and determine the wire size and the number of conductors per coil side.

E-4. SUMMARY OF REWINDING DATA.

E-5.

The information necessary for rewinding the motor is now available. It may be summarized as follows:

E-5.1 Length of coil from step b, less one-half inch.

E-5.2 Coil span from step d.

E-5.3 Coils per group from step g.

E-5.4 Number of parallel conductors from step k.

E-5.5 Number of conductors from step w.

E-5.6 Conductor size or sizes from step w.

E-5.7 Connection, whether wye, delta, or parallel, from step t.

APPENDIX F

DESCRIPTIONS AND FEDERAL STOCK NUMBERS OF ELECTRICAL INSULATING MATERIALS

F-1. SCOPE.

This Appendix provides pertinent data, to include current Federal Stock Numbers (FSN) or Navy Stock Numbers (NSN), for insulating materials carried in the Naval Supply System. It has been prepared to assist repair personnel in the selection of the correct electrical insulating materials for the maintenance and repair of electrical equipment.

F-2. AVAILABILITY OF MATERIALS.

Not every type, form, class, and size of insulating material is carried in the Naval Supply System. Materials that require purchase from commercial suppliers should be only those that conform to the latest edition of the applicable military specification.

F-3. ROUND MAGNET WIRE.

Film-coated type round magnet wire shown on shipboard electrical equipment drawings may be listed as T2, B2, L2, H2, K2, M2, or with other numeric suffixes. The number indicates the insulation film thickness. A blank (no number) indicates single, 2 indicates heavy, 3 means triple, and 4 is quadruple. The letter symbols indicate the temperature class: T=105° C, B=130° C, L=155° C, H=180° C, K=200° C, M=220° C. Fibrous coverings may be shown as G2V, Dg, or Dg2. The G means a single glass serving, G2 means double glass, V means varnished, Dg means single Dacron-glass, and Dg2 means a double Dacron-glass serving. Round magnet wire per Military Specification J-W-1177 must be utilized as shown in table F-1. Table F-2 shows magnet wire types.

NOTE

Use of respooled wire should be avoided if possible.

Table F-1 Identification of Types of Magnet Wire

Present Magnet Wire Types	Recommended Rewind Magnet Wire Types	
T, B, L, H, K, M	M	
T2, B2, L2, H2, K2, M2	M2	
T3, B3, L3, H3, K3, M3	M3	
T4, B4, L4, H4, K4, M4	M3	
BV, G2V, Dg, Dg2, TGV, T2GV, T2G2V,	DGg, BDg2, BDgV, BDg2V, B2Dg, B2Dg2	For 155°C Ins. Sys.
BGV, B2GV, BDg, B2Dg2, B2Dg2V,	H2GX, H2G2X	For 155°C Ins. Sys.
LDg, L2Dg2, HDg, H2Dg,	LDgH, LDg2H, L2DgH, L2Eg2H	For 155°C Ins. Sys.
HDgG, H2DgG, MDgGM, M2DgGM	M2DgGM	For 155°C Ins. Sys.

Table F-2 Round Film Insulated Magnetic Wire (J-W-1177) [1], [2]

AWG	Type [3]	NSN 6145-00	Weight (lb.)	Unit of Issue (U/I)
#7	M2	937-8587	250	Reel
#8	M2	937-8585	200	Reel
#9	M2	937-8583	250	Reel
#10	M2	937-8410	250	Reel

