U.S. Department of Transportation
United States Coast Guard

Commandant (G-MTH-2)
United States Coast Guard

Mailing Address

Washington, DC 20593-0001
Phone: (202) 267-2206

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NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 2-89

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Subj: Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units

1. PURPOSE. This Circular has been prepared to provide guidance concerning electrical installations on merchant vessels and mobile offshore drilling units. It is intended to provide the marine industry with information on regulatory intent and background, and on practices which have been found to provide a level of safety equivalent to that provided for by the specific regulations.

2. DISCUSSION. Enclosure (1) is a guide to the Coast Guard Electrical Engineering Regulations, 46 CFR 110-113. It augments the CFR, giving details on acceptable methods of complying with those regulations as well as other important information related to electrical installations. It must be emphasized that other alternatives may be equally acceptable based upon the specific installation. Nothing contained in this guide shall be taken as amending the applicable requirements set forth in the Code of Federal Regulations, nor as limiting the authority of the Officer in Charge, Marine Inspection in his determination of acceptable materials and installation methods.

3. IMPLEMENTATION. Any party interested in electrical installations on merchant vessels and mobile offshore drilling units should consider the guidance in this Circular.

J. D. SIPES
Chief, Office of Marine Safety
Security and Environmental Protection

Encl: (1) Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units

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GUIDE FOR ELECTRICAL INSTALLATIONS ON MERCHANT VESSELS AND MOBILE OFFSHORE DRILLING UNITS

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1. Introduction

1.1 Purpose. The Electrical Engineering Regulations, 46 CFR Subchapter J, are, in many areas, complex and difficult to understand. The CFR is limited to telling what must or must not be done. Regulatory intent, explanation, policy, equivalency information, requirement derivation, inspection aids, and examples are not provided. Sometimes, the preamble to a regulation can provide useful information, but this is a one-time issue in the Federal Register, and is usually lost over time. This NVIC provides information to fill the void caused by the limitations of the regulations as they apply to electrical equipment and systems on merchant vessels and mobile offshore drilling units. It also promulgates information on equipment, systems, materials and methods that have been determined by the Commandant (MTH) to provide an equivalent level of safety. Further, it describes how electrical reviews and inspections are typically performed, and provides useful training information for novice designers, marine and electrical engineers, naval architects, or inspectors.

It is not the purpose of this guide to repeat the regulations, but to augment them. Nothing contained in this guide shall be taken as amending the Code of Federal Regulations, nor as limiting the authority of the Officer in Charge, Marine Inspection (OCMI) in the determination of acceptable materials, systems, and installation methods. Some information contained in the Marine Safety Manual (COMDTINST M1600 Series) is repeated here for convenience.

Generally this NVIC follows the basic outline of the regulations, starting with the applicability and reference document information, and progressing to specific items of equipment. It emphasizes those areas of the regulations where there is a history of repeated inquiries, where misunderstandings or inconsistent interpretations are known to exist, or where there have been equivalency determinations or policies made that need wide dissemination.

Users of this NVIC are encouraged to provide feedback on its contents and to propose additions or amendments to the material presented. Proposals should include the reason for change, and should be forwarded to Commandant (G-MTH-2), U.S. Coast Guard, Washington, DC 20593-0001.

1.2 Background. Since the first electrical installations on the passenger ships "CITY OF BERLIN" and "MENDOZA" in 1879, a complex set of standards and regulations has evolved to address the hazards presented and the benefits provided by electrical equipment and systems. Domestically, early efforts involved the early Bureau of Marine Inspection and Navigation (predecessor to the Coast Guard's Marine Inspection Program) and the American Institute of Electrical Engineers (predecessor to the Institute of Electrical and Electronics Engineers). Internationally, these involved the individual classification societies, the Intergovernmental Maritime Consultative Organization (predecessor to the International Maritime Organization) and the International Electrotechnical Commission. In the last two decades, the number of standards-making bodies affecting the marine electrical community has increased significantly.

The current Subchapter J was revised and updated in 1982. It represents the regulatory philosphy prevalent in the mid-to-late 1970's and is for the most part, technically and environmentally up-to-date. However, with changes in regulatory philosophy, and the shift of U.S. flag construction abroad, some minor revisions to the regulations could be beneficial. Efforts to make such revisions are presently underway. Also, efforts are underway through ASTM and IEEE to develop complete marine electrical standards that could be referenced in Subchapter J. This would greatly simplify regulation development and maintenance, and ease the burden on industry by allowing for more timely updating to ever-changing technologies.

1.3 The Electrical Program. The Marine Inspection Program uses plan review, and on-site inspection to ensure that electrical installations are designed, built and maintained in a manner to promote the safety of the vessel, its crew and passengers. The Electrical Engineering Regulations provide uniform minimum requirements for electrical equipment and systems in accordance with the intent of various statutes, the International Convention for Safety of Life at Sea (SOLAS), and other treaties that contain requirements regarding electrical installations. These requirements are intended to ensure electrical installations aboard vessels provide services necessary to protect passengers, crew members and other persons from electrical hazards.

1.4 Electrical Safety. Electrical Safety on ships includes the prevention of shock, fire and panic.

On a steel hulled vessel, a person is usually walking on or touching ground at all times, and is usually within reach of power cables or electrical equipment containing lethal voltages. The currents that can flow from an energized conductor to ground can be very large, even in an ungrounded system. Currents as low as twenty-five thousandths of an ampere (25 milliamps) that pass through the heart can cause death. Currents of a non-fatal magnitude, or currents having a path to ground through other parts of the body can cause severe burns and injury. Minor shocks can also create severe secondary injuries when muscles contract involuntarily.

Fire is the greatest dread of seamen, and electricity is one of the most frequent causes of fire. A fire hazard can exist wherever electrical potential is present, and on a ship, the electrical installation covers a far greater area than any other type of installation.

How can electricity start a fire? Current flowing through a conductor encounters resistance. This resistance generates heat. If the conductor is properly sized, the heat is harmlessly dissipated. Where the conductor is not adequate sized for the current, or where the heat generated by the current is prevented from properly dissipating, whether it is the normal current, an overload current, or a fault (high or low impedance) current, the heat can become excessive, and can start a fire in nearby combustible materials, such as cable insulation.

