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NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 302

ELECTRIC MOTORS AND CONTROLLERS

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ELECTRIC MOTORS AND CONTROLLERS

NAVSHIPS 0901-LP-630-0002 (July 1972 Edition), Chapter 9630, Naval Ships' Technical Manual (NSTM) is superseded by Chapter 302 as follows:

1. This revision results from the Naval Sea Systems Command's program to revise, repackage, and reissue the NSTM.

2. All holders of the NSTM shall replace old Chapter 9630 with new Chapter 302.

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CHAPTER 302
ELECTRIC MOTORS AND CONTROLLERS

SECTION 1. INTRODUCTION

302−1.1 SCOPE

302−1.2 This chapter covers description of and non−specific operating instructions for motors and controllers other than those used for electric propulsion. For instructions on the operation of electric propulsion installations, see chapter 235 (9413). For instructions on maintenance and care which are generally applicable to motors and controllers, irrespective of their use, see chapter 300 (9600). For specific information and instructions relating to a particular motor or controller, refer to applicable Allowance Parts List (APL) and information furnished by the manufacturer with the equipment, such as identification plate data, connection diagrams, wiring diagrams, and technical manuals furnished with equipment.

302−1.3 SAFETY PRECAUTIONS

302−1.4 Safety precautions shall always be observed when working around electrical equipment and circuits to avoid injury to personnel and damage to equipment. See chapter 300 (9600) for electrical safety precautions.

302−1.5 Fatal accidents have been caused by making the wrong connection of the grounding conductor on portable tools or equipment. It must be connected correctly or it will be a source of danger rather than a protection against electric shock. Be sure to check portable tools and equipment for correct connections before using them for the first time. See chapter 300 (9600) for full instructions on how to make this check.

SECTION 2. MOTORS

302−2.1 GENERAL

302−2.2 Electric motors are provided for two types of service on combatant ships. Motors for driven auxiliaries which are essential for the military effectiveness of the ship are furnished as **Navy Service A**. These motors are heavy−duty high−impact−shock−resistant type. Motors for auxiliaries which 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.

302−2.3 Motors are rated for continuous, intermittent varying, or short time duty as required by the driven auxiliaries. The assigned duty cycle will permit the motor to operate for the time duration indicated on the nameplate without exceeding the allowable temperature limit.

302−2.4 Motors installed in ships are designed to operate at ± 10% variation in voltage indicated on the nameplate. Ac motors are also designed to operate at ± 5% 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.

302−2.5 ALTERNATING CURRENT MOTORS DESCRIPTION

302−2.6 POLYPHASE INDUCTION MOTORS. Almost all ac motors which are used on naval ships and which are above the fractional horsepower size are polyphase induction motors. Polyphase induction motors have a primary winding (usually the stator winding) which is connected to the power supply, and a secondary winding (usually 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. Most motors are single speed. However, for some applications, multiple speed or variable speed motors, as described in paragraphs 302−2.8 through 302−2.12, are used.

302−2.7 SYNCHRONOUS SPEED AND SLIP. The speed of rotation of the rotating magnetic field is known as the synchronous speed. The rotor of an induction motor runs at somewhat less than synchronous speed. The difference between synchronous speed and rotor speed is known as the slip. Synchronous speed (revolutions per minute) is 120 times the frequency of the power supply (Hz) divided by the number of poles in the primary winding. Synchronous speeds for 60 Hz motors are contained in Table 302−1.

Table 302−1. 60 Hz MOTOR SPEEDS

Poles	Synchronous Speed (rpm)	Normal Full Load Speed (rpm)
2	3600	3450
4	1800	1740
6	1200	1160
8	900	870

NOTE

Full load speeds given in Table 302−1 are approximate for normal−slip motors. Motors of special design may operate at slightly higher or considerably lower speeds.

302−2.8 SQUIRREL CAGE INDUCTION MOTORS. The squirrel cage induction motor has a rotor winding made of longitudinal bars in slots just below the outer surface of the rotor. The bars are connected to and short circuited by rings at the ends of the rotor. The rotor winding may be of individual bars and rings of conducting material connected together, or it may be a one−piece structure made by die casting the rings and bars together. In the diecast construction, the fan blades for cooling the motor are frequently cast in one piece with the rotor winding. The rotor winding is energized by induction produced from the slip frequency.

302−2.9 Variable Speed Systems. Squirrel cage induction motors used for variable speed systems require certain additional considerations. Any conventional squirrel cage motor with known electrical characteristics may be used (as limited by heat dissipation at lower speeds) in a speed control system of the adjustable frequency type which incorporates a constant frequency to voltage ratio. With this method of control, the motor speed varies in proportion to the frequency and voltage of the system. For example, a 440−volt 60−Hz motor would operate at 50% speed at the 50% frequency and voltage (220v, 30 Hz) setting of the controller.

302−2.10 A special design, variable voltage, high slip, high heat dissipation squirrel cage induction motor is required for a speed control system which utilizes variable voltage at constant frequency. This system controls motor speed through control of the motor rotor slip. In this system the motor draws high current throughout the speed range with peak current and maximum heat dissipation requirements occurring at approximately two thirds rated speed and load.

302−2.11 Multiple−Speed Squirrel Cage Induction Motors. The following kinds of multiple−speed squirrel cage induction motors are used on naval ships:

1. One primary winding − two ways of connecting − two synchronous speeds in the ratio of 2 to 1.

2. Two primary windings − one way of connecting each winding − two synchronous speeds which are not in the ratio of 2 to 1.

3. Two primary windings − two synchronous speeds in the ratio of 2 to 1 for each winding − total of four synchronous speeds; for example, 1800, 1200, 900, and 600 rpm.

4. Two primary windings − two synchronous speeds in ratio of 2 to 1 for one winding and one synchronous speed for second winding; for example 1800, 1200 and 600 rpm.

302−2.12 WOUND−ROTOR INDUCTION MOTORS. The wound−rotor induction motor is similar to the squirrel cage motor except that the rotor winding is made of individually insulated coils. Connections from the coils are brought to collector rings. The rotor circuit is not short circuited on itself as in the squirrel cage motor, but is completed through external resistors connected to brushes which bear on the collector rings. Motor speed, starting current, and other characteristics can be adjusted by varying the external resistors. Only relatively few wound−rotor induction motors are used on naval ships.

302−2.13 CURRENT, VOLTAGE, AND POWER. The line current (I_L), kilovolt ampere (kVA) input, and kilowatt (k_W) input of any motor can be calculated if the line voltage (E_L), motor efficiency (eff), motor power factor (pf), and horsepower (hp) output are known.

1. For three−phase motors, the relations are:

$$I_L = \frac{746\ (hp)}{1.73(E_L)(pf)(eff)}$$

$$\text{kVA input} = \frac{1.73\ (I_L)\ (E_L)}{1000}$$

2. For single−phase motors, the relations are:

$$I_L = \frac{746\ (hp)}{(E_L)(pf)(eff)}$$

$$\text{kVA input} = \frac{(I_L)(E_L)}{1000}$$

$$\text{kW input} = \text{kVA x pf}$$

302−2.14 TORQUE AND POWER. The relation between torque and horsepower for a motor, as for other rotating devices, is expressed by equation:

$$hp = \frac{2\pi(rpm)(torque)}{33000}$$

Thus, to calculate torque at rated (or known) speed and horsepower, the formula may be expressed:

$$\text{Torque (ft/lb)} = \frac{5250\ (hp)}{rpm}$$

302−2.15 DIRECT CURRENT MOTORS

302−2.16 TYPES AND APPLICATIONS. Dc motors may be shunt, series, compound, or stabilized shunt motors.

302−2.17 Shunt Motors. These motors have field coils connected in parallel with the armature. Shunt motors are used in applications which require only moderate starting torque and a speed which is substantially unaffected by changes in load.

302−2.18 Series Motors. Series motors have field coils connected in series with the armature. The speed of a series motor varies widely with load and may be excessive at no load. Series motors are limited to applications where the load is directly connected and change in speed with load is desirable, or can be tolerated. Series motors provide high starting torque.

302−2.19 Compound Motors. Compound motors have one set of field coils connected in parallel with the armature and another set connected in series with the armature. These shunt and series field coils are proportioned to give the desired compromise between the characteristics of shunt and series motors.

302−2.20 Stabilized Shunt Motors. These motors are similar to compound motors except that the series field coils are of relatively low strength. Without the stabilizing series field, some shunt motors would increase in speed with an increase in load.

302−2.21 COMMUTATING WINDING. The commutating winding is wound on poles placed midway between the main field poles. Commutating poles consequently are frequently referred to as interpoles. The commutating winding is connected in series with the armature. Its purpose is to improve commutation.

302−2.22 CURRENT, VOLTAGE, AND POWER. For dc motors, the relations between I_L, E_L, motor hp, and motor eff are:

$$I_L = \frac{746\ (hp)}{(E_L)(eff)}$$

$$kW\ input = \frac{0.746\ (hp)}{eff}$$

$$kW\ output = \frac{I_L\ E_L}{1000}$$

302−2.23 OPERATIONAL PRECAUTIONS

302−2.24 PRELIMINARY. Before starting an ac or dc motor at any time:

1. Verify that covers and guards are in place. This requirement may be waived when performing maintenance which necessitates motor operation with the absence of covers or guards.

2. Verify that all personnel are clear of the motor and equipment which it drives.

302−2.25 Before starting a dc series motor at any time verify that the motor is securely connected to a substantial load. A series motor will run up to a destructive speed if not loaded.

302−2.26 In addition to the foregoing, observe the following precautions before starting any motor for the first time after installation, repair, or a long period of idleness:

1. Verify that all mechanical fasteners are tight, that the motor is firmly anchored to its foundation and properly assembled to its mating equipment.

2. Verify that accessible internal and external electrical connections are tight, that there is no visible evidence of damaged insulation or inadequate clearance between conductors of different polarity and conductors and ground, and that the conductors in the terminal box are not squeezed into contact with each other or with metal parts of the terminal box or cover.

3. Examine air gap clearances and verify that rotating parts do not rub against stationary parts.

4. Examine bearings to the extent possible without disassembly; make sure that lubricant appears clean and in proper quantity, and that oil rings, if provided, are free to turn.