Table F-2 Round Film Insulated Magnetic Wire (J-W-1177) [1], [2] - Continued

AWG	Type [3]	NSN 6145-00	Weight (lb.)	Unit of Issue (U/I)
#11	M2	937-8408	75	Reel
#12	M2	937-8406	75	Reel
#13	M2	937-8404	75	Reel
#14	M	937-8376	75	Reel
	M2*	937-8889	75	Reel
#15	M	937-8374	75	Reel
	M2*	937-7862	75	Reel
#16	M	937-7858	75	Reel
	M2*	937-8402	75	Reel
#17	M	937-7869	75	Reel
	M2	937-8400	75	Reel
#18	M	937-8372	75	Reel
	M2*	937-8398	75	Reel
	M2	937-8886	75	Reel
#19	M	937-8370	75	Reel
	M2*	937-8396	75	Reel
#20	M	937-8368	75	Reel
	M2*	937-8394	75	Reel
#21	M	937-8366	75	Reel
	M2*	937-7864	75	Reel
#22	M	937-8243	75	Reel
	M2*	937-8579	75	Reel
#23	M	937-8563	75	Reel
	M2*	937-8211	75	Reel
#24	M	937-8241	75	Reel
	M2*	937-8392	75	Reel
#25	M	937-7848	75	Reel
	M2*	937-8213	75	Reel
#26	M	937-8239	75	Reel
	M2*	937-8390	75	Reel
#27	M	937-8237	75	Reel
	M2*	937-8215	75	Reel
#28	M	937-7850	75	Reel
	M2*	937-8577	75	Reel
#29	M	937-8235	75	Reel
	M2*	937-8199	75	Reel
#30	M	937-8233	8	Spool
	M2*	937-8207	8	Spool
#31	M	937-7852	8	Spool
	M2~	937-8225	8	Spool
#32	M	937-8231	8	Spool
	M2*	937-8575	8	Spool
#33	M	937-8561	8	Spool
	M2*	937-8573	8	Spool
#34	M	937-8229	8	Spool
	M2*	937-7866	8	Spool
#35	M	937-8644	2	Spool

Table F-2 Round Film Insulated Magnetic Wire (J-W-1177) [1], [2] - Continued

AWG	Type [3]	NSN 6145-00	Weight (lb.)	Unit of Issue (U/I)
	M2*	937-8197	2	Spool
#36	M	937-8642	2	Spool
	M2*	937-8201	2	Spool
#37	M	937-8640	2	Spool
	M2*	937-8209	2	Spool
#38	M	937-7854	2	Spool
	M2*	937-8203	2	Spool
#39	M	937-8227	2	Spool
	M2*	937-8386	2	Spool
#40	M	937-8638	2	Spool
	M2*	937-8384	2	Spool
#41	M	937-8636	2	Spool
	M2*	937-5871	2	Spool
#42[4]	M	937-8634	3/4	Spool
	M2*	937-8205	3/4	Spool
#43 [4]	M2*	937-8569	3/4	Spool
#44 [4]	M2*	937-8382	3/4	Spool

[1]In instances where these types of wire are not available for Federal Spec J-W-1177, the NEMA Standard Publication No. MW 1000 for Magnetic wire as listed in the applicable J-W-1177 slash sheet can be substituted.

[2]J-W-1177, Wire Magnet, Electrical, General Specification

[3]Preferred magnet wire types are designated *.

[4]AWG Sizes 42, 43, and 44 2343 formerly supplied in 2-lb spools.

F-4. INSULATION SHEET, FLEXIBLE.

Slot and phase insulation may also be designated as ground insulation, slot liner, basic insulation, core insulation or just ″insulation.″ Drawings may show any of the following materials as slot and phase insulation: mica glass, fish paper, varnished cambric, mylar, DMD, silicone mica glass, varnished glass, mica paper. Slot and phase insulation must be used as shown in table F-3 and table F-4.

Table F-3 Slot and Phase Insulation

Present Slot and Phase Insulation	Recommended Rewind Slot and Phase Insulation
Mica-glass types per MIL-I-3503	For equipment rated over 600 volts, use mica-glass composites per MIL-I-3505.
Mica paper types per MIL-I-21070	
Fish paper and composites per MIL-U-695	
Polyethylene-terephthalate composites (DMD) per MIL-I-22834	For equipment rated 600 volts and below, use polyamide paper per MIL-I-24204 or use varnished glass fiber cloth MIL-I-17205, Grade 5, not less than.007 inch thick.
Mylar per MIL-I-631	

Table F-4 MIL-I-24204, Polyamide Paper, Federal Supply Class 5970 (For Equipment Rated 600 Volts and Below)

Thickness (in.)	Width (in.)	Length (in.)	NSN 5970-00-	U/I
0.005	36	36	016-3053	Sheet
0.007	36	36	016-3342	Sheet
0.010	36	36	016-3367	Sheet
0.015	36	36	016-3375	Sheet
0.020	36	36	016-3377	Sheet
0.030	36	36	016-3492	Sheet

F-5. INSULATION SLEEVING.

Older types of sleeving crack when bent, creating potential for eventual failure at a joint or connection. Present types of sleeving must meet a 90-degree bend test. Sleeving must be used as shown in table F-5, table F-6, table F-7, and table F-8.