Electrically-caused fires most often involve wire and cable. Most vessels have many miles of cable run throughout the entire vessel, spreading their risks to all locations. Whenever the protective insulation of a wire or cable is damaged by heat, moisture, oils, corrosive materials, vibration, abrasion, or impact, or where faulty installation or operating conditions result in loose connections, the threat of fire exists.

Motors are also a frequent source of electrically-caused fires. Motor fires can be caused by overheating, such as would be caused by overloading, single phasing, inadequate ventilation, malfunctions, such as internal faults and arcing, and bearing failure caused by inadequate lubrication.

Proper shipboard electrical installations also help reduce or prevent panic during an emergency. Put an individual, such as a vessel passenger, in the dark, in a strange place, in threatening circumstances, and the stage is set for panic. Electrical installations are designed to keep the lights on, power vital equipment, and allow needed information to be passed to passengers and crew.

2. General Provisions of the Electrical Engineering Regulations

The existing Subchapter J applies to vessels contracted for after May 31, 1982, where Subchapters D, H, I, IA, O, R, T, or U require electrical installations to meet that subchapter. In general, it is not retroactive. Installations in accordance with the edition of the electrical regulations in effect at the time the vessel was contracted for remain acceptable (unless specifically identified as requiring "upgrade" by other documents such as SOLAS, Title 33 of the CFR, etc.).

2.1 Referenced Editions of Specifications, Standards and Codes

The regulations reference many industry standards. For the most part, these standards are dynamic and ever-changing. The "official" referenced edition of an industry standard is listed in the "Finding Aids" section of the CFR. Often, that edition may not be the latest edition of the standard. This could create availability problems; where the requirements of a standard have changed, and where manufacturers have modified their equipment to meet the later version, equipment may not be available that meets the referenced edition. However, standard changes often respond to an identified problem or hazard, and usually result in safer equipment. In most instances, equipment constructed and tested in accordance with a more recent edition of a referenced document can be accepted as providing a level of safety equivalent to that provided by equipment constructed and tested to the edition identified in the CFR.

2.2 Meeting Referenced Standards

One of the purposes of the Marine Inspection Program is to provide passengers and crew on U.S. flag vessels with an environment that has a level of safety comparable to that ashore. In most domestic "land" installations, electrical equipment is of U.S. manufacture and is listed by an independent electrical equipment certification agency acceptable to the governing jurisdiction. In the majority of installations in this country, the equipment is listed by Underwriters Laboratories Inc. (UL). The existing Coast Guard Electrical Engineering Regulations evolved from this situation. With the movement of U.S. flag construction abroad, there has been an influx of electrical equipment that is constructed to meet other standards and that is listed by independent third party certifying agencies similar to UL. Some equipment is built to manufacturer's standards and is not third party certified. Both of these types of equipment need to be evaluated for equivalence to the standards referenced in the Electrical Engineering Regulations before acceptance for installation.

The Electrical Engineering Regulations require many electrical items to meet a specific UL Standard. For such items, listing by UL is not required. While evidence of such listing may be the most expeditious method to determine compliance, it is not the only method. 46 CFR 110.25-1(p) requires the submission of "plans and information sufficient to evaluate equipment required by this subchapter to meet a referenced standard..." Equipment may be accepted by having evidence of listing, by manufacturer's certification, or by determining the standard it does meet is equivalent to the referenced standard.

Equipment required to meet an IEEE or NEMA standard or a military specification (e.g. cable or switchgear) is usually certified by the manufacturer to be in accordance with the standard. Equipment manufactured in the U.S. is usually designed to these standards, and it is not uncommon for foreign equipment to be designed to these standards. The manufacturer's marking on the item usually indicates compliance with the standard. This is adequate to demonstrate compliance with the regulations.

More commonly, however, foreign equipment is designed to foreign national and/or International Electrotechnical Commission (IEC) standards, and compliance with, or equivalence to, the referenced document must be determined. The usual starting point for an equivalency determination has been the "line-by-line comparison" demonstrating that the construction and testing of the particular equipment meets, or is "equivalent" to, the referenced document.

Evaluation efforts must involve the exercise of "good engineering judgment" to reduce the burdens of line-by-line comparisons imposed on a case-by-case basis. Although "good engineering judgment" is typically "something someone didn't have when something happened that shouldn't have," there are several basic guidelines that recognize limited review resources and that are appropriate in assessing electrical equipment equivalency:

(1) The level of evaluation should be commensurate with the level of risk imposed by the item. For example, an outlet box is a relatively simple passive item, providing protection and access to a few simple components, while a circuit breaker is a complex active device that is designed to operate at varying times under both small overloads and large damaging faults, providing system-wide protection. The evaluation of a circuit breaker should be far more involved than the review of an outlet box. This does not mean that evaluation of an outlet box is not important; however, the evaluator should not need to spend an inordinate amount of time to obtain a reasonable level of confidence that the equipment will perform in a safe manner. The evaluator should ask some basic questions: "What will happen if this equipment fails? Will someone be shocked? Will it start a fire? Will a failure be readily

apparent during normal operations or will it be hidden and gradually worsen? Does the <u>system</u> configuration provide additional safety measures that mitigate the effect of the failure? How likely is this failure?"

(2) The evaluator should have a reasonable level of confidence in the equipment. Obtaining this level of confidence with equivalencies often involves subjective judgements concerning the manufacturer as well as specific, technical determinations regarding the hardware itself. A well-known manufacturer that has been in business for an extended period, is a recognized leader in his field, has contributed to the development of industry standards, and has a solid reputation may not need close scrutiny. On the other hand, a "newcomer" to the equipment field or U.S. market place, or an organization that is outside its primary business, such as a shipyard that now decides to manufacture its own panelboards and lighting fixtures just for a particular vessel, may need a higher initial level of review to obtain that same level of confidence.

(3) The evaluator should look for the safety intent in referenced standards. Industry standards have evolved over many years, and for the most part, represent a national consensus by technical professionals of what is required to ensure that electrical equipment is safe. It is not easy to look at a standard, such as a UL standard and identify those requirements that are not related to safety. Nearly all requirements are safety related, either directly, such as by ensuring adequate dielectric strength, or indirectly, such as by ensuring adequate mechanical strength so the equipment can safely withstand the rigors of installation and use. For equipment built to another standard, the evaluator should see if that standard adequately addresses the concerns addressed by the referenced standard.