5. Remove all dirt, foreign matter, and extraneous material from within the motor and the terminal box.

6. Verify that all belts, if used, are in good condition, and that guards for belts or gears are in place.

7. Wipe all accessible parts with a clean, dry lintless cloth.

8. Measure and record insulation resistance. If the value is less than one megohm, determine whether it is reasonable in view of all factors, see chapter 300 (9600). Verify that corrective measures are performed before starting the motor.

9. Place covers in position and fasten.

10. Check equipment driven by the motor and verify that it is ready to run.

11. Verify that resiliently mounted motors are provided with ground straps.

302−2.27 AC Motors. If energizing an ac motor for the first time, or if changes have been made in the power supply connections since previous operation, use a phase rotation indicator (chapter 491 (9690)) to check the phase rotation of the power supply for three−phase motors, and verify that the motor will run in proper direction. A thorough check before starting is essential. Running some types of equipment in the wrong direction will damage the equipment and possibly injure personnel. If it is definitely known that the mating equipment can rotate in either direction without injury, this check may be omitted and the direction of rotation can be observed when the motor is started. Interchanging any two of the power supply leads will reverse the direction of a three−phase induction motor.

302−2.28 DC Motors. If energizing a dc motor for the first time, check the connections and verify that they will give the correct direction of rotation. Insofar as possible without disassembly, ensure that the commutating field coils, series field coils (if present), and shunt field coils are connected with the correct polarity and are not open circuited or short circuited. When shunt field coils are incorrectly connected or open circuited, the motor may run away and cause serious damage to equipment or injury to personnel. Verify that brushes are in place.

302−2.29 STARTING. Start the motor in accordance with the instructions on its controller. If any unusual noise, vibration, speed, or temperature rise develops, stop the motor immediately and investigate. After starting a motor for the first time after installation or long period of idleness, check the direction of rotation and verify that oil rings, if provided, are turning.

302−2.30 TROUBLES

302−2.31 TROUBLE DIAGNOSIS TABLES. Table 302−2, Table 302−3 and Table 302−4 list probable causes of the more common motor troubles and give a suggested procedure to follow in order to determine the cause and remedy it. In most cases, the remedy is obvious as soon as the cause is definitely known. Table 302−2 lists troubles common to all electric motors while Table 302−3 and Table 302−4 list troubles common to ac motors and dc motors respectively.

3**302−2.32 ELECTRICAL MEASUREMENTS**. Proper use of electrical testing equipment will do much to detect and correct abnormalities in operation and forestall permanent damage to equipment. Motor identification plates show line voltage and line current corresponding to rated horsepower. The field current for dc motors is given in the test data on the motor drawing. Measurements made with portable instruments on line voltage, line current, and field current will show at once, and with certainty, whether the trouble is caused by high or low line voltage, excessive line current (indicating on overload), or incorrect field current. Measurement of the current in each phase of a three−phase motor will show whether there is a current unbalance which may cause overheating or unsatisfactory performance. For instruction on the use of electrical measuring instruments, see chapter 491 (9690).

302−2.33 OVERHEATED BEARINGS. The temperature of sleeve bearings and the outer races of ball bearings should not be allowed to exceed the values indicated on Table 302−5. All bearings under normal operating conditions will operate at a steady temperature level. These temperature levels should be known from past experience, and from factory test data on the motor drawings. Deviation from normal operating temperature indicates trouble which should be corrected as soon as possible.

302−2.34 The permissible operating temperature is too high to be estimated by the sense of touch. Temperature measurements are needed to determine whether a bearing is overheated. Despite the desirability of measuring temperature directly on the bearing, a glass thermometer should not be inserted in the bearing housing. It may break and necessitate disassembly to remove glass and mercury. A thermometer securely fastened to an outer bearing surface will usually give satisfactory temperature measurements. See chapter 300 (9600) for information on temperature measurements. (No mercury or mercury containing instruments shall be used with submarine motors.)

302−2.35 A motor with overheated sleeve bearings should be unloaded, if possible, without stopping the motor. If stopped immediately, the bearing may seize. The best way to limit bearing damage is to keep the motor running at light load and supply plenty of cool, clean oil until the bearing cools down.

302−2.36 For details of operation and maintenance of both sliding and rolling contact bearings, see chapter 244 (9431).

302−2.37 OVERHEATED INSULATION. The life of electrical insulation is reduced by approximately one−half when the insulation is operated at 10 °C in excess of design temperatures. For this reason, the operating temperature of electrical equipment is highly important. Except where justified by even more important considerations, the temperature of motors should not be allowed to exceed the temperatures shown on the equipment drawings of technical manuals furnished with the equipment. When such are not available, Table 302−5 may be used as a guide to maximum permissible temperature rise of insulation and other parts of motors. Temperature of insulation and other parts of the motor shall be measured as described in the following paragraphs.

302−2.38 Method 1. This is the thermometer method and consists of the determination of temperature by mercury thermometers, resistance thermometers, alcohol thermometers, or by surface and contact thermocouples; any of these instruments being applied to the hottest part of the equipment accessible to mercury or alcohol thermometers. This method is preferred for uninsulated windings, exposed metal parts, gases, and liquids. It is also preferred for surface measurements generally and wherever other methods are not applicable or practical as in the case of some windings with very low resistance. Thermocouples are preferred for measuring rapidly changing surface temperatures, as in the case of resistors, commutators, collector rings, and other parts of rotating equipment.

302−2.39 The number of thermometers or thermocouples used shall be liberal and shall be so disposed as to ascertain the highest temperature. Thermometer bulbs or the thermocouple contact points shall be placed in such positions that they make the maximum practicable contact with the part whose temperature is to be measured, and shall be so firmly supported that this degree of contact will not be altered by gravity and vibration. The bulbs of thermometers shall be surrounded by a small amount of oil putty or equivalent to help maintain contact. The probes of contact thermocouples shall be sufficiently sharp to penetrate any oxide film present on the (metal) surface being measured.

Table 302–2. ELECTRIC MOTOR TROUBLE DIAGNOSIS

Trouble	Probable Cause	Suggested Procedure
Motor fails to start	Power not connected because of open supply switch or circuit breaker or blown fuses	Close switch or circuit breaker; check fuses and replace if necessary.
	Overload relay or circuit breaker in supply line trips	Reset overload relay or circuit breaker and restart. If it trips again, inspect for short circuit and check other causes for failure to start.
	Low voltage	See if voltage shown on motor name plate agrees with voltage agrees with voltage of supply line. Measure voltage at motor terminals with motor connected to see if voltage drop in line is excessive.
	Loose connections, broken connections, or open circuit in controller or wiring to motor	Check connections.
	Incorrect connections in controller or to motor	Check connections with wiring diagrams for controller and motor. Make sure that motor is connected for correct direction of rotation.
	Open circuit in motor windings	See chapter 300 (9600)
	Short circuit in motor windings	See chapter 300 (9600)
	Grounded motor windings	See chapter 300 (9600)
	Overload on driven machine	Reduce load, if possible, and start with the driven machine partially or completely unloaded. Except dc series motors.
	Excessive friction due to (a) Belt tension. (b) Gear side thrust. (c) Misalinement (d) Stiff grease in ball bearings. (e) Insufficient lubrication of sleeve bearings. (f) Bent and sprung shaft. (g) Rotor rubbing stator. (h) Driven machine seized.	Check possible causes. Disconnect motor from driven machine, if necessary, to localize source of trouble. Except dc series motors.
	Stiff bearings	Free bearings
	Frozen bearings	Replace bearings and for sleeve bearings resurface and polish shaft.
	Electric brake (if installed) fails to release	Check operation of brake
	Driven machine locked or jammed	Disconnect motor from driven machine. Except dc series motors. If motor starts and runs all right, check driven machine.
Motor stops after it has been running	Power supply fails because a generator circuit breaker trips out	Restart motor when power is reestablished.
	Circuit breaker or overload relay trips out because of shock or overload	Reset circuit breaker or overload relay and restart motor. If it trips again, check for overload.
Vibration or excessive noise	Inadequate foundation or loose holding-down bolts on motor or driven machine	Tighten holding-down bolts.
	Loose punchings or rotor loose on shaft	Tighten bolts, keys, and mechanical fastenings, or replace rotor and shaft assembly.
	Loose electrical connections	Tighten.
	Coupling misalined or loose	Check alinement and tighten coupling bolts.
	Excessive belt tension	Loosen belts.

Table 302–2. ELECTRIC MOTOR TROUBLE DIAGNOSIS (Continued)

Trouble	Probable Cause	Suggested Procedure
	Air gaps not uniform	Center the rotor. Replace bearings if necessary.
	Rotor rubbing the stator, an aggravated case of air gaps not uniform	
	Dirt in air gap	Clean.
	Objects caught between fan and end shields	Stop motor and clean out.
	Motor or driven machine unbalanced	Disconnect motor from driven machine and run alone to determine where the trouble is. Except dc series motors. Balance the unit that is unbalanced.
	Excessive load	Reduce load.
	Short-circuited coils	See chapter 300 (9600)
	Bearing troubles (a) Insufficient oil supply or oil rings sticking (sleeve bearings) (b) Overgreased ball bearings (c) Excessive end play which allows shaft to bump back and forth (d) Poor fit, bearings too tight or too loose	 (a) Add oil and check rings. (b) Remove drain plug and allow excess grease to run out. (c) Check end play and belt alinement if belts are used. (d) Check fit and replace bearings, if necessary.
Bearings overheat (both sleeve and ball bearings). See paragraph 302-2.33 for permissable bearing temperatures	End shields loose or not replaced properly	Verify end shields fit squarely and are properly tightened.
	Too much belt tension, if belted, or too much gear side thrust if geared	Reduce belt tension or gear side thrust. See that gear side thrust is not being transferred to motor.
	Misalined couplings or belts	Check and correct alinement
	Bent or sprung shaft	Straighten shaft, or replace with new shaft, or replace entire rotor.
	Too much heat conducted to bearings from overheated rotor	Correct cause of overheated rotor.
	Too much heat conducted to bearings from overheated windings	Correct cause of overheated windings.
Sleeve bearings overheat	Not enough oil	Add oil. If oil is very low, drain, clean, and refill to proper oil level.
	Foreign material or dirt in oil	Drain oil, clean reservoir, and refill.
	Oil ring rotates too slowly or not at all	Check oil to verify that too heavy oil is not being used. Check oil ring for worn spots, and, if worn, replace.
	Oil rings bent or jammed	Replace with new rings.
	Oil ring out of slot or retaining clip out of place	Put ring in slot, and replace retaining clip.
	Defective bearings or scored shaft	Replace bearings and polish shaft.
	Bearings too light	Loosen bearings.
Ball bearings overheat	Too much grease	Remove drain plug, let motor run, and allow excess grease to run out. See also chapter 300 (9600)
	Not enough grease	Add grease. See chapter 300 (9600)
	Wrong grade of grease	Replace with proper grade. See chapter 300 (9600)
	Dirt in grease	See chapter 300 (9600)
	Bearings not alined	Check bearing assembly and see that races are perpendicular to the shaft.