Table F-5 Insulation Sleeving

Present Type of Sleeving	Recommended Types for Rewind
Cotton braid A-A-1, A-A-2 per MIL-I-3190C	For Class A, B, or F insulation system, use acrylic-glass (Class 155).
	For class H or N insulation systems rewound with Class F system thermally upgraded materials, use silicone rubber glass (class 200) on ac or dc equipment.
Glass braid B-A-1, B-B-1 per MIL-I-3190C	Insulation system
Glass braid H-A-1, H-B-1, H-C-1 per MIL-I-3190C Glass braid, vinyl per MIL-I-21557B	Use silicone rubber glass (class 200) on ac systems and polyamide-glass (Class 220) on dc systems.

Table F-6 Insulation Sleeving, MIL-I-3190C, Acrylic Glass (Temperature Index 155) Federal Supply Class 5790, U/I Ft.

Size No.	Nominal ID (in.)	Wall Thickness (in.)	NSN 9G 5970-00-
24	0.022	0.030	488-7811
22	0.027	0.030	488-7794
20	0.034	0.030	488-7792
18	0.042	0.030	488-7789
17	0.047	0.030	488-7784
16	0.053	0.030	488-7477
15	0.059	0.030	488-7448
14	0.066	0.045	488-7447
13	0.076	0.045	488-7431
12	0.085	0.045	488-7429
11	0.095	0.045	488-7261
10	0.106	0.045	488-7208
9	0.118	0.045	488-7046
8	0.133	0.045	488-7043
7	0.148	0.045	488-7016
6	0.166	0.045	488-7014
5	0.186	0.045	488-6997
4	0.208	0.045	488-6918

Table F-6 Insulation Sleeving, MIL-I-3190C, Acrylic Glass (Temperature Index 155) Federal Supply Class 5790, U/I Ft. - Continued

Size No.	Nominal ID (in.)	Wall Thickness (in.)	NSN 9G 5970-00-
3	0.234	0.045	488-6917
2	0.263	0.055	488-6648
0	0.330	0.055	488-6623
3/8	0.387	0.055	488-6621
5/8	0.640	0.065	488-6592
3/4	0.768	0.075	488-6464
7/8	0.893	0.075	488-6244
1	1.018	0.075	488-5710

Table F-7 Insulation Sleeving, MIL-I-3190C, Silicone Rubber Glass (Temperature Index 200) Federal Supply Class 5790, U/I Ft.

Size No.	Nominal ID (in.)	Wall Thickness (in.)	NSN 9G 5970-00-
18	0.042	0.030	838-7278
17	0.047	0.030	025-1789
16	0.053	0.030	825-3680
15	0.059	0.030	025-1788
14	0.066	0.045	825-3678
12	0.085	0.045	953-8478
11	0.095	0.045	025-1782
10	0.106	0.045	025-1781
9	0.118	0.045	578-9037
8	0.133	0.045	852-2654
7	0.148	0.045	825-3677
5	0.186	0.045	025-1780
4	0.208	0.045	025-1779
3	0.234	0.045	285-0489
2	0.263	0.055	025-1778
1	0.294	0.055	285-0490
0	0.330	0.055	025-1777
3/8	0.387	0.055	852-4758
7/16	0.450	0.065	
1/2	0.512	0.065	285-0492
5/8	0.640	0.065	
3/4	0.768	0.075	285-0493
7/8	0.893	0.075	
1	1.018	0.075	

Table F-8 MIL-I-3190C, Polyamide Glass (Temperature Index 220) Federal Supply Class 5970, U/I Ft.

Size No.	Nominal ID (in.)	Wall Thickness (in.)	NSN 5970-00-
16	0.053	0.030	488-5091
14	0.066	0.030	488-5087
12	0.085	0.045	488-5082

Table F-8 MIL-I-3190C, Polyamide Glass (Temperature Index 220) Federal Supply Class 5970, U/I Ft. - Continued

Size No.	Nominal ID (in.)	Wall Thickness (in.)	NSN 5970-00-
10	0.106	0.045	488-4991
8	0.133	0.045	488-4942
6	0.166	0.045	488-4883
2	0.263	0.055	488-4660
0	0.330	0.055	

F-6. INSULATION, LAMINATES, SHEETS.

