

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 320

**ELECTRIC POWER
DISTRIBUTION SYSTEMS**

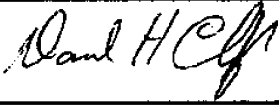
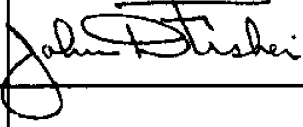
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CHAPTER 320

ELECTRIC POWER DISTRIBUTION SYSTEMS

SECTION 1.

DESCRIPTION OF ELECTRICAL SYSTEMS AND EQUIPMENT

320-1.1 GENERAL

320-1.1.1 IMPORTANCE OF ELECTRIC POWER. Electric power is essential to a modern naval ship's fighting and functional effectiveness. Electric power trains elevate gun turrets and missile launchers; operate the rudder's hydraulic system; run auxiliaries; provide light; and power interior communication, weapons control, radio, radar, sonar, and missile systems. A ship without electric power is useless as a fighting or supporting unit and is almost totally defenseless against enemy attack.

320-1.1.2 SAFETY PRECAUTIONS. Safety precautions must always be taken when working around electrical equipment and circuits to avoid injury and possibly death of personnel, and equipment damage. See **NSTM Chapter 300, Electric Plant - General**, for electrical safety precautions. Paragraphs [320-1.2.5.4](#), [320-1.2.8.2](#), [320-2.2.6.2](#), and [320-2.2.6.4](#) of this document provide additional safety details for electrical distribution systems.

320-1.1.3 DISTRIBUTION SYSTEMS. The distribution system is the vital link connecting the generators that produce electric power to the equipment that uses it. It transmits electric power from the power source to the power user. The distribution system also protects (by means of circuit breakers and fuses) itself, and its generators from damage that might otherwise be caused by faults in the system or connected equipment.

320-1.1.3.1 Alternating Current or Direct Current. The primary power distribution system installed in ships is alternating current (ac). Direct current (dc) distribution systems are used for combat systems, auxiliary systems, and emergency systems in submarines. Small dc networks, supplied by rectifiers or ac/dc motor-generator sets, supply outlets for battery charging. The New Attack Submarine (NSSL) has high voltage dc generators that supply static frequency converters to produce 450V, three-phase, 60 Hz power for the ship's user equipment, and to provide dc power for main battery charging.

320-1.2 ALTERNATING CURRENT DISTRIBUTION SYSTEMS

320-1.2.1 VOLTAGE, PHASE, AND FREQUENCY. The primary power distribution voltage, phase, and frequency used on U.S. Navy ships is 450 volts (V), three-phase, 60 hertz (Hz). Secondary voltage, phase, and frequency is 120V, three-phase, 60 Hz. It is supplied from the 450V system through transformer banks. Lighting distribution systems are 120V, three-phase, 60 Hz, and are supplied from the power circuits through transformer banks. Single-phase power is available from the 450V and 120V systems. Most ships also have 450V and 120V, 400-Hz power systems for supplying weapons systems and electronic equipment, and for servicing aircraft and landing craft. Some aircraft carriers have 4160V, three-phase, 60 Hz generators and main switchboards that supply the 450V AC system through transformers.

320-1.2.1.1 System Grounding. All ac distribution systems on U.S. Navy ships are ungrounded. However, certain avionics shops, aircraft servicing systems, and landing craft air cushion (LCAC) servicing outlets are supplied from three-phase, four-wire systems that are supplied by transformers with a grounded, wye-connected sec-

ondary and single-phase, three wire grounded outlets with two pole ground fault current interruption (GFCI) protection are provided where required by the user equipment (see paragraph 320-1.2.1.3). Only one ground connection point is allowed for each grounded power system. Ungrounded electrical systems have no intentional connections between the electrical conductors and the ground (ship's hull). These systems were chosen for their higher reliability because grounding of a single conductor will not typically produce enough fault current to interrupt power. Grounds must be removed as soon as possible to maintain this advantage, however, because a second ground on another phase will cause a power loss and could endanger personnel.

320-1.2.1.2 Types of Power. Power system bus voltages are rated 450V and 120V, while nominal voltage ratings for utilization equipment are 440V and 115V. The lower utilization equipment voltage ratings account for the voltage drops that are normal in any electrical distribution system. Voltage at the utilization equipment terminals can vary because of changing loads and their effect on generator voltage and distribution cable voltage drops. The various groups of utilization equipment aboard Navy ships require an electrical power supply with different characteristics. To meet the needs of these groups, standards have been established for the interface (the point at which the user equipment connects to the power system). These standards' power characteristics have been coordinated with the North Atlantic Treaty Organization (NATO); they are listed in Table 320-1-1. The following paragraphs define the three types of electric power supply at the user equipment interface.

- a. Type I, 60-Hz power. The 440V and 115V power supplied to equipment by the ship's power and lighting distribution systems is designated type I power.
- b. Type II and Type III, 400-Hz power. The 440V and 115V, 400-Hz power supplied to equipment by 400-Hz motor generator sets or solid-state converters is designated type II or type III. As seen in Table 320-1-1, the tolerances for type III power are much tighter than the tolerances for type II power. In general, the ship service 400-Hz distribution system supplies type II power to the loads. Where loads require more precise voltage or frequency regulation, the system is designed or equipment (such as line voltage regulators) is added to ensure that the type III power characteristics are met.

320-1.2.1.3 Special Power Types. Grounded three-phase, four-wire power is provided for avionics shops, aircraft servicing, and LCAC servicing as follows:

- a. Type I, 115/200V, 60-Hz power for certain avionics shops where equipment requires a grounded three-phase power source.
- b. Type III, 115/200V, 400-Hz power for avionics shops.
- c. 115/200V, 400-Hz power for starting and servicing aircraft with the characteristics required as defined by the Naval Air Systems Command (NAVAIR). Typically, aircraft starting stations provide power to the aircraft in accordance with MIL-STD-704, **Aircraft Electric Power Characteristics**, which includes steady-state voltage limits of 113V to 118V, measured at the aircraft's external power receptacle. Similar power is provided for LCAC servicing outlets. The 115/200V at the user equipment terminals of a grounded four-wire system is nominally 115V, measured from a phase conductor to neutral, and 200V measured between any two phases. The actual voltage will vary because of changes in the system loads.

320-1.2.1.4 Key Power Characteristics. The power characteristics listed in Table 320-1-1 are fully defined in MIL-STD-1399, **Interface Standard for Shipboard System**, Section 300A. The following describes selected power characteristics for the user equipment terminals as specified in Table 320-1-1:

- a. **Nominal Frequency and Frequency Tolerance**. Nominal frequency is the designated frequency of the

power system. In actual fact, the system often operates at a frequency that is slightly above or below this nominal value. The frequency tolerance defines the maximum and minimum permissible system frequency, excluding transients and modulation.

- b. **Nominal User Voltage and User Voltage Tolerance** . Nominal user voltage is the designated voltage at the user equipment terminals. The actual terminal voltage can vary from this nominal value because of operator adjustments of the generator voltage, varying load currents in the cables supplying the user equipment (which causes varying distribution system voltage drops), and various other reasons. User voltage tolerances define the maximum and minimum permissible voltages at the user equipment terminals. The distribution system is designed to limit the voltage drops in the system so that the combination of generator voltage regulation and distribution voltage drops are still within the user voltage tolerances for the required type of power. The voltage tolerances for any one line-to-line voltage are slightly wider than those for the average of all three-phase voltages. This allows for some imbalance in the individual phase voltages.

Table 320-1-1 ELECTRIC POWER SYSTEM CHARACTERISTICS AT THE USER INTERFACE

Characteristics	Type I	Type II ¹	Type III ¹
Frequency:			
(a) Nominal frequency	60 Hz	400 Hz	400 Hz
(b) Frequency tolerances	Plus or minus 3 percent (5 percent for Submarines)	Plus or minus 5 percent	Plus or minus 1/2 percent
(c) Frequency modulation	1/2 percent	1/2 percent	1/2 percent
(d) Frequency transient			
(1) Tolerance	Plus or minus 4 percent	Plus or minus 4 percent	Plus or minus 1 percent
(2) Recovery time	2 seconds	2 seconds	0.25 second
(e) The worst case frequency excursion from nominal frequency resulting from (b), (c), and (d) (1) combined except under emergency conditions	Plus or minus 5-1/2 percent	Plus or minus 6-1/2 percent	Plus or minus 1-1/2 percent
Voltage:			
(f) Nominal user voltage	440, 115 or 115/200V rms ²	440, 115V or rms	440 or 115V 115/200V rms ²
(g) User voltage tolerance	(See paragraph 320-1.2.1.2)	(See paragraph 320-1.2.1.4.b)	
(1) Average of the three line-to-line voltages	Plus or minus 5 percent	Plus or minus 5 percent	Plus or minus 2 percent (Plus or minus 1/2 percent for avionic shops only)
(2) Any one line-to-line voltage including (g) (1) and line voltage unbalance (h)	Plus or minus 7 percent	Plus or minus 7 percent	Plus or minus 3 percent (plus 3V minus 2V) ² Plus or minus 1-1/6 percent for avionic shops only)

Table 320-1-1 ELECTRIC POWER SYSTEM CHARACTERISTICS AT
THE USER INTERFACE - Continued

Characteristics	Type I	Type II ¹	Type III ¹
(h) Line voltage imbalance	3 percent (0.5 percent for 440V) (1 percent for 115V; for submarines)	3 percent	2 percent (1 percent for avionic shops only)
(i) Voltage modulation	2 percent	2 percent	1 percent
(j) Voltage transient			
(1) Voltage transient tolerance	Plus or minus 16 percent	Plus or minus 16 percent	Plus or minus 5 percent
(2) Voltage transient recovery time	2 seconds	2 seconds	0.25 second
(k) Voltage spike (peak value, includes, fundamental)	Plus or minus 2,500V (440V system) 1,000V (115V system)	Plus or minus 2,500V (440V system) 1,000V (115V system)	Plus or minus 2,500V (440V system) 1,000V (115V system)
(l) The maximum departure voltage resulting from (g) (1), (g) (2), (h), and (i) combined, except under transient or emergency conditions	Plus or minus 6 percent	Plus or minus 6 percent	Plus or minus 2-1/2 percent
(m) The worst case voltage excursion from nominal user voltage resulting from (g) (1), (g) (2), (h), (i) and (j) (1) combined, except under emergency conditions	Plus or minus 20 percent	Plus or minus 20 percent	Plus or minus 5-1/2 percent
(n) Insulation resistance test			
(1) Surface ships	500-Vdc	500-Vdc	500-Vdc
(2) Submarines active ground detector test	megohmmeter 500V average full wave rectified dc	megohmmeter N/A	megohmmeter N/A
Waveform (voltage):			
(o) Maximum total harmonic	5 percent	5 percent	3 percent
(p) Maximum single harmonic	3 percent	3 percent	2 percent
(q) Maximum deviation factor	5 percent (3 percent for submarines)	5 percent (3 percent for submarines)	5 percent (3 percent for submarines)
Emergency conditions:			
(r) Frequency excursion ³	Minus 100 to plus 12 percent	Minus 100 to plus 12 percent	Minus 100 to plus 12 percent
(s) Duration of frequency excursion	Up to 2 minutes	Up to 2 minutes	Up to 2 minutes
(t) Voltage excursion	Minus 100 to plus 35 percent	Minus 100 to plus 35 percent	Minus 100 to plus 35 percent

Table 320-1-1 ELECTRIC POWER SYSTEM CHARACTERISTICS AT
THE USER INTERFACE - Continued

Characteristics	Type I	Type II ¹	Type III ¹
Emergency conditions (Cont'd):			
(u) Duration of voltage excursion			
(1) Lower limit (minus 100 percent)	Up to 2 minutes	Up to 2 minutes	Up to 2 minutes
(2) Upper limit (plus 35 percent)	2 minutes	0.17 second	0.17 second
NOTES: 1. Type II or III power is provided by deviation request only. Type I, 60-Hz power is used for new user equipment development unless a deviation request is granted. 2. For 115/200V, four-wire grounded systems, the characteristics apply to the line to neutral power unless the parameter is inappropriate; for example, line balance would not apply. 3. Frequency will not decrease to (minus 100 percent) without a decrease in voltage.			

- c. **Line Voltage Imbalance Tolerance** . Power system equipment is designed to produce balanced three-phase voltages, and every effort is made in designing the electrical distribution systems to connect loads equally across each of the three phases. Because of normal variations in the amount of single-phase loads, the system is seldom perfectly balanced and some differences will be measured in the individual phase voltages. The difference between the minimum and maximum values of the individual phase voltages is limited to the percentages of nominal voltage indicated in [Table 320-1-1](#), or:

$$\left(\frac{E_{\max} - E_{\min}}{E_{\text{nominal}}} \right) \times 100 < \% \text{ Unbalance Tolerance}$$

Figure c.

- d. **Voltage Frequency Transient Tolerance Recovery Time** . Suddenly applying a large load (such as a fire pump), tripping a generator off-line, or operating a circuit breaker to clear a fault can result in system voltages or frequencies that are outside the normal tolerances. However, power generators' governors and voltage regulators respond to these large system changes and restore voltage and frequency to normal values within approximately 2 seconds (within 0.25 second for type III power systems). Wider voltage and frequency tolerances are allowed during the transient condition, provided values return to the normal tolerance limits within the specified recovery time.

320-1.2.1.5 Power Interruption. From time to time, electric power will be interrupted. These interruptions can occur because of a loss of the power source, power system fault or user equipment casualty, training exercise, system test, or operator error. Power interruptions can last from less than 100 milliseconds (for example, automatic transfer to the alternate source) to several minutes. When the power interruption is due to loss of the 60-Hz generator's prime mover, the frequency decays to 40 Hz in approximately 5 to 20 seconds (depending on the type of prime mover, initial load, and inertia of the generator set). The 60-Hz system voltage initially remains unaffected, but may start to decay as the generator frequency drops below 40 Hz. Loss of input power to a 60- to 400-Hz motor generator (MG) set will cause the frequency and voltage of the 400-Hz system to decay. A voltage and frequency monitor (VFM) will sense the out-of-specification condition and trip the MG 400-Hz output breaker within 100 to 170 milliseconds. Solid-state frequency changers monitor input power and will shut themselves down within 2 milliseconds of input power loss, resulting in a 400-Hz power interruption.

320-1.2.1.6 Phase Loading. In the original design plans, power and lighting distribution are carefully designed to ensure equal or nearly equal division of the load among the three system phases. Equal division of single-phase loads among the phases should be maintained, as much as possible, whenever lighting or power equipment is relocated or added. Imbalance can be corrected by reconnecting single-phase loads in one or more local distribution panels or boxes from heavily loaded phases to those that are less heavily used. When loads are shifted to other phases, ensure that loads that are required to remain on the same phase as another component (such as synchro reference leads) are also shifted.

320-1.2.2 SHIP SERVICE DISTRIBUTION SYSTEM. Most ship service power distribution systems are either radial or combination radial and zonal systems. Power flows outward from the switchboards to the loads either directly or through load centers and power distribution panels. In a radial system, each load is connected to only one switchboard at any one time. [Figure 320-1-1](#) and [Figure 320-1-2](#) illustrate the distribution systems for typical combatant ships. [Figure 320-1-3](#) illustrates a combined radial and zonal distribution system. The major components distributing power from the generating sources to the individual loads are described as follows:

- a. **Ship Service Switchboards.** Switchboards provide a point of connection for ship service generators and local generator controls. They are the starting points of the distribution system, feeding power directly to large and vital loads (such as steering gear) and supplying power to load centers and power panels for further distribution to loads. The number and location of ship service switchboards depends on the main machinery compartmentation, as well as the number and location of the ship service generators. Switchboards are usually located near the generators they serve and are spread as far apart as possible to minimize the possibility of a single casualty damaging more than one of them.
- b. **Bus Ties.** Bus ties can be closed to interconnect ship service switchboards so that one switchboard can feed power from its generator to one or more of the other switchboards. Bus ties can also connect two or more switchboards together to parallel their generator plants.
- c. **Load Centers.** Load centers are installed on most large- and some medium- sized ships to supply groups of loads and large auxiliaries located in the same general area. Load centers reduce the number of switchboard feeder circuits. They are located centrally to the loads they feed to minimize the size, weight, and length of cabling to the loads. Load centers may supply loads directly, or may feed power panels that, in turn, feed the loads.
- d. **Power Distribution Panels.** Power distribution panels provide for control of selected portions of the distribution system. They supply groups of loads that are located in close proximity to each other, or that operate together to perform a function. Power panels can also feed other power panels, distribution panels, or distribution boxes that in turn feed loads. Dedicated panels are provided for the following loads or groups of loads:
 - 1 Aqueous film forming foam (AFFF) stations
 - 2 Galley
 - 3 Steering gear
 - 4 Ventilation systems
 - 5 Electronics
 - 6 Lighting
 - 7 Machinery spaces
 - 8 Weapons systems
 - 9 115V receptacles

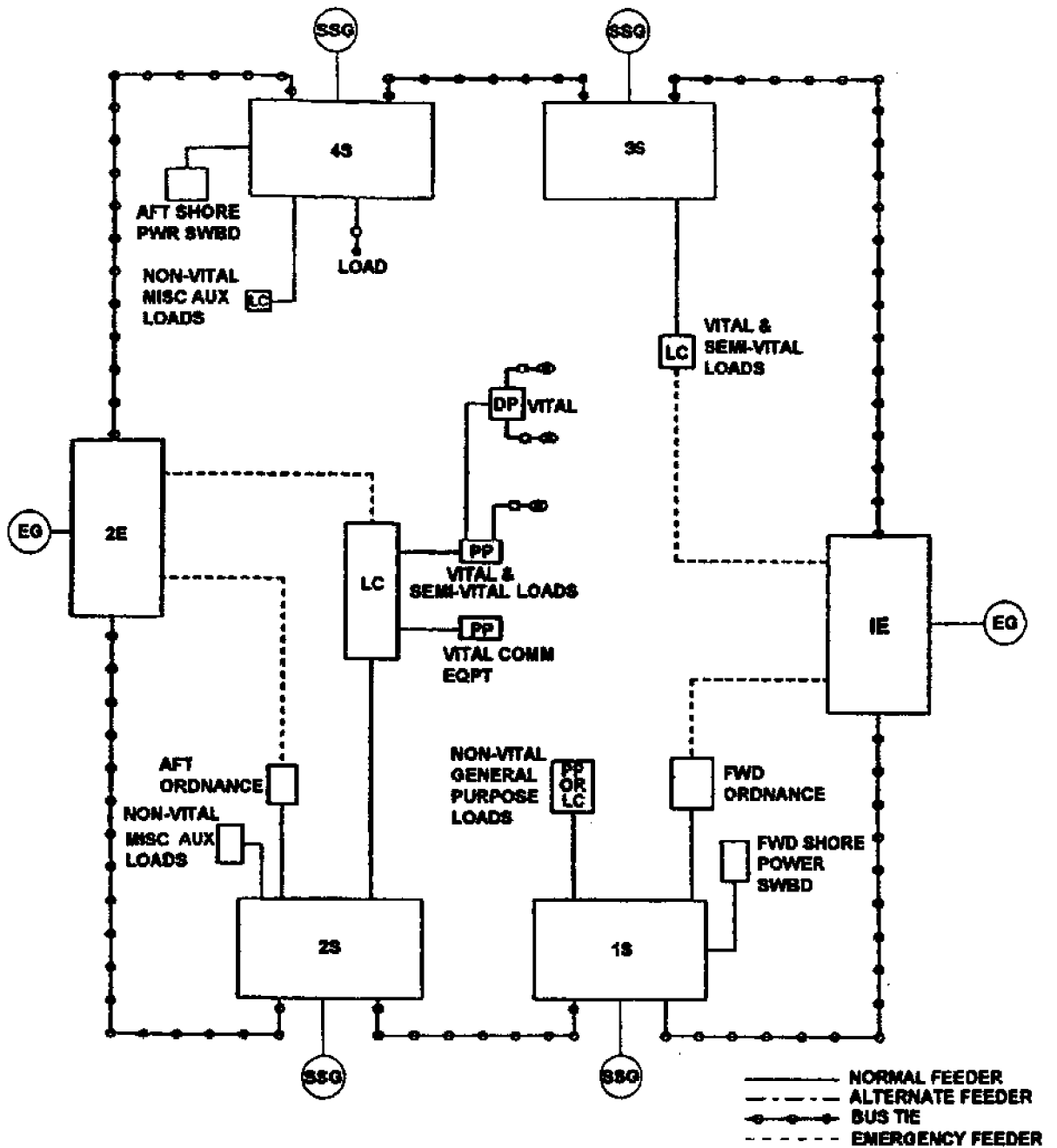


Figure 320-1-1 Combatant Ship Service Radial Distribution with Dedicated Emergency Generators