Equipment evaluators should use the above guidelines in evaluating electrical equipment and in comparing it to the requirements of a referenced standard. To facilitate the review process, the following procedures may be used:

(1) For equipment required to be constructed to an industry standard (domestic or foreign) and either listed by a nationally recognized (domestically or in the foreign nation) independent testing laboratory or certified by the manufacturer to be in compliance with the standard:

(a) Manufacturer should submit evidence of listing (listing number in bill of materials, copy of listing card or documentation provided by the laboratory) or affidavit of compliance. The documentation should identify the specific construction and testing standard.

(b) Evaluators should establish that the foreign standard is complete, applicable and comparable to the referenced standard. (They may request a copy of the standard and/or that a standards comparison be submitted). This comparison may establish whether the <u>overall</u> <u>level</u> <u>of</u> <u>safety</u> provided by the foreign standard is comparable to that provided by the referenced standard, including applicable marine supplements.

(c) For specific items for which comparability has not been established by comparing standards, such as would be the case if the foreign standard was for "land type" equipment and did not have requirements comparable to those in the marine supplement of a referenced UL standard, the manufacturer should submit documentation demonstrating compliance with the supplement requirements.

(d) Once standard comparability has been established, for similar applications, no further comparisons need be requested on subsequent submittals using the same foreign standard. If the edition of either the referenced standard, as identified in the Finding Aids Section of the CFR, or of the foreign standard has changed, the specific changes need to be re-evaluated). To this end, the evaluators should maintain a listing of acceptable "equivalent" foreign standards, citing the specific editions compared. Additionally, the specific submitter should be encouraged to reference the acceptance letter in future submittals.

(2) For equipment not constructed to nationally (foreign or domestic) recognized standards:

(a) The equipment manufacturer should submit a complete line-by-line comparison of actual construction and testing to that required by the reference standard, including any applicable marine supplement. Testing may be performed by the manufacturer. For those areas that are not in complete compliance with the reference standard, the manufacturer should submit technical arguments for equivalency. These should be evaluated using the guidelines previously discussed.

(b) Once equipment comparability has been established, no further comparisons need be requested for that specific equipment from that specific manufacturer when equipment use is proposed on another vessel (again, this assumes the referenced edition has not changed). Listings should be maintained and notifications should be made in a manner similar to that used for standards comparability. The manufacturer should provide a copy of the acceptance letter with subsequent submittals.

(3) For issues that can be resolved based upon on-site visual examination, the evaluator may defer the acceptability of that equipment to the inspection activity (Officer-in-Charge, Marine Inspection or ABS if acting on behalf of the Coast Guard). In such cases, the specific issue deferred should be fully identified and documented. The inspection activity should also document the acceptance or rejection, and should provide the plan review activity with inspection comments on the deferred issues.

The above procedure is for equipment required to meet a referenced standard. It should NOT be used for equipment required to be listed or labeled by an independent third party certification agency (i.e. fuses and equipment for use in hazardous locations).

Note that the Marine Safety Manual Vol. II, 12.E.4 permits the OCMI to accept on vessels of the Military Sealift Command, equipment or materials complying with any of the following: (1) technical bureaus of the U.S. Navy; (2) MILSPEC's; (3) federal specifications for military purchases, and; (4) National Military Establishment (NME) specifications.

2.3 Equipment Required to be Listed or Labeled

The regulations require fuses, explosionproof equipment, and intrinsically safe systems to be listed by an acceptable independent testing laboratory. The U. S. Department of Labor's Occupational Safety and Health Administration (OSHA) has now established procedures for the acceptance of equipment required to be labeled or approved for safety by 23 provisions in OSHA safety standards. Under the procedures, effective 13 June 1988, OSHA is deleting all current references in its standards to Underwriters Laboratories Inc. and Factory Mutual Research Corp. (FM), relying instead on the generic term "nationally recognized testing laboratory" (NRTL). The new rule establishes criteria for a "nationally recognized testing laboratory," sets a procedure to recognize these laboratories, and permits these laboratories to label or approve equipment for safety as required by OSHA standards. OSHA will recognize NRTL's for five-year periods, with initial five-year recognition granted to UL and FM. Other testing laboratories must apply to OSHA for recognition and will be evaluated by OSHA staff. This does not affect references to UL standards for construction and testing requirements (as used in Coast Guard regulations when equipment is required to meet a UL standard).

The criteria for acceptance by the Commandant as an "other independent laboratory" under 46 CFR 111.53 and 111.105-7 is acceptance by OSHA as an NRTL. Accordingly, listing or labeling by an NRTL is an acceptable alternative to listing or labeling by one of the individual laboratories specifically mentioned in the regulations, or by a laboratory that has been subsequently recognized. At this time, the Coast Guard recognizes UL for listing fuses; UL, FM, CSA, and MET Electrical Testing Company for listing intrinsically safe systems; and UL, FM, and CSA for listing explosionproof equipment.

3. Electrical Systems

The Electrical Engineering Regulations are a combination of equipment and system requirements designed to ensure that electrical installations are both safe and functional. They consist of general requirements related to across-the-board "good marine practice," and specific requirements related to the various apparatus, their proper design, installation and use.

In years past, emphasis was placed on equipment design requirements, as the system was considered the sum of the components (equipment). Today, equipment quality has generally improved and manufacturers have become more aware of product safety and liability. Comprehensive industry standards now exist and are used for most apparatus. This is allowing the review emphasis to shift towards a systems approach. As indicated previously, evaluations of equipment should consider overall safety comparability. With today's limited resources for plan review and inspection, concentration should be on proper application of equipment, effect of failures on required system functions, and on vital safety features. Emphasis should be on evaluating the "system" -

Is the apparatus enclosure appropriate for the location?
Is the fixture adequately grounded to reduce the shock hazard?
Is the fixture enclosure fire retardant and not surrounded by combustibles?
Will a fault in the fixture be safely cleared by the first upstream overcurrent device so that other parts of the electrical system are not needlessly affected?
If it is a vital safety system, is the failure indicated and an alternative or back-up provided?
Do the components go together?

This is the "systems" approach. This does not imply that individual equipment design details are not important, but stresses that where there are limiting constraints, the system should be given a higher priority.