Use table F-9 to determine the proper sheet insulation.

Table F-9 MIL-P-997, Glass Silicone Type GSG (Temperature Index 200)

Thickness (in.)	NSN-5970-00-	U/I
0.031	198-8327	lb.
0.062	905-8772	lb.
0.094	198-8325	lb.
0.125	198-8324	lb.
0.250	905-8774	lb.

F-7. LACING AND TYING TAPE.

Lacing and tying cords and tapes have been made from twisted cords, braided cords, and braided flat tapes using cotton, flax, or glass yarns. Finishes applied to these materials to improve knot strength and application have been waxes, synthetic rubbers, and resin coatings. Lacing and typing tape must be used as shown in table F-10 and table F-11.

Table F-10 Identification of Types of Tape

Present Types	Recommended Type
Glass cord per MIL-Y-1140	Polyamide, Type V, Finish A (natural) per MIL-T-43435A
Cotton cord per MIL-T-713 (also flax, hemp or resin)	

Table F-11 MIL-T-43435A, Polyamide Tape - Heat Resistant, Flat Braids, Navy Supply Class 5970

NSN 5970-00-	Size	Width (in.)	Thickness (in.)	Breaking Strength (lb.)	U/I Yds. per Spool
001-9356	1	0.225	0.014	85	500
001-9357	2	0.125	0.012	50	500
001-9358	3	0.090	0.012	35	500
001-9359	4	0.062	0.08	25	500

F-8. INSULATION TAPE.

Utilize as shown in table F-12, table F-13, and table F-14.

Table F-12 MIL-Y-1140, Tape, Textile, Glass, Untreated, ECC-B, Federal Supply Class 8315

NSN 8315-00-	Width (in.)	Thickness (in.)	Breaking Strength (lb.)	U/I
290-8265	3/8	0.003	45	Roll
290-8256	3/8	0.007	115	Roll
290-8266	1/2	0.003	60	Roll
290-8260	1/2	0.005	135	Roll
290-8276	1/2	0.007	135	Roll
290-8264	3/4	0.003	95	Roll
290-8259	3/4	0.005	225	Roll
290-8254	3/4	0.007	225	Roll
290-8258	1	0.005	310	Roll
290-8278	1	0.007	310	Roll

Table F-13 MIL-T-15126, Tape, Adhesive, Glass Backing Federal Supply Class 5970 (Temperature Index 155)

NSN 5970-00-	Width (in.)	Thickness (in.)	Diel. Str. (volts)	U/I
543-1154	1/2	0.007	1000	Roll
686-9151	1	0.007		Roll

Table F-14 MIL-T-19166, Tape, Adhesive, Glass Backing Federal Supply Class 5970 (Temperature Index 200)

NSN 5970-00-	Width (in.)	Thickness (in.)	Diel. Str. (Volts)	U/I
709-0045	0.625	0.007	2000	Roll
933-1406	0.250	0.007	200	Roll
650-5345	0.500	0.012	4000	Roll

F-9. LEAD WIRE.

Use table F-15 to select the proper lead wire.

Table F-15 Lead Wire, MIL-W-16878

AWG	Diameter (in.)	NSN 6145-00-
Type EPDM (Ethylene-Propylene Diene Elastomer) Class 150° C, 600V		
18	0.142	01-212-4772
16	0.155	01-212-4773
14	0.170	01-212-4774
12	0.197	01-212-8028
10	0.252	01-212-1603
8	0.327	01-212-1604
6	0.383	01-270-8558
4	0.440	01-212-1341
2	0.494	01-212-4775
Type FF Silicone Rubber Glass Braid (Class 200) [1]		
22	0.100	284-1480
20	0.108	284-1481
18	0.118	284-1482

Table F-15 Lead Wire, MIL-W-16878 - Continued

AWG	Diameter (in.)	NSN 6145-00-
16	0.127	284-1483
14	0.176	284-1484
12	0.195	284-148S
10	0.230	284-1486
8	0.327	284-1487
6	0.356	284-1488
4	0.412	284-1489
2	0.495	284-1490
1	0.552	284-1491
0	0.598	284-1492
00	0.651	284-1493
0000	0.775	284-1494
Type EE Tetrafluoroethylene (Class 200)		
24	0.0S4	01-995-1603
22	0.060	00-643-2494
20	0.068	00-811-2232
18	0.079	01-062-4011
16	0.089	00-089-6563
14	0.100	00-089-6289
12	0.124	01-089-6562
10	0.14S	01-957-1985
8	0.207	00-542-6677

[1]Silicone lead wire shall not be used in nonventilated brush-type machines.