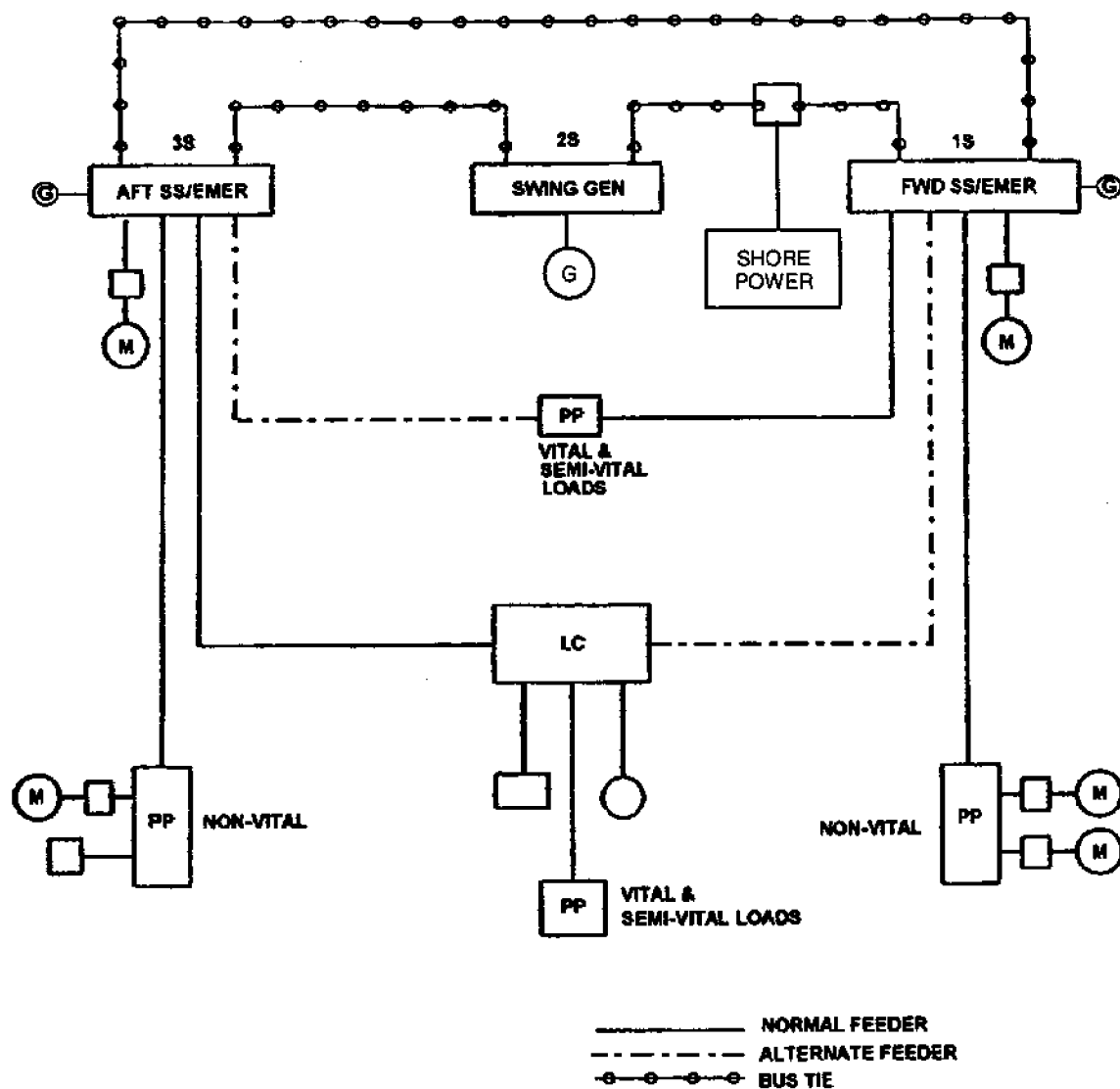


Figure 320-1-2 Combatant Ship Service Radial Distribution with Dual Purpose Generators

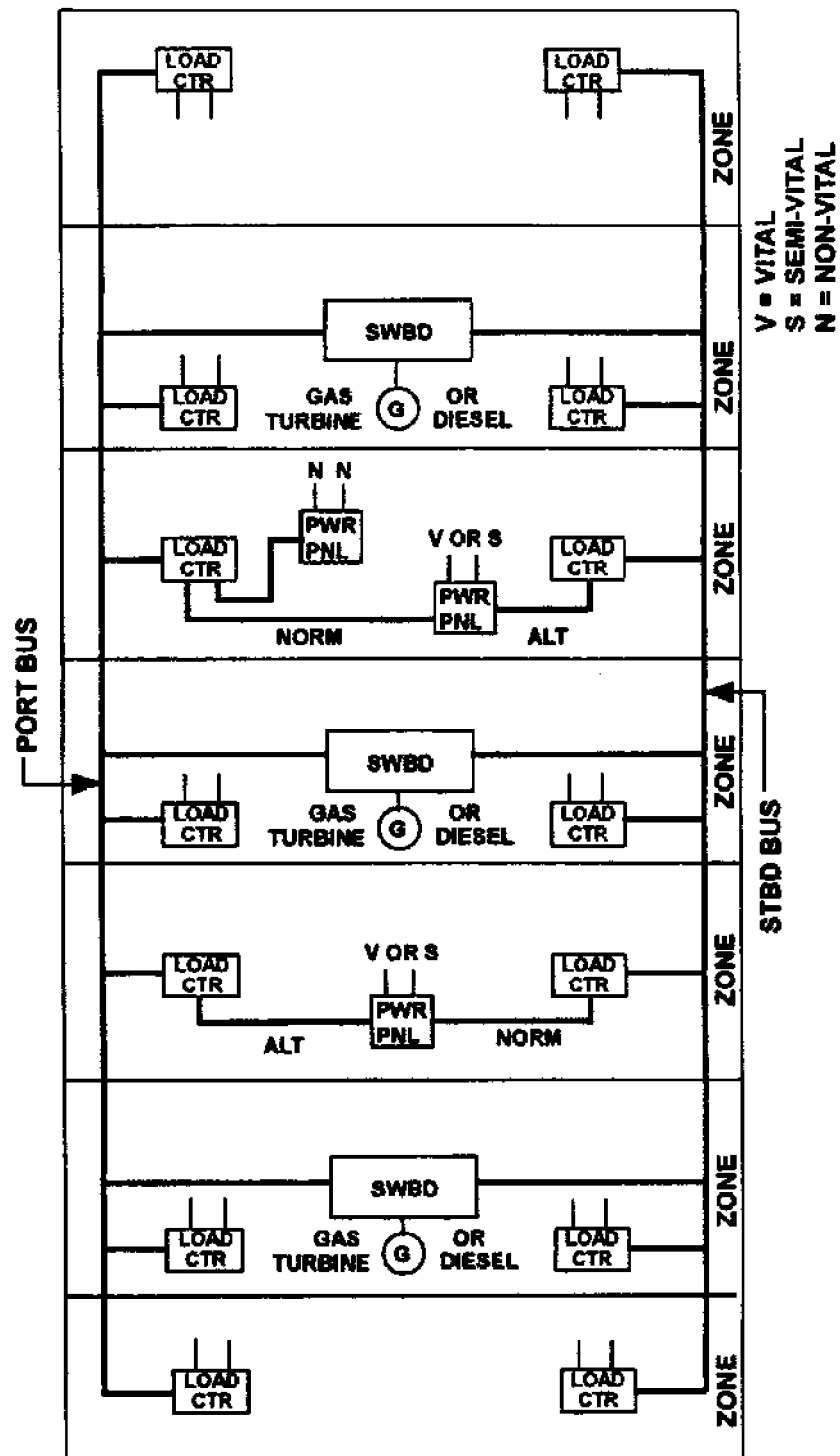


Figure 320-1-3 Surface Ship Zonal Distribution System (Normal and Alternate Power Supplies)

Only loads associated with the particular function can be connected to these panels. To minimize the amount of cabling required aboard ship, the power panels are located centrally to the loads.

320-1.2.2.1 Zone Distribution. On certain large ships, such as aircraft carriers, a zone distribution system is used. The ship is divided into a number of vertical zones, using main subdivision bulkheads as boundaries. Each zone contains one or more load centers that supply power to the electrical loads located there. One or more ship service or emergency switchboards feed the load center. Zone distribution reduces the amount of cabling and watertight penetrations required, and simplifies damage control and maintenance. Some load centers are provided with casualty power terminals and thus are considered sources of casualty power. A modification to the above zone distribution system is also being installed that combines the zonal system with radial load distribution from some load centers. This system utilizes a port and starboard bus as illustrated in [Figure 320-1-3](#). In this system the switchboards provide power to the port and starboard bus. Each zone has at least one port and one starboard load center connected to the respective bus. These load centers provide normal and alternate power to loads within the zone. This distribution system is used to further reduce cable length and minimize cable penetrations of watertight bulkheads. This improves ship producibility and results in lower installation cost.

320-1.2.2.2 Power Distribution to Ventilating Systems. The ship's ventilating system is divided into six different classes of fans, each designed to operate only under specific ship material conditions. To maximize the amount of power available for propulsion, electronics, and other mission-essential functions, the power supplies to nonvital ventilation systems are designed so that they can be secured easily. It is also necessary to quickly secure circle W supply and exhaust fans that serve spaces manned during general quarters if there is a chemical, biological, or radiological (CBR) threat. To simplify control of these ventilation systems, different classes of fans are assigned to one of the following three classes of ventilation system power panels:

320-1.2.2.2.1 Z Power Panels. Z power panels supply nonessential Z, essential Z, and Y ventilating systems. Z panels are fed directly from a ship service switchboard or load center, so that whole groups of Z, and Y fans can be secured.

320-1.2.2.2.2 Circle W Power Panels. Circle W power panels supply only circle W or class X fans. Separate circle W power panels are provided for circle W ventilation systems servicing machinery spaces and emergency generator rooms, with start and stop control provided outside the space but adjacent to the access. (On certain ships, this remote control function is incorporated into the enclosed operating station.) Circle W panels generally receive two sources of supply through a bus transfer switch. The normal supply is from a ship service switchboard or load center. The alternate supply is generally from an emergency switchboard or a ship service switchboard or load center associated with a different generating plant.

320-1.2.2.2.3 Class W Power Panels. Separate power panels are provided for class W ventilation associated with the collective protection system (CPS). Other class W ventilation (recirculating fans serving spaces manned during general quarters) can be supplied from any power panel other than a Z or circle W panel. Panels to which class W fans are connected usually receive two sources of supply, either normal and alternate or normal and emergency. These fans normally operate under all ship material conditions and are only secured to prevent the spread of smoke and fumes.

320-1.2.2.2.4 Deenergizing Power Panels. Circle W and Z ventilation power distribution panels can be momentarily deenergized by opening the switchboard circuit breaker that supplies power to the panel. This will deenergize the fan controllers long enough to drop out the low voltage protection (LVP) control circuit, even if the panels are supplied through automatic bus transfer switches. The circuit breaker should then be closed, reenergizing the feeder so that fans can be restarted locally when dictated by command. Fans serving spaces in which

fixed inert gas fire-protection systems are installed are provided with a pressure-operated switch that stops the fan motor when inert gas is released. [Table 320-1-2](#) outlines the power supply, motor controller, and material conditions under which each class of fan is operated or secured.

320-1.2.3 EMERGENCY DISTRIBUTION SYSTEM. The emergency power system is a highly reliable power source for vital ship functions. It includes one or more emergency generators with dedicated switchboards and an emergency distribution system that is separate from the ship service distribution system. Each feeder from the emergency switchboards supplies distribution panels or individual loads that require emergency power. An emergency feeder may supply remote transformer banks (through automatic bus-transfer equipment) for emergency lighting. Some ships have dual purpose generators in lieu of dedicated emergency generators. These generators are configured to come on line following loss of one or more operating generators. Submarine switchboards are normally called vital and nonvital instead of emergency and ship service.

320-1.2.3.1 Location. Wherever practical, emergency generators and switchboards are installed near the center line and above the water line to minimize the risk of loss from battle damage or flooding. Emergency generators, switchboards, and feeders are situated to obtain maximum practical separation from ship service generators, switchboards, and feeders. This arrangement minimizes the possibility of physical damage to both systems from a single casualty.

Table 320-1-2 VENTILATING SYSTEM CLASSIFICATION

Characteristics	Operation	Power Source	Control
W (recirculating and CPS supply and exhaust)	Operate under all material conditions, secured only to prevent spread of damage	CPS supplied from dedicated panels, Other class W supplied from any power panel other than circle W or Z panel generally has two power sources	Local start and stop control with low voltage release (LVR) or low voltage release effect (LVRE)
Circle W (supply and exhaust fans serving spaces manned during general quarters)	Secured by switchboard operator when chemical attack alarm sounds	Circle W power panel, generally having two sources of power	Local start and stop control with low voltage protection (LVP)
Circle W (supply and exhaust fans serving machinery spaces and emergency generator rooms)	Secured by switchboard operator at sounding of chemical attack alarm	Separate circle W power panels	Local and remote start and stop control with LVP. Remote control located outside space adjacent to access
X (blowout fans)	Normally secured, operate only with approval of damage control officer when blowout of a space is required	Circle W power panels	
Essential Z	May be energized during prolonged periods of general quarters to permit preparation of food, operation of sanitary facilities, etc.	Z power panels	Local start and stop control with LVP
Y	Operate only when space served is in operation.	Z power panels	Local start and stop control

Table 320-1-2 VENTILATING SYSTEM CLASSIFICATION - Continued

Characteristics	Operation	Power Source	Control
Z (recirculating systems serving nonvital spaces)	Secured when ship goes into condition ZEBRA	Z power panels	

320-1.2.3.2 Interconnections Between Emergency and Ship Service Distribution Systems. The emergency switchboard is connected by bus ties to one or more ship service switchboards. One of these ship service switchboard feeders is designated as the normal source of power to the emergency switchboard. When the normal source of ship service power experiences a power failure, bus transfer equipment automatically transfers the emergency switchboard to the alternate source of ship service power. Upon return of voltage to the normal power source, the bus transfer will automatically retransfer to the normal source. If both sources of ship service power fail, the emergency generator automatically starts. When the emergency generator reaches approximately 90 percent of rated voltage, the generator breaker closes and the emergency generator supplies power to the emergency switchboard. Transfer from the emergency generator to either ship service source and shutdown of the emergency generator must be done manually. With this arrangement, the emergency switchboard and emergency distribution system are almost always energized and ready to supply power to vital loads.

320-1.2.3.3 Restoring Power from Emergency Switchboards. Emergency switchboards can feed emergency generator power back through bus ties to connected ship service switchboards. A selector switch on the emergency bus transfer unit permits manual operation of bus transfer circuit breakers to make the connection from the emergency switchboard back to the ship service switchboard. This feature can be used in cold ship starting and damage control operations.

320-1.2.3.4 Emergency Generator Capacity. The capacity of emergency generators is generally not sufficient to provide power to operate all ship system loads. Loads assigned to the emergency distribution system are limited to minimize the possibility of overloading the emergency generator. The electric plant operators must still take care to prevent overloading of emergency generators (see paragraphs [320-2.2.4](#) through [320-2.2.4.4](#) for operating instructions).

320-1.2.4 SPECIAL FREQUENCY POWER SYSTEMS. In addition to the 60-Hz power supplied by the ship service and emergency generators, most ships also have a special frequency 400-Hz power distribution system. The following ship classes use motor-generator sets to provide special power: CV's, CVN's, LST's, LHA's, LPD's, LPH's, AOE's, AOR's, AE's, AS's, AD's, AFS's, older CG's and CGN's, and some SSN's and SSBN's. On FFG's, CG 47 class, LHD's, DDG's, LSD's, and DD's, the special frequency power is usually provided by static 60-Hz to 400-Hz frequency converters (even though some motor generators are used for dedicated loads). The 400-Hz power is used by communications, combat systems, navigation and other electronic systems. The system features described for the 60-Hz power distribution also apply to the special frequency distribution system. The major components of the special distribution system are the following:

- a. **Special Frequency Switchboards** . Special frequency power is usually distributed through switchboards interconnected by bus-ties. The switchboards are also the connection point for the special frequency power sources. The number and location of the special frequency switchboards (1SF, 2SF,...) installed depends on the number and location of the supply equipment. The switchboards are spaced as far apart as possible to minimize the possibility of a single casualty damaging more than one of them.
- b. **Bus-Ties** . Bus-ties interconnect the special frequency switchboards. This allows any switchboard to be con-

nected to feed power from its power source to the other switchboards. Two (or more) switchboards can also be tied together to parallel the sources. Figure 320-1-4 illustrates a typical arrangement of bus-ties between special frequency switchboards.

- c. **Power Distribution Panels** . Special frequency power distribution panels control and distribute power to groups of 400-Hz loads that operate together or that are located in the same general area. On large ships (such as aircraft carriers), load centers are installed to provide a major distribution point for loads that are a greater distance from the 400-Hz sources. This arrangement simplifies the installation and requires less weight, space, and materials than if each load was connected to a switchboard. Bus transfer devices (ABT's or MBT's) are generally used to supply vital load panels with normal and alternate sources as illustrated in Figure 320-1-4. The power panels and bus transfer devices are located close to the load to keep distribution cables short. This also minimizes the chance of a vital system being lost because of cable damage on a circuit feeding one of the system components.

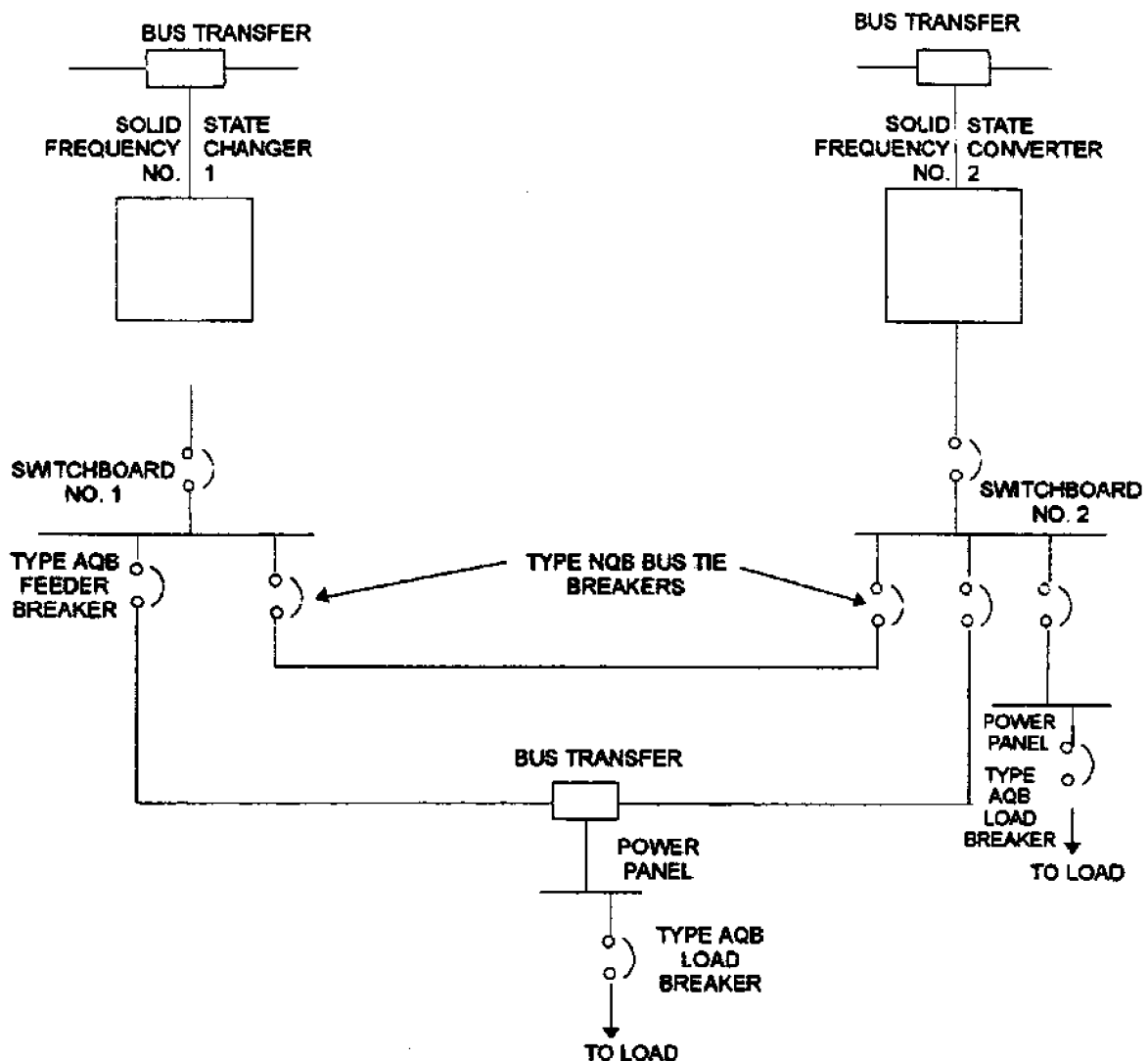


Figure 320-1-4 Special Frequency Distribution Using a Solid-State Frequency Converter

320-1.2.4.1 Aircraft Starting and Servicing Systems. Aircraft carriers have a 115/200V, three-phase, four-wire, 400-Hz electrical power system that supplies up to 60 kilo-voltampere (kVA) for aircraft servicing. Some air-

capable ships have 30 and 45 kVA systems for helicopter starting and servicing. Each aircraft electrical servicing system station consists of a disconnect switch, three single-phase line voltage regulators (LVR's), an available load monitor (ALM), a connection box, a remote control switch with indicator light, and a portable servicing cable and cable head. Systems rated equal to or less than 30 kVA do not require LVR's with special design features.

320-1.2.5 LIGHTING SYSTEM. The ship's lighting system is a subsystem of the ship service and emergency power systems. Its primary function is to light the ship. It also provides power to small appliances and service receptacles. The lighting system provides for general, detail, special, low level, and emergency illumination. Overhead and bulkhead-mounted lighting fixtures provide general lighting for compartments and spaces. Detail lighting is added where general lighting is inadequate for a specific task. Special purpose lighting includes temporary lighting (portable lanterns, relay lanterns, and portable floodlights), deck lighting, ship numeral lights, and boom lights. Low level lighting includes red, yellow, low level white (LLW), and broad band blue (BBB) illumination. Red lighting fixtures are installed to minimize interference with dark vision. This is done in selected living spaces, and access routes to the bridge and weather deck stations involved in signaling, flight operations, and other nighttime topside duties. All weather deck red lighting, except navigation and signal lights, and any internal red lighting, that could be seen by another ship, are converted to yellow lighting during peacetime conditions. This eliminates possible confusion with navigation lights. BBB lighting is used in command and control spaces of some ships to minimize interference with viewing of display consoles. Emergency lighting consists of a selected group of fixtures provided for all spaces and interior watchstations where continuous illumination is essential. LLW lighting is used on submarines in command and control spaces to minimize interference with viewing of display consoles, and to provide dark adaptation for nighttime periscope viewing. Some surface ships have LLW installed in command and control spaces that have color display consoles.