A recent casualty can be used to illustrate the necessity of "systems" thinking. While working on a motor controller, a crew member's screwdriver caused a short circuit. The upstream circuit breaker on the main board became damaged and did not open. Eventually, the generator circuit breaker tripped, but only after the switchboard had been destroyed, with the bus bars torn from their bases and internal components and wiring destroyed by fire. Two separate items, a faulty circuit breaker and the cleaning fluid used in the switchboard months before, were initially blamed. However, upon further analysis, improper system design features became suspect. The upstream circuit breaker probably did not clear the fault because it did not have adequate interrupting capacity for the available fault current. The switchboard was damaged because it was not braced for the available fault currents. The common denominator was the fault current analysis. The existing components were not appropriate for the system in which they were installed. The electrical plant was, either in the original design or during subsequent modifications, most likely considered an assembly of components. These components may have been acceptable if used within their design limitations, but were not adequate when used in a system with high available fault currents.

The systems approach usually begins with an analysis of the "one-line diagram" and it's supporting information. Appendix 1 consists of a "typical" shipboard electrical one-line diagram and index to the applicable requirements in 46 CFR Subchapter J, the National Electrical Code, IEEE-45, etc.

3.1 General Requirements

For electrical equipment on ships, it is not the intent of the regulations to require a separate class of "marine electrical equipment." The intent is to permit normal, off-the-shelf commercial and industrial equipment to the maximum extent practicable, with additional "marine" requirements only when needed. The acceptance of this type of equipment is made possible by careful consideration of equipment application, location and placement. Subchapter J contains general requirements for electrical equipment to ensure that passengers, crew, and other persons, and the vessel are protected from electrical hazards. It also ensures that equipment necessary under both normal and emergency conditions is located in a manner that allows for routine maintenance and testing, thus helping to ensure that the equipment will function properly when needed.

Location and Placement. Optimal equipment location should be sought. In general, electrical equipment should be located in as dry a location as practicable, and electronic equipment located in a controlled environment. In evaluating location, both normal and abnormal conditions should be considered. Abnormal conditions include items such as piping leaks (overhead for lower pressures and "in the vicinity" for higher pressures). For more critical equipment, such as the main switchboard, the regulations provide specific construction and location details. Generally, equipment should be located where it would not be subjected to oil vapors, steam, or dripping liquids. However, where relocation is not practicable, or where additional safeguards are warranted, the equipment should be designed to withstand these influences. Equipment should also be located to minimize the risks to personnel when routine service is being performed.

Degree of Enclosure. Where exposed to the weather, or in a space exposed to seas, washdowns, or similar moisture, equipment must be in a watertight enclosure (NEMA 4 or 4X). A watertight enclosure is one that does not leak when subjected to a specified hose or immersion test. Motors must be waterproof. Waterproof motors may experience some leakage when subjected to the hose test, however, the leakage must not hinder operation, or enter any oil reservoir, and provision must be made for automatic draining before the level becomes damaging. Where dripping liquids could fall on equipment, that equipment enclosure should be dripproof (i.e., NEMA 2, or NEMA 12, or NEMA 1 with a dripshield). Dripproof equipment is ordinarily designed to prevent falling drops of liquid or solid particles from interfering with the operation of the equipment when striking the enclosure downward at any angle from 0 to 15 degrees from the vertical. Some equipment is designed for angles up to 45 degrees. It should be verified during vessel inspection that electrical equipment is suitably located - away from damaging liquid (unless impracticable, in which case it must be suitably designed), and accessible for inspection, adjustment and testing.

Corrosion. The corrosiveness of the marine environment is well known, and protection can usually be accommodated at the design stage. Much of the equipment that finds its way to sea was originally intended for a commercial or industrial installation on land, and could quickly fail in a salt-water environment if additional precautions are not taken. For this reason, equipment located in the weather, or in other locations subjected to salt water, must be evaluated to ensure corrosion resistance. Not only must the enclosure be corrosion-resistant, but current-carrying components and internal parts whose failure would create an unsafe condition must also be corrosion-resistant.

Porcelain. Porcelain should not be used for lamp sockets, switches, etc. unless resiliently mounted. The concern is that rigidly mounted porcelain may fail under shipboard vibration and create a shock, fire or other hazard to the vessel and its personnel. Some off-the-shelf equipment, designed for typical land installations, only comes with rigidly mounted porcelain insulated components. In these instances, it may be necessary to add resilient mounts to the porcelain insulating material. Only in instances where porcelain failure would not create a hazard, or where there is data available to support a shipboard application, such as vibration and shock (impact) testing, should such rigid installations be evaluated for general safety equivalency.

Temperature. The present regulations assume an ambient temperature of 40 degrees Celsius, except for enginerooms, boiler rooms, and auxiliary spaces, which are assumed to be 50 degrees (unless shown or designed to be less, in which case 40 degrees is assumed). There are, however, differences in national and international standards on assumed values of ambient temperatures. IEEE-45, 1983 allows for both 45 and 50 degree ambient temperatures for enginerooms, and allows switchboard apparatus (other than molded case circuit breakers) rated for 40 degrees to be used in 50 degree environments under some conditions (see Section 17.6 of IEEE-45.) The American Bureau of Shipping's Rules assume a 45 degree ambient for enginerooms, but indicate that rotating machinery is to be rated for a 50 degree ambient. ABS is in agreement with the requirements in the IEC standards. In looking at the differences in these standards, it must be remembered that assumed ambient temperatures reflect an opinion on the overall average or the typical or expected temperatures, not the range of temperatures that equipment may be expected to experience under all conditions of operation. It must also be remembered that although consensus opinions concerning a standard may change, the length of time it takes to implement those changes varies widely.

In the case of overcurrent devices that are heat dependent, such as a fuse or the thermal trip on a circuit breaker, temperature is important, as it relates to the time it takes to remove an undesirable condition (overload.) A device that is in an temperature lower than it is rated for will be a little slower to trip on overload. If the temperature is higher, it will trip sooner. In specific instances, either of these could be the undesired event. In the fault current range, the time effect is negligible. It should also be noted that many of these mass produced devices do not perform uniformly.