F-10. INSULATION, SLOT WEDGES.

Use as shown in table F-16.

Table F-16 Formed Polyamide Paper (U Shape) Federal Supply Class 5970, U/I Ft.

Shape	Width (in.)	Thickness (in.)	NSN 5970-00-	FSCM (Mfr. Code)	Mfr. Type
Curve	5/32	11/64	004-4491	87952	NHT 70-30
Curve	7/32	3/16	004-4490	87952	NHT 86-30
Curve	1/4	7/32	004-4489	87952	NHT 99-30
Curve	5/16	1/4	004-4488	87952	NHT 117-30
Curve	3/8	5/16	004-4487	87952	NHT 144-30
Square	5/32	7/32	004-4486	87952	NHT 30-10-14
Square	1/4	11/64	004-4492	87952	NHT 30-16-11
Square	23/64	1/4	004-4493	87952	NHT 30-23-16

F-11. MISCELLANEOUS CONSUMABLE MATERIALS.

See table F-17 through table F-24 for details on various consumables.

Table F-17 Miscellaneous Consumable Materials

1.	Slot Sticks-silicone glass 1/16″ thick MIL-P-15037	9Q-5970-00-905-8336
2.	U-Shaped Wedges-NOMEX	
	Curved 5.32 NHT-70-30	9Q-5970-00-004-4491
	Curved 7/32 NHT-86-30	9Q-5970-00-004-4490
	Curved 1/4 NHT-99-30	9Q-5970-00-004-4489
	Curved 5/16 NHT-117-30	9Q-5970-00-004-4488
	Curved 3/8 NHT-144-30	9Q-5970-00-004-4487
	Square 5/32 HHT-30-10-14	9Q-5970-00-004-4486
	Square 1/4 HHT-30-16-11	9Q-5970-00-004-4492
	Square 23-64 HHT-30-23-16	9Q-5970-00-004-4493
3.	Flat Tape, Glass Braided Lacing Type V-Finish A MIL-T-43435A Natural (0.225)	9Q-5970-00-001-9356
4.	Thermo Setting Tape, 1/2 inch MIL-T-15126	9Q-5970-00-543-1154
5.	High Temperature Resistance Insulation Paper, Synthetic 24 inches x 36 inches, .007 Thickness NOMEX Type 40 or Equivalent MIL-I-24204	9Q-5970-00-016-3342
6.	Temporary Slot Sticks Wood-Rag-NOMEX (use U-shaped wedges or scrap)	
	Cotton Sail Twine	

Table F-18 MIL-I-24092, Varnish, Clear, Baking, Solvent-Containing Types [1]

Class	NSN 5970-00-	U/I	Thinner
155	931-2413	1 gal can	Xylene
155	931-1170	5 gal can	Xylene
200	931-2414	5 gal can	Xylene
200	548-7211	1 gal can	Xylene

[1]Xylene thinner is grade B per TT-X-916: NSN 6810-00-584-4070, 5 gal.

Table F-19 MIL-I-24092, Varnish, Clear, Air-Drying, Solvent-Containing Type [1]

Grade	NSN 5790-01-	U/I	Thinner	Mfr. Brand No.
CA	190-5473	1 gal. can	Mineral spirits	AC 41 Dolph
CA	252-7481	1 gal. can	Mineral spirits	AC 43 Dolph

[1]Mineral spirits is grade I per TT-T-291: NSN 8010-00-558-7026, 5 gal.

Table F-20 MIL-I-24092, Varnish, Clear, Air-Drying Type

Type	NSN 5970-01-	U/I	Mfr.	Part No.
CA	078-5636	1 gal.	Sterling	U-122

Table F-21 Red Insulating Varnish, Air Dry [1]

Type	U/I	NSN	Mfr Brand No.
Air dry - moisture, oil, and salt water resistant	16 oz. spray can	579-00-076-8988	ER-41 Red

[1]For SWBD buswork, frame coating, etc.