Table 302–2. ELECTRIC MOTOR TROUBLE DIAGNOSIS (Continued)

Trouble	Probable Cause	Suggested Procedure
Windings overheat. See paragraph 302-2.37 for permissible insulation temperatures	Bearings damaged or corroded	Replace bearings. See chapter 300 (9600).
	Heat conducted to windings from overheated bearings	Correct cause of overheating of bearings.
	Incorrect bearing	Check applicable tech manual and bearing stock number.
	Short-circuited coils	See chapter 300 (9600).
	Overload	Check electric power input to motor. See paragraph 302-2.32. Reduce load if possible.
	Incorrect connection of motor internally or to external circuit	Check connections with wiring diagram and correct, if necessary.
	Rotor rubbing stator	Check air gaps and center rotor.
	Restricted ventilation	See that fans and baffles are correctly assembled. Clean air passages and windings.
	Too frequent starting or running at a more severe duty cycle than the motor is built for, failure of protective devices to function, and indiscriminate use of emergency run feature, particularly under conditions of overload.	Check operation control devices if motor is on full automatic control. Check duty cycle with name plate rating on motor.
	Low voltage on supply line Overheating due to any of the causes enumerated above.	Check voltage at motor terminals when motor is running
Motor burns out	Insulation failure due to (a) Excessive moisture in windings (b) Grease, oil, or dirt on the windings (c) Faulty insulation	Replace by spare motor or rewind.

Table 302–3. AC MOTOR TROUBLE DIAGNOSIS

Trouble	Probable Cause	Suggested Procedure
Motor fails to start	Motor single phased. Frequently indicated by a humming sound	Check power line to make sure that power is available on all three phases. Check connections from supply line to motor for open circuits. Check motor winding for open circuit.
Noisy motor	Motor running single phase. Usually indicated by a humming noise	Stop motor, bring it to rest, and try to restart. If single phased, will not start. See above for further steps.
	Currents in three phases unbalanced	Measure currents in three phases. See paragraph 302-2.32. If unequal, check winding for open circuits, short circuits, and grounds.
Motor overheats	Running single phase or with unbalanced currents in the three phases	See above underNoisy motor.
	Poor connection between rotor bars and short circuiting end rings	Tighten connections and braze bars to end rings, or replace rotor assembly.

Table 302–4. DC MOTOR TROUBLE DIAGNOSIS

Trouble	Probable Cause	Suggested Procedure
Motor attempts to start but overload relay trips	Weak field or no field	If an adjustable speed motor, check field rheostat for correct setting. If correct, check condition of rheostat. Check field coils for open circuit. Check wiring for loose or broken connections.
Motor runs too slow under load	Line voltage too low	Check line voltage and correct.
	Brushes set ahead of neutral	Adjust brushes to neutral. See chapter 300 (9600).
	Overload	Check electric power input to motor. See paragraph 302-2.32.
Motor runs too fast under load	Weak field	Check field circuit and rheostat for loose connections. Measure field current.
	Incorrect series field polarity	Check series field connection.
	Line voltage too high	Measure line voltage at motor terminals and correct line voltage if high.
	Brushes set back of neutral	Set brushes on neutral. See chapter 300 (9600).
Faulty commutation– High, white spark under one brush. Grooving of commutator	Copper embedded in the brush	Scrape copper off brush with a knife. Sand brush to fit. Recondition comutator, if necessary. See chapter 300 (9600).
Periodic sparking. Some highly polished bars with adjacent commutator bars dull or burned	Loose commutator with high bar	Stop motor, tap high bar back into place with block of wood and mallet. Tighten commutator nuts. Season and resurface commutator, if necessary.
Blue, snappy sparks	Defective armature coils, open circuited or short circuited	Locate and replace defective coils or replace armature.
Ring of fire	Defective armature coils or rough and dirty commutator	Replace coils or recondition commutator.
Continuous, heavy sparking	Overload	Check line current, and reduce overload if practical. Check for overspeed.
	Weak or open main field circuit	Check for loose or broken connection or open circuits. Measure field current.
	Reversed commutating pole or main pole connections	Check connections with wiring diagram.
	Incorrect adjustment of commutating pole air gap	See paragraph 302-2.44
	Brushes off neutral Brushes unevenly spaced around commutator	See chapter 300 (9600).
	Brush studs not parallel to commutator bars	See chapter 300 (9600).

Table 302−4. DC MOTOR TROUBLE DIAGNOSIS (Continued)

Trouble	Probable Cause	Suggested Procedure
	Brushes wedged in holders or wrong brush pressure Brush holders too near or too far from commutator	See chapter 300 (9600). Free brushes in holders. Test brush pressure. See chapter 300 (9600). See chapter 300 (9600).
	Loose or high resistance pigtail connections	Tighten or replace brushes, if necessary.
	Incorrect grade of brush	Check motor drawings for correct brush grade.
	High mica or pitted mica	Undercut mica. See chapter 300 (9600).
	Dirty or rough commutator	Clean or recondition commutator. See chapter 300 (9600).
	Vibrating brushes	Check to see if there is excessive machine-vibration, rough or eccentric commutator, incorrect brush pressure, wrong grade of brushes, wrong brush angle, incorrect distance from brush holders to commutator, high mica.
	Brushes do not fit commutator	Sand brushes to fit. See chapter 300 (9600).
	Brushes worn too short or broken	Replace brushes.
	Insufficient or excessive brush pressure	See chapter 300 (9600).
	Use of emery cloth or paper on the commutator	Remove all emery from commutator and mica, and replace brushes. Never use emery cloth or emery paper to clean the commutator or fit brushes.

302−2.40 Method 2. This is the resistance method and consists of the determination of temperature by comparison of the resistance of a winding at the temperature to be determined, with the resistance at a known temperature. This method is preferred for insulated windings, except for windings of such low resistance that measurements cannot be accurately made due to uncontrollable resistance in contacts or where it is impractical to make connections to obtain measurements before an undesirable drop in temperature occurs.

302−2.41 In the application of method 2, accuracy is essential in the measurement of all resistances and of the temperature of the windings at which the cold resistance is measured. Care shall also be taken not to include any unnecessary external resistances. The following formula shall be used in computing temperature rise by the resistance method.

Temperature rise

$$(°\text{C}) = (234.5 + \text{tc})\,\frac{\text{Rh}}{\text{Rc}} - (234.5 + \text{ta})$$

When:
- Rc = Cold resistance of winding
- Rh = Hot resistance of winding
- tc = Temperature (°C) of winding when cold resistance was measured.
- ta = Ambient temperature (°C) during the last quarter of the test.

302−2.42 To convert from Fahrenheit to Centigrade temperatures, use:

$$\text{C} = \frac{5}{9}\,(\text{F} - 32)$$

$$\text{F} = (\frac{5}{9}\,\text{C}) + 32$$

302−2.43 When temperature measurements are made, either by the thermometer or resistance method, they should be made at 2− or 3− minute intervals following shutdown until a maximum temperature is reached. The maximum temperature of any part is to be taken as the operating temperature of that part, whether the maximum occurs at shutdown or sometime later.

302−2.44 COMMUTATING POLE STRENGTH. Changes necessary to adjust incorrect commutating pole strength will normally be beyond the capacity of ship's forces. Such changes are normally made at a repair activity. Normally, there is no need for a change after installation. If, however, there is good reason to suspect that incorrect commutating pole strength is responsible for unsatisfactory motor operation, a check can be made as follows:

1. Make sure that the brushes are set on neutral. See chapter 300 (9600) for instructions.

2. With a low reading voltmeter (range of about 3 volts), read the voltage between a fixed point on the brush and four points on the commutator spaced at equal intervals along the brush span. See Figure 302−1. Use a carbon prod held in insulating material to make contact with the commutator. The machine should be running at normal load and voltage. Readings should be taken from position 1 to 4 in the direction of rotation. A curve similar to curve B of Figure 302−1 indicates correct commutating pole strength. Curve A indicates that the pole strength is too weak (air gaps too long) and curve C that the pole strength is too strong (air gaps too short).

302−2.45 TROUBLE REPORTS. Completeness and clarity should be the primary considerations in preparing reports on troubles or derangements. See chapter 300 (9600) for the information which should be included in such reports.

302−2.46 MAINTENANCE

NOTE

Where the Planned Maintenance Subsystem (PMS) is installed on board ship, use the Maintenance Requirement Cards (MRC) for maintenance.

302−2.47 GENERAL. For general instructions the following apply:

1. Maintenance including cleaning and rewinding of motors, see Chapter 300 (9600)
2. Bearings, see chapter 244 (9431)
3. Lubrication, see:
   a. MRC cards
   b. Equipment technical manual
   c. Motor master drawing
   d. Chapter 300 (9600)
4. Post overhaul tests, see paragraph 302−2.23.
5. To replace motor shaft, see motor master drawing.