The National Electrical Code (Code) indicates that for Code applications with Code wiring, the ampacity of the conductors connected to molded-case circuit breakers should be limited to that of 60 or 75 degrees Celsius wiring, even though the attached conductors may have a higher rating. Shipboard requirements in IEEE-45 and in the Electrical Engineering Regulations do not impose this limit; such a limitation does not apply on ships and MODUs. Ship systems do not use Code wiring, and are not typical of common applications addressed by the Code. IEEE-45 cable constructions have ampacities based upon rated conductor temperatures up to 100 degrees Celsius. Shipboard cables may be connected to circuit breakers without consideration of the NEC limitation.

Standard Voltages and Frequency. The standards indicated in the regulations are typical. Other voltages have been successfully used on vessels and

MODUs. For drilling installations, 600 and 750 v.d.c. are typical. For large floating industrial plants, 13.8 K.v. has been generated and stepped-up to 34.5 K.v. for undersea transmission. The regulations require that non-standard distribution systems, voltages, or frequencies be accepted by the Commandant. This does not imply some are unacceptable. The concern is that equipment items are compatible with each other, and with their environment, and that any unique hazards are adequately addressed. When high voltage equipment is used, and marine standards and equipment are not available for equipment at that voltage, technical evaluation is needed to ensure the safe application of shoreside industrial standards to a marine installation. Also, higher voltage equipment may need special maintenance considerations.

3.2 Equipment Ground, Grounded Systems, and Ground Detection

The term "grounding" is often misunderstood due to use in several different concepts. A basic understanding of the various uses is important. There are three basic applications of "grounding" associated with safety of personnel or protection of electrical equipment. These are: (1) the grounding of metal frames or housings of electrical equipment (chassis ground); (2) the grounding of the neutral current-carrying conductor of an electrical distribution system; and (3) the grounding of an electrical source of power in such a manner that the earth (or its substitute such as the hull) is used as a current-carrying conductor.

The first application is one of the most important uses of grounding to protect personnel from electric shock. Fixed equipment is usually grounded by its method of attachment to the vessel. Isolation mounted equipment is usually grounded by a flexible grounding strap between the enclosure and the hull. Portable equipment is usually grounded by a grounding conductor in the supply cable. This should connect the equipment housing to the vessel's hull. Under normal conditions, the housing is not energized. However, internal insulation breakdown or other failure can bring energized components in contact with the housing. If the housing were not grounded, the voltage on the housing could equal the voltage of the power source, and a person touching the housing would be exposed to this voltage. Grounding the equipment reduces the shock hazard. Conductors used to ground equipment are called grounding conductors. On an extension or portable tool cord, this is the green insulated conductor. Portable equipment such as power tools, that are identified as "double insulated" need not have a grounding conductor in the attachment cord. These items have a basic (functional) insulation system and a supplemental (protective) insulation system, with the two insulation systems physically separated so that they are not simultaneously subjected to the same deteriorating influences.

The second application is the intentional grounding of a single pole or terminal of the power supply of an electrical distribution system. This is accomplished by connecting a low resistance conductor from the pole to the ground (the hull). The purpose of grounding one of the conductors is to limit the voltage that the system can be subjected to under certain fault conditions. Grounding can also be accomplished through a resistor (resistance grounding) or through an inductor (inductive grounding). In these methods, the resistor or inductor is used to limit the line-to-ground fault current; these require special considerations and analysis. It is important that a grounded system have only a single point of connection to the hull, regardless of the number of power sources, and that it be accessible for inspection. Multiple grounding points could create potentially dangerous and damaging circulating currents through the hull.

The neutral of each generation and distribution system must be grounded at the generator switchboard, except for the neutral of an emergency power generation system. This must have no direct connection to ground at the emergency switchboard. The emergency switchboard neutral bus must be permanently connected to the neutral bus on the main switchboard, and there must not be any fuse, switch, or circuit breaker that opens the neutral conductor of the bus-tie feeder.

Grounded distribution systems of less than 3000 volts line-to-line are prohibited on tank vessels by SOLAS. The concern is that fault currents going through the hull may cross discontinuities, such as riveted joints, ladders, etc., and there may be an arc and subsequent ignition of flammable vapors. Systems greater than 3000 volts may be grounded provided any resultant fault current would not flow through the cargo tank area. This is usually not a problem as electrical loads operating at these voltages (other than possibly a bow thruster) are typically not located separate from the machinery space.

On some merchant vessels, the electrical distribution systems are ungrounded. There is no intentional connection to ground. This is primarily for circuit reliability. The electrical system can sustain damage that "grounds" one of the conductors and still function (i.e. provide continuity of service).

There is often the assumption that a person can contact an energized conductor in an ungrounded system, and not receive an electric shock since there is no return path for the current to flow back to the distribution system. Such an assumption can lead to fatal consequences. In practical applications, there is always a return path, and a system is always "grounded" to a certain extent. Paths exist through deteriorated or damaged insulation, and moisture, salt and other contaminants that are ever present. The issue is one of "degree." In ungrounded alternating current systems there is always a capacitance between conductors and between conductors and ground. This impedance can effectively "ground" an intentionally ungrounded system.

The third application is the grounding of a power supply and an electrical load such that the hull is used as a normal current-carrying conductor. This is commonly referred to as "hull return" and is prohibited on vessels except for impressed current cathodic protection systems and limited and locally grounded systems such as engine cranking batteries. Insulation level monitoring systems and welding systems (on other than tank vessels) may also use the hull as a current-carrying conductor. One of the problems with hull return pertains to galvanic corrosion. Where the hull current passes through a welded joint or a joint of dissimilar metals, corrosion is likely to occur.

Ground Detection. Grounds can be a source of fire and electric shock. In an ungrounded system, a single ground has no appreciable effect on current flow. However, if low resistance grounds occur on conductors of different potentials, very large currents can result. In a grounded system, a single low impedance ground can result in large fault currents. To provide for the detection of grounds, the regulations require that ground detection means be provided for each electric propulsion system, each ship's service power system, each lighting system, and each power or lighting system that is isolated from the ship's service power and lighting system by transformers, motor generator sets, or other devices. This indication need not be part of the main switchboard but should be co-located with the switchboard (i.e. at the engineering control console adjacent to the main switchboard). The indication may be accomplished by a single bank of lights with a switch which selects the power system to be tested, or by a set of ground detector lights for each system monitored.

In an ungrounded three-phase system, ground detection lamps are used. The ground lamps are connected in a "wye" configuration with the common point grounded. A normally-closed switch is provided in the ground connection. This is illustrated in Figure 1.