Table F-22 Solventless Baking Varnish for Dipping for Use on Submarine Equipment

Composition	Mfr. Brand No.	Mfr.
Polyester	Esterlite 605	Epoxylite
Polyester	Isolite 862M	Schenectady Chemical

Table F-23 Solder

NSN 3439-00-	Solder, SN10WRP2 (LEAD) U/I	Diameter in.
003-8601	1 lb	0.028
265-7102	1 lb	0.063

Table F-24 Flux

NSN 3439-00-	Flux, Soldering, Noncorrosive U/I
255-4566	Can

APPENDIX G

ELECTRIC MOTOR REWIND QUICK REFERENCE

G-1. SCOPE.

The data in this appendix have been assembled to provide a single location for quick reference. Many of the formulas here can also be found throughout this manual. Additional formulas and data of interest to electrical rewind and maintenance personnel are also included.

G-2. OHM'S LAW.

E	Voltage (electromotive force) in volts
I	Current in Amperes (Amps)
R	Resistance in Ohms
P	Power

$E = IR$ $I = E/R$ $R = E/I$ $P = EI$ or $P = I^2 R$

G-3. MINIMUM INSULATION RESISTANCE FOR AC MOTORS CORRECTED TO 25° C.

Table G-1 Insulation Resistance for Motors

AC MOTORS OTHER THAN PROPULSION				
	Insulation Resistance (megohms at 25°C) [1]			
Circuit	Minimum for Operation	After Cleaning in Ship	After Recndtn	After Rewinding
Stator circuit of generators and motors	0.2	1.0	25	200

G-4. TEMPERATURE CONVERSION.

Celsius to Fahrenheit: *°F = (9/5 x °C) +32*

Fahrenheit to Celsius: *°C = (5/9) °F-32)*

G-5. THIXOTROPIC INDEX AT 73° F (23° C).

Thixotropic Index = Avg. vis. at 2 r/m / Avg. vis. at 20 r/m

G-6. CLEANING COMPOUND MIXED WITH WATER FOR RECONDITIONING MOTORS

G-6.1 Cleaning Compound. Cleaning compound P-D-220 (NSN 7930-00-249-8036) or a nonionic-type detergent according to MIL-D-16791 (NSN 7930-01-055-6121 [quantity 1 gallon] or NSN 7930-00-282-9700 [quantity 55 gallons]). Both should be mixed in a proportion of 1 pound to 2-1/4 gallons of water. The formula for gallons of water in a tank is:

7.48 gallons of water = 1 ft ^{3}

Number of gallons = Number of cubic feet x 7.48

Number of pounds of compound = Number of gallons/2.25

G-6.2 Powdered Salt Water Soap. Powdered salt water soap (synthetic detergent) MIL-D-12182 (NSN 7930-00-252-6797) may be used in either soft or hard water. It should be mixed in a proportion of 1 pound to 50 gallons of water. This compound has the advantage of being neutral. It is neither acidic nor alkaline. The formula is:

Pounds of compound = Gallons/50

G-6.3 Steam Cleaning Compound. Steam cleaning compound and butyl alcohol are added to water in the proportions of 15 to 20 pounds of compound and 1 quart of butyl alcohol per 1,000 gallons of water. Steam cleaning compound is available in 25-pound drums (NSN 6850-00-965-2087) or 400-pound drums (NSN 6850-00-965-2329).

G-6.4 Dishwashing Compound. Dishwashing compound is mixed 1 pound to 25 gallons of water.

G-7. TEMPERATURE OF STATOR FOR DIPPING.

Do not dip the stator if it is too hot. It must cool to approximately 140° F (60° C) before it is dipped.

G-8. ANNEALING TEMPERATURE.

302° F (150° C) for 4 hours.

G-9. MAXIMUM OVEN TEMPERATURES.

Table G-2 provides maximum oven temperatures for drying motors, baking, and burnout.

Table G-2 Oven Temperatures

Process	Maximum Temperature
Drying motors	300° F (149° C)
Baking	302° F (250° C) ±10 percent
Burnout	700° F (371° C)
	600° F (316° C) for T Frame

G-10. MOTOR SPEED.

Table G-3 Motor Speed Table

Operating Speed	Synchronous Speed	Poles
3450 - 3575	3600	2
1725 - 1775	1800	4
1150 - 1175	1200	6
825 - 875	900	8
675 - 690	720	10
500 - 575	600	12

G-11. NUMBER OF POLES.