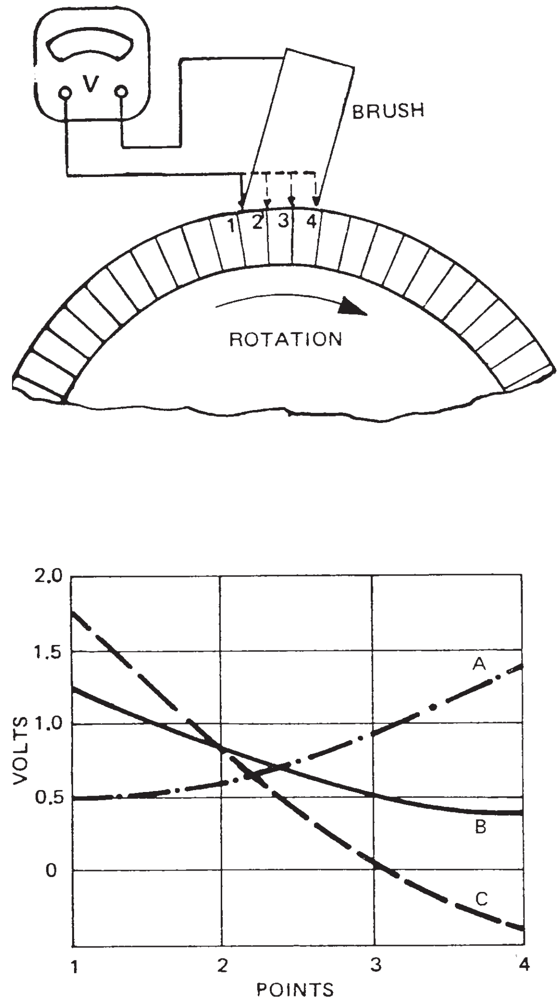

Figure 302−1. Measuring Commutating Pole Strength

302−2.48 INSULATION RESISTANCE. Measure the insulation resistance of motors at least once each quarter and more often if motors are exposed to excessive dirt or moisture. Measure insulation resistance after repairs and before using a motor which has stood idle for a long time. See chapter 300 (9600) for criteria on the measurement of insulation resistance and drying out machines with insulation which has absorbed moisture.

Table 302–5. MAXIMUM PERMISSIBLE TEMPERATURE RISES

Item	Insulation Type	40°C Ambient					50°C Ambient					65°C Ambient					80°C Ambient	
		A	B	F	H	N	A	B	F	H	N	A	B	F	H	N	H	N
1	Windings other than those specified in item 4																	
	(a) Dripproof protected Method 2	60	80	105	125	145	50	70	95	115	135	35	55	80	110	120	95	105
	(b) Totally enclosed fan cooled, spraytight fan cooled, watertight fan cooled Method 2	60	80	105	125	145	50	70	95	115	135	35	55	80	110	120	95	105
	(c) Others Method 2	65	85	110	135	150	55	75	100	125	140	40	60	85	115	125	95	105
2	Cores and mechanical parts in contact with or adjacent to the insulation																	
	(a) Motors specified under 1(a) Method 1		50	70	95	115	135	40	60	85	105	125	25	45	70	90	110	75
	(b) Motors specified under 1(b) and 1(c) Method 1	55	75	100	125	145	45	65	90	115	135	30	50	75	100	120	85	105
3	Collector rings																	
	(a) If class A insulation is employed in collector rings or is adjacent thereto	65	65	-	-	-	55	55	-	-	-	40	40	-	-	-	-	-
	(b) If class B insulation is employed in collector rings	85	85	-	-	-	75	75	-	-	-	60	60	-	-	-	-	-
	(c) If class H or N insulation is employed in collector rings	-	-	-	125	145	-	-	-	115	135	-	-	-	85	120	85	105
4	Bare copper windings and single-layer field windings with exposed uninsulated surfaces																	
	(a) Motors specified under 1(a)	60	80	105	130	150	50	70	95	120	160	35	55	80	105	125	90	110
	(b) Motors specified under 1(b) and 1(c)	65	85	110	135	150	55	75	100	125	165	40	60	85	110	130	95	115
5	Bearings, ball	70	70	70	110	110	60	60	60	100	100	45	45	45	85	85	70	70
	Bearing sleeve, imbedded thermocouple	53	53	53	53	53	43	43	43	43	43	-	-	-	-	-	-	-
	Bearing oil, sump	42	42	42	42	42	32	32	32	32	32	-	-	-	-	-	-	-

SECTION 3. CONTROLLERS

302−3.1 GENERAL

302−3.2 SCOPE. For detailed information on any specific installation, reference should be made to the wiring and elementary diagrams and operational description in the controller enclosure, the Ship Information Book, the drawings applying to the equipment, and the equipment technical manual.

302−3.3 Equipment which is considered in this section includes:

1. Motor controllers
2. Motor static variable speed controllers
3. Master switches
4. Electric brakes

302−3.4 The fundamental purposes of these devices are governing and protecting the motors to which they are connected. It is the purpose of this section to describe some of the governing functions and protective features, and to provide general instructions covering operation and troubleshooting of motor control equipment.

302−3.5 DEFINITIONS. The following definitions apply to the terms as used herein. Unless otherwise specified, the definitions apply to both ac and dc equipment.

1. A **motor controller** is a device or group of devices which serves to govern, in some predetermined manner, the operation of the motor to which it is connected.

2. A **motor static variable speed controller** is an arrangement of solid state and other devices which regulate the speed of a motor in infinite increments through a predetermined range of speed. Speed control is accomplished by a manual adjustment or actuation of a device which senses and converts a system parameter into an electrical signal which is utilized to set the motor speed automatically.

3. A **manual controller** is one wherein the contacts normally used to energize and deenergize the connected load are closed and usually opened through a mechanical system directly actuated by an operator.

4. A **magnetic controller** is one wherein the contacts normally used to energize and deenergize the connected load are closed and opened by electromechanically operated switches located within the controller enclosure or at a distance from the controller.

5. An **across−line controller** throws the connected load directly across the main supply line.

6. A **resistor controller** (dc only) inserts a resistor in the armature circuit of a dc motor during starting, and may also use the resistor for speed control after starting.

7. A **primary resistor controller** (ac only) inserts resistors in the primary circuit of an ac motor for starting, or for starting and speed control.

8. A **secondary resistor controller** (ac only) inserts resistors in the secondary circuit of a wound−rotor type ac motor for starting or speed control.

9. A **compensator or auto−transformer controller** (ac only) starts the motor at reduced voltage through an auto−transformer, and subsequently connects the motor line voltage after acceleration. The compensator is divided into two types which operate as follows:

   a. The open−transition type cuts off power to the motors during the transition period of shifting the motor from the auto−transformer to direct connection with the supply line. In the short time that it is disconnected, the motor may coast and slip out of phase with the power supply. When the motor is then connected directly to the power line, a high transition current may result.

   b. The closed−transition type keeps the motor connected to the power supply at all times during the transition period, thus not permitting the motor to fall out of phase. Accordingly, no high transition current is developed.

10. A **reactor controller** (ac only) inserts a reactor in the primary circuit of an ac motor during starting, and subsequently short circuits the reactor to apply line voltage to the motor.

11. A **nonautomatic controller** is a manual controller.

12. A **semiautomatic controller** is a magnetic controller, all of whose functions are normally governed by one or more manual switches.

13. An **automatic controller** is a magnetic controller any of whose functions is normally governed by one or more automatic master switches after the controller is initially energized through operation of a manual master switch.

14. A **full and semiautomatic controller** is a controller that can be operated either as an automatic controller, or as a semiautomatic controller by the closing of a switch to select the type of performance desired.

15. A **master switch** is a device such as a pushbutton, pressure switch, or thermostatic switch, which governs the electrical operation of a controller.

16. A **manual master switch** is one which performs its function through the intervention of an operator (for example, drum, selector, and pushbutton switches).

17. An **automatic master switch** is one which performs its function through the effect of physical

forces other than an operator (for example, float, limit and pressure switches).

18. A **local master switch** is one mounted in the controller enclosure and usually operable from outside the enclosure.

19. A **remote master switch** is one mounted separate from the enclosure.

20. A **momentary contact master switch** is one in which the contact is momentarily closed or opened to start a series of operations, and then returns to its original condition.

21. A **maintaining contact master switch** is one in which the contact is closed or opened to start a series of operations, and does not return to its operations, and does not return to its original condition until again actuated.

22. An **interlock** is a device actuated by a second device to which it is connected, to govern succeeding operations of the second or other devices. Interlocks may be either electrical or mechanical.

23. **Normally open or normally closed**, when applied to contacts and interlocks of control devices such as contactors, relays, and master switches, indicates the position taken (open or closed, respectively) when the control device is deenergized. The deenergized condition for a manual controller is considered the off position.

24. An **electric brake** is a device, operated by electromagnetic means, which functions to bring a load to rest mechanically and hold it at rest.

25. A **rewiring diagram or connection diagram** of control equipment is a pictorial representation by means of standardized symbols to show the following:

a. The items (for example, contacts, interlocks, and coils) comprising each control device and the approximate location of each item relative to other items of control.
b. The terminals and connectors of control devices.
c. The electrical wiring as actually made between each device, terminal, and connector.

26. An **elementary diagram or schematic diagram** of control equipment is a pictorial representation by means of standardized symbols to show the electrical location and the sequence of operation of the individual items comprising the control equipment. Elementary diagrams are used in connection with the more complicated control equipments and do not indicate the relative physical location of the elements or devices.

27. An **auxiliary** is a fan, pump, compressor, lathe, or other equipment driven by the motor with which a controller is used.

302−3.6 DESCRIPTION

302−3.7 ENCLOSURES. The following types of enclosures are used for motor controllers as required by such factors as location, atmospheric condition, and presence of explosive vapor or liquid:

1. Open
2. Dripproof
3. Spraytight
4. Watertight
5. Submersible
6. Explosionproof (Group D)

302−3.8 CLASSIFICATION. Controllers are classified as manual or magnetic in operation. Magnetic controllers are classified as semiautomatic or automatic in operation. See paragraph 302−3.5 for definitions.

302−3.9 TYPES. Ac controllers for naval shipboard use are of the following types, defined in paragraph 302−3.5:

1. Across−line ac controllers are the most common because of their simplicity.
2. Some primary resistor ac controllers are used to limit the starting current of large ac motors. Primary resistor controllers may also be used for speed control of small ac motors.
3. Secondary resistor controllers may be used to limit starting currents but are usually used for speed control of large ac motors.
4. The compensator or autotransformer controller is the most common form used for starting at reduced voltage to limit starting current. The open−transition form has the disadvantage of permitting large transition currents which can cause circuit breakers to open. The closed−transition form is preferable because it prevents large transition currents.
5. The reactor controller is not widely used. It is becoming more common for starting large ac motors because it does not have the high transition currents of the open−transition compensator and is smaller than the closed−transition compensator.

302−3.10 Dc controllers are of the across−line or resistor types, defined in paragraph 302−3.5. These controllers may have a rheostat in the motor shunt field circuit for speed control. They are used as follows:

1. Across−line dc controllers are limited to small motors.

2. The resistor type is the most common form of dc controller. These controllers are usually used to limit motor starting current to prevent damage to

the motor and overloading of the power system. Another form of resistor type controller uses resistors to control motor speed as well as limit starting current.