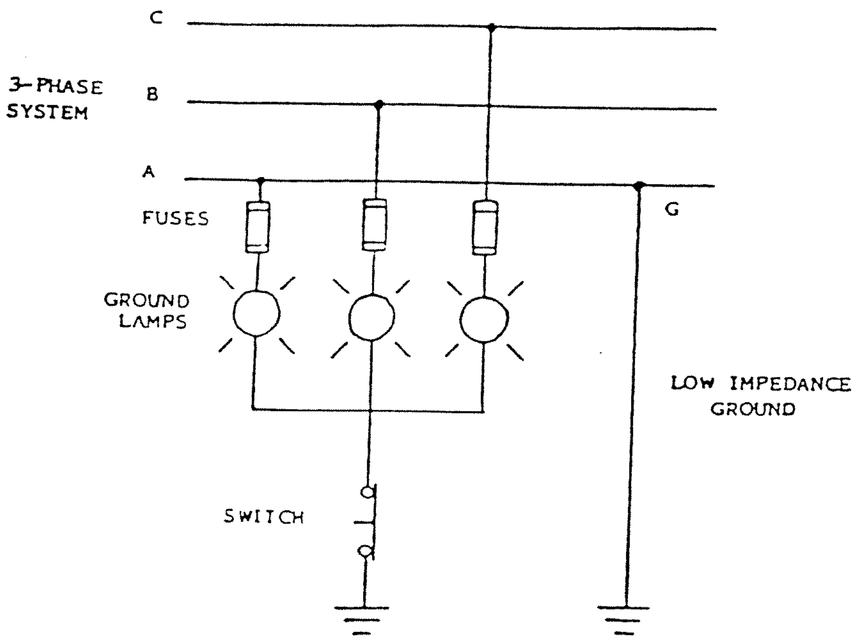


FIGURE 1

If no ground is present on the system, each lamp will see one-half of the phase-to-phase voltage and will be illuminated at equal intensity. If line "A" is grounded at point "G" by a low impedance ground, the lamp connected to line "A" will be shunted out and the lamp will be dark. The other two lamps will be energized at phase-to-phase voltage and will be brighter than usual. If a low resistance ground occurs on any line, the lamp connected to that line will be dimmed slightly and the other two lamps will brighten slightly. The switch is provided to aid in detecting high impedance grounds that produce only a slight voltage shift. When the ground connection is opened by the switch, the voltage across each lamp returns to normal (phase voltage) and each lamp will have the same intensity. This provides a means to observe contrast between normal voltage and voltages that have shifted slightly. Lamp wattages of between 5 and 25 watts when operating at one-half phase-to-phase voltage (without a ground present) have been found to perform adequately, giving a viewer adequate illumination contrast for high impedance grounds. Should a solid ground occur, the lamps will still be within their rating and will not be damaged. For lesser grounds, the lumen output of the lamps will vary approximately proportional to the cube of the voltage. This exponential change in lamp brightness (increasing in two and decreasing in one) provides the necessary contrast.

On grounded dual voltage systems, an ammeter is used for ground detection. This ammeter is connected in series with the connection between the neutral and the vessel ground. To provide for the detection of high impedance grounds with correspondingly low ground currents, the regulations specify an ammeter scale of 0 to 10 amperes. However, the meter must be able to withstand, without damage, much higher ground currents, typically around 500 amperes. This feature is usually provided by the use of a special transducer such as a saturable reactor in the meter circuit. Some ammeters use a non-linear scale to provide for ease in detecting movement at low current values. An example of this is shown in Figure 2 below.

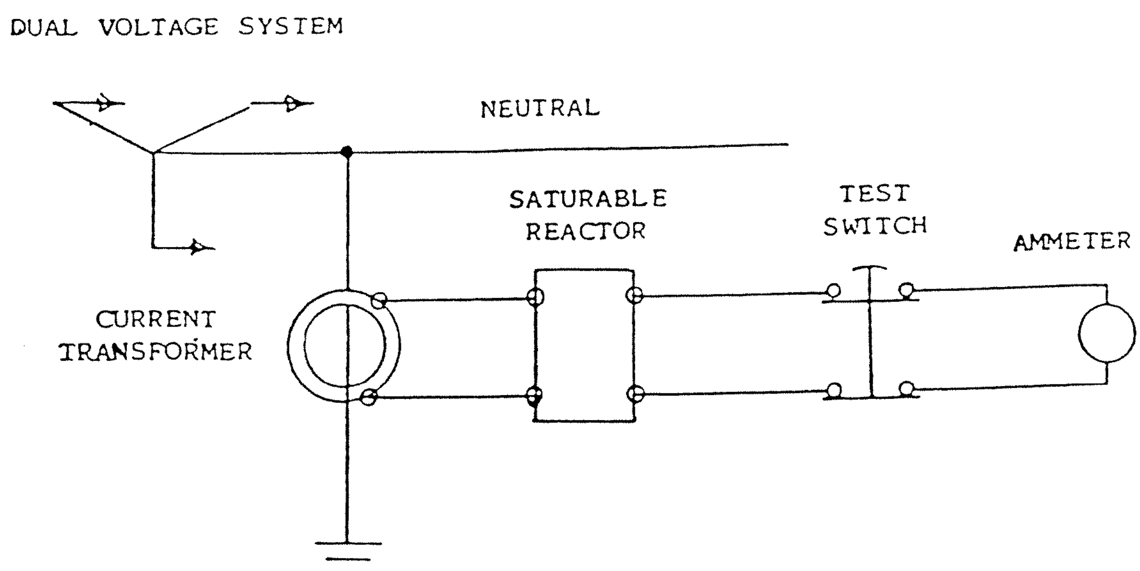


FIGURE 2

Other types of solid-state devices are becoming available that can provide ground detection. They should not be prohibited, but should be evaluated to determine that they are functionally equivalent to the lights and ammeters historically used. Some systems also include a visual and/or audible alarm at a preset level of ground current.

3.3 Power Supply

Capacity. Determining the number and size of generating sets needed for a vessel requires a careful analysis of the normal and maximum demands during various phases of operation, including at sea, maneuvering, and in port.

Also, any special or unique operational considerations should be addressed. It is the intent of the regulations to ensure all normal "ship's service" loads can be kept energized with the largest generator out of operation, and without use of the emergency generator. It is not the intent of the regulations to ensure that the vessel can continue to perform an industrial function, such as drilling or dredging, with a generator in reserve. Ship's service loads are defined in detail in 46 CFR 111.10-1.