320-1.2.5.1 Lighting Distribution System. In planning the ship's lighting system, the ship was divided into zones. Each of these is supplied power from a lighting load center or lighting distribution panel. Zone boundaries normally correspond to fire zone boundaries. When the lighting load center or lighting distribution panel is centrally located within the zone, circuits are short and the weight of the cables is minimized. The lighting system receives power from the ship service power system. Emergency lighting is normally supplied from this system also with automatic transfer via ABT's to the emergency power system (or an alternate source if no emergency power system is installed). Lighting transformers are used to convert 450V, 60 Hz, three-phase power to 120V power for distribution to the lighting system. Lighting distribution panels are supplied from 450/120V transformers or from three-phase, 120V buses in the lighting load center. Lighting distribution system feeders, mains, and submains are three-phase circuits. Branch circuits are single-phase. At least two separate single-phase circuits (separately protected and fed from different phases) are provided for manned vital spaces or living spaces, where several people may be grouped for extended periods of time. Single-phase circuits are connected so that, under operating conditions, the single-phase loads on the three-phase circuits are balanced. The number of lighting fixtures installed on each circuit is determined to save weight or cable and wiring equipment costs. Also considered are allowable voltage drop, required control features, current carrying capacity of the cable, and rating of branch circuit fuse or circuit breaker.

320-1.2.5.2 Lighting Transformers. The 120V lighting circuits receive power from the secondaries of lighting transformers connected to the ship service and emergency power systems. Lighting transformers are either single-phase or three-phase, dry-type, naturally-ventilated units. Transformer banks consisting of three single-phase transformers are connected in **closed delta**. If any one of the three fails, the two remaining transformers can be connected in **open delta** to obtain 58 percent of the bank's capacity. Lighting transformers are located either near the generator and distribution switchboards (to energize switchboard buses that supply lighting circuits) or in the vicinity of the lighting distribution panels.

320-1.2.5.3 Lighting Control. The switching for detail lighting fixtures is separate from the general lighting switches. General lighting switches for compartments are inside the compartments, as close to the access as possible. Because the lighting system is not grounded (both conductors are energized at a potential different than the ship's hull ground), switches are all double-poled to break both sides of the lighting circuit. For lighting circuits where the New Emergency Automatic Lighting System (NEALS) is installed, it is necessary to secure the upstream circuit protection device from the switch to ensure that all power sources to the NEALS fixtures are secured.

320-1.2.5.4 Isolated Receptacle Circuits. The 120V receptacle circuits are isolated from the rest of the distribution system by either a 450/120V or a 120/120V isolation transformer that is rated at 3 kVA minimum. Isolated receptacle circuits are used as a safety measure. The metal case of a hand-held electric tool can become energized by a broken or chafed conductor. The operator could be fatally shocked, even though the system is ungrounded, because of the leakage current when the ship's 120V lighting system has a high capacitance to ground. The probability of accidental electrocution is significantly reduced by isolating receptacle circuits from the main power system. This limits the leakage current by limiting the capacitance to ground. To keep the capacitance to ground low and the resulting leakage current within safe limits, the total length of the cable in all isolated receptacle circuits supplied by an isolation transformer is limited to 1500 feet. A label plate shall be installed on or near each panel, junction box, or distribution box supplying the isolated receptacle circuits. It shall be inscribed as follows:

CAUTION

Do not connect additional fixtures or receptacles to this circuit.

In surface ship medical spaces, receptacles and a switch and receptacles for surgical lights and relay lanterns are usually supplied from isolated receptacle circuits energized from the emergency system. All receptacles are provided with a grounded contact to protect against shock if an energized conductor contacts the metal case of a hand-held electric tool. **NSTM Chapter 300** provides additional explanation of isolated receptacle circuits and information on maintenance of grounded receptacles.

320-1.2.5.4.1 Loads Supplied by Isolated Receptacle Circuits. Typically, isolated receptacle circuits supply grounded receptacles for portable electrical and electronic devices rated less than 15 amperes. Commercial-off-the-shelf (COTS) equipment shall be energized through marine type computer strips (surge suppressors) as directed in **NSTM Chapter 300**.

320-1.2.5.5 Phase Loading. The original plans for power and lighting distribution were based on careful computations to ensure equal or nearly equal division of the load among the three system phases. This should be maintained, as much as possible, whenever relocating or adding lighting or power equipment. Imbalance resulting from previous lighting or power equipment changes can be corrected by altering connections in one or more local distribution panels or boxes. This action will shift some loads from heavily used phases to those less heavily used. When loads are shifted to other phases, ensure that those loads required to remain on the same phase as another component (such as synchro reference leads) are not shifted.

320-1.2.6 SHORE POWER. At or near a suitable weather deck location, groups of 400 A receptacles are provided for a shore power connection. Portable cables can be attached to them from the shore or from a ship alongside. The shore power system only has enough power to operate necessary machinery and provide lighting for habitability and the accomplishment of necessary work. Only an ungrounded shore power source is acceptable for supplying electric power. The same connection can be used to supply power from ship service generators to

a ship alongside. To tabulate the voltage and frequency of shore power supplies in different parts of the world, and for information on the effects of using 50-Hz power for 60-Hz equipment, see [Table 320-A-1](#) in Appendix A.

320-1.2.7 ALONGSIDE POWER. Tenders and repair ships are provided with specified alongside power facilities. The number and capacity of the alongside power facilities are determined by the maximum number of ships and types to be supplied simultaneously and the mooring arrangements of these ships.

320-1.2.8 CASUALTY POWER. When installed, the casualty power distribution system permits the use of temporary connections to span damaged portions of permanently installed ship service and emergency distribution systems. This system is not intended to supply power to all the electrical equipment on the ship. It is limited to equipment necessary to keep the ship afloat, extinguish shipboard fires, propel the ship out of a danger area, maintain sufficient combat system capability for minimal self-protection of the damaged ship, and sustain internal shipboard control and monitoring and external ship communications. The casualty power system for rigging temporary circuits is separate from the electrical cage control equipment. This equipment consists of tools and appliances for cutting cables and making splices for temporary repair of permanently installed ship service and emergency distribution systems.

320-1.2.8.1 Casualty Power Supply Connections. Casualty power supply connections are generally provided for the following:

- a. Selected electronic equipment panels
- b. Fire pump motor controllers
- c. Load centers (in the design of the casualty power systems, these load centers are considered sources of casualty power)
- d. Combat system self defense power panels
- e. Interior communications switchboards and power panels
- f. Lighting system transformers (except when located with casualty power equipped switchboards)
- g. Machinery space propulsion and electric plant auxiliaries control center or power panels
- h. Power distribution panels serving outlets for portable submersible pumps and other damage control equipment
- i. AFFF station control panels
- j. Replenishment-at-sea machinery power panels on ships capable of underway delivery
- k. Steering gear system power panels

320-1.2.8.2 Components of the Casualty Power Distribution System. The casualty power distribution system includes portable cables, bulkhead terminals, risers, riser terminals, and switchboard terminals. Suitable lengths of portable cables are stowed throughout the ship close to locations where they may be needed. Bulkhead terminals are permanently installed in watertight bulkheads in chosen locations. These terminals permit cable connection on either side of the bulkhead, allowing power to be transmitted through the watertight bulkhead without loss of watertight integrity. Risers, consisting of two riser terminals connected by a permanently installed cable, perform the same function between decks. Where structural arrangements prevent the use of the bulkhead terminals to penetrate a watertight transverse bulkhead, riser terminals are used. Casualty power terminals are provided at switchboards as well as at some distribution panels. Portable cables can be connected at these points to obtain

power from, or supply power to, the bus bars. Casualty power circuit breakers are installed at switchboards and load centers to deenergize the switchboard casualty power terminals. Casualty power circuit breakers are not installed at power panels. Warning plates, reading DANGER - SHOCK HAZARD. THESE TERMINALS ARE NORMALLY ENERGIZED, should be provided on all casualty power terminals that are permanently energized. Locations of portable cables, bulkhead terminals, and risers are chosen so that connections can be made to many vital electrical auxiliaries from any ship service or emergency generators. Casualty power terminals and casualty power cable conductors are marked to identify (both by sight and by touch) the A, B, and C phases. Older-style casualty power cables terminate at each end in individual conductors with copper ferrules. Rings of twine or O-rings are applied over the conductor insulation so that the phases can be identified by sight and touch. The A phase has one ring; the B phase, two rings; and the C phase, three rings. More recent casualty power cables are provided at each end with a three-phase, keyed plug (a plug that can be plugged only into the proper phases of the casualty power terminal).

320-1.3 POWER PLANT RELIABILITY.

320-1.3.1 GENERAL. A reliable supply of power is maintained for vital electrical loads. This is done by supplying two (or more) sources of power to these loads, providing load shedding of nonvital loads to avoid overloading the remaining generating capacity, and supplying redundant equipment from separate power sources and distribution circuits. The supporting auxiliaries for a piece of equipment shall be supplied power from the same source of power as the main piece of equipment.

320-1.3.2 NORMAL AND ALTERNATE SOURCES OF POWER. At least two independent sources of power supply vital 60-Hz and 400-Hz loads. The normal source of 60-Hz power is a ship service switchboard. The other source is either another ship service switchboard or an emergency switchboard (if installed). The second switchboard should be located in a different watertight subdivision of the ship, where possible. The vital systems to be provided with two sources of power are determined by the design characteristics of the ship and its mission. Vital loads are grouped into one of three categories, as listed in [Table 320-1-3](#), with Category I having the highest priority. Category I loads are supplied emergency power from the emergency switchboard. If multiple emergency switchboards are installed, similar loads are distributed among them to maintain maximum reliability. Assignment of loads to switchboards is determined by the location of the switchboards and the loads, and by the capacity of the associated emergency generators. Additional Category II and Category III loads are assigned an alternate supply from the emergency switchboard if there is enough emergency generator capacity. If the emergency generator cannot supply all Category I through Category III loads, the electric plant is arranged so that the ship service generators can be operated in a split-plant mode. This is so that at least two independent sources of ship service power can be provided. Vital 400-Hz loads fed from the special frequency distribution system are also supplied power via normal and alternate feeders from two special frequency switchboards.

320-1.3.2.1 Bus Transfer Equipment. Bus transfer equipment is installed at load centers, distribution panels, or loads that are fed by two power sources. This equipment is used to select either the normal or alternate feeder, or to obtain power from the emergency distribution system (if an emergency feeder is provided). Bus transfer switches are located adjacent to the panel or equipment they supply. They are either automatic or manual. Automatic bus transfer (ABT) units transfer to the alternate feeder automatically whenever the normal feeder voltage drops to 60 to 70 percent of normal voltage for more than 0.3 to 0.5 seconds. They generally will automatically retransfer back to the normal feeder when its voltage recovers to 85 to 95 percent of normal voltage. On power systems, there is a short time delay after the normal feeder is deenergized before the automatic bus transfer switch transfers to the alternate source. This time delay feature also is in effect when the ABT transfers from the alternate source back to the normal source, and allows motor voltages to die down before reenergizing them. Applying an out-of-phase voltage from the alternate source while the motor still has too much residual voltage could

damage the motor and its driven equipment. During the time delay, the load is without power. Magnetic relays and contactors (such as those in motor controllers), that are energized from the ABT, may drop out. When power is restored by the transfer to the alternate load, it may be necessary to manually restart some of the loads. Manual bus transfer, (MBT) units are often used instead of ABT's for many applications where a bus transfer device is required for loads that must be manually restarted after loss of power. ABT switches on lighting systems are either the time delay type or instantaneous. Using the output from one ABT to input power to a second ABT shall be avoided. ABT's are usually installed for the following vital loads:

- a. AFFF pumps
- b. Collective protection system class W ventilation
- c. Emergency lighting
- d. Fire extinguishing auxiliaries and controls
- e. Fire pumps
- f. IC switchboard and panels
- g. Pumps associated with the main and auxiliary machinery plant having low voltage release (LVR) control
- h. Steering gear power panel
- i. Close In Weapons System (CIWS)
- j. Machinery Control Systems

Table 320-1-3 DESIRED POWER SOURCES

Equipment that Requires Two Power Sources	Desired Power Sources ⁴		
	Normal	Alternate	Emergency
CATEGORY I. In all cases, when emergency power is provided, an emergency switchboard supplies loads associated with EMERGENCY SHIP CONTROL that includes the following:			
Aqueous Film Forming Foam (AFFF) Pumps	X		X
Auxiliaries to support the emergency generator prime mover such as:			
Booster Pumps	X		X
Compartment Ventilation Motors	X		X
Fuel Transfer Pumps	X		X
Starting Air Pumps	X		X
Close-in Weapons System (CIWS) ²	X		X
Collective Protection System Class W Ventilation	X		X
Emergency Communications	X		X
Emergency Lighting	X		X
Fire Pumps	X		X
Interior Communications	X	X ³	X
Machinery Space Circle W Ventilation	X		X
Steering Gear Auxiliaries	X	X ³	X ¹
Surface Search Radar	X		X
VHF Bridge-to-Bridge Radio	X		X

Table 320-1-3 DESIRED POWER SOURCES - Continued

Equipment that Requires Two Power Sources	Desired Power Sources ⁴		
	Normal	Alternate	Emergency
Vital propulsion auxiliaries are required for cold-starting the ship's plant and are necessary for machinery protection, including as a minimum:			
Emergency or Standby Lubricating Oil Service Pumps	X		X
Feed Transfer Pumps	X		X
Forced Draft Blowers (Low Speed)	X		X
Fuel Service Pumps	X		X
Motor-Operated Boiler Stop Valves	X		X
Turbine Generator Pumps	X		X
CATEGORY II . The following loads:			
Air Conditioning Serving Electronic or Control Spaces	X	X	
All Electronics (except weapon systems) ²	X	X	
Circle W and Recirculating W Fans Serving Electronic Spaces	X	X	
Degaussing	X	X	
Fire Extinguishing Auxiliaries and Controls	X	X	
Medical Equipment	X	X	
3-Inch Gun Mounts and Control Systems	X	X	
CATEGORY III . On ships with guided missile systems or gun weapon systems, the following loads:			
Air-Conditioning Plant Auxiliaries	X	X	
Circle W and Recirculating W Fans Serving Missile Control Spaces	X	X	
Missile System Components	X	X	
Missile System Power Conversion Units	X	X	
Naval Tactical Data Systems (NTDS)	X	X	
Ship Service 400-Hz Power Conversion Equipment	X	X	
5-Inch Gun Mounts (or larger) and Control Systems	X	X	
On aircraft carriers and amphibious support ships, the following loads:	X	X	
Airborne Systems Electronics	X	X	
Aircraft Defueling Pumps	X	X	
Aircraft Elevators	X	X	
Aircraft Landing Support Equipment	X	X	
Air-Conditioning Plant Auxiliaries	X	X	
Circle W and Recirculating W Fans	X	X	
Hangar Division Doors	X	X	
Integrated Operations Intelligence Equipment	X	X	
Naval Tactical Data System (NTDS)	X	X	
Ship Service 400-Hz Power Conversion Equipment	X		
Weapon Elevators	X	X	
On attack type cargo ships and landing ships:	---	---	
	---	---	
	---	---	

Table 320-1-3 DESIRED POWER SOURCES - Continued

Equipment that Requires Two Power Sources	Desired Power Sources ⁴		
	Normal	Alternate	Emergency
Winches, Elevators, Ramps, and Gates in Support of Offloading Operations	X	X	
1. Normal and alternate power sources have been used when the emergency generator plant has insufficient capacity. 2. Power supplies for system electronic components are segregated for power supplies to associated system non-electronic components. 3. Some ships may have three sources of power. 4. For ships without emergency generator, an alternate source will be used.			

The ABT associated with each high capacity firefighting foam (HCFF) station is located within the same material condition ZEBRA boundaries as, and within or adjacent to, the HCFF station it serves and serves no other loads. MBT units are installed for all other loads that require two sources of power. Loads that have LVR or low voltage protection (LVP) control features, other than firefighting systems, may be combined and supplied from one ABT.

320-1.3.2.2 Routing of Normal and Alternate Feeder Cables. Normal and alternate or emergency feeders to a vital load are spaced as far apart as feasible to minimize the possibility of more than one feeder being damaged from a single casualty. Main fore and aft cableways are located port and starboard, and high and low in the ship to obtain both athwartship and vertical separation of these feeders. Cable runs are located to obtain maximum protection from the ship's structure.

320-1.3.3 LOAD SHEDDING SYSTEMS. An automatic load shedding system, when provided, disconnects selected nonessential loads from the distribution system in response to an electrical system overload. An overload condition can occur when one on-line generator suddenly fails or a large demand is suddenly applied to the plant when it is operating with some generators secured. The remaining on-line generator(s) may overload in an attempt to supply the ship's full load. For a diesel or steam plant, overload will cause frequency or voltage to drop but the unit is not likely to trip off line. Gas turbines, on the other hand, are very sensitive to overload and may trip off line on high turbine inlet temperature. To protect the operational generators and prevent their sequential loss, a load shedding system, depending on its design, can; 1) automatically reduce the ship's load to be within the remaining generating capacity, 2) split the plant by opening bus ties to isolate the failing generator, and 3) call for automatic starting and engagement of the standby generator(s). There is no "typical" load shed scheme. Each ship class that has a load shed system has unique features that determine when and how its load shed system operates.

320-1.3.3.1 Staged Load Shedding. Load shedding is normally provided in several stages or levels that reduce the electric plant load to within the capacity of the on-line generators. If the first load shed stage does not reduce the load sufficiently, additional stages are activated after time delays to further reduce the load. Electrically operated equipment supplied by a ship service switchboard, emergency switchboard, or load center is assigned to one of several load shed classes. In a two-stage load shedding scheme, the following load classes would normally be used:

- a. Nonvital (Nonessential) - Readily sheddable loads that can be immediately secured without adversely affecting ship operations, survivability, or life. Examples are hotel loads such as heating and galley; ship, avionics, and ground support equipment shops; aircraft fueling systems; refrigeration systems; and other loads that can be shut down for a short time until full electric power capability is restored.

- b. Semivital (Semiessential) - Loads important to the ship but that can be shut down or switched to the alternate plant in order to prevent total loss of ship's electrical power. Examples include aircraft and cargo elevators, deballasting compressors, assault systems, some radar, communications, and seawater service pumps.
- c. Vital (Essential) - Nonsheddable loads that affect the survivability of ship or life. Power to these loads is not intentionally interrupted as part of a load shedding scheme. Examples of vital loads are generators, boilers, and their auxiliaries; close-in weapon systems; electronic countermeasures; tactical data system equipments with volatile memories; medical and dental operating rooms; and primary air search radar.

320-1.3.3.1.1 During the ship's design, loads with the same load shedding priority are distributed approximately evenly among the ship service switchboards. This way each stage of load shedding results in about the same percentage reduction in operating load at each switchboard. In some cases, certain semivital loads may be assigned to the first load shedding stage to get the necessary percentage reduction in load at that switchboard. During the ship's life, it is important that new loads are assigned to a load shedding class.

320-1.3.3.2 Load Shedding Devices. A load shedding system uses real power (watt) sensors located in each generator switchboard to monitor the output of that generator. When the load on any generator exceeds a preset limit (for example, 92 percent of generator rating) for a preset length of time (for example, 11 cycles of the power system frequency), the first stage of load shedding is activated. Relays in each switchboard and load center, that are paralleled with the overloaded generator pick-up, send a shunt trip signal to open the feeder circuit breakers that supply first-stage loads. If load shedding stage 1 does not reduce the electric plant load sufficiently, load shedding stage 2 (and additional load shedding stages, if provided) will automatically shunt trip the breakers, supplying their loads after a time delay. Auxiliary contacts in the bus tie circuit breakers interconnect the load shedding control circuits between paralleled switchboards. This interconnection is done so that activation of the load shedding system reduces the load on all switchboards and load centers connected to an overloaded generator. Loads fed from an isolated, split plant, however, will not be affected. The load sensing device is typically adjustable throughout the range of 90 to 120 percent of the generator's rated power capacity. Time delays for the second (and subsequent) load shedding stages can vary from less than a second for gas turbine generators to 30 seconds or more for diesel generator sets. Whenever the sensed load drops below the load shedding activation value, the system automatically resets. This allows any or all of the tripped circuit breakers to be reclosed. Both automatic and manual control of the load shedding system are usually provided. Manual load shedding activation allows the electric plant operator to engage one or all of the load shedding stages to avoid a potential overload condition or test system operation.

320-1.3.3.3 Turbine Overtemperature Protection System. Ships equipped with gas turbine generators may have a second subsystem installed that can initiate the load shedding system. The turbine overtemperature protection system (TOPS) continuously monitors the ship's electrical status. The TOPS automatically takes corrective action to prevent gas turbine overtemperature if a paralleled gas turbine generator is about to fail. One of its corrective actions is to signal for a load shedding. This signal is sent directly to the load shedding relays. TOPS normally will initiate load shedding faster than the electrical load shed system.

320-1.3.3.4 Splitting the Plant. Depending on the load shedding system design, bus tie circuit breakers may also be controlled. These breakers will always be controlled by stage 1 load shedding actuation. Reducing generator load and splitting the plant by opening the bus tie circuit breakers may allow the overloaded generator to recover. It will also prevent the loss of one generator from overloading other on-line generators.

320-1.3.3.5 Automatic Starting of a Standby Generator. The STANDBY ship service generator or emergency generator will start when loss of voltage is sensed on a bus. Depending on the generator's automatic startup sequence, and the load shedding system's actions in splitting the plant, the generator breaker may be closed

manually to parallel the standby generator with the system. The added generation will help relieve the overload condition. In other systems, the generator is started but the generator breaker must be closed by the operator. Normally, the circuit breakers for an emergency generator close automatically onto an emergency bus.

320-1.3.4 PLANT RELIABILITY. The electrical distribution system can restore the plant after loss of propulsion power at sea. For equipment in the same machinery space, separate and independent distribution panels are provided for the auxiliaries of each piece of equipment. The independent panels ensure that operation of redundant equipment is not affected if the distribution panel or its feeder circuit is lost or if power to the panel must be secured. Separate vital distribution panels, fed from two sources of power via a bus transfer unit, are provided for redundant equipment that requires two sources of power. Where there is more than one propulsion plant, each with only electrically driven pumps; one plant's fuel service, lube oil service, main condensate, and main feed booster pumps are normally connected to a vital distribution panel of the other plant. In this way, each plant can be restarted with power from the other plant.