302−3.11 FUNCTIONS. A controller performs a combination of the following functions: starting, stopping, reversing, and speed control. Speed control is classified as speed selection or speed regulation.

302−3.12 SPEED SELECTION. Speed selection provides for motor operation at any one of certain definite speeds but not at intermediate speeds. Speed selection is commonly used for multiple−speed ac motors and for dc winches, windlasses, and capstans where fixed resistors are inserted or removed from the armature circuit. It is also used in some dc applications where a fixed (as opposed to an adjustable) field resistor is cut into or out of the motor circuit to change motor speed.

302−3.13 SPEED REGULATION. Speed regulation provides for operation at any speed within a definite range. In ac applications, this is usually done by changing a rheostat in the secondary circuit of a wound−rotor induction motor. In dc applications, it is usually done with a rheostat in the motor shunt field circuit.

302−3.14 PROTECTIVE FEATURES. The more common forms of protection provided by motor controllers are:

1. Low voltage protection
2. Low voltage release
3. Low voltage release effect
4. Overload protection
5. Short circuit protection
6. Full field protection
7. Jamming (step back) protection

302−3.15 Low Voltage Protection. Low voltage (or under voltage) protection is the feature which provides for disconnecting the motor from the power supply upon reduction or loss of voltage; and keeping it disconnected after voltage returns until the operator restarts the motor.

302−3.16 Low voltage protection in magnetic controllers is usually obtained by a normally open momentary contact master switch, in parallel with a normally open interlock on the main contactor. Low voltage protection (Figure 302−2) operates as follows:

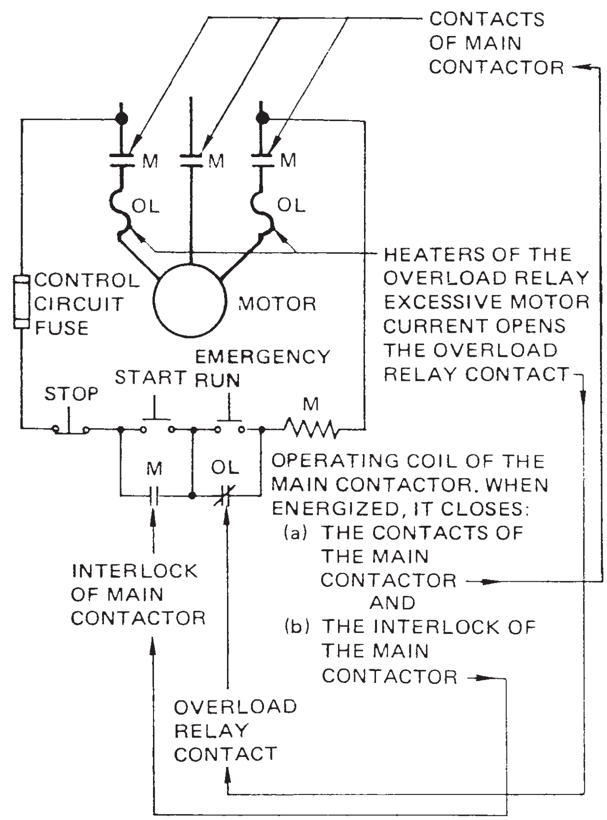

Figure 302−2. Low Voltage Protection

1. When normally open START switch is closed, current flows through normally closed STOP switch, momentarily closed START switch, the overload relay contact, and the main contactor operating coil.

2. The operating coil closes the main contactor and the main contactor interlock.

3. When the START switch is released, current flows through the STOP switch, the main contactor interlock (which is now closed), the overload relay contact, and the main contactor operating coil.

4. Upon reduction or loss of voltage, the main contactor operating coil is deenergized, and the main contactor opens to disconnect the motor from the power supply.

5. The main contactor interlock also opens. This breaks the current path through the main contactor operating coil and the motor will not start after restoration of voltage until the operator closes the START switch.

302−3.17 Low voltage protection in manual controllers is usually provided by means of a coil connected across two of the load terminals. The coil is energized and picks up its armature when an operator closes the main contacts. Upon reduction or loss of voltage, the armature is released and allows a spring to open the main contacts. The motor will not start after restoration of voltage until the operator again closes the main contacts.

302−3.18 All auxiliaries governed by controllers with low voltage protection will stop on reduction or loss of voltage and will not restart when power is restored until the START switch is closed. The generator is thus relieved of the load of these auxiliaries while power is being restored. For this reason, low voltage protection is desirable for auxiliaries which are not so essential that they must be restarted immediately upon restoration of power.

302−3.19 Low Voltage Release. Low voltage (or under voltage) release is the feature which provides for disconnecting the motor from the power supply upon reduction or loss of voltage and for keeping it disconnected until power returns; and then automatically reconnecting the motor to the power line to restart it.

302−3.20 Low voltage release is obtainable only in magnetic controllers. It is usually obtained by the use of on ON−OFF master switch (START−STOP buttons) in series with the operating coil of the main contactor (Figure 302−3). When the master switch is closed by pressing the START button, a circuit is completed through the operating coil of the main contactor and the main contactor closes. Upon reduction or loss of voltage, the operating coil is deenergized and the main contactor opens. Upon restoration of power, the operating coil is energized again and the motor restarts automatically. In the case of large motors which are started at reduced voltage, the restart after a voltage failure is automatically made at reduced voltage and the motor is then connected to line voltage.

302−3.21 All auxiliaries governed by controllers with low voltage release will stop upon reduction or loss of voltage and will restart automatically upon restoration of power. The generator is thus required to supply power to these auxiliaries as power is being restored. For this reason low voltage release is desirable only in controllers for auxiliaries which must be restarted automatically upon restoration of voltage.

302−3.22 Low Voltage Release Effect. Low voltage (or under voltage) release effect is the feature which provides the same effect in manual controllers as is obtainable in low voltage release type magnetic controllers. This is accomplished by leaving the motor connected to the power supply upon reduction or loss of voltage; and permitting the motor to restart upon restoration of voltage.

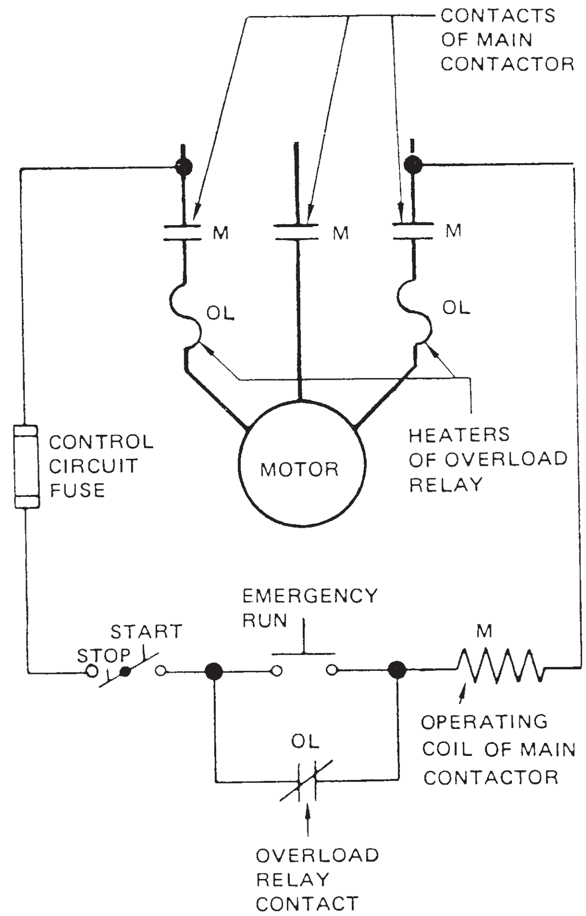

Figure 302−3. Low Voltage Release Protection

302−3.23 Low voltage release effect is obtainable in manual controllers only. It is obtained by the use of a manually operated switch or main contactor. This remains closed on reduction or loss of power, and the motor simply starts up again when power is restored.

302−3.24 All auxiliaries governed by controllers with low voltage release effect will restart automatically upon restoration of power and immediately load the generator. For this reason, low voltage release effect is desirable only for auxiliaries which must be started automatically upon restoration of power, or for small auxiliaries which have low starting currents.

302−3.25 Overload Protection. The purpose of overload protection in a motor controller is to prevent overheating the motor by excessive current.

This feature is incorporated in nearly all Navy controllers. It is usually provided by an overload relay.

302–3.26 Overload relays in magnetic controllers have a normally closed contact which is opened by a mechanical device that is tripped by an overload current. Opening the overload relay contact breaks the circuit through the operating coil of the main contactor, causes the main contactor to open, shutting off power to the motor. See Figure 302–2, Figure 302–3, Figure 302–4, Figure 302–5, Figure 302–6, Figure 302–7 and Figure 302–8. Overload relays in manual controllers operate mechanically to trip the main contacts and allow them to open.

302–3.27 Overload relays for naval shipboard use are usually required to be adjustable. Such relays can be adjusted to trip at the right current to protect the motor if it is found that the rated tripping current of the relay does not fit the motor it is intended to protect.

302–3.28 Thermal type overload relays are required to be compensated; that is, they are so constructed that the current needed to trip the relay is practically unchanged by variations in the ambient (room) temperature where the controller is located.

302–3.29 All controllers with overload protection have an overload relay reset. This is used to reset the relay after it has tripped so that the motor can again be operated with overload protection. Many controllers also have an emergency–run switch, so that the motor can be run without overload protection in an emergency.

302–3.30 Overload relays are of the magnetic or thermal type.

302–3.31 Magnetic Type Overload Relay. The magnetic type of overload relay has a coil connected in series with the motor load circuit and a tripping armature or plunger. When the motor current exceeds the tripping current, the armature opens the overload relay contact. Magnetic relays are of the instantaneous or time–delay type.

302–3.32 The instantaneous type operates instantaneously when the motor current exceeds the tripping current. It must be set at a tripping current higher than the starting current of the motor, otherwise it would trip every time an attempt is made to start the motor. It is limited in application. One use is in motor controllers for reduced voltage starting in which starting current peaks are less than the stalled rotor current.