120 x frequency/Speed

Motor speed may be obtained from the nameplate.

G-12. POLE PHASE GROUP (PPG).

Use the number of poles to determine the number of pole phase groups in the motor. The number of phases for which the motor is designed will be on the nameplate of the motor.

PPG = P x Ø, where

PPG = Pole phase groups

P = Number of poles determined using paragraph 8-9.1.

Ø = Phases for which the motor is designed.

G-13. COILS PER PPG (CPPG).

Individual coils are wound together or connected to form a pole phase group. To determine the number of coils in one pole phase group for a distributed winding (two coil sides per slot in a single winding):

Coils per group = Total active coils/(Number of phases) x (Number of poles)

An active coil is a coil that is electrically connected in the stator circuit *(Total active coils = Active coils per phase x Number of phases).*

G-14. COILS PER GROUP (CPG).

Coils per group = Stator slots/Pole Phase Groups

G-15. PHASE RESISTANCE BALANCE FOR MOTORS OVER 3 HP.

G-15.1 Perform a phase resistance balance test to determine if the internal resistance of the phases is within allowable limits. For motors over 3 horsepower (hp), the resistance of each phase must be within 5 percent of the others.

G-15.2 The stator must be rewound if the difference between the high and low readings is greater than 5 percent.

Highest - lowest = Answer No. 1

Highest x .05 = Answer No. 2

Answer No. 1 must be less than Answer No. 2.

G-16.

Use the formula below to find the quantity of energy required to increase the temperature of a material:

Kilowatt hours = 3.5 x weight in pounds x °F rise/100,000

G-17.

Use the formula below to determine the rime required to raise the temperature:

T (time in hours) = Desired temperature rise/7

G-18. POLARIZATION INDEX (PI).

G-18.1 Use an electronic megohmmeter to obtain the insulation resistance of the machine at 1 minute and 10 minutes after applying the voltage. Use a megohmmeter voltage of 500 volts or as recommended by the equipment technical manual. Use the insulation resistance values obtained at 10 minutes and 1 minute to calculate the Polarization Index (PI).

G-18.2 To calculate the PI, divide the 10-minute value by the 1-minute value. If the 1-minute insulation resistance measurement (corrected to 25° C) is less than *2 x (1 + E/1,000) megohms* where E is the machine's rated voltage, the winding is not suitable for application of the high-potential test.

G-18.3 For most motors the minimum acceptable PI is 2.0.

G-19. CORE TEST CALCULATION.

a. Using the 1/64th scale on an engineer's rule, measure the stator core length (CL), core depth (CD), core bore diameter (CD), and slot depth (SD).

b. Effective stator core length is obtained as follows:

CL = Measured core length x 0.80

c. To determine the stator core depth, measure from the bottom of the coil slot to the core's outer circumference.

Effective core cross section area = (CL) x (CD).
Estimated voltage per turn = 0.26 x core area.

d. The number of cable turns to be placed through the stator core is equal to the supply voltage divided by the estimated volts per turn.

Effective stator core diameter (ECD) = CID + (2SD) 4 + CD.
Ampere turns (AT) = 45 x ECD
Current required = AT/Turns

G-20. VOLTAGE CALCULATION FOR AC HIPOT TEST.

Calculate the test voltage for the winding using the design voltage.

New windings: 2E + 1,000 = *test voltage* where E = design voltage of the winding.

Reconditioned windings: 2/3 (2E + 1,000) = *test voltage* .

G-21. VOLTAGE CALCULATION FOR DC HIPOT TEST.

G-21.1 The maximum test voltage for new insulation should be (2E + 1000) x 1.6.

G-21.2 E is the rated voltage of the machine.

G-21.3 Reconditioned windings should be tested at a maximum voltage of 1.1 x (2E + 1000).

G-22. VOLTAGE CALCULATION FOR SURGE TEST.

G-22.1 The test voltage should be (2E + 1000) x 1.4 for new windings.

G-22.2 E is the rated voltage of the machine. Reconditioned windings should be 2/3((2E + 1000)) x 1.4).

G-23. MAXIMUM SHAFT RADIAL RUNOUT

The maximum shaft radial runout is 0.002 inch.

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