320-1.3.5 PROTECTION AGAINST POWER LOSS. Ships with ship service, emergency, and casualty power distribution systems can be protected against power loss (according to the type of failure) as follows:

- a. **Failure of One Generator** . A remote generator can be connected by bus ties to power the switchboard that normally receives power from the failed generator.
- b. **Circuit or Switchboard Failure** . Vital loads can be transferred to an alternate or emergency source of power by means of a transfer switch near the user equipment.
- c. **Failure of Both Normal and Alternate Power Supplies** . On some ships, when both normal and alternate sources of ship power fail, vital auxiliaries connected to an emergency switchboard receive power from an emergency or dual purpose generator. A dedicated emergency system is not provided on all ships.
- d. **Failure of Ship Service and Emergency Circuits** . Temporary circuits can be rigged with the casualty power distribution system. They will supply power to vital auxiliaries if any ship service or emergency generator can be operated.

320-1.4 POWER OUTLETS

320-1.4.1 MULTIPURPOSE POWER OUTLETS. Multipurpose power outlets supply 450V, three-phase power for portable hoists, submersible pumps, tools that require 450V power, and welding units for repair, maintenance, and damage repair, including underwater welding and cutting. Multipurpose power outlets are grounded and are used with grounded plugs and cables having a ground wire. When the plug is inserted into the receptacle, the ground wire grounds the metallic case and exposed metal parts of the tool or equipment used. The ground wire provides a positive, highly conductive path that prevents dangerous potentials between the tool housing and ship structure, and protects the user from shock. Multipurpose power outlets are situated so two different outlets can supply portable pumps in any compartment by using a 75-foot cable or, for some larger ships, a 150-foot cable. Extension cables with triple-outlet, portable receptacle boxes make it possible to operate at least six portable pumps in any watertight compartment. The number of outlets fed from any one power distribution panel is kept to a minimum to provide the greatest, practical supply diversity. An adapter is provided with the 75-foot extension cables for connecting the submersible pump to a casualty power bulkhead terminal. This provides power via the casualty power system if power from permanent outlets is unavailable.

320-1.4.2 120-VOLT GROUNDED RECEPTACLES. Since the danger of electrical shock is always present at 120V shipboard circuits, normal practice is to use grounded plugs and receptacles supplied from isolated receptacle circuits on all surface ships and submarines. General purpose grounded receptacles, as described in **NSTM Chapter 300**, are provided as follows:

- a. Double, 120V, 15-ampere, single-phase ac or two-wire dc, bladed-type receptacles for below deck applications. These receptacles are similar in appearance to those used on shore, however, both blades are hot with the third pin as a ground to the ship's hull. They admit either three-prong grounded plugs or two-prong plugs. Only two-prong plugs attached to double insulated, portable, plastic, electrical equipment (such as shavers, erasers, drills, grinders, and sanders) are permitted in these receptacles on board ship. Double insulated housings do not require grounding for personnel safety.
- b. Single, 120V, 15-ampere, single-phase ac or two-wire DC, watertight, bladed-type receptacles. They are used on radar platforms, close in weapons system mounts, open bridges, and other weather deck locations with electronic test equipment and portable tools.
- c. Single, 120V, 10 or 15-ampere, single-phase ac or two-wire dc, stub-type submersible receptacles. They are used topside and for applications where a watertight receptacle is required, except on radar platforms and open bridges.

320-1.4.2.1 Extension Cords. Only approved extension cords shall be used. Authorized for inclusion in the ship's allowance are 25-foot extension cords and three outlet, 25-foot extension cords for use with portable tools and equipment. For use on flight, hangar and well decks, and floating drydock basins, 100-foot extension cords are authorized. Additionally, 100-foot extension cords, labeled For Emergency Use Only, are authorized for placement in damage control lockers. These extension cords may be manufactured using three conductor flexible cable (12/3), type SO or ST as listed in the Federal Stock Catalog, Class 6145, and attaching a grounding plug (NSN 5935-01-0905-3579) to one end and a grounding receptacle (NSN 5935-01-012-3066) to the other end. Commercially available, UL approved equivalent items may be used. Commercially available, UL approved 25 and 100 foot extension cords with 12/3 wire may also be used.

320-1.4.2.2 120-Volt Receptacle Spacing. Receptacles are spaced so that portable tools can be used within weather boundaries throughout the ship without requiring more than 50 feet of flexible cable between receptacle and tool. This requirement prevents excessive voltage drops from the receptacle to the power tool, and excessive grounding conductor impedance. Grounded 120V receptacles installed for other applications (such as for radiant heaters) are included in the 50-foot receptacle spacing regulation and may be used with portable tools. Receptacles installed for portable tools are also intended for use with portable lights. If additional receptacles are required, care must be taken to prevent overloading of the circuits or exceeding the total cable length limits of an isolated circuit.

320-1.4.2.3 Precautions for Maintenance and Use of 120-Volt Receptacles and Extension Cords. **NSTM Chapter 300** contains information and precautions on wiring, testing and use of grounded receptacle plugs, and extension cords.

320-1.5 DIRECT CURRENT DISTRIBUTION SYSTEM

320-1.5.1 SURFACE SHIP BATTERY CHARGING SYSTEMS. Battery charging stations and battery maintenance shops are placed at strategic locations in ships. Battery chargers are usually mounted permanently wherever batteries are installed. In the case of portable batteries, a charging station may be provided for several batteries. Charging stations for lift and tow truck batteries are located in an area where the truck can be brought to

the charger. Voltage and current ratings of chargers are selected to suit the requirements of the installation. Some charging stations may also have a small distribution system that supplies battery charging outlets. This may be the case if one charger maintains the batteries of several motor boats or launches located close together. Rectifiers or motor-generator sets also supply special loads requiring dc power. Portable battery chargers charge boat batteries on some ships.

320-1.5.2 SUBMARINE SYSTEMS. On nuclear submarines, an electric propulsion motor, an emergency lighting system, and any auxiliaries that must operate following loss of ac power are connected to the dc system that is supplied by the ship's battery. Motor-generator sets are driven from the ac system to charge the ship's battery and supply dc power to the auxiliaries that are connected to the dc system. Upon loss of ac generation, the battery supplies dc power to the auxiliaries connected to the dc bus. The motor-generator sets operate dc to ac to briefly provide emergency ac power to vital ac loads. The voltage on submarines is normally 250V, varying from 210V when the battery is discharged, to 355V, when the batteries are being charged. On AGSS 555 (USS DOLPHIN), the batteries are the only source of power when the submarine is submerged below snorkel depth. The batteries are charged by diesel-driven generators while the submarine is surfaced or snorkeling. This ship uses a three-wire system to provide 500 Vdc for propulsion, and 250 Vdc for auxiliaries. The New Attack Submarine (NSSN) has high voltage dc generators that supply static frequency converters to charge the battery, and to produce 450 V, 3 phase, 60 hz power for ship's systems.

320-1.5.3 SMALL BOAT LOW VOLTAGE SYSTEMS. Landing craft and small boats use low voltage, 12V or 24V systems. Generators driven by propulsion engines in some installations, and by small auxiliary engines in others, supply power. Storage batteries supply power when generators are not running. Some boats without emergency generators have 28-Vdc navigation light systems energized by a battery and battery charging rectifier.

320-1.5.4 HELICOPTER STARTING AND SERVICING SYSTEMS. Strategically located rectifiers and outlets are provided on ships having helicopters to provide 28.5 Vdc for starting, aircraft servicing, and avionics shops. These rectifiers are designed specifically for this service.

320-1.6 DISTRIBUTION SYSTEM EQUIPMENT

320-1.6.1 RELIABILITY AND MAINTENANCE. Electrical equipment for naval ships is constructed so it has a practical amount of dependability and shock resistance. It is installed so it receives maximum protection from the ship's structure. It is dispersed so that duplicate items that perform the same duties are physically separated, minimizing the possibility that both will be damaged by the same casualty. Equipment is designed with special attention to maintenance. Designers use documentation on long-term maintenance experiences to design better maintenance features into the equipment.

320-1.6.2 KINDS OF EQUIPMENT. An electrical distribution system is made up of numerous components including instruments (volt meters, ammeters), switching equipment (such as bus-transfer switches), current and voltage sensitive relays, protective equipment (circuit breakers and fuses), conductors (bus bars and cables), and transformers.

320-1.6.3 SWITCHBOARDS. Much of the equipment that makes up a distribution system is mounted on switchboards or switchgear groups. A switchgear group essentially consists of two or more individual sections connected by cables and separated to localize damage from fire or shock.

320-1.6.3.1 Functions. A generator and distribution switchboard or switchgear group is provided for each generator or group of generators. These switchboards serve to

- a. Provide for control, operation and protection of their associated generators.
- b. Control, through appropriate switching equipment, the distribution of electric power.
- c. Mount measuring instruments, indicating devices, indicator lights, and protective and regulating equipment associated with the generators or distribution systems.

320-1.6.3.2 Construction. Switchboards are constructed to withstand high-impact shocks. Switchboard units consist of a sturdy box framework, built of angles and structural shapes, to provide enough strength to resist breakage and distortion due to shock, and stiffness to prevent excessive vibration. They are dead-front construction (no exposed energized components) sheet metal enclosures. Only meters, operating handles, and switches protrude through the front of the switchboard for protection of personnel. The front of the switchboard also provides a grip rail for personnel to safely stand watch or implement operating orders. Expanded metal or solid louvered panels enclose the rear of the switchboard to allow ventilation while protecting personnel. Submarine switchboards are normally of spraytight construction.

320-1.6.3.3 Arrangements. Modern switchboards have equipment grouped to form a number of units, such as the ac generator unit, ac bus tie unit, and power distribution unit. Each unit is complete with a separate front panel and all required accessories. A number of units mounted on a common base make up a section. A switchboard may consist of a single section or of several sections that are physically separated, but are connected by cables to form a switchgear group. This arrangement tends to minimize damage from shock because several small structures can more easily be made shock-resistant than a single large structure. It localizes damage from fire so a fire in one section is not as likely to affect the others. It also provides for easier removal of damaged sections for repair or replacement.

320-1.6.3.3.1 Electrical Switchgear or Load Center Post Fire Inspection Procedure. Major fires in electrical switchgear are usually the result of arc faults (an arc fault is phase-to -phase current flow through the air). As each arc strikes, in-line, phase-to-phase, etc., loud popping noises will be heard and electric plant meters will exhibit erratic operation. An inspection shall be conducted on any switchgear that suffers extensive damage from an arc fault or suspected arc fault. This inspection shall be conducted prior to any repair action unless the switchgear is critical to the operation of the ship and repair is within ships force capability. The specific purpose of the inspection is to attempt to determine the actual cause of the casualty. Although not exhaustive, the following steps shall be included in the inspection of failed switchgear. A copy of all information gathered during the inspection shall be forwarded to NAVSEA 03ZE.

- a. Inspect and document the damaged switchgear.
Visually inspect the switchgear damage. Document at least the following items (make hand sketches or mark up photo copied portions of technical manual drawings to support observations):
 - 1 Location(s) of the overall damage and particular components involved.
 - 2 Location(s) of the heaviest damage. (NOTE: This damage usually occurs when the arc lingers or is trapped at a particular spot for some reason. This area may experience a burn through of the enclosure).
 - 3 If the switchgear is comprised of multiple units, add comments on the number of units and the degree of damage each unit suffered.

- 4 Inspect bus bar edges for arc trails to determine arc movement and spread. (NOTE: Arc trails are usually visible to the eye. Arc movement can often be determined fairly accurately keeping in mind that an arc always travels away from the source of power.)
 - 5 Look for obvious signs of the cause, e.g., partially melted foreign conductive object.
 - 6 Note location(s) of incoming power cables and which power cables were energized at the time of the casualty.
- b. Record data.
- Record, at a minimum, the following data:
- 1 Ship name, time and date of the casualty, switchgear involved, etc.
 - 2 The exact plant line-up at the time of and several hours prior to the casualty.
 - 3 If the plant had undergone changes (cross connect, load switching, DC exercises, ship evolution, etc.) at the time of or shortly before the casualty.
 - 4 If there are loads supplied by this switchgear that cycle periodically (e.g., air compressors).
 - 5 What, if any, circuit breakers tripped during the casualty.
 - 6 If the switchgear had recently (within the past year) undergone any form of repair or other invasive work.
 - 7 When the most recent PMS was conducted including thermal imaging.
 - 8 If the bus bars are insulated and the type of insulation used (e.g., glyptal varnish, enamel, heat shrink tubing or tape, etc.) and the relative condition of the insulation.
 - 9 If the ship has an Arc Fault Detector installed and, in particular, if the damaged switchgear is protected by the AFD System. If installed, record if the system functioned properly (i.e., had warnings or alarms been experienced).
 - 10 Photograph the damaged switchgear taking care to include as many details as possible.
 - 11 Photograph, if possible, a similar undamaged switchgear for comparison.
- c. Interview personnel on duty, in the space and adjacent spaces, at the time of the casualty.
- The information gathered from ships force can be used to help create a time line and a sequence of events. From interviews of personnel, include as much of the following, as possible:
- 1 Number of noises.
 - 2 Flashes and fire balls observed.
 - 3 Actions during the casualty (emptied three 10 lb fire extinguishers in the failed switchgear).
 - 4 Actions after the casualty.
 - 5 Rapid changes in voltage (V) and current (I) up, down or both.
 - 6 Unstable control conditions.

320-1.6.3.4 Electric Plant Control Panel and Electric Plant Control Console. A separate electric plant control panel (EPCP) or electric plant control console (EPCC) is provided when any of the following conditions exist:

- a. Generators with an individual capacity of 1500 kW or larger are installed.
- b. High interrupting (85,000 amperes symmetrical or 100,000 amperes symmetrical) capacity circuit breakers are installed, making electrical operation necessary.
- c. A central control is established such as an enclosed operating station.

320-1.6.3.4.1 Mounted on the EPCP or EPCC are all generator control equipment, measuring instruments, and controls for electrically operated equipment to centralize control of the generators and major switching opera-

tions. To assist the operator, the EPCP or EPCC has a mimic bus with indicator lights, showing the circuit breaker positions (open or closed). Ships with a machinery control center usually have CRT displays for use in controlling the electric plant. On ships that are not provided with an EPCP or EPCC, metering and control equipment is mounted on the front panels of the units in the switchboard or switchgear groups.

320-1.6.3.5 Interior Communication and Weapons Control Switchboards. For information on these switchboards, see **NSTM Chapter 430, Interior Communication Installations**.

320-1.6.4 MEASURING EQUIPMENT. Instruments are installed on the switchboards or switchgear groups to permit safe and efficient monitoring and operation of the electrical system. AC distribution systems are generally provided with voltmeters, ammeters, wattmeters, frequency meters, synchrosopes, and synchronizing lamps. Voltmeters and ammeters are usually the only instruments provided for dc distribution systems. See **NSTM Chapter 491, Electrical Measuring and Test Instruments**, for information and instructions on the use and care of electrical measuring instruments.

320-1.6.5 CIRCUIT BREAKERS. Circuit breakers are mounted as an integral part of switchboards, switchgear groups, and distribution panels. Circuit breakers used on naval ships are classified ACB, AQB, AQB-LF, AQB-LL, NQB, ALB, and NLB. All of these types are open case, molded case, and insulated case circuit breakers.

320-1.6.5.1 ACB Type. ACB circuit breakers have an open, metallic frame construction and may be either manually or electrically operated. Electrical operation allows the circuit breaker to be used for remote control operation as well as for protection. ACB circuit breakers are commonly used to connect ship service and emergency generators to the power distribution system. They are also used on bus ties, some shore power connection circuits, and some larger feeder circuits.

320-1.6.5.2 AQB Type. AQB circuit breakers are in a supporting and enclosing housing of insulating material with direct-acting automatic tripping devices. They are used to protect most switchboard, load center, and distribution panel circuits where the maximum available short circuit current is within the interrupting rating of an AQB breaker. See Appendixes B, C and D for AQB breaker cross references.

320-1.6.5.3 AQB-LF Type. AQB-LF circuit breakers have the same design as the AQB's except high interrupting capacity fuses have been incorporated into them. They may be used on switchgear feeders and other circuits where the short-circuited current exceeds the interrupting capacity of an AQB breaker, but is less than 100,000 amperes asymmetrical.

320-1.6.5.4 AQB-LL Type. AQB-LL circuit breakers are similar to type AQB except they have an interrupting capacity of 100,000 amperes asymmetrical without the use of fuses.

320-1.6.5.5 NQB Type. NQB circuit breakers are similar in construction to AQB breakers, but they have no automatic tripping devices for short circuit or overload protection. NQB breakers are used for circuit isolation and as manual bus transfer devices.

320-1.6.5.6 ALB Type. ALB circuit breakers are small and limited in current-carrying capacity. They are supported and enclosed in an insulated housing. They have a nonselectable direct-acting overcurrent tripping device. These breakers are designed for use on low voltage power and lighting distribution systems (24 Vdc, 120 Vac and Vdc).

320-1.6.5.7 NLB Type. NLB circuit breakers are similar in construction to ALB breakers, but they do not have any overcurrent trip capability. These devices are used to break load by operating a manual toggle switch handle. They are designed for use on low voltage power and lighting distribution systems.

320-1.6.6 FUSES. A fuse consists of a metal conductor inserted into a tube of glass or other insulating material, that melts when the current through the conductor exceeds the rated level, opening the circuit. Metal ferrules at each end of the fuse make contact with fuse clips or contacts in the carriage of a screw-type fuse holder. Fuses are used as protective devices in power and lighting circuits. They are in some user equipment, where their performance is preferred over that of a circuit breaker or their use is considered more economical. Motors rated up to 7-1/2 horsepower (hp) are often supplied from group control centers having 30-ampere fuses. Fuses are not used in 450V circuits supplying motors in excess of 7-1/2 hp. Unlike circuit breakers, a fuse must be replaced when it fails. See **NSTM Chapter 300** for directions on removing and replacing fuses.

320-1.6.6.1 Fuse Characteristics. There are three types of fuses with one of the following characteristics:

- a. Characteristic A - normal blowing
- b. Characteristic B - time lag (slow blow)
- c. Characteristic C - very high (100,000 amperes) interrupting capacity

C fuses are used where the available fault current exceeds the 10,000 amperes maximum interrupting capacity of A or B fuses.

WARNING

If A or B fuses are used in an application requiring type C fuses, the fuse may explode, causing fire and personnel injury and equipment damage.

320-1.6.7 CURRENT TIME SENSING AND SIGNALING DEVICE. A current time sensing (CTS) device is designed for use with AQB-A101, -A250, -A400, and -A800 shunt trip circuit breakers. They are presently installed only for protecting 400-Hz systems that are supplied by solid-state frequency changers (SSFC) because these SSFC's are current limited and self protect before they can actuate thermal or magnetic trip circuit breakers. A CTS's time-current characteristics are more precise and adjustable than those of AQB circuit breakers with thermal and magnetic trips. The CTS device supplements the breaker's time-current characteristics with a selectable time delay for fault currents below the breaker's instantaneous pickup. A CTS monitors the current through its associated circuit breaker and directly activates the shunt trip mechanism of the circuit breaker in response to overload and fault conditions. Ships with AQB-A102 circuit breakers (electronic trip) do not need CTS monitors. 400-Hz systems supplied by motor generator sets do not use CTS or CLD because they are not current limited.

320-1.6.7.1 CTS Adjustments. CTS settings include a time delay and an instantaneous trip current level. The appropriate settings are selected during the design phase, and any subsequent system modifications by analyzing the fault currents and plotting selected time-current characteristics ([Figure 320-1-5](#)). Coordination with other protective devices is also determined in this way. Unauthorized changes to the design settings could result in improper operation of the 400-Hz system's protective devices and loss of the entire 400-Hz power supply to vital combat and electronic equipment.

320-1.6.8 CURRENT LIMITING DEVICES (CLD). A current limiting device (CLD) is a three-phase protection device used in some ships in 400-Hz electric power distribution systems supplied by SSFC's because on 400 Hz systems supplied by SSFC's, the amount of fault current the source can produce and the length of time it can produce it is very limited. To prevent the SSFC's from shutting down to protect themselves from a fault in the frequency distribution system, several ship classes are outfitted with CLD's installed on switchboard feeder circuits. The CLD automatically inserts a series impedance in a faulted switchboard feeder circuit. The added CLD impedance limits fault currents to levels that the frequency changers can supply without degrading the switchboard voltage. The CLD impedance is inserted long enough to allow the circuit breaker supplying the faulted circuit to trip. If the required circuit breaker does not trip, the CLD clears the fault by shunt tripping the switchboard feeder circuit breaker. If the shunt trip signal is sent and the fault current is still present, the CLD shuts down to protect itself and prevent the spread of the fault to the rest of the system.

320-1.6.9 POWER SYSTEM MONITORS. Power system monitors sense various power system conditions. Types of monitors include available load, reverse power, power sensing, voltage, and frequency. These devices can trip an associated circuit breaker to improve power system performance or eliminate an unwanted condition.