302–3.33 The time–delay type is essentially the same as the instantaneous type except for the addition of a time–delay device. The time–delay device is usually an oil dashpot with a piston which is attached to the tripping armature of the relay. This piston has a hole through which oil passes when the tripping armature is moved by an overload current. The size of the hole can be adjusted to change the speed at which the piston moves for a given pull on the tripping armature. For a given size hole, the faster operation. The motor is thus allowed to carry a small overload current longer than a large overload current. The relay can be set to trip at a current well below the stalled rotor current because the time–delay gives the motor time to accelerate to full speed before the relay operates. By this time the current will have dropped to full load current which is well below the relay trip setting.

302–3.34 In both the instantaneous and time–delay magnetic overload relays, the tripping current is usually adjusted by changing the distance between the series coil and the tripping armature. More current is needed to actuate the armature when distance is increased. Compensation for changes in ambient temperature is not needed for magnetic overload relays because they are practically unaffected by changes in temperature.

302–3.35 Thermal Type Overload Relay. The thermal type overload relay has a heat–sensitive element and an overload heater which is connected in series with the motor load circuit. When the motor current is excessive, heat from the heater causes the heat–sensitive element to open the overload relay contact. This breaks the circuit through the operating coil of the main contactor, and disconnects the motor from the power supply. Since it takes time for parts to heat up, the thermal type of overload relay has an inherent time–delay. This permits the motor to do maximum work at any reasonable current but only as long as the motor is not being overheated; when it is, the overload relay disconnects the motor. Thermal overload relays are of the solder pot, bimetal, single metal, or induction type.

1. **Solder pot type**. The heat–sensitive element is a solder pot which consists of a cylinder inside a hollow tube. These are normally held together by a film of solder. In case of an overload, the heater melts the solder, breaks the bond between the tube and cylinder, and releases the tripping device of the relay. After the relay trips, the solder cools and solidifies, and the relay can be reset for subsequent operation.

2. **Bimetal type**. The heat–sensitive element is a strip or coil of two different metals fused together

along one side. When heated, one metal expands more than the other and causes the strip or coil to deflect. The deflection is used to open the overload relay contact.

3. **Single metal type**. The heat−sensitive element is a metal tube around the heater. The tube lengthens when heated and opens the overload relay contact.

4. **Induction type**. The previously described types of thermal overload relay can be used for either ac or dc applications. The induction type can be used only for ac applications. The heater consists of a coil in the motor load circuit and a copper tube inside the coil. The copper tube acts as the short−circuited secondary of a transformer and is heated by the current induced in it. The heat−sensitive element is usually a bimetal strip or coil.

302−3.36 Changes in the ambient temperature in the room where a thermal overload relay is located will change its tripping characteristics unless the relay is compensated against ambient temperature changes. Different means are used for different types. See the technical manual furnished with the equipment on which the controller is used for information on the particular form of compensation provided.

302−3.37 Coarse adjustment of the tripping current of thermal type overload relays is made by changing the heater element. Fine adjustment is made in different ways, depending upon the type of overload relay. One form of fine adjustment consists of changing the distance between the heater and the heat sensitive element. Increasing this distance will increase the tripping current. Another form consists of changing the distance a bimetal strip has to move before the overload relay contact is opened. See the technical manual furnished with the controller is used for details on the particular kind of adjustment provided.

302−3.38 Overload Relay Resets. After an overload relay has operated to stop a motor, it must be reset before the motor can again be run with overload protection. Magnetic type overloaded relays can be reset immediately after tripping. Thermal type overload relays must be allowed to cool before they can be reset. This may take a minute or more. After the overload relay has been reset, the motor can be restarted. The three forms of overload reset are the hand, automatic, and electric reset.

302−3.39 The hand reset is the most common form. It usually consists of a rod, button, or lever which is operated by hand and returns the relay tripping mechanism to its original position, resetting any interlocks as well, so the motor can again be run with overload protection. The hand reset is located in the controller enclosure which contains the overload relay.

302−3.40 The automatic reset is usually a spring or gravity operated device. It resets the overload relay without the intervention of an operator.

302−3.41 The electric reset is actuated by an electromagnet controlled by a pushbutton. This form is used when it is desired to reset an overload relay from a remote operating point.

302−3.42 Emergency Run Feature. Many controllers have an emergency run feature, particularly controllers for auxiliaries where a prolonged stoppage in the middle of an operating cycle would be a potential source of danger. By using the emergency run feature, an operator can keep the auxiliary running with the motor overloaded until a standby unit can take over, until the operating cycle is completed, or until the emergency has passed.

NOTE

The emergency run feature is provided for emergency use only and should not be used for any other purpose.

302−3.43 Emergency run is provided by various means. In all cases, the lever or button to be used is clearly marked and must be held closed during the entire duration of the emergency. Common methods of providing emergency run in magnetic controllers are:

1. A separate EMERGENCY RUN pushbutton with normally open contacts in parallel with the normally closed contact of the overload relay shown in Figure 302−2, Figure 302−3, Figure 302−6, Figure 302−7 and Figure 302−8. For emergency run operation, the operator must hold the EMERGENCY RUN pushbutton down and press the START switch t to start the motor. As long as the EMERGENCY RUN pushbutton is held down, the motor cannot be stopped by the opening of the overload relay contact.

2. A combined RESET−EMERGENCY RUN rod or lever is shown in Figure 302−4. The rod or lever holds the overload relay contact closed as long as the rod is held down. The START switch must be momentarily closed to start the motor.

3. A combined START−EMERGENCY RUN pushbutton is shown in Figure 302−5. The motor will start when the button is pushed, and will continue to run without overload protection as long as it is held down. For this reason, pushbuttons which are marked START−EMERGENCY RUN should not be kept closed for more than a second or two unless emergency run operation is desired.

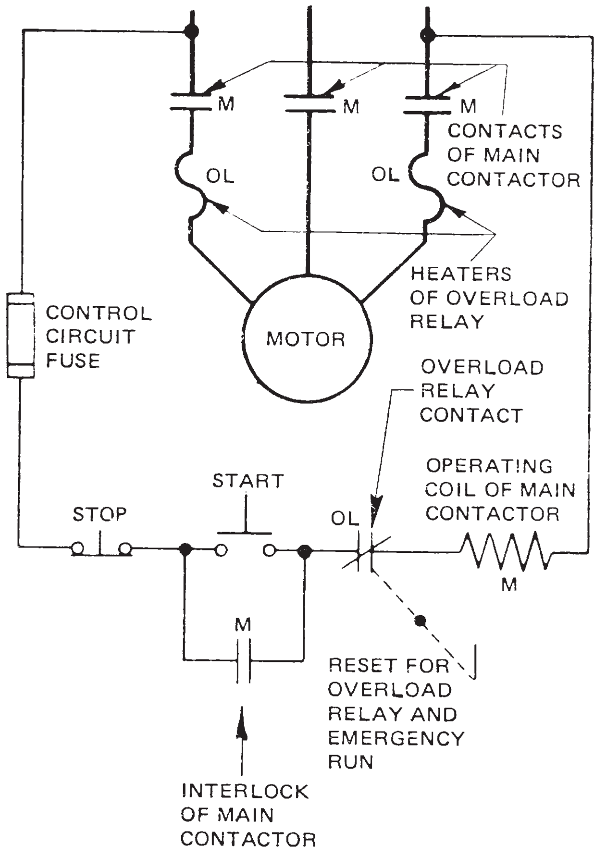

Figure 302−4. RESET−EMERGENCY RUN Feature

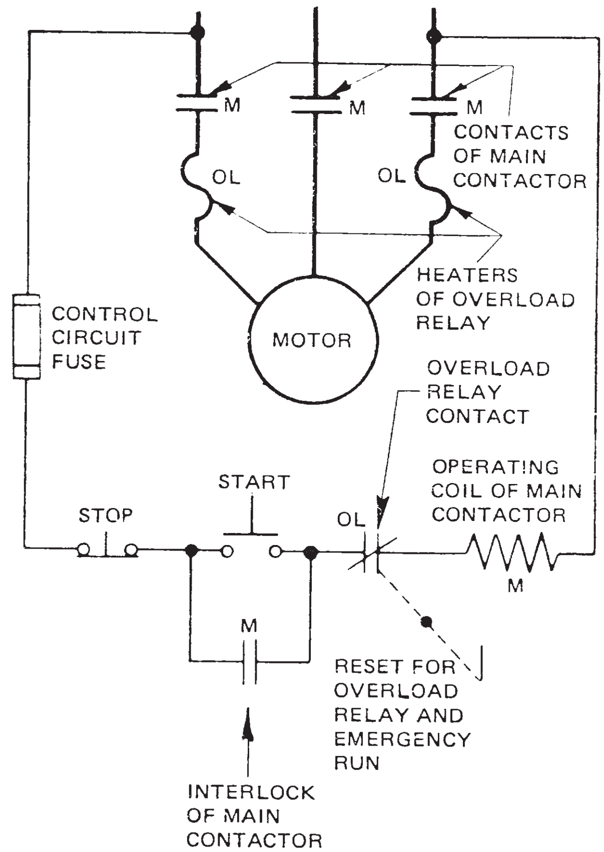

Figure 302−5. START−EMERGENCY RUN Feature

302−3.44 Manual controllers may also be provided with emergency run. This is usually done by means of a START−EMERGENCY RUN pushbutton or lever which keeps the main contacts closed despite the tripping action of the overload relay mechanism.

302−3.45 Short Circuit Protection. Overload relays and contactors are usually not designed to protect motors from currents greater than about six times normal rated current of ac motors, or four times normal rated current of dc motors. Protection against short circuit currents, which will be of considerably greater magnitude, is obtained by other devices. Recent Navy practice has been not to provide short circuit protection in motor controllers where it would protect only the motor, but to provide short circuit protection by circuit breakers placed in the power supply system. This practice protects the cables to the controller as well as the controller and motor.

302−3.46 There are some cases, however, when short circuit protection is provided in the controller. One is when it is not otherwise provided by the power distribution system. Another is when the short circuit protection in the distribution system protects two or more motors, and has too high a rating to protect the individual motors satisfactorily.

302−3.47 Short circuit protection for control circuits is provided by fuses in the controller enclosure. The fuses are connected in control circuits which run to remote pushbuttons, pressure switches, and so forth. In general, each control wire that leaves a controller should be protected by a fuse if the lead is not already protected by a current limiting device, such as a coil or resistor, located in the enclosure.