Of special note is that refrigerated container loads are considered "ship's service" loads. This is so cargo preservation attempts will not require sacrificing the more traditional ship's service loads should an operating generator fail. Other arrangements, such as a separate generating system, or a reefer load-shedding/load management system can provide an equivalent level of safety.

Procedures for conducting a thorough load analysis, typical ship's service operating load factors, and a sample load analysis are contained in Appendix 2.

<u>Main engine dependent generators</u>. The most commonly used prime movers for ship's service generators are dedicated diesel engines and steam turbines supplied by the propulsion boiler(s). However, due to escalating fuel costs, owners and designers are always looking for less expensive means to provide the necessary electric power. Shaft-driven generators, power take-off (PTO) generators, and waste heat driven turbogenerators offer flexibility and greater efficiency. In many cases, however, they are constrained to certain main engine speed and power operating ranges.

SOLAS states that the arrangements of the ship's main source of power shall be such that the ships service loads can be <u>maintained</u> regardless of the speed and direction of the main propelling engines or shafting. This is reflected in 46 CFR 111.10-4(b) and (c), which require that <u>ship's service</u> electrical power be provided continuously, regardless of propulsion shaft speed or direction. In the worst case, this means that an "engine stop" or "full astern" command on the bridge propulsion control lever while operating at the minimum engine speed for full generator output must not result in interruption of ship's service power.

Generators may be mechanically driven by the main diesel engine directly by the line shaft, by means of a PTO from the engine, or through intermediate gearing. Because changes in main engine speed would normally result in changes in the generator speed (and, therefore, frequency), a variety of methods has been developed to maintain constant frequency. These include the operation of the main diesel engine at a constant speed with the pitch of a controllable pitch propeller independently controlled, the use of a constant speed gear drive to give a constant output shaft speed over a range of input shaft speeds, and the application of a static rectifier-inverter combination to transform variable frequency AC to constant frequency AC.

Waste heat energy from the main diesel engine can be recovered in an exhaust gas boiler to generate low pressure steam to drive a turbogenerator. This generator can be operated only when sufficient exhaust heat is available, so start-up and shutdown are usually manually initiated. To optimize the recovery of exhaust heat, a generator loading control system may be used with load-sharing and speed (governor) controls to maximize turbogenerator loading when operating in parallel with other generators.

Any main engine or waste heat driven generator which is not capable of providing power under <u>all</u> operating conditions, including maneuvering and in port, cannot be counted towards the required ship's service generating capacity. Such a generator may, however, be provided as a supplemental generator. In any case, one of the required generators must be independent of the main propelling engines and shafting.

Where a supplemental generator is used to supply power for ship's service loads, it must provide a continuous and uninterrupted source of power under normal operational conditions, including any speed change or throttle movement. Automatic start-up of and load transfer to a standby diesel generator must be provided to prevent power interruptions when conditions are such that the supplemental generator is unable to supply the ship's service load. A finite time is required to start, synchronize, and parallel a standby diesel generator, and the main engine-driven generator must remain on line until the standby generator has assumed the load. A signal from the propulsion control and a shaft speed signal may be used to automatically initiate connection of the standby generator. Once a throttle change has been made, the time required for the main engine to slow to the point where the generator cannot supply the ship's service load depends on the original speed as well as the coast-down characteristics of the hull and propulsion plant. In many cases, the coast-down time for a two-stroke slow speed main diesel engine is long enough to allow the standby generator to assume the load without power interruption. If it is not, the disconnection of the shaft or PTO generator must be delayed. To prevent power interruptions from occurring, the speed of the main engine may be automatically held at or above the lower operating threshold for generator operation for approximately 10 seconds. This delay, automatically activated only when needed, is considered to be comparable to the the time necessary for crew response to maneuvering bells in a manned engineroom. Since the typical main engine dependent generator installation employs automated start and synchronization controls for the standby generator(s), careful design and detailed review to the requirements of 46 CFR Part 62 is generally required to ensure compliance with 46 CFR 111.10-4.

<u>Ship's Service Supply Transformers</u>. The regulations state that where transformers are used to supply the ship's service distribution system, there must be at least two separate ship's service supply systems. The intent is to duplicate supplies to the ship's service switchboard, as is done with generating sets. This would normally exist on a vessel generating at a higher voltage, such as 600 or 4160 volts. It is not the intent, nor is it required, that transformers fed by the ship's service switchboard, such as 460/120 volt transformers be duplicated.

Each transformer must have the capacity to supply the ship's service loads. The duplicated supply should consist of transformers, overcurrent devices, and cables. Automatic changeover upon a transformer failure is not required. It could be inferred from the transformer/generator analogy of SOLAS II-1/45, that automatic transformer transfer is required by the SOLAS II-1/53 requirements for automatic starting and connection of a stand-by generator. That analogy has, however, not been applied to transformers since the precise wording of Reg. 53 addresses generators, and not "essential parts of the electric supply system." Additionally, the reliability and availability of a "static" transformer, and its cable and overcurrent device is much better than a rotating generator, its prime-mover and control system. Transformer faults are rare, and the requirement for duplication is considered from a "take-home" standpoint. (This is similar to the requirement for a split bus arrangement on a ship with a large electrical system. There is no requirement to automatically disconnect switchboard sections and attempt to maintain power upon a switchboard fault. The requirement for splitting the bus is to provide the capability for onboard engineers to be able to isolate a fault and restore limited service.)

Generator Construction and Protection. Generator excitation, construction, and voltage regulation, should meet sections 35.23, 35.25, and 35.31, respectively, of the ABS Rules. Generator protection, provided by power circuit breakers, should meet the specific requirements in the Electrical Engineering Regulations. There are many types of circuit breaker trips: inverse time, instantaneous, reverse-power/current, under and overvoltage, ground fault, under and over frequency, and trips operated by auxiliary contacts. 46 CFR 111.12-11 specifies the required trips for generator circuit breakers. The inverse time trips are devices that open the circuit breaker in a time that relates to the amount of overcurrent. The greater the overcurrent, the quicker they open the circuit. They are adjustable and should be set so that downstream or feeder breakers have had the opportunity to open and clear faults on the feeder circuits. Instantaneous trips are quick-acting devices that have no intentional time delay in opening the circuit breaker under high level currents. Instantaneous trips are not permitted for generators unless three or more generators can be paralleled. This is to provide continuity of service under a fault condition. Reverse-power or reverse current trips are required where generators can be paralleled. These are quick-acting devices that will open the circuit of a generator that has current from other generators feeding into it. Additional information on circuit breakers is provided later.