320-1.6.9.1 Voltage Monitors and Voltage and Frequency Monitors. Electronic equipment can be damaged by continued operation under abnormal voltages and frequencies. Voltage monitors (VM's) or voltage frequency monitors (VFM's) are used to check system operation. When the voltage or frequency exceeds allowable limits for a predetermined length of time, the power supply or feeder circuit breaker is tripped. Although these monitors can operate on both 60-Hz and 400-Hz systems, they are normally used to protect 400-Hz electronic equipment for 400-Hz systems. One VFM is typically installed on the generator side of the generator circuit breaker. Special frequency (400-Hz) distribution systems with line voltage regulators will normally have VM's installed on the load side of the line voltage regulators. VM's are not used with aircraft servicing systems because aircraft has its own voltage monitor-to-drop load if the voltage source is not within limits. The VFM's at the generator trip the generator circuit breaker. The VM at the load trips the local circuit breaker to disconnect the load. When a load is supplied via an ABT, the VM undervoltage trip is defeated so the VM does not trip the circuit breakers while a transfer is taking place. VFM's are set for the nominal voltage (115, 200, or 440) and system type (type II or III). The VFM and VM are set to trip the supply breaker within 170 milliseconds (ms) (plus the breaker operating time = 250 ms) if the voltage or frequency exceeds the following limits:

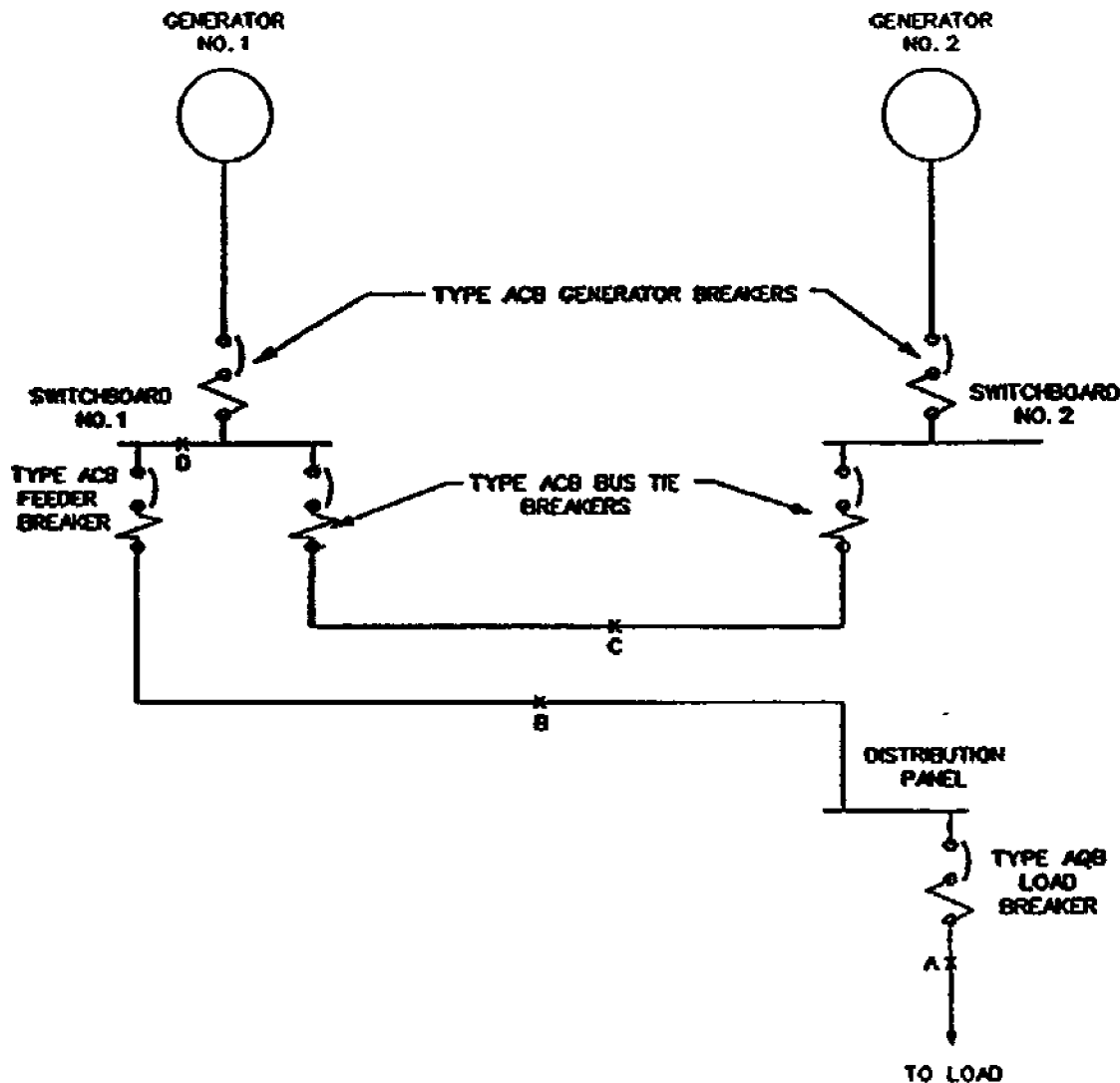


Figure 320-1-5 Overcurrent Protection Circuit (Typical)

a. Type II Power:

- 1 Above 120 to 130 percent of nominal voltage in any phase, measured line-to-line.
- 2 Below 70 to 80 percent of normal voltage in any phase, measured line-to-line.
- 3 Above 425 to 435 Hz (VFM only)
- 4 Below 365 to 375 Hz (VFM only)

b. Type III Power:

- 1 Above 110 to 120 percent of nominal voltage in any phase, measured line-to-line on delta-connected systems and line-to-neutral on wye-connected systems
- 2 Below 84 to 90 percent of nominal voltage in any phase, line-to-line on delta-connected systems and line-to-neutral on wye-connected systems
- 3 Above 415 to 425 Hz (VFM only)
- 4 Below 375 to 385 Hz (VFM only)

320-1.6.9.2 Power Sensing Monitors. These devices, also called Multi-Function Monitors (MFM's), monitor power flow in an electric circuit and respond to a predetermined power level to operate control circuits. A power monitoring relay may contain electromagnetic devices, solid state circuitry, or a combination of both.

320-1.6.9.3 Ground Fault Detectors. Ground fault detectors (GFD's) presently installed on many Navy ships monitor phase-to-ground voltages using three lights. These lights are connected from each phase to the ship's hull (ground). A ground fault on an ungrounded three-phase system causes the phase-to-ground voltage in the faulted phase to decrease while the voltages in the two unfaulted phases increase. Ground faults are detected by changes in the brightness of the lights. A solid ground fault causes the light in the faulted phase to go dark. This type of GFD is primarily intended for detecting low resistance grounds. High resistance faults may not provide enough shift in the line-to-ground voltages to give a positive indication of the grounded phase.

320-1.6.10 ELECTRIC CABLES. Electric cables are a major part of any ship's electrical distribution system. Nearly all cable types can be provided with or without armor. In most cases, an armored cable is a standard cable type with a woven aluminum or braid basket-weave layer over the outermost cable jacket. This armor provides physical protection for the cable jacket during initial cable installation and ship construction; thereafter, it serves no useful purpose. The use of armored cabling has been declining because of improved cable design and material changes, better installation methods, and the need to reduce weight and simplify cable installation (by eliminating the need to ground armor at interior and exterior boundaries). Unarmored cable has been installed on most new construction. Also, all new cables are of low smoke construction. [Table 320-1-4](#) through [Table 320-1-8](#) list the most currently used shipboard cable types and their typical applications. Only basic designations are listed. A complete cable designation consists of the basic type plus a number which indicates either the conductor size or the number of conductors, depending on the particular cable type. With few exceptions, all types listed are unarmored. MIL-C-24643 and MIL-C-24640 cables are newer types designed with standard wire gauges and low-smoke jacket materials. MIL-C-24640 cables are also designed to have a reduced weight. Ships built before 1985 generally use MIL-C-915 and MIL-C-2194 cables.

Table 320-1-4 MIL-C-24643 CABLE APPLICATION DATA

Application	Cable Type		Rated Voltage Maximum ac or dc
	Nonflexing Service	Repeated Flexing	
General Usage - For all portions of power, lighting, interior communication, weapons control, and electronics systems, except where circuit parameters (for example, audio or radio frequency, low level microphone, synchro, scale voltage, and other types of signals) require special types of cable. Types LSMU, LS3U, LSDNW, LSTNW, LSFNW, LSMNW, LSSSGU, LSDSGU, LSTSGU, LSFSGU, LS6SGU, LS7SGU, LSMSCU, LSMU, LS3U, LSSHOF, LSDHOF, LSTHOF, LSFHOF, LSMHOF, LSDCOP, LSTCOP, and LSMCOS shall be used only for runs that are either totally within one compartment or totally within two contiguous compartments, except where a watertight deck or bulkhead below flooding water level II (FWL-II) is penetrated. Type SG cable shall be used for connections between the ship service generators and their respective switchboards, between sections of the ship service switchboards, between switchboards, and between switchboards and load centers.	LSDNW		1,000
	LSTNW		1,000
	LSFNW		1,000
	LSMNW		1,000
	LSSSGU		1,000
	LSDSGU		1,000
	LSTSGU		1,000
	LSFSGU		1,000
	LS6SGU		1,000
	LS7SGU		1,000
	LSMSCU		1,000
	LSMU		300
	LS3U		300
		LSSHOF	600
		LSDHOF	600
		LSTHOF	600
		LSFHOF	600
		LSMHOF	600
		LSDCOP	300
		LSTCOP	300
		LSMCOS	600
High Voltage 60-Hz - For 3,000 and 5,000 volt, three-phase power applications	LS5KVTSQU		5,000
Casualty Power		LSTHOF-42	600
400-Hz Power - For 400-Hz service for static frequency changer or motor generator cables, bus ties, and feeders where cable of lower impedance is required to reduce voltage drop.	LS6SGU		1,000
	LS2U		600
	LS3SJ		600
	LS3SU		600
	LS3SWU		600
	LS4SJ		600
	LSMS		300
		LSTTRS	300
Shielded Circuits - For combat systems interior communications, light, and power circuits, where shielding of 400-Hz (for example, synchro, pulse, scale voltage) signals, or other signals is required. Where a watertight deck or bulkhead below FWL-II is penetrated; types LS1SMWU, LS2SWAU, LS2WAU, and LS3SWU shall be used.	LS1SAU		600
	LS1SMU		600
	LS1SMWU		600
	LS1SWU		600
	LS1SU		600
	LS1S50MW		300
	LS1S75MW		300
	LS2AU		600
	LS2SJ		600
	LS2SWAU		600
	LS2SWU		600
	LS2SU		600
	LS2UW		
	LS2WAU		600
Microphone Circuits		LSMCOS	600
		LSMMOP	300

Table 320-1-4 MIL-C-24643 CABLE APPLICATION DATA - Continued

Application	Cable Type		Rated Voltage Maximum ac or dc
	Nonflexing Service	Repeated Flexing	
Audio and Telephone - For audio, telephone call bell, announcing and alarm systems. May also be used for other interior communications and weapons control systems provided ampere rating of the cable and voltage drop to the system are not exceeded. Type LSTPNW, LSTTOP, and TTX shall be used only for runs that are either totally within one compartment or totally within two contiguous compartments, except where a watertight deck or watertight bulkhead below FWL-II is penetrated.	LSTPNW LSTTSU	LSTTOP	300 300 300
Radio	LSSRW LSDRW LSTRW		
Radio Frequency - For applications up to 2 MHz	LSTTRS	LSTTRS	300 300
Maximum total copper operating temperature shall not exceed 75°C			
Position Indicator	LSPI		
Degaussing	LSSSGU LSDSGU LSTSGU LSFSGU LS6SGU LSMDU LSMDY LSMSCU		1,000 1,000 1,000 1,000 1,000 600 600 1,000
Thermocouple and Pyrometer Temperature Range: Type LSTCTS, 125° to 260°C Type LSTCJX, 150° to 540°C Type LSTCKY, 260° to 870°C			
	LSTCTX LSTCJX LSTCKX LSTCJU LSTCTU LSPBTMU		600
	NOTE: The cables may be provided with variations in armored, unarmored, and unarmored with overall shields, as specified on the applicable specification sheet of MIL-C-24643.		

Table 320-1-5 MIL-C-24640 CABLE APPLICATION DATA

Application	Cable Type		Rated Voltage Maximum ac or dc
	Nonflexing Service	Repeated Flexing	
General Usage - For all portions of power, lighting, interior communication, weapons control, and electronics systems, except where circuit parameters (e.g., audio or radio frequency, low level microphone, synchro, scale voltage, and other types of signals) require special types of cable. Types DS, TX, FX, and MXO shall be used only for runs that are either totally within one compartment or totally within two contiguous compartments. These type cables shall not be used, however, where a watertight deck or watertight bulkhead below FWL-II is penetrated.	DX		600
	TX		600
	FX		600
	DWX		600
	TXW		600
	FXW		600
	7XW		600
	MXO		600
	MXCW		600
Audio and Telephone - For audio, telephone, call bell, announcing, and alarm systems. May also be used for other interior communication and weapons control systems provided ampere rating of the cable and voltage drop for the system are not exceeded. Type TTX shall be used only for runs that are either totally within one compartment or totally within two contiguous compartments. This type cable shall not be used, however, where a watertight deck or watertight bulkhead below FWL-II is penetrated.	TTX		600
	TTXW		600
Radio Frequency - For applications up to 2 Mhz. Maximum total copper operating temperature shall not exceed 75°C.	TTXS		600
Shielded circuits - For combat systems, interior communications, lighting, and power circuits, where shielding of 400-Hz (e.g., synchro, pulse, scale voltage) signals, or other signals is required. Where a watertight deck or bulkhead below FWL-II is penetrated; types 1XSOW, 2XSAW, 2XSW, 2XOW, and 3XSW shall be used.	2XAO		600
	1XMSO		600
	2XS		600
	MXSO		600
	3XS		600
	2XO		600
	2XSO		600
	1XSOW		600
	2XSAW		600
	2XSW		600
	2XOW		600
	3XSO		600
NOTE: Cables may be provided with variations in armored, unarmored and unarmored with overall shields, as specified on the applicable specification sheet of MIL-C-24640.			


 美军电缆
Table 320-1-6 MIL-C-915 CABLE APPLICATION DATA

Application	Cable Type		Rated Voltage Maximum ac or dc
	Nonflexing Service	Repeated Flexing	
Outboard and Submersible - For hydrophones, transducers, outboard dial telephones, retractable antennae, and similar equipment. Types 1PR-A20E, 1PR-16, 7PR-16, 2SPR-16, 3PR-16, 1Q-16, 1TR-16, and TSPR-16S are only for submarine outboard use.	MSPW TSPA 1PR-A20E 1PR-16 7PR-16 2SPR-16 3PR-16 1Q-16 1TR-16 7SPR-16S		300
		MSP	
		TSP	300
		5SS	600
		S2S	600
		DSS	600
		FSS	600
		TSS	600
		MWF	600
		DSWS	high voltage
		MCSF	600
		1SWF	300
		2SWF	300
		TPUM	600
		TRF	600
		TRXF	125
Welding Electrode Circuit		DLT	300
Diver's Line and Telephone		THOF-400 THOF-500	600
Shore-to-Ship Power		CVSF-4	600
400-Hz Aircraft Servicing		JAS-250	600
DC Aircraft Servicing			

Table 320-1-7 SPECIAL PURPOSE CABLE APPLICATION DATA

Application	Cable Type		Rated Voltage Maximum ac or dc
	Nonflexing Service	Repeated Flexing	
Cable Assembly Electronic Test Equipment	MIL-C-28777		125/250 Vac, 28 Vdcd
Cable, Coaxial for Submarine Use	MIL-C-23020		

Table 320-1-8 COMMERCIAL CABLE APPLICATION DATA

Application	Cable Type		Rated Voltage Maximum ac or dc
	Nonflexing Service	Repeated Flexing	
Cords for Portable Tools and Equipment - For power supply to electric typewriters, office machines, electric drills, sanders, por- table extension lights, and similar equip- ment. Safety ground conductors, where required, shall be green.		Underwriters Approved S, SO, ST, SJ, SJO, SJT	
Extension Cords	Fed Spec. J-C-175		

320-1.6.11 CABLE PENETRATION OF STRUCTURES

320-1.6.11.1 Metal Stuffing Tubes or Multiple Cable Penetrations. Only metal stuffing tubes are installed in decks and bulkheads that form the boundaries of spaces containing volatile, combustible, or explosive materials. Metal stuffing tubes or multiple cable penetrators are used for watertight cable penetration of the following:

- a. Watertight cable trunks
- b. Watertight decks and bulkheads surrounding compartments subject to flooding by sprinklers
- c. Bulkheads and decks exposed to the weather
- d. Bulkheads designed to withstand a water head
- e. The portion of bulkheads specified to be watertight to a certain height
- f. The portion of bulkheads below the height of the sill or the coaming of compartment accesses
- g. Cable penetrations into garbage rooms, battery charging shops, medical operating rooms, and medical wards
- h. Multiple cable penetrations used in decks or bulkheads exposed to the weather shall have CRES or glass reinforced plastic (GRP) accessories.

320-1.6.11.2 Nipples or Collars. Nipples (for single cable penetration) and welded collars (for multiple cable penetrations) are used for nonwatertight cable penetrations. Where nipples and collars penetrate airtight or fume-tight compartment boundaries, they are packed with plastic sealer. The primary reason for sealing cable penetrations in nontight bulkheads is to form a fire stop. The plastic sealer prevents fire and smoke from traveling along the cableway from one compartment to another. The installation and packing of nipples and collars are in accordance with standard methods. Nipples and collars are used at the following locations:

- a. Nonwatertight decks
- b. Nonwatertight structural bulkheads
- c. Airtight bulkheads
- d. Fume-tight bulkheads
- e. Multiple cable (two or more) penetrations of

- 1 Nonstructural steel bulkheads (other than wire mesh or expanded metal)
- 2 Bents, web frames, transverse girders, and longitudinal girders

320-1.6.11.3 Cable Segregation for Interference Reduction. Cables supply power and interconnect electrically-operated equipment for control and communication. To properly protect and operate these cables on today's complex ships, it is necessary to group electrical cables into categories and segregate, route, shield and isolate the various groups. To reduce interference, each shipboard cable can be classified as active, passive, or susceptible. Active and susceptible cabling are generally found in electronics systems. Examples of active cables are radar and radio transmitter cables. Radio and radar receiver cables are examples of susceptible cables. Passive cables include power, lighting, control, indication, and integrated circuit cables. When installing cables, the electromagnetic interference currents and voltages can be reduced by selecting the proper cable types, shielding, and routes, and by following installation guidelines. Care should be taken to maintain minimum cable separation distances, especially in cableways, whenever cable is installed by ship's force.

320-1.7 SYSTEM PROTECTION

320-1.7.1 GENERAL. The electrical distribution system and the generators may be damaged by a moderate overcurrent if it is of sufficient duration. They may also be damaged by an equipment failure, such as an electrical fault in cables or switchboard, or failure of a generator prime mover to provide power. On 400-Hz power systems, equipment also may be damaged by continuous abnormal voltage or frequency conditions. Moderate overcurrents or overloads can be endured for the time it takes the operator to recognize the condition and take steps to correct it. No automatic protection is provided for moderate overcurrent or overvoltage. For certain other conditions, extensive damage can occur so quickly that immediate action is necessary. Automatic protective devices are installed

- a. To keep a generator prime mover from being driven by its generator if the prime mover fails.
- b. To isolate faulted circuits that allow the flow of excessive overcurrent, with minimum interruption of power supply to the rest of the system.
- c. To remove abnormal voltage or frequency conditions from equipment requiring 400-Hz power.

320-1.7.2 GENERATOR REVERSE POWER AND CURRENT PROTECTION. When a generator is operating in parallel with other generators and its prime mover fails, the generator will take power from the system, run as a motor, and drive the prime mover. This could damage the prime mover. A motoring generator, if allowed to remain on line, could also overload the other on-line generators, resulting in a total loss of ship service power. To prevent this, the reverse power or reverse current relay trips the generator circuit breaker and takes the generator off the bus when the relay setting is exceeded. The setting is chosen according to the particular requirements of each generator set. Commonly used values are a reverse current setting of about 5 percent of rated generator current for a maximum duration of 10 seconds. On ac systems, the reverse power relay can be a separate device or combined with a power monitor. On dc systems, the reverse current device is part of the dc generator circuit breaker.

320-1.7.3 SHORT-CIRCUIT OVERCURRENT PROTECTION. The purpose of short-circuit protection is to isolate the faulted section of the distribution system, while maintaining power continuity to as much of the remainder of the system as possible. The following paragraphs outlines the method by which this selective short-circuit protection is obtained.

320-1.7.3.1 By properly selecting the settings of the various circuit breakers, the time-current characteristics of the protective devices can be coordinated to trip the circuit breaker closest to the fault.

320-1.7.3.2 [Figure 320-1-5](#) is a schematic diagram of part of a distribution system that has circuit breakers with the time-current characteristics shown in [Figure 320-1-6](#). [Figure 320-1-6](#) shows the tripping times in response to different magnitudes of fault current for a group of circuit breakers. The behavior of individual breakers of the same type and rating will differ slightly because of manufacturing tolerances. All breakers of that type and rating, however, will have characteristics that fall within the band.