302−3.48 Full Field Protection. Full field protection is required in controllers for dc motors in which a shunt field rheostat or resistor is used to weaken the motor field and obtain motor operation at speeds in excess of 150 percent of the speed at rated field current. Full field protection is an automatic feature performed by a relay which shunts out the shunt field rheostat for initial acceleration of the motor, and then cuts it into the motor field circuit. In this way, the motor first accelerates to 100 percent, or full speed, and then further accelerates to the weakened field speed determined by the rheostat settings.

302–3.49 Jamming (Step Back) Protection. This feature is found in controllers for anchor windlasses. If the motor is excessively overloaded, the controller automatically cuts back the speed to a lower point and relieves the motor of excessive load.

302–3.50 TWO–SPEED AC MOTOR CONTROLLER. Figure 302–6 is an elementary diagram of a controller for a two–speed ac motor with separate high–speed and low–speed windings. Circuit operation is apparent from a study of the diagram.

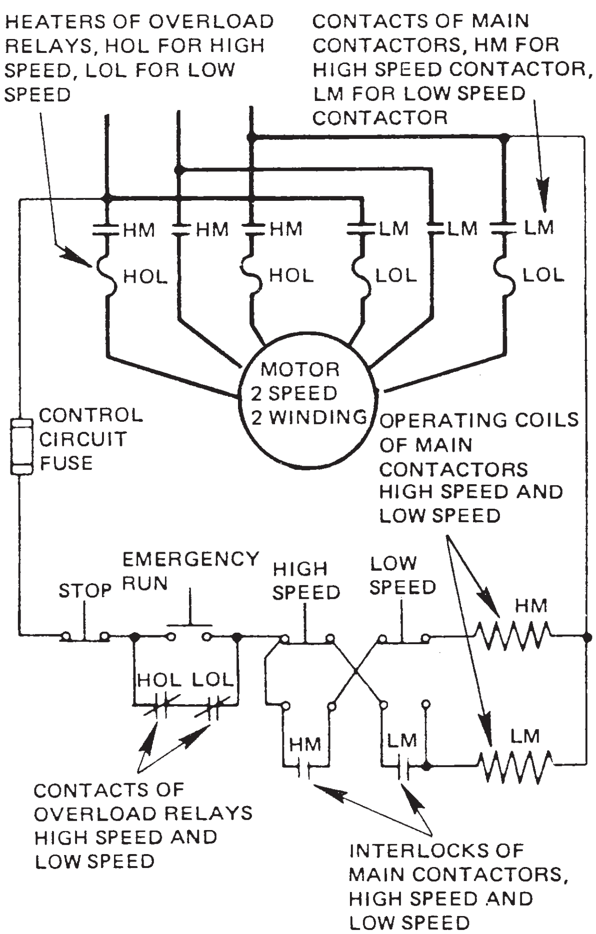

Figure 302–6. Two–Speed AC Motor Controller Circuit

302–3.51 SEMI–AUTOMATIC/FULL AUTOMATIC CONTROLLER. When the SELECTOR switch is turned to the MANUAL position, see Figure 302–7, the motor is under the control of the operator irrespective of what the automatic master switch may do. Pushing the START switch energizes the control relay and closes the control relay interlock in parallel with the START switch. It also energizes the operating coil of the main contactor and closes the main contactor. Henceforth, the motor will continue to run until the operator presses the STOP switch or the overload relay contact opens.

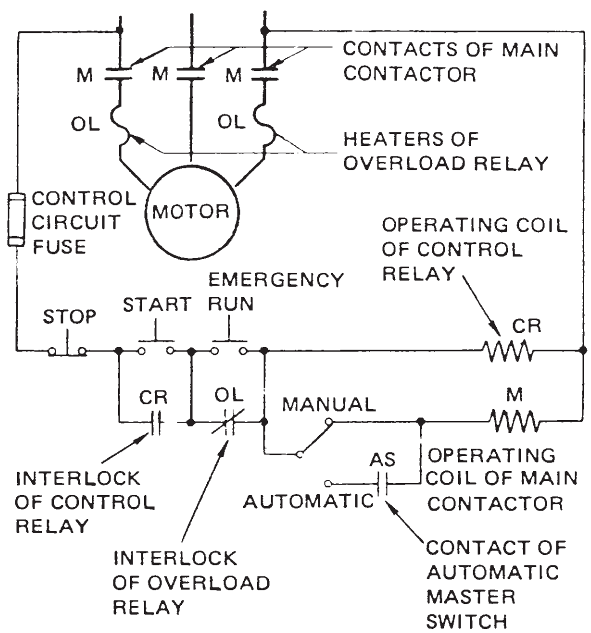

Figure 302–7. Semi–Automatic/Full Automatic Controller Circuit

302–3.52 When the SELECTOR switch is turned to the AUTOMATIC position and the operator presses the START switch, the motor is under the control of the automatic master switch. This may be a pressure, float, or other similar type switch. Pressing the START switch closes the interlock of the control relay. Henceforth, the motor will run when the automatic master switch is closed, stop when the switch opens, and restart when the switch closes. If the operator presses the STOP switch, the interlock of the control relay opens. The motor will not run, irrespective of what the automatic master switch may do, until the START switch is pressed again.

302–3.53 MAGNETIC DC CONTROLLERS. Most dc controllers are of the magnetic, resistor type. A common form uses current acceleration or series relay acceleration, see Figure 302–8. When the START switch is pressed, the main contactor closes and holds itself in electrically by its interlock. The high inrush motor current through the 1SR series relay opens the 1SR interlock, breaks the circuit through the 1A operating coil, and keeps the first accelerating contactor open. The current decreases as the motor speeds up, the first series relay drops out, its interlock closes, and current passes through the 1A operating coil. The first accelerating contactor closes. This shorts out the first step of starting resistance and sets up the second series relay circuit. The process is repeated until all steps of starting resistance are cut out and the armature is connected directly to the power line.

302–3.54 Another type of magnetic controller uses definite time–delay acceleration. Mechanical or electrical timing devices are used instead of series relays. When the main contactor closes, the timing device starts. After a time–delay, which is generally adjustable, it closes an accelerating contact and shorts out one step of starting resistance. This procedure continues until the motor is connected directly across the line.

302–3.55 ELECTRIC BRAKES. Electric brakes used on naval ships are generally of the disk or shoe types. They consist of a spring–operated braking device which is released when the brake solenoid or motor is energized. The releasing solenoid or motor is connected to the controller for the equipment on which the brake is used. When the motor driving the equipment is energized, the brake solenoid or motor is also energized and the brake is released. When the equipment motor is deenergized, the brake solenoid or motor is also deenergized and the brake sets. Brakes are usually fitted with a hand release which can be used to release the brake when power is not available. Electric brakes find their widest shipboard application on hoisting and lowering equipment.

302–3.56 Electric brakes are generally operated with a solenoid or motor. Some brakes have a solenoid which operates through a mechanical system to release the brake. Some brakes have a small electric motor which operates by means of a mechanical or hydraulic system to release the brake.

302–3.57 OPERATION

302–3.58 GENERAL. Operation of simple controllers involves no more than depressing the proper pushbutton switch. Operation of a more complicated controller may require study of the way it is intended to operate. Controllers meeting full Navy requirements have wiring and elementary diagrams and an operational description fastened to the inside of the enclosure door. These diagrams and descriptions should be studied. For further and more detailed instructions and drawings, the technical manuals should be consulted.

302–3.59 INITIAL OPERATIONAL PRECAUTIONS. Before operating a controller for the first time after installation or overhaul, verify the following:

1. The controller is mounted securely and true to the deck or bulkhead.

2. The mounting bolts do not twist the controller out of line.

3. The interior and all parts are clean, particularly of metal shavings or filings.

4. All parts operate freely and without binding. Many controllers are equipped with mechanical linkages to prevent malfunctioning from mechanical shocks; these linkages may prevent manual operation.

5. Adjustable relays are at proper settings.

6. All current–carrying parts, especially terminals and incoming and outgoing leads, have ample creepage and clearance distances from each other and from grounded pads.

7. All screws, nuts, bolts, and electrical connections are tight.

8. Arc shunts are in place.

9. Enclosure doors are closed except when observation of operation is necessary.

CAUTION

Explosion–proof controllers should never be operated with enclosure doors open unless specific precautions have been taken to ensure that no explosive vapors are present.

10. The motor which will be started by operation of the controller is ready to run. See paragraph 302–3.23.

302–3.60 SUBSEQUENT OPERATION. When the controller is operated after the first time following installation or overhaul:

1. Operate the controller in the way prescribed by the manufacturer.

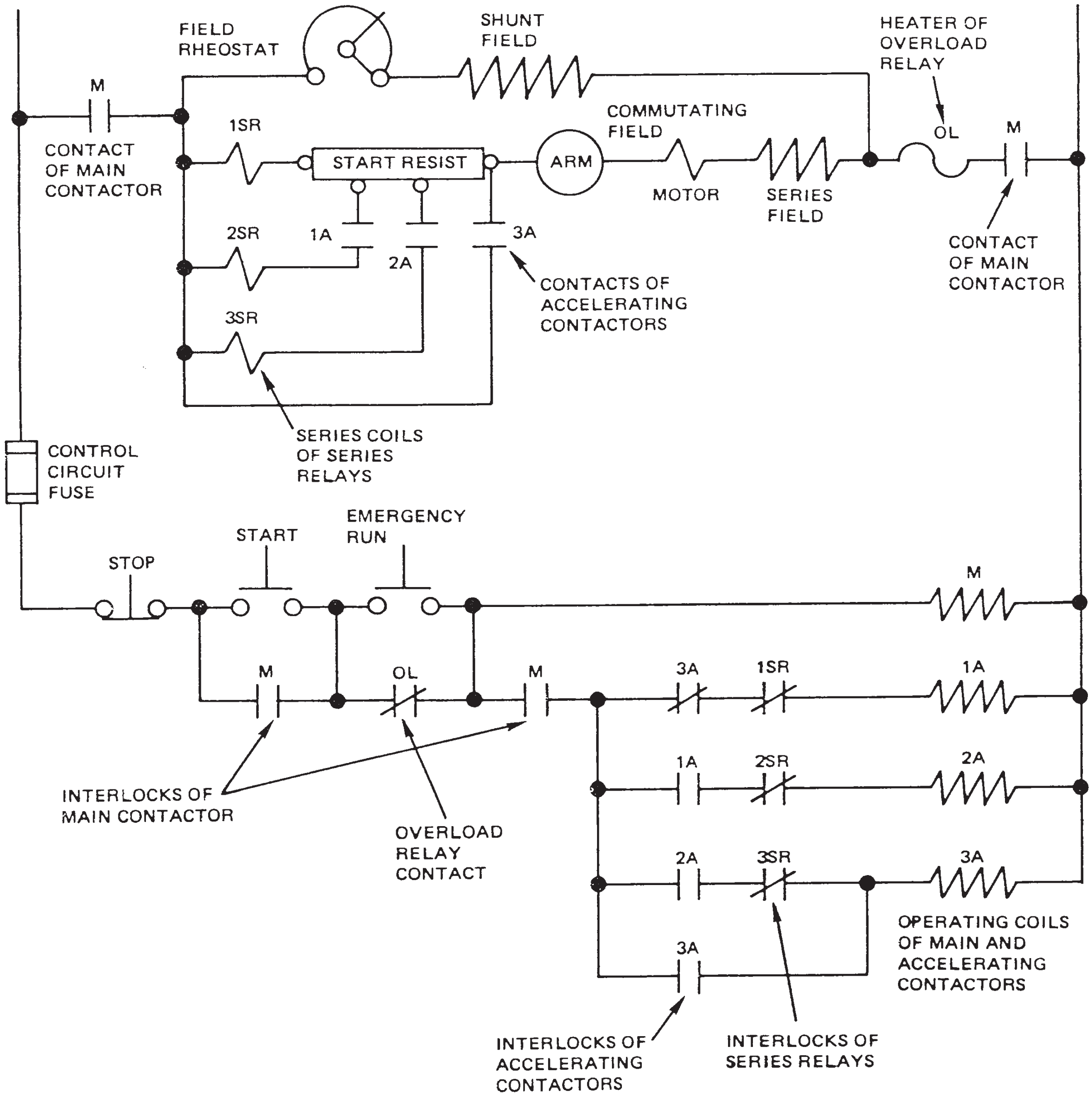

Figure 302–8. Magnetic DC Controller Circuit

2. Investigate immediately if there are any apparent inconsistencies in operation or if the motor does not come up to speed promptly.

3. Listen to the controller during and after starting. This simple check will often reveal faulty operation or help to locate a wire that has loosened from vibration or a bad contact before dangerous trouble occurs.

4. Keep the door of the enclosure properly secured.

5. Avoid frequent starts and stops unless the motor and its controller are designed for this type of duty. Frequent starts and stops generate heat in a motor and its controller and may overheat equipment that is not designed for this duty.

6. Check temperature roughly by feeling the

enclosure after a controller has been running for about an hour. Excessive temperature is a sign of trouble.

7. Listen for loud humming or chattering and investigate the cause, if observed.

302−3.61 EMERGENCY RUN FEATURE. The emergency run feature is for emergencies and must not be used carelessly. A motor kept running by use of the emergency run feature is running without overload protection and may burn out. This risk is justified in an emergency; it is not in normal operation. If the overload relay trips when a motor is started, the cause of the trouble should be found and corrected, and the emergency run feature should not be used unless an emergency exists.

302−3.62 When a motor trips out because of overload but must be restarted immediately because of an emergency:

1. Hold the EMERGENCY RUN switch down.

2. Push the START switch if the motor does not start. This step is neither necessary nor possible with a controller like that shown in Figure 302−5, in which there is a combined START−EMERGENCY RUN switch. It may or may not be necessary with a controller such as that shown in Figure 302−3, depending upon the position of the maintaining contact START master switch. It will always be necessary with a controller such as that shown in Figure 302−2.

3. Keep the EMERGENCY RUN switch down as long as emergency run operation is necessary.

302−3.63 TROUBLES

302−3.64 Controller troubles are usually caused by contacts, coils, magnets, mechanical parts, or overload relays. Table 302−6 lists common controller troubles, probable causes, and remedies.

302−3.65 Table 302−7 lists common electric brake troubles, probable causes, and remedies.

302−3.66 MAINTENANCE

302−3.67 See chapter 300 (9600) for instructions on the maintenance of motor control equipment.

Table 302−6. CONTROLLER TROUBLE DIAGNOSIS

Trouble	Probable Cause	Remedy
CONTACTS		
Contact chatter	Poor contact in control relay	Clean relay contact.
	Broken shading coil	Replace.
	Excessive jogging	Caution operator to avoid excessive jogging.
Overheated contact tips	Dirty contact tips	Clean and dress, if necessary, in accordance with chapter 300 (9600) or manufacturer's instructions.
	Sustained overloads	Find and remedy the cause of the overloads.
	Insufficient tip pressure	Clean and adjust.
	Loose connections	Clean and tighten.
Weak tip pressure	Wear allowance gone	Replace contacts and adjust.
	Poor tip adjustment	Adjust gap and wipe.
	Low voltage which prevents magnet sealing	Correct voltage condition.
Short tip life	Excessive filing or dressing	Follow manufacturer's instructions.
	Excessive jogging	Instruct operator in correct operation.
Welding or fusing	Abnormal starting currents	Operate manual controllers slower. Check automatic controllers for correct starting resistors and proper functioning of timing devices or accelerating relays.
	Rapid jogging	Instruct operator in correct operation.
	Short circuit currents on contacts	Find and remedy causes of short circuits. Check feeder fuses for proper size and replace, if necessary.

Table 302–6. CONTROLLER TROUBLE DIAGNOSIS (Continued)

Trouble	Probable Cause	Remedy
Failure of the flexible conductors between fixed and moving parts of contactor.	Improper installation	See manufacturer's instructions.
	Worn out mechanically by large number of operations.	Replace
	Moisture or corrosive atomosphere	Replace with flexible conductors suitable for application.
	Burned by arcing or overheating from loose, oxidized, or corroded connections	Clean and tighten connections.
	COILS	
Coil failure: (a) Not overheated	Moisture, corrosive atmosphere	Use correctly insulated coils.
	Mechanical damage	Avoid handling coils by the leads.
	Vibration or shock damage	Secure coils properly.
(b) Overheated	Overvoltage or high ambient temperature	Check current and application.
	Wrong coil	Use only the manufacturer's recommended coil.
	Too frequent use, or rapid jogging	Use correct operating procedure.
	Undervoltage, failure of magnet to seal in	Check circuit and correct cause of low voltage.
	Used above current rating	Install correct coil for the application.
	Loose connections to coil, or corrosion or oxidation of connection surfaces.	Clean and tighten connection.
	Improper installation	See manufacturer's instructions.
	MAGNETS AND MECHANICAL PARTS	
Worn or broken parts	Heavy slamming caused by over-voltage or wrong coil	Replace part and correct cause.
	Chattering caused by broken shading coil or poor contact in control circuit	
	Excessive jogging	
	Mechanical abuse	
Noisy magnet	Broken shading coil	Replace.
	Magnet faces not true, result of mounting strain	Correct mounting.
	Dirt or rust on magnet face	Clean.
	Low voltage	Check system voltage and correct if wrong.
	Improper adjustment, magnet overloaded	Check and adjust according to manufacturer's instructions.
Broken shading coil	Heavy slamming caused by over-voltage, magnet under-loaded, weak tip pressure	Replace coil and correct the cause.
Failure to drop out	Gummy substances on magnet faces	Clean with approved solvent.
	Worn bearings	Replace.
	Nonmagnetic gap in magnet circuit	Replace magnet.
	Voltage not removed	Check coil voltage.
	Not enough mechanical load on magnet, improper adjustment	Adjust in accordance with manufacturer's adjustment instructions.
	OVERLOAD RELAYS	
Magnetic, instantaneous type: High or low trip	Wrong coil	Install correct coil.
	Mechanical binding, dirt, corrosion, etc.	Clean with approved solvent, adjust.
	Shorted turns (High trip)	Test coil, and replace if defective.
	Assembled incorrectly	Refer to manufacturer's instructions for correct assembly.
	Wrong calibration	Replace.

Table 302−6. CONTROLLER TROUBLE DIAGNOSIS (Continued)

Trouble	Probable Cause	Remedy
Magnetic, inverse time-delay type: Slow trip	Fluid dirty, gummy, etc.	Change fluid and fill to correct level.
	Mechanical binding, corrosion, etc.	Clean with approved solvent, adjust.
	Worn or broken parts	Replace and adjust.
	Fluid too low	Drain and refill to correct level.
Thermal type: Failure to trip	Wrong size heater	Install correct size.
	Mechanical binding, dirt, corrosion, etc.	Clean with approved solvent and adjust.
	Relay damaged by a previous short circuit.	Replace.
Trips at too low temperature	Wrong size heater	Install correct size.
	Assembled incorrectly	See technical manual for correct assembly.
	Wrong calibration	Replace.
Failure to reset	Broken mechanism or worn parts	Replace.
	Corrosion, dirt, etc.	Clean and adjust.
Burning and welding of control contacts	Short circuits in control circuits with fuses that are too large	Correct causes of short circuits and make sure that fuses are right size.
Timing relays, flux decay type: Too short time	Dirt in air gap	Clean.
	Shim too thick	Replace with thinner shim.
	Too much spring or tip pressure	Adjust in accordance with technical manual.
	Misalinement	Correct alinement, and remedy cause of misalinement.
Too long time	Shim worn too thin	Replace with thicker shim.
	Weak spring and tip pressure	Adjust in accordance with technical manual.
	Gummy substance on magnet face or mechanical binding.	Clean with approved solvent and adjust.

Table 302−7. ELECTRIC BRAKE TROUBLE DIAGNOSIS

Trouble	Probable Cause	Remedy
Worn or broken parts	High inertial loads, misapplication, excess temperature	Replace parts and refer to technical manual for correct procedures.
Failure to hold load	Worn parts, out of adjustment, wrong brake lining	Replace parts with correct materials and adjust according to technical manual.
	Grease or oil on brake drum	Clean thoroughly with approved solvent.
Failure to set	Out of adjustment, worn parts	Replace worn parts and adjust in accordance with technical manual.
	Mechanical binding	Clean and adjust.
	Coil not deenergized	Check circuit to make sure current is cut off.
Failure to release	Out of adjustment	Adjust in accordance with technical manual.
	Coil not energized	Check and repair circuit.
	Wrong coil	Replace with correct coil.
	Coil open or short circuited	Replace coil
	Motor will not run	Refer to technical manual.
	Motor binds	Aline correctly, check bearings.

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