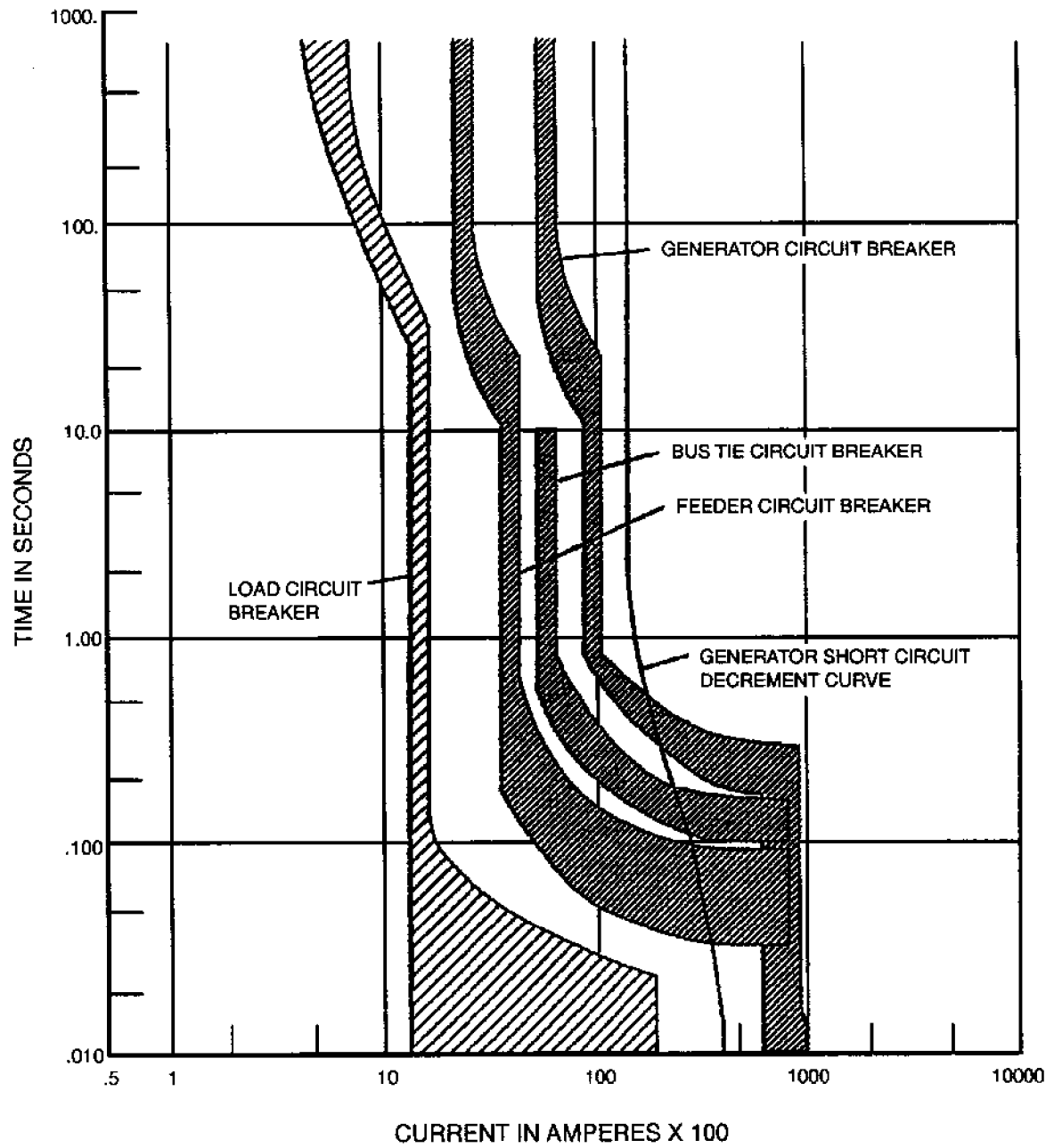


Figure 320-1-6 Time-Current Characteristics of Selectively Tripping Circuit Breakers

320-1.7.3.3 The tripping time indicated in [Figure 320-1-6](#) is the time required for a breaker to open and clear a circuit when breaker operation is not intentionally delayed. The figure also compares the generator circuit breaker characteristics with the generator short-circuit decremental curve. The decrement curve shows how generator short-circuit current changes with time. The instantaneous trip settings of generator circuit breakers are usually set to be 20 percent greater than the short-circuit current the generator can produce. The generator circuit breaker will not trip instantaneously. It will, however, trip after a time delay determined by the crossover of the generator decrement curve and the generator breaker time-current characteristic (as shown in [Figure 320-1-6](#)). This gives circuit breakers in the distribution system time to clear the fault before tripping the generator off-line for fault currents. For the same reason, bus-tie circuit breakers are usually not set to trip instantaneously, but will eventually trip after a short time delay (that is shorter than the delay for the generator breaker trip).

320-1.7.3.4 For currents less than the instantaneous trip current setting, an intentional delay in the operation of the breaker is used. The time delay is greater for small currents than for large currents. This is known as an inverse time delay. Consider a 10,000-ampere fault occurring at point A on the system shown in [Figure 320-1-5](#). Referring to [Figure 320-1-6](#), a 10,000-ampere current would trip the AQB load circuit breaker instantly, clearing the circuit within the breaker's instantaneous trip time. The ACB feeder circuit breaker in this example will not trip on a current of 10,000 amperes unless the current flows for 50 to 120 ms. If the 10,000 amperes of fault current flow through the bus tie circuit, the bus tie circuit breakers will only open if the current flows long enough to reach their time delay setting (between 300 and 400 ms in this example). The generator circuit breaker will open after its time delay setting is reached (about 700 ms) if it is not cleared by a circuit breaker nearer to the fault before that time. The differences in the time-current characteristics of breakers connected in series permit the breaker farthest downstream (the AQB load breaker) to trip first. This clears the fault from the circuit before the next breaker upstream from it (the ACB feeder breaker) operates. Fault current does not flow through the upstream circuit breakers (feeder, bus tie, or generator breakers) long enough to trip them, and they will remain closed. A fault at point B in the system shown in [Figure 320-1-5](#) would trip the feeder breaker, but not the generator or bus tie breakers. A fault at point C in [Figure 320-1-5](#) would trip either or both bus tie breakers, but not the generator breaker. In each case, the faulted section of the system is isolated. Power continuity is maintained to as much of the system as possible, considering the fault location because the circuit breaker nearest the fault interrupts power to a minimum portion of the system load.

320-1.7.3.5 Fused breakers (AQB-LF) are often used as switchboard feeder breakers. The fuses used with these breakers give them the required higher interrupting rating. The remainder of the distribution system is not changed. The AQB-LF breaker fuses will limit the fault current, thereby protecting the AQB breaker and the distribution system downstream, when the fault current is higher than the breaker can interrupt.

320-1.7.3.6 The circuit breaker settings that give the best protection are not the same in all installations. For full information on a specific installation, refer to the ship's plan, which shows circuit breaker time-current characteristics in curves similar to those in [Figure 320-1-6](#).

320-1.7.3.7 To obtain selective tripping, the time-current characteristics of different circuit breakers are carefully coordinated during system design. For example, if the system illustrated in [Figure 320-1-5](#) is operating split plant (bus ties open), and if the settings for the ACB feeder breaker and ACB generator breaker were interchanged (and the bands in [Figure 320-1-6](#) reversed), a fault at B in [Figure 320-1-5](#) would trip the no. 1 generator off line, but leave the feeder connected to the switchboard. This would cut off power to all equipment served by the no. 1 switchboard, but would not isolate the faulted section. Thus, because the selective protection scheme could be completely disrupted, unauthorized changes should not be made in circuit breaker trip settings.

320-1.7.4 FUSES. It is unfeasible to provide system protection on all types of naval ships and all circuits using circuit breakers only. In some cases, it is also necessary to use fuses as part of the system's circuit protection. Where fuses are used in series, some degree of coordination can be achieved by using fuses of different sizes or time characteristics. Progressively larger fuse sizes from load to generator give some degree of selectivity for overload and fault conditions. Available fuse sizes and characteristics, however, will limit the amount of time delay that can be obtained, and therefore the number of series fuses that can be used in a selective protection system. Care should be exercised in the replacement of fuses to ensure that

- a. Fuses are of the proper voltage rating.
- b. Fuses are of the proper interrupting capacity.
- c. For special fast-acting fuses supplying electronic equipment there may be no equivalent types. In this case, replacement fuses must be identical.
- d. Fuses used for protecting transformers and noninductive loads should be rated not less than 125 percent of the rated load current. Fuses used for protecting motor loads should be rated at 250 to 400 percent of the motor full load rating.
- e. Fuses rated for 15 amperes, or 15-ampere rated ALB-1 circuit breakers, are typically used to protect 60-Hz receptacle circuits for which a load is not specifically indicated.

SECTION 2.

OPERATION

320-2.1 CHARACTERISTICS OF ELECTRICAL INSTALLATION

320-2.1.1 GENERAL. Naval electrical installations are simple, rugged, reliable, and flexible so that they can continue to function even when part of the equipment has been damaged. Those who operate these plants are to use their capabilities fully and are responsible for maintaining, as much as possible, uninterrupted availability of electric power where it is needed. To be able to do this, operating personnel should have the following:

- a. Thorough knowledge of operation and maintenance of component parts of the electric plant.
- b. Complete familiarity with the whole electric plant.
- c. Comprehensive understanding of system operation.
- d. Ability to apply general principles to specific installations.
- e. Knowledge of a few basic rules of system operation that are applicable to all naval installations.

320-2.1.2 NSTM REFERENCES. Instructions for specific items of electrical equipment are contained in other chapters of this manual and in manufacturers' technical manuals. In particular, see the following Naval Ships' Technical Manual (NSTM) chapters:

NSTM Chapter 074 Volume 1, Welding and Allied Processes

NSTM Chapter 079 Volume 3, Damage Control - Engineering Casualty Control

NSTM Chapter 223 Volume 1, Submarine Storage Batteries - Lead Acid Batteries

NSTM Chapter 233 Diesel Engines

NSTM Chapter 235 Electric Propulsion Installations

NSTM Chapter 300 Electric Plant - General

NSTM Chapter 302 Electric Motors and Controllers

NSTM Chapter 310 Electric Power Generators and Conversion Equipment

NSTM Chapter 313 Portable Storage and Dry Batteries

NSTM Chapter 330 Lighting

NSTM Chapter 400 Electronics

NSTM Chapter 422 Navigation and Signal Lights

NSTM Chapter 430 Interior Communication Installations

NSTM Chapter 434 Motion Picture Equipment

NSTM Chapter 475 Magnetic Silencing

NSTM Chapter 491 Electrical Measuring and Test Instruments

320-2.1.3 OTHER REFERENCES. You can become familiar with the electrical system as a whole by studying information related specifically to that installation. Valuable information on a ship's electrical installation can be found in the Ship Information Book (SIB), particularly volume 3 for power and lighting systems; the ship book of onboard plans; training aid booklets; and manufacturers' technical manuals supplied with many items of equipment. Supplement this study with a thorough study of the hardware itself so that generators, switchboards, distribution panels, and cables are not merely symbols on a plan but physical entities; and so that you know and thoroughly understand the functions, and relation of the hardware to the rest of the system.

320-2.2 GENERAL PRINCIPLES OF OPERATION

320-2.2.1 OVERVIEW. General principles of system operation are a guide to the procedures that should be followed to maintain continuous availability of power and to operate safely within limits of installed protective devices. The general principles considered here relate to

- a. Electric plant operation
- b. Choice of power source
- c. Prevention of overloads
- d. Operation under casualty conditions

320-2.2.2 ELECTRIC PLANT OPERATION. The ship's electric power and lighting systems are designed to provide flexibility to ensure continuous service to vital power and lighting loads under normal and casualty conditions. The ship service generators and distribution systems in most naval ships are designed so that the electric plants can be operated in parallel or separately (split plant). Parallel operation provides continuity of power to all ship service loads even if one generator suddenly trips offline and minimizes the magnitude of system voltage and frequency variations. Selective tripping virtually eliminates the likelihood that all the circuit breakers for paralleled generators will trip as a result of a system fault. For these reasons, parallel operation is the preferred mode of operating ship service generators on most surface ships. It is often necessary to restrict the number of generators that are operated in parallel to avoid exceeding the interrupting rating of circuit breakers. For this reason, the electric plant on many ships can be configured in a combination of parallel and split plant operation of genera-

tors, with one or more groups of generators operating in parallel and the electric plant split by opening the bus ties at some location. Split plant operation is the preferred mode of operating ship service generators on submarines because maintaining continuity of electrical power is secondary to preventing total loss of power.

320-2.2.2.1 Limits on Number of Parallel Generators. All ships are provided with multiple ship service generators, that are required to be capable of parallel operation. In determining the number of generators that can be operated in parallel without exceeding the interrupting rating of circuit breakers, calculations are made to determine the impedance of cables from generators to the point of the fault and also the current that motors contribute to the fault. If a high magnitude fault current passes through a circuit breaker with insufficient interrupting capacity, the circuit breaker, switchboard section, and the generator can be damaged. In addition, personnel around the fault can be injured from arcing, fire, and exploding equipment. Various electric plants on major combatant and support ships of the U.S. Navy have been analyzed to determine the maximum number of generators that may be safely operated in parallel within limits of installed circuit breaker protective devices. The results are listed in [Table 320-2-1](#). Ship personnel should annotate the SIB to read as follows:

A maximum of ship service generators may be safely operated in parallel without exceeding the interrupting capacity of the existing circuit breakers. This does not limit the number of ship service generators that may be paralleled momentarily for transfer of load or synchronizing.

After major overhauls, if either generators or protective devices have been changed, the maximum number of generators that may be safely operated in parallel should be checked with the Naval Sea Systems Command and the SIB updated accordingly.

320-2.2.2.2 Diesel Generator Set Loading. On ships with diesel generators, generators should be operated so that the load on engines used is not less than 50 percent of full load (**NSTM Chapter 233**).

320-2.2.3 CHOICE OF POWER SOURCE. When both normal and alternate feeders are connected to a load, the normal source of power should be used when available.

320-2.2.4 PREVENTION OF OVERLOADS. It is extremely important for operating personnel to realize that no automatically operated devices are installed to protect either the distribution system or the generators from damage by an overcurrent that only slightly exceeds rated capacity. The operator is responsible for monitoring the plant to guard against moderate overcurrents and power overloads. Because these conditions will not be picked up by the system's automatic protective devices, they can cause excessive heating of the generators if allowed to continue for too long. The operator can intervene because a moderate overcurrent or overload can be carried without damage long enough to permit the operator to recognize it from the ammeter and wattmeter readings, and to take steps to correct the problem.

320-2.2.4.1 When switchboard instruments reveal an overload condition or when an increase in load that will exceed the capacity of the operating generators is anticipated, another generator should be brought on line. (See **NSTM Chapter 310** for instructions on generator operation.)

320-2.2.4.2 Emergency switchboards are connected by feeders to loads that may need emergency power. Emergency generators do not have enough capacity, however, to provide power for the simultaneous operation of all loads that can be connected to the emergency switchboard. If ship service power is lost, an unsystematic use of emergency power may very quickly overload an emergency generator and stall its engine. The automatically applied load on each emergency generator is limited to less than the generator's capacity. Loads are then selectively added by the electric plant operator to approach generator capacity.

320-2.2.4.3 To use emergency power effectively and to ensure its availability when needed most, the engineering force on each ship must establish an operating procedure for the emergency switchboard. Under each condition of operation (cruising, general quarters), the operator must know which loads should have preference as well as the priority for additional loads that can be carried if one of the preferred loads is lost because of equipment damage.

320-2.2.4.4 Because of the limited capacity of emergency generators, the feedback tie from the emergency switchboard to the ship service switchboard installed on some ships should not be used to supply power to the ship service distribution system. Its use should be limited to special circumstances, such as dock conditions, when it is desirable to secure the ship service generators; and in cases where it is necessary to feed power through ship service switchboards to certain auxiliaries to start ship service generators, and to momentarily parallel with ship service systems to transfer power from the emergency power system to the ship service power system. When the feedback tie is used, increased watchfulness is necessary to prevent overloading of the emergency generators.

320-2.2.5 OPERATION UNDER CASUALTY CONDITIONS. Operation under casualty conditions depends on the type of casualty. Parallel operation is the preferred mode because the loss of a generator will not interrupt power to all loads in the parallel electric plant when generators are paralleled. If the loss of generating capacity results in an overload or approaches the 100-percent rating of existing generators, remove nonessential loads from the system until additional generating capacity can be brought on the line.

320-2.2.6 APPLICATION OF GENERAL PRINCIPLES. While general principles form an excellent guide to system operation, they are not enough. An operator who is thoroughly familiar with general principles only might know just what to do in any circumstance and still be unable to do it. Principles must be applied to specific installations to be of practical value, and they should be applied before, not after, an emergency. Water does not stop rising in bilges just to give an electrician time to figure out how to get power to submerged pumps. Operating personnel should study the capabilities and limitations of their installation and figure out how to get power to where it is needed after any conceivable casualties using any combination of generators still able to supply electric power. Personnel should be drilled again and again to become proficient. Simulating casualties that test the ability of the operating crew to provide power is excellent practice. To be most valuable, these tests should be made at an unannounced time. They should, however, be made only in such a way and under such circumstances that equipment will not be damaged, and a temporary loss of power will not endanger the ship. Personnel should be thoroughly familiar with the following specific points in applying general principles to a particular installation:

Table 320-2-1 PARALLEL SHIP SERVICE GENERATOR

Combatant and Support Ships	Max. No. of Generators In Parallel
AE 22, 28, 29, 33, 34	3
AO 177, 178, 179, 180, 186	3
AOE 1, 2, 3, 4	3
AOE 6 Class	3
AOR 2, 3, 4, 5, 6, 7	3
AR 8	3
AS 33, 39, 40, 41	3
CG 47 Class	2
CGN 36 Class, 38 Class	2
CV 62, 63, 64	3

Table 320-2-1 PARALLEL SHIP SERVICE GENERATOR - Continued

Combatant and Support Ships	Max. No. of Generators In Parallel
CV 67	3-Split Port and Starboard or 2-Otherwise
CVN 65	2
CVN 68 Class	2
DD 963 Class (except DD 964)	2
DDG 993 Class	2
DDG 51 Class	2
DDG 964	3
FFG 7 Class	4
LHD 1 Class	2
LPD 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15	3
LSD 36 Class, 41 Class, 49 Class	3
LST 1179 Class	3
LCC 19, 20 Class	3
LHA 1 Class	3
LHA 115, 117	4
LPH 9, 11	2
MCM 1 Class	2
AGF 3, 11	3
MCS 12	2
MHC 51 Class	2
NOTE: This table lists, for each major combatant and support ship, the maximum number of ship service generators that can be safely and continuously operated in parallel without exceeding the interrupting capacity of circuit breakers and jeopardizing personnel and equipment safety.	

- a. All sources of electric power for important auxiliaries. Personnel should know exactly where bus-transfer equipment is located and should be thoroughly drilled in using it to transfer from one power source to another.
- b. The capabilities of the casualty power system, if installed. Personnel should memorize the location of casualty power fittings and cables and should be drilled in their use. Hypothetical damage conditions should be assumed and connections for each case practiced.
- c. The location of stowage spaces for portable submersible pumps, the location of power outlets from which these pumps can be operated, and how to connect pumps to the casualty power system if power is unavailable at power outlets.
- d. The electrical damage control equipment that consists of tools and appliances for making temporary splices, and its use for making temporary repairs to the permanently installed ship service emergency distribution system. All electrical diagrams included in the Damage Control Book should be kept up to date in accordance with instructions in **NSTM Chapter 079** .
- e. Personnel preparing drills and engaged in drills should know which equipment (such as electronic equipment) might be damaged by unexpected power interruptions. Damage might occur because power to cooling equipment is interrupted while heat-sensitive electronic equipment is still operating or has had no chance to cool down. (Normal shutdown may require operation of cooling equipment for some time after heat-sensitive equipment is secured.) Electronic equipment may be damaged because of high transient voltages on the system. Transients on the electric power system can be either the high frequency, high voltage, short-time type

or the long-time type. Short-time transient spikes can be produced whenever there is a sudden change to the electrical circuit (such as a circuit breaker operating). The long-time type dims lights and dips meters during motor starting or fault clearing. The short-time type is particularly dangerous to sensitive semiconductors. If electronic equipment cannot withstand these transients (either short- or long-time), they should be protected during drills. Equipment that may be damaged from loss of cooling is extremely vulnerable during battle conditions when power interruptions may occur. For drills, this equipment should be transferred carefully to power sources not involved in drills.

320-2.2.6.1 Automatic Starting of Diesel or Gas Turbine-Driven Emergency and Standby Generators. Diesel and gas turbine-driven emergency generators can be set for manual or automatic starting as follows:

- a. Automatic starting is required whenever the ship is underway or operating on its own ship service generators. Automatic starting should also be required when the ship is operating on shore power to ensure an alternate power source (particularly for fire pumps) if shore power is lost.
- b. On ships that can parallel their ship service generators with shore power, emergency generator controls should be left in the automatic start position. Ships without this capability should put emergency generator controls in the manual mode. When ship service and shore power are not paralleled, there will be no voltage at the switchboard the instant a ship service switchboard is transferred from ship service power or to shore power and vice versa. Emergency switchboards are always energized from ship service switchboards. Upon loss of voltage from the ship's supply to any emergency switchboard, the emergency generator associated with that switchboard will start automatically. Thus, before making a transfer causing momentary loss of ship service voltage on the emergency switchboard, the automatic starting circuit should be made inoperative for the transfer period. After the transfer has been made, the switchboard, generators, and automatic starting device should be set for automatic start. When this setup is made, extreme care should be taken to ensure that all auxiliaries for the diesel generator function properly.
- c. Emergency generators will be set for automatic start when they may be unattended. Precautions must be taken to avoid prolonged periods of operation under these unattended conditions. Operation of emergency generators shall be checked whenever there has been, or there is believed to have been, a failure of either ship or shore power. Momentary power failure may begin the generator starting sequence, causing it to start and continue running. A rapid return to normal power, however, may result in no load being transferred to the emergency generator. This would make it difficult to detect that the generator is running. Methods of stopping emergency generators are normally provided in the compartment in which the generator is installed. Furthermore, it is usually necessary to set up the lube oil alarm manually after the generator starts.
- d. When the ship is on shore power and shore power is lost, precautions should be taken to ensure that the feedback procedure is not begun until it is confirmed that the shore power breakers or other isolating breakers are opened. These precautions are taken to avoid unintentional out-of-phase paralleling of ship's power with shore power if shore power is unexpectedly restored.
- e. On many ships that have diesel or gas-turbine driven ship service generators, separate emergency generators are not provided. This is because the ship's service generators can be automatically or manually started and then manually placed on-line as rapidly as typical emergency generators. On ships with only ship service generators, a generator that is not on-line is normally designated as the standby generator. It is set up for either automatic start or rapid manual start in the event of a power failure or overload condition. Although a ship's control system may be able to safely bring a standby generator on the line when operating on ship's power, this capability may not exist when the ship is on shore power. The preferred lineup when a ship is on shore power is to have a standby generator set for automatic start and assumption of load upon loss of shore power, providing the ship's control system is designed to isolate shore power from ship's power. Precautions should

be taken to ensure that this isolation remains and is not defeated. These precautions will prevent an out-of-phase paralleling of ship's power with shore power if shore power is unexpectedly restored after the standby generator is on the line.

320-2.2.6.2 Protection of Personnel. Grab rods and guardrails should always be in position around switchboards and other power distribution equipment when the equipment is energized (unless emergency repairs are necessary). Grab rods and guardrails should be carefully maintained to ensure that they are secure and will not be accidentally dislodged. Insulating matings covering the deck in the front and the rear of the switchboards should always be in place. In addition, the following precautions should be taken.

- a. When maintenance work is performed on a circuit, ensure that the circuit remains dead and is not energized by the closing of a remote circuit breaker. All circuit breakers or switches that could energize the circuit if closed shall be tagged with a red danger tag. The tag is not to be removed until work is complete (see **NSTM Chapter 300**). Although an option, it is recommended that a handle-locking device be attached (see **NSTM Chapter 300**), if available, to switches and circuit breakers that have been tagged.
- b. Even though all circuit breakers to and from a switchboard are open, voltage can be present in the switchboard through control circuits. Examine switchboard and ship system drawings to determine if control voltages could be present. Add a note to deenergize control power to standard procedures for maintaining or troubleshooting such switchboards.
- c. If removable covers (plates or grilles) are provided on switchgear units, use great care in removing them when equipment is energized. A cover may tip in after removing some fastenings or while it is being lifted off. This could result in contact with a live part that could cause a short circuit, an arc, or injury to personnel.
- d. For protection of personnel, ground all enclosures and equipment frames to the ship. Particular attention should be paid to the stored capacitance potential present in the 4160V aircraft carrier switchboards.

320-2.2.6.3 Moisture in Switchboards. Under some conditions, moisture may condense within switchboards, particularly those having barriers between units. Condensation can form when switchboard parts cool down (such as when a switchboard is secured); lower than normal temperatures exist within a compartment when the compartment is secured; or steam escapes from open drain lines when lighting off cold equipment. Switchboards should be inspected and corrective measures taken when moisture is found or conditions favorable to moisture condensation exist. The corrective measures should follow the applicable Planned Maintenance System's Maintenance Requirement Card.

320-2.2.6.4 Electric Plant Operating Rules. A few basic operating rules should be observed on all installations.

- a. Watch switchboard instruments. They indicate the operating condition of the system, revealing overcurrents or overloads, improper division of kilowatt load or reactive current between generators operating in parallel, and other abnormal operating conditions.
- b. Keep the frequency (on ac systems) and voltage at their correct values. Departure from either affects, to some extent, the operation of all equipment supplied with electric power. The operation of vital electronic, interior communication, and weapons control equipment may be seriously affected. This sensitive equipment requires careful adjustment of voltage regulators and prime mover governors to obtain satisfactory performance.
- c. Use judgment when closing circuit breakers after they have tripped automatically. If a circuit breaker trips immediately upon the first closure, investigate before closing it again. The circuit breaker may, however, be closed a second time without investigation if the immediate restoration of power to the circuit is important and the interrupting disturbance when the circuit breaker was tripped was not excessive. Repeated closing and

tripping could damage the circuit breaker and increase the repair or replacement work needed to get the circuit operating again. Some ships have preventive logic (fault circuit protection to prevent automatic circuit breaker reclosings after they were tripped due to a fault).

- d. Use the hold-in device (not available on new ships) on circuit breakers with judgment and only when necessary. The hold-in device enables an operator to hold a trip-free circuit breaker closed when the current is in excess of the tripping value. The circuit breaker opens automatically as soon as the hold-in device is released if the current is more than the tripping current. In an emergency, it may be vitally important to obtain power even at the risk of burning out equipment. The hold-in device makes it possible to do this. When holding a circuit breaker closed, however, keep in mind that the circuit is not protected against damage by excessive current. The longer the circuit breaker is held closed, the greater the chance of permanently damaging circuits or equipment. A circuit breaker should never be held closed unless there is an emergency that justifies this risk.
- e. Never parallel ship service generators until they have been synchronized (see **NSTM Chapter 310**).
- f. Never close bus tie circuit breakers to parallel buses on two energized switchboards until the buses have been synchronized.
- g. Never close the bus tie circuit breaker to restore power to a switchboard that has lost it because of failure of a local generator. The breaker may be closed if the generator circuit breaker has first been tripped by hand or if it has been definitely established that the generator circuit breaker is in the open position. Do not rely on the reverse power relay to trip the generator circuit breaker.
- h. Never parallel ship service generators with shore power except for the short interval required to transfer the load from one source of power to the other.
 - 1 Never parallel ship service generators with shore power of a different frequency (such as 50 Hz).
 - 2 Never parallel with shore power for transferring a load without using a synchroscope or synchronizing lights. On ships not provided with a synchroscope for synchronizing between shore power and the bus, generator breakers shall be opened first. Then, the shore power breaker shall be closed. On some ships, shore power may be connected to the bus tie with bus tie breakers open. Synchronizing can then be accomplished across bus tie breakers.
 - 3 When the shore power and ship service generators are placed in parallel, the normal synchronizing process is reversed. The incoming shore power is the controlling source. Several precautions should be taken when paralleling with shore power, in addition to the usual ones when paralleling two ship service generators. The shore power connection phase rotation must be the same as the ship phase rotation. This is easily determined with a phase-sequence indicator. If more than one shore power connection is to be paralleled, actual phases of the shore power must be in the same rotation and also be connected to match ship phases. This prevents a short circuit through the ship system. If shore power phases 1, 2, and 3 are connected respectively to ship phases A, B, and C at shore power connection no. 1, then the connection at shore power connection no. 2 must also be connected 1, 2, and 3 to A, B, and C, respectively. When paralleling with shore power to transfer the load, bring the ship voltage up to, or as close as possible to, the shore power voltage.
 - 4 In some cases, the shore power voltage will be about 480V. Increase the ship's generator voltage to match shore power voltage. Bring the ship frequency to that of the shore power. Turn on the synchroscope, synchronize the ship power with the shore power, and close the shore power breakers. Quickly transfer load to shore power. Trip the ship service generator breakers.
- i. Always check phase sequence before connecting to a shore power supply. Be sure that connections are made so that the phase sequence on the ship will be A, B, and C. If the shore power is connected so that the wrong phase sequence results on the ship, motors (such as those on ventilation exhaust fans) will run in the wrong direction.

- j. Never parallel an emergency generator with any other generator because loss of the other generator may cause the emergency generator to become over loaded and trip off line. An emergency generator (standby set), however, may be temporarily paralleled with a main generator to 1) provide a smoother transfer of power at cold ship start for sensitive loads or 2) when cold ship start loads are only accessible through main switchboards.
- k. Always observe electrical safety precautions (see **NSTM Chapter 300**).
- l. Never adjust a ventilation opening, for personal comfort of watchstanders, to a position that allows spray or solid water entering the ventilation system through weather openings to be discharged onto switchboards, distribution panels, bus bars, or other electrical equipment.
- m. Always operate switchboards and distribution system equipment as if no automatic protective devices are installed. Sooner or later, problems will result from careless operating practices that assume that automatic protective devices will either prevent incorrect operation or prevent damage from incorrect operation. Automatic protective devices used with the distribution system are intended to protect against damage as a consequence of equipment failure, not operator failure. The operator must read and follow instructions on warning plates and indicator lights and know the system and how to operate it correctly. The operator must never depend on automatic devices to eliminate mistakes or a mistake's consequences.
- n. Only operate bus disconnects (disconnect links) when they are not energized. Exception may be taken under emergency conditions and in those instances where a normal means of deenergizing the bus disconnect is not provided, such as in a submarine battery power distribution system. Bus disconnects shall never be opened or closed under load. Not energized is defined as that condition in which no source of voltage is available on either side of the disconnect. Under load is defined as that condition in which current will be interrupted when opening or current will flow immediately after closing the bus disconnect.
- o. To secure an ac generator operating in parallel with another generator or other generators
 - 1 Turn the governor motor control switch of the generator being secured in the DECREASE speed direction. Turn the governor motor control switch (or switches) of the other generator(s) in the INCREASE speed direction until all the load is shifted from the generator being secured.
 - 2 Trip the circuit breaker of the generator being secured.
 - 3 Return the automatic voltage regulator control to the manual position and the manual voltage control rheostat to the decrease voltage position.

320-2.2.7 SHORE POWER.

320-2.2.7.1 Shore Power Overvoltage Precautions. To minimize the dangers of overvoltages on ac shore power to ships, the following precautions should be taken:

- a. **New construction and conversion** . The contractor or building yard is responsible for ensuring that overvoltages do not occur on any ship under construction or conversion.
- b. **Other ships** . The yard or base must take every reasonable precaution to ensure against overvoltages when supplying any ship or submarine with 60-Hz shore power.
- c. **Maximum voltage tolerance** . The voltage, as measured at the ship's main switchboard, should not be allowed to exceed the maximum steady-state voltage of 462V. This voltage may be exceeded prior to assuming shore power. Once the shore power load is assumed, however, the voltage should drop to the steady-state range as a result of losses in the shore power cables and ship distribution system.

320-2.2.7.2 Instructions and Procedures for Shore Power Connection. Shore power arrangements and hardware used on both ship and shore installations are so diversified that no specific installation instructions can be outlined in detail. A shore installation that has one circuit breaker supplying a number of cable sets presents a particular hazard. In this case, phase rotation and phase orientation can be verified only by energizing all shore terminals. Phase rotation should be checked with only one set of cables installed. The latest designs have a single, three-phase receptacle for ship and shore power terminals. These receptacles are keyed such that phase rotation cannot be altered provided both the ship and shore use these receptacles, and the cables are not spliced. Systems using three-phase receptacles are normally designed so that interlocks on the receptacles automatically trip associated circuit breakers whenever the receptacle cover is open and a shore power cable plug is not in place. Voltage to these receptacles, however, should still be checked to ensure they are deenergized prior to installing the shore cables. The following instructions assume that the shore installation has a separate circuit breaker or disconnect for each set of cables and that three-phase receptacles are used. These basic instructions and procedures shall be followed prior to and when connecting to shore power.

1. To avoid personnel injury and equipment damage, carefully inspect shore power fittings for any defects prior to making shore power connections. Follow installation instructions, Maintenance Requirement Card (MRC) procedures, and check-off lists cautiously when completing the shore power connection. Also do this when performing any other steps necessary for transfer of the load from ship generators to shore power.
2. Connect and disconnect shore power under the direct supervision of the Electrical Officer, a qualified leading electrician, and the shore activity personnel.
3. Visually inspect shore power cables for any defects (such as cracks, bulges, and indications of overheating). Thoroughly examine spliced cables, in particular, since improperly spliced ones are extremely dangerous because the cable phase continuity may have been altered during splicing. Strip lug-to-lug connection splices of insulation and check the connection itself for cleanliness, tightness, and good surface contact. Repair all defects and reinsulate all lugs before placing cables in service. Check cables for insulation resistance using a 500V megger (megohmmeter). Insulation resistance readings shall meet the requirements of **NSTM Chapter 300**. Check resistance between phases and between each phase and ground. For this test, shore ground shall be the enclosure that houses shore power terminals or receptacles. On ships, ground shall be the ship hull or any metal extension of the hull. During the physical inspection and megger tests, check the phase identification of the cables.
4. Ensure shore power cables connected to a ship are the same length to avoid voltage unbalance among cables.
5. Tag with high voltage signs and, if possible, rope off the work area surrounding the ship's shore power terminal box or receptacle. This box or receptacle is exposed to elements, and any moisture can cause a serious problem. With the ship's shore power breaker tagged in the open position, disconnect all equipment (for example, meters and indicator lights) that could be damaged by a megger test or cause a false reading. Test terminals in the ship's shore power terminal box or receptacle with a voltage tester to ensure that they are deenergized. Next, with a 500V megger, test the insulation resistance between terminals and from each terminal to ground.
6. Lay out the cable between the supplying shore power outlet and the ship's shore power terminals box or receptacle. Ensure that the cable is of sufficient length to allow enough slack for the rise and fall of the tide but not of such length as to permit the cable to dip into the water or become wedged between the ship and pier. Do not permit cables to rest on sharp or ragged objects such as gunwales. Avoid sharp bends. Lay cables in wood saddles or wrap in canvas. Raise splices and connectors from the deck or pier to protect against water contamination. Protect excess cable in a manner that will minimize damage from vehicle and pedestrian movements.
7. Connect shore cables to ship's shore power terminals according to phase or polarity in the box and on the cables.

8. Ensure correct phase orientation (phase relationship) by checking color coding or phase identification markings on cables. Reconfirm correct phase identification by meggering between like phases of cables, and using a phase orientation meter. Cables that give a zero indication will have the same phase relationship. After meggering, reconnect any disconnected equipment.
9. With a voltmeter, that has just been checked with a known energized source, check to ensure that shore power terminals are deenergized.
10. Connect shore power cable to terminals.
11. Check for proper phase rotation either by alternately energizing shore power receptacles one at a time and observing the ship phase rotation indicator mounted in the ship service switchboard, or by means of a portable meter connected to an appropriate bus. After checking phase rotation, deenergize each source shore power receptacle prior to energizing the next receptacle for the phase rotation check.
12. Energize all shore power terminals or receptacles and proceed with the transfer of electrical load to shore power in accordance with Engineering Department Operating Instructions. Instructions will vary depending on whether or not the ship is equipped to synchronize with shore power. After cables are carrying the load, inspect all connections to locate any possible overheating resulting from poor connections or reduced copper in the circuit. Inspect cable ends at the connection point for heavy strain or overheating.

320-2.2.7.3 Operation from Shore Power. Shore power cables are rated at 400 amperes. Switchboard meters must be checked to ensure that the total load on shore power cables does not exceed the combined rating of the shore power cables. Total shore power load in amperes should be no more than 400 times the number of three-phase shore power cables connected.

320-2.2.7.4 Shore Power Disconnection. When disconnecting shore power, observe the same safety precautions outlined in the connecting sequence except for those regarding meggering cables and checking phase orientation and phase rotation. Again, tag shore power breakers and disconnect in accordance with safety procedures. Determine that the shore power bus and cables are deenergized by using a voltage tester that has just been checked with a known energized power source.

320-2.2.7.5 Addition Shore Power Precautions. Normally, moving energized shore power cables is prohibited. Shore power disconnect links (submarines only) should never be opened or closed when either shore power cables or the ship's power bus is energized.

320-2.2.8 CASUALTY POWER. Casualty power cables are to be rigged only when required for use or for practice in rigging the casualty power system. In rigging cables, connections should be made from the load to the supply to avoid handling energized cables. During practice sessions, connections should not be made to an energized casualty power terminal, such as terminals provided for power panels. Where casualty power connections are to be made to a casualty power terminal supplying a load or power panel, all power to the load or power panel should be secured and the circuit breakers tagged out before the drill is performed. Refer to **NSTM Chapter 079, Volume 3**, for procedures that should be followed when rigging casualty power cables.

320-2.2.9 INDICATOR LIGHT COLOR DESIGNATION. The ability to operate the electrical system properly requires a knowledge of the meaning of indications made by color. Because a limited number of colors can be readily distinguished, only a few colors are used for all designations, and each color is used for a number of designations.

- a. Indicator light color designation (except for special applications in dark adapted spaces) is as follows:

- 1 **RED** - danger or emergency condition requiring immediate attention or corrective action
 - 2 **GREEN** - normal condition
 - 3 **WHITE** - power available or power on
 - 4 **BLUE** - closed, advisory
 - 5 **CLEAR** (not etched) - synchronizing or ground detector lights
 - 6 **YELLOW** - Abnormal, but not requiring immediate attention
- b. Indicators with red lenses and stencil-type marker discs are used in dark spaces requiring visual adaptation by personnel.

SECTION 3.

MAINTENANCE

320-3.1 PREVENTIVE MAINTENANCE

320-3.1.1 **PLANNED MAINTENANCE SYSTEM (PMS).** When the PMS is installed, preventive maintenance shall be performed in accordance with applicable Maintenance Requirement Cards (MRC's).

320-3.2 GENERAL MAINTENANCE

320-3.2.1 **FUNDAMENTAL RULES.** Three fundamental rules for the maintenance of electrical equipment are

- a. Keep equipment clean and dry.
- b. Keep electrical connections and mechanical fastenings tight.
- c. Inspect and test at sufficiently short intervals to make sure that the equipment is in operating condition.

320-3.2.2 **EQUIPMENT CLASSES.** Distribution system equipment requiring maintenance can be grouped into two general classes: 1) cables, with their fittings, and 2) switchboards (including distribution panels) with their associated equipment. **NSTM Chapter 300** provides maintenance instructions for both classes of equipment.

320-3.3 PHASE IDENTIFICATION

320-3.3.1 **GENERAL.** The terminals on switchboards, distribution panels, and equipment are marked with the letter A, B, or C to identify the phase. The standard arrangement of phases in power and lighting switchboards, distribution panels, feeder distribution boxes, feeder junction boxes, and feeder connection boxes is in the order A, B, C from top to bottom, front to back, or right to left, as viewed from the front of the switchboard, panel, or box (hence, left to right when viewed from the rear). [Table 320-3-1](#) shows the color coding on cables for three-phase ac systems.

320-3.3.2 **PHASE SEQUENCE.** The phase sequence on United States Navy ships is ABC; that is, for a delta-connected system, maximum positive voltages on the three phases are reached in this order, AB, then BC, then CA. Phase sequence determines the rotation direction of three-phase motors.

320-3.4 CASUALTY POWER

320-3.4.1 The older-style, casualty power portable cable terminates at each end of individual conductors with copper ferrules. Each individual conductor's insulation is exposed to shipboard ambient temperatures oil or oil fumes, and accidental damage. After 5 years or more of exposure, the conductor insulation may have aged and lost elasticity to the extent that it will crack open when bent during rigging of the casualty power system for emergency use. Exposed ends of individual conductor casualty power cables should be inspected at least once a year. The more recently designed casualty power components consist of molded, three-phase plugs or connectors. The cable shall be inspected in the same manner as older-style components. The best method of detecting insulation deterioration is to bend all conductors sharply by hand. If no cracks develop, the insulation is satisfactory. If cracking is noted, the following repair must be made.

1. Cut off protruding ends and prepare new terminations as indicated for end preparation of cable for ac systems (see **NSTM Chapter 079, Volume 3**). To avoid baring the conductor when inserting it in bulkhead terminal, do not strip more than one inch of the insulation from the conductor (see [Figure 320-3-1](#)).
2. Make cut ends of the cable insulation watertight by applying one heavy coat of clear, airdrying varnish.

Table 320-3-1 COLOR CODING ON THREE-PHASE AC SYSTEMS

Cable Type	Phase or Polarity	Color Code
4 Conductor	A	Black
	B	White
	C	Red
	Neutral	Green
3 Conductor	A	Black
	B	White
	C	Red

3. Place round copper ferrule on the conductor and secure it by forming it as shown in [Figure 320-3-1](#).
4. Fabricate forming die as shown in [Figure 320-3-2](#) or order through the supply system.
5. For phase identification by touch, use the following method 1 or 2:
 - a Method 1 - Apply close wrapping of cotton twine of approximately 3/64-inch diameter as follows: black wire (A phase), one wrapping; white wire (B-phase), two wrappings; and red wire (C phase), three wrappings.
 - b Method 2 - As an alternative to cotton twine, install O-rings for phase markings. Slip shrink tubing of required color over O-rings as follows: black wire (A phase), one O-ring, black tubing; white wire (B phase), two O-rings, white tubing; and red wire (C phase), three O-rings, red tubing. Apply heat in accordance with manufacturer's instructions to shrink the tubing to hold the O-rings securely in place on the conductor. If colored tubing is unavailable, use transparent tubing.
6. For watertight effectiveness, extend heat shrinkable tubing approximately 1/8 inch over the copper ferrule.
7. For end preparation of cables for dc system, see [Figure 320-3-3](#).
8. Seize ends of bare conductors with 0.025-inch-diameter copper wire; solder in place. Care should be taken to preserve the flexibility of the remaining bared conductor.
9. Seal cut ends of cable insulation by applying a heavy coat of clean air-drying varnish.
10. Terminate casualty power cables using one of the following two acceptable methods:

- a Heat shrink tubing - Apply heat shrink tubing to the cable, extend it 1/8-inch over the ferrule, and apply varnish to provide watertightness.
- b No heat shrink tubing - Strip the cable insulation back 1/8 inch over the ferrule and apply varnish to provide water-tightness.

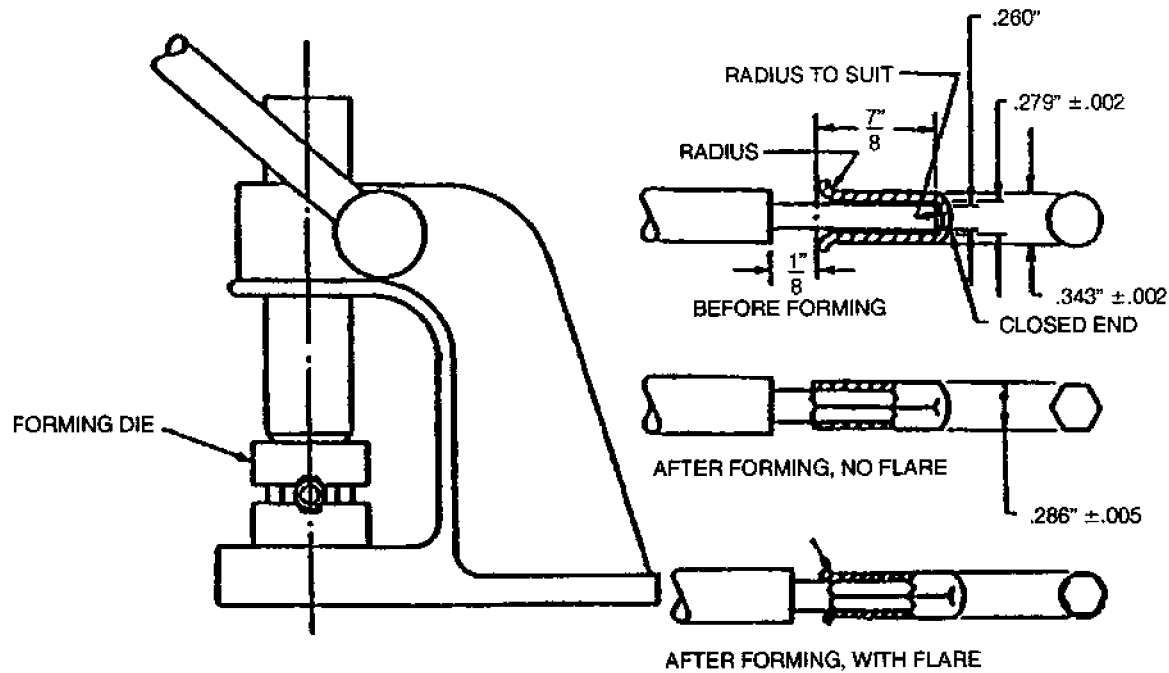


Figure 320-3-1 Securing Copper Ferrule to Conductor (Typical)

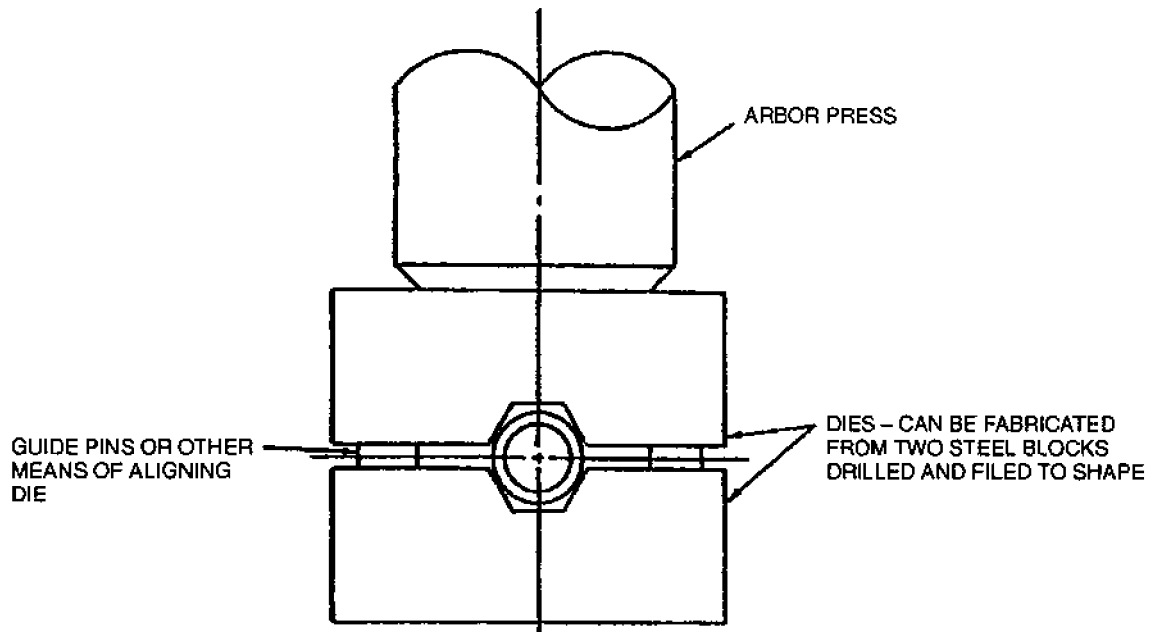


Figure 320-3-2 Forming Die

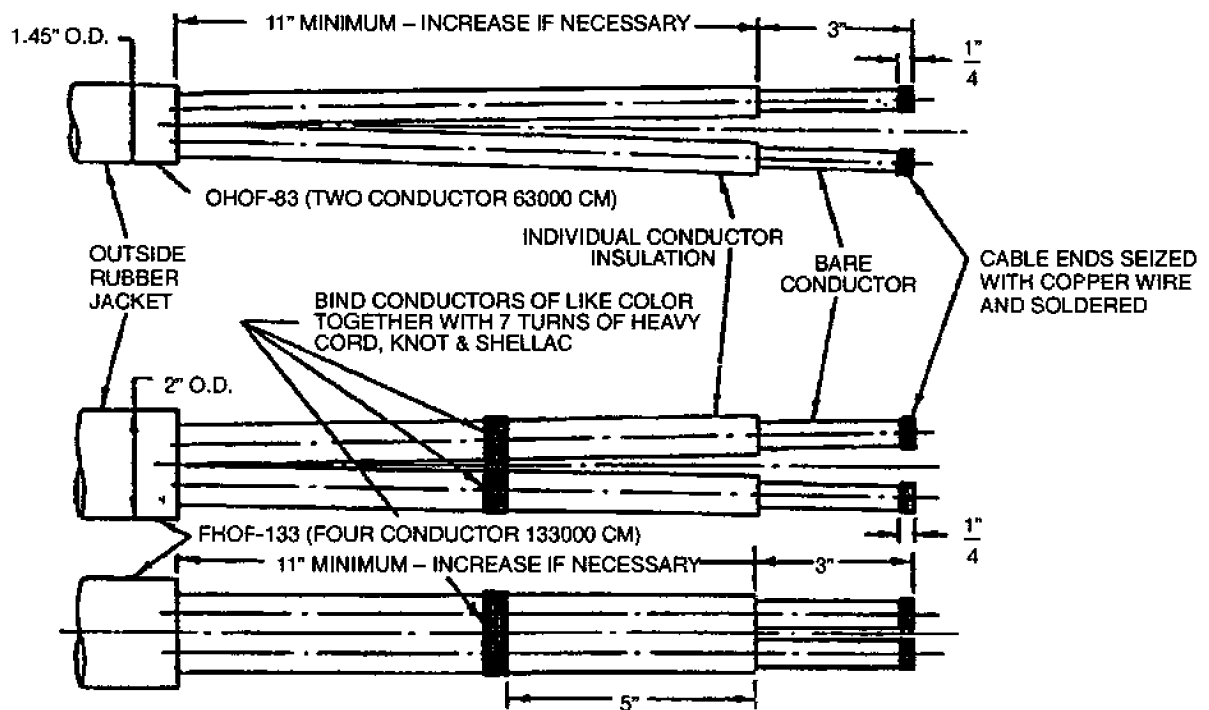


Figure 320-3-3 Portable Casualty Power Cable Ends (DC Systems Only)
APPENDIX A.

PRINCIPAL POWER SUPPLIES IN FOREIGN COUNTRIES

The listings in this appendix represent types of electrical supplies most generally used in various countries. For power supply characteristics of particular cities in foreign countries, refer to *Electric Current Abroad*, a publication of the U.S. Department of Commerce, Bureau of International Commerce, Washington, D.C., 20230. In cases where definite information relative to specific locations is necessary, consult the Electrical Division of the above named bureau.

Table 320-A-1 POWER SUPPLY TYPES IN GENERAL USAGE

Territory	Volts, Direct Current (VDC)	Volts, Alternating Current (VAC)	Freq. (Hz)
North and Central America:		---	---
		---	---
Alaska		110*, 220*	60
Bermuda		120, 208, 240	60
Belize		110, 220, 440	60
Canada		120*, 240	60
Costa Rica		120, 240	60
El Salvador		115, 230	60
Guatemala		120*, 240	60
Honduras		110*, 220	60
Mexico		127*, 220	60
Nicaragua		120, 240	60
Panama (Republic)		110, 120, 220, 240	60
Panama (Canal Zone)		115, 120, 230, 240	60
West Indies:		---	---
		---	---
Antigua		230, 440	60
Aruba		115, 127*, 220, 230	60
Bahamas		120, 208, 240	60
Barbados		115, 200, 230	60
Cayman Islands		120, 240	60
Cuba		115*, 120, 208, 230	60
Curacao		127, 220*, 380	50
Dominica		230, 400	50
Dominican Republic		110, 220	60
Grenada		230, 400	50
Guadeloupe		220, 380	50
Haiti		110, 220	50, 60
Jamaica		110*, 220	50
Montserrat		230, 400	60
Martinique		220, 380	50
Puerto Rico		120*, 240	60
St. Kitts and Nevis		230, 400	60
St. Lucia		240, 416	50
St. Martin		110, 220	50, 60
St. Vincent	230, 400	50	50
Trinidad and Tabago	115, 230, 400	60	60
Virgin Islands (American)	120, 240	60	60
Virgin Islands (British)	100	60	60

Table 320-A-1 POWER SUPPLY TYPES IN GENERAL USAGE -

Continued

Territory	Volts, Direct Current (VDC)	Volts, Alternating Current (VAC)	Freq. (Hz)
South America:	---	---	---
	---	---	---
Argentina	220*, 240	220*, 380	50
Brazil		110, 127*, 220, 240,	60
Guyana		380	50*
Chile		110, 220	60
Columbia		220*, 380	50
Ecuador		110, 220	60
French Guyana		120, 127, 208, 220,	60
Peru		240	50
Surinam		220, 380	60
Uruguay		110*, 220	60
Venezuela		127, 220	50
		110*, 240	60*
Europe:		---	---
		---	---
Albania		125, 220*, 230	50
Azores Islands		110, 190, 220*, 380	50
Belgium		220*, 380, 400	50
Bulgaria		230, 380	50
Channel Islands		230, 240, 400, 415	50
Cmwlth of Ind. States		220, 380	50
Corsica		120, 127*, 200, 220	50
Crete		220, 380	50
Denmark		220*, 380	50
Dodecanese Islands		220, 380	50
England		240, 415, 480	50
Estonia		220, 380	50
Faeroe		220, 380	50
Finland		220, 380	50
France		220, 380	50
Germany		220*, 380	50
Gibraltar		240, 415	50
Greece		220*, 380	50
Greenland		220, 380	50
Iceland		220*, 380	50
Isle of Man		240, 415	50
Ionian Islands		220, 380	50
Ireland, Northern		220, 380	50
Ireland, Republic		220, 380	50
Italy		127*, 220, 380	50
Latvia		220, 380	50
Lithuania		220, 380	50

Table 320-A-1 POWER SUPPLY TYPES IN GENERAL USAGE -

Continued

Territory	Volts, Direct Current (VDC)	Volts, Alternating Current (VAC)	Freq. (Hz)
Malta		240, 415	50
Monaco		127, 220, 380	50
Netherlands		220*, 380	50
Norway		230	50
Poland		220, 380	50
Portugal		220*, 380	50
Romania		220, 380	50
Scotland		240, 415	50
Spain		127*, 220*, 380	50
Sweden		220*, 380	50
Yugoslavia		220, 380	50
Wales		240, 415	50
Asia:	---	---	---
Aden	---	230, 400	50
Bahrain	---	220, 380	50
Bangladesh	---	230, 400	50
Burma	---	230, 400	50
Cambodia	---	120*, 220, 208, 380	50
China	---	220*, 380	50
Cyprus	---	240, 415	50
Hong Kong	225, 300, 450, 600	200, 346	50
India	---	225, 230, 400, 440, 460	50
Indonesia	---	127, 220, 380	50
Iran	---	220*, 380	50
Iraq	---	220, 380	50
Israel	---	230, 400	50
Japan	---	100, 200	50, 60*
Jordan	---	220, 380	50
Korea	---	110, 220, 380	60
Kuwait	---	240, 415	50
Lebanon	---	110*, 190, 220, 380	50
Macao	---	220, 346	50
Malayan Federation	---	230, 400	50
Malaysia	---	230, 240, 400, 415	50
Maldives	---	230, 440	50
Okinawa	---	100, 120, 200, 240	60
Oman	---	220, 380	60
Philippines	---	110, 115, 220, 230	50
Qatar	---	240, 415	50
Sarawak	---	230	50
Saudi Arabia	---	127, 220	60*
Seychelles	---	240	50

Table 320-A-1 POWER SUPPLY TYPES IN GENERAL USAGE -

Continued

Territory	Volts, Direct Current (VDC)	Volts, Alternating Current (VAC)	Freq. (Hz)
Singapore	---	230, 400	50
Sri Lanka	---	230, 400	50
Syria	---	220, 380	50
Taiwan	---	100, 220	60
Thailand	---	220*, 380	50
Turkey	---	220, 380	50
United Arab Emirates	220, 240	220, 380, 415	50
Vietnam	---	120*, 127, 208, 220, 380	50
Yemen Arab Republic	---	220, 230, 400	50
Africa:	---	---	---
Algeria	---	127, 220, 380	50
Angola	---	220, 380	50
Behin	---	220, 380	50
Cameroon	---	127*, 220, 230, 380, 400	50
Canary Islands	---	127, 220, 380	50
Cape Verde, Republic of	---	220, 380	50
Comoros	---	220, 380	50
Congo, Republic of	---	220, 380	50
Dahomey	---	220, 380	50
Duibouti, Republic of	---	220, 380	50
Ethiopia	---	220*, 380	50
Equatorial Guinea	---	220	50
French Somahland	220	220, 380	50
Egypt	---	220, 380	50
Gabon	---	127, 220, 280	50
Gambia	---	220, 380	50
Ghana	---	230, 400	50
Guinea	---	220, 380	50
Guinea-Bissau Cote d'Ivoire	220	220, 380	50
Kenya	---	240, 415	50
Liberia	---	120, 208, 240	60
Libya	---	127, 220, 230, 400	50
Madeira	220*, 440	220*, 380	50
Madagascar	---	220	50
Mauritania	---	220	50
Mauritius	---	230, 400	50
Morocco	---	127, 220, 380	50
Mozambique	---	220, 380	50
Namibia	---	220, 230, 380, 400	50
Nigeria	---	230, 412	50
Senegal	---	127, 220	50
Sierra Leone	---	230, 400	50

Table 320-A-1 POWER SUPPLY TYPES IN GENERAL USAGE -

Continued

Territory	Volts, Direct Current (VDC)	Volts, Alternating Current (VAC)	Freq. (Hz)
Somalia	230, 450	110, 220*, 230, 380, 440	50
South Africa	---	220*, 380	50
Sudan	---	240, 415	50
Tanzania	---	230, 400	50
Togo	---	127, 220, 380	50
Tunisia	---	127, 220, 380	50
Oceania:		---	---
		---	---
American Samoa		120, 240, 480	60
Australia		240*, 250, 415, 440	50
Fiji		240, 415	50
Guam		110, 120, 208, 220	60
Hawaii		110, 120*, 208, 240	60
New Caledonia		220, 380	50
New Guinea		110, 220, 440	50
New Zealand		230*, 400	50
Papua New Guinea		240, 415	50
Society Islands		127, 220	60
Tonga		240, 415	50
Western Samoa		230, 400	50
NOTES: 1. An asterisk (*) indicates the predominate voltage and frequency where different kinds of supply exist. Where approximately equal quantities of alternating current and direct current are available, an asterisk follows each of the principal voltages. Voltages and frequencies are listed in order of preference. 2. As general guidance, the 50-Hz power will have the following effect of 60-Hz shipboard equipment: a. Alternating current motors will run at approximately 83 percent normal speed. b. All alternating current equipment, such as motors, transformers, solenoids, and devices provided with magnetic circuits, will operate at higher temperatures. c. Some instruments, such as watt-hour meters, will be considerably in error. d. Devices sensitive to frequency variation to the extent of operating improperly, such as a gyrocompass and radar equipment, should preferably be deenergized. e. Synchro devices overheat excessively when operated longer than 1 hour. These devices and battle-announcing amplifiers should be deenergized except for emergency use. f. All 60-Hz electrical devices operating on 50 Hz should be checked regularly for excessive temperature rises. It may be desirable as a last resort to use lower 50-Hz voltage rather than the rated 60-Hz voltage to reduce temperature rises.			

APPENDIX B.**AQB-101/AQB-102 CIRCUIT BREAKER INTERCHANGEABILITY INFORMATION**

1. AQB-101 and AQB-102 circuit breakers are interchangeable and use the same accessories (mounting bases, fuse units, etc.). The AQB-102 has an electronic trip unit that allows for more flexibility in trip curve shaping. The AQB-102 is equipped with either an 8 position (6X, 7.5X, 9.5X, 13X, 15X, 30X or 40X the trip element ampere rating) or a 10 position (6X, 7.75X, 9.5X, 11.25X, 13X, 15X, 17.5X, 20X, 30X, or 40X the trip element ampere rating). It also has a field adjustable instantaneous trip setting and a 4 position field adjustable short time delay pick up (3X, 5X, 7X, and 10X the element ampere rating). The long time delay, and the short time delay inverse time delay are not adjustable. The AQB-102 is available with non interchangeable trip units of 15A, 25A, 50A, 75A and 100A for use with 60 HZ and 400HZ applications.
2. The following replacement procedure allows an AQB-102 breaker to emulate an AQB-101:
 - A. Note the AQB-101 instantaneous trip setting (HI or LO) and remove the AQB-101.
 - B. Adjust the instantaneous and short time delay on the AQB-102 using the following settings:

AQB-101 Settings			AQB-102 Type "E" Trip Unit Equivalent Settings	
Trip Element	Instantaneous Trip Rating (Amps)	Continuous Ampere Rating	Instantaneous Pick-up (Amps)	Short Time Delay Pick-up (Amps)
15A	LO (90)	15	6X (90)	5X (75)
15A	HI (195)	15	13X (195)	10X (150)
25A	LO (150)	25	6X (150)	5X (125)
25A	HI (325)	25	13X (325)	10X (250)
50A	LO (300)	50	6X (300)	5X (250)
50A	HI (650)	50	13X (650)	10X (500)
75A	LO (450)	75	6X (450)	5X (375)
75A	HI (975)	75	13X (975)	10X (750)
100A	LO (600)	100	6X (600)	5X (500)
100A	HI (1300)	100	13X (1300)	10X (1000)

- C. Install the AQB-102 breaker in the same mounting base that the AQB-101 was removed from.

APPENDIX C.

AQB-101/AQB-102 TYPE "E1" CIRCUIT BREAKER INTERCHANGEABILITY INFORMATION

1. AQB-101 and AQB-102 type "E1" circuit breakers are interchangeable and use the same accessories (mounting bases, fuse units, etc.). The AQB-102 type "E1" has an electronic trip unit that allows for more flexibility in trip curve shaping. The AQB-102 type "E1" is equipped with a field adjustable 10 position instantaneous trip setting (3X, 4X, 6X, 8X, 10X, 12X, 15X, 20X, 30X, or 40X the continuous current settings). It also has a 7 position field adjustable short time delay pick up (2X, 3X, 4X, 6X, 8X, 10X and 15X, the element ampere rating). There are also 3 field adjustable short time delay bands (.040, .080. and .120 seconds). The long time delay is not adjustable. The AQB-102 type "E1" is available with non interchangeable trip units of 15A, 25A, 50A, 75A and 100A for use with 60 HZ and 400HZ applications.
2. The following replacement procedure allows an AQB-102 type "E1" breaker to emulate an AQB-101:
 - A. Note the AQB-101 instantaneous trip setting (HI or LO) and remove the AQB-101.
 - B. Adjust the instantaneous and short time delay on the AQB-102 type "E1" using the following settings:

AQB-101 Settings			AQB-102 Trip Unit Equivalent Settings		
Trip Element	Instantaneous Trip Rating (Amps)	Continuous Ampere Rating	Instantaneous Pick-up (Amps)	Short Time Delay Pick-up (Amps)	Short Time Delay Time Band Set
15A	LO (90)	15	3X (300)	6X (90)	1
15A	HI (195)	15	3X (300)	10X (150)	2
25A	LO (150)	25	3X (300)	6X (150)	1
25A	HI (325)	25	3X (300)	10X (250)	3
50A	LO (300)	50	3X (300)	6X (300)	1
50A	HI (650)	50	6X (650)	10X (500)	3
75A	LO (450)	75	5X (500)	6X (450)	3
75A	HI (975)	75	10X (1000)	10X (750)	3
100A	LO (600)	100	6X (600)	6X (600)	1
100A	HI (1300)	100	12X (1200)	10X (1000)	3

- C. Install the AQB-102 type "E1" breaker in the same mounting base that the AQB-101 was removed from.

APPENDIX D.**AQB-101/AQB-103 CIRCUIT BREAKER INTERCHANGEABILITY INFORMATION**

1. AQB-101 and AQB-103 circuit breakers are interchangeable. The AQB-103 is available in two separate frame sizes, 25A and 100A for use in 60HZ and 400HZ applications. Both frame sizes use the same accessories (mounting bases, fuse units, etc.) as the AQB-101. The 25A frame size has field adjustable element ratings of 10A, 12.5A, 15A, 20A and 25A. The 100A frame size has field adjustable element ratings of 40A, 50A, 60A, 80A and 100A. Both frames have an electronic trip unit that allows for more flexibility in trip curve shaping. The AQB-103 is equipped with a field adjustable 8 position instantaneous trip setting (6X, 8X, 10X, 12X, 15X, 20X, 30X, or 40X the continuous current settings). It also has a 5 position field adjustable short time delay pick up (2X, 3X, 4X, 6X, 8X, 10X and 15X, the element ampere rating). There are also 3 field adjustable short time delay pick up (3X, 5X, 7X, 10X and 13X the element ampere rating). There are also 5 field adjustable short time delay bands ("min" (0.05), 2.0, 4.0, 8.0 and "max" (16) seconds). The long time delay is not adjustable.
2. The following replacement procedure allows an AQB-103 breaker to emulate an AQB-101:
 - A. Note the AQB-101 instantaneous trip setting (HI or LO) and remove the AQB-101.
 - B. Adjust the instantaneous and short time delay on the AQB-103 using the following settings:

AQB-101 Settings			AQB-103 Trip Unit Equivalent Settings		
Trip Element	Instantaneous Trip Rating (Amps)	Frame Rating	Continuous Ampere Rating	Instantaneous Pick-up (Amps)	Short Time Delay Pick-up (Amps)
15A	LO (90)	25	15	6X (150)	7X (105)
15A	HI (195)	25	15	8X (200)	13X (195)
25A	LO (150)	25	25	6X (150)	7X (175)
25A	HI (325)	25	25	15X (375)	13X (325)
50A	LO (300)	100	50	6X (600)	7X (350)
50A	HI (650)	100	50	8X (800)	13X (650)
75A	LO (450)	100	80	6X (650)	5X (400)
75A	HI (975)	100	80	10X (1000)	13X (1040)
100A	LO (600)	100	100	6X (600)	7X (700)
100A	HI (1300)	100	100	15X (1500)	13X (1300)

- C. Install the AQB-103 breaker in the same mounting base that the AQB-101 was removed from.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION
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