Generator overcurrent protective devices must be on the ship's service switchboard and the switchboard and a generator must be in the same space. An adjacent dedicated switchgear and SCR room on a MODU, and a control room inside the machinery casing are not considered separate spaces even though they may be separated by a watertight bulkhead. In unusual installations where the switchboard and a generator are separated by a bulkhead or enclosure that is not required for either subdivision or fire protection purposes, the spaces may also be treated as a single space for the purpose of this requirement. Additional precautions may be needed, such as current sensing at the generators that, upon sensing excessive overcurrent, removes excitation and shuts down the prime mover.

The Marine Engineering Regulations contain the requirements for prime movers in 46 CFR 58.10. Additional requirements for prime movers for emergency generators are found in 46 CFR 112.50, and are discussed later in this NVIC. Each diesel engine prime mover must have an overspeed device that is independent of the normal operating governor and is adjusted so that the speed cannot exceed the maximum rated speed by more than 15%. Additionally, the prime mover should automatically shut down upon loss of lubricating oil pressure to the generator bearings. These shutdowns should be tested at each inspection for certification.

3.4 Batteries and Battery Installations

Electrical storage batteries have many shipboard applications, including engine starting, temporary or final emergency power source, and backup power supply. In general, the requirements of 46 CFR Subpart 111.15 are applicable to all such battery installations. Note that storage batteries used for required emergency power and lighting systems must also comply with Subpart 112.55.

Battery types & equivalence. Batteries may be classified according to the chemical composition of their plates and/or the type of electrolyte solution -- thus the terms lead-acid, alkaline, nickel-cadmium (Ni Cad), etc. A nickel-cadmium battery is a particular type of alkaline (electrolyte) battery. Storage batteries other than the lead-acid or alkaline type may be accepted provided they do not spill electrolyte when the battery is inclined at 30 degrees from the vertical, are suitably constructed to comply with 46 CFR 111.15-2(a), and generate hydrogen at a rate not to exceed that of an equivalent lead-acid battery installation under worst case conditions.

Hazardous locations. The Electrical Engineering Regulations categorize battery installations into one of three types, based upon the power output of the battery charger and the corresponding amount of highly flammable hydrogen gas which may be generated. Each room, locker, and box containing storage batteries must be arranged or ventilated to prevent the accumulation of this gas. Large battery installations may be located only in a dedicated battery room or in a box on deck. Such a battery room is considered to be a hazardous location; only electrical equipment approved for use in a Class I, Division 1, Group B location may be used in such a battery room. The regulations do not define the hazardous area as extending to a radius of 10 feet (3 meters) from doors, hatches, or other openings into the battery room. However, the use of explosionproof or intrinsically safe electrical equipment or apparatus and the avoidance of ignition sources near such openings is recommended.

The classification of battery installations based upon the power output of the charger may not be appropriate for some types of batteries (such as gel-cells) which generate very little hydrogen gas. In such cases, the quantity of gas generated should be compared to the amount released by lead-acid batteries to determine whether the installation should be considered large, moderate, or small. The battery manufacturer, equipment designer, or shipbuilder should provide this comparison to the Coast Guard. Sealed batteries, which release gas only when a relief valve opens following an over-voltage charge, may also be accepted. However, their installation must consider the over-charge condition, and allow released gas to be safely dissipated.

Installation. The lining requirement of 46 CFR 111.15-5(g) allows the acceptance of plastic battery trays and liners certified by the manufacturer as resistant to the corrosive effects of the battery electrolyte. Battery chargers which meet UL 1564 (Industrial Chargers) plus the marine supplement to UL 1236 may be accepted as equivalent to those meeting UL 1236.

Emergency Power Batteries. Automotive-type batteries are not suitable for emergency power applications, as indicated in NEC Article 700-12. Automotive batteries are designed for frequent, short duration, high-current loading; emergency power systems usually operate less frequently, for longer periods, at lower current levels. Automotive batteries also have a shorter life (3 - 5 years) than lead-acid storage batteries designed for use in emergency power systems (15 - 20 years). Storage batteries for emergency power service usually have either a threaded stud or a rectangular blade for connection of a bus link. They commonly have external cell connectors. Automotive batteries have either side terminals that can accept a threaded bolt, or top round posts for the common automotive battery cable.

3.5 Switchboards

Location. The main switchboard is required by 46 CFR 111.12-11(g) and 111.30-1(a)(4) to be located in a machinery space that contains at least one ship's service generator. This requirement is consistent with the SOLAS Amendments, Chapter II-1, Regulation 41.3. A control room that is located within the machinery casing or a dedicated switchgear and SCR room on a Mobile Offshore Drilling Unit which is adjacent to and on the same level as the generator machinery space, is not considered to be a separate space. Any such control room containing the main switchboard should, as far as practicable, be located so that the generator(s) are in sight and direct access to the generator(s) is facilitated.

Adjacent piping. Each switchboard must be located in as dry a location as possible. Dripshields are required by CFR 111.30-9(b). An equivalent installation is a switchboard that extends to the overhead and which cannot be subjected to leaks or falling objects. Piping above or adjacent to switchboards should be avoided. Piping which must be located in the vicinity of a switchboard must be provided with suitable spray shields and have only welded joints.

Removable Breakers, Sectionalization and Redundant Transformers. The Electrical Engineering Regulations require molded-case circuit breakers on switchboards to be mounted so that the breaker can be removed from the front without first unbolting the bus or cable connections or de-energizing the supply to the breaker. The intent of this requirement is to make possible the safe removal of a circuit breaker for repair or replacement without de-energizing other essential loads. This requirement is for circuit breakers in ship's service switchboards; removable or draw-out breakers are not required for dedicated industrial switchboards, but are recommended for safety. Where the main ship's service bus is subdivided into two sections, a comparable level of safety can be provided by an arrangement where all circuits necessary for the safe navigation of the vessel can be supplied by either section of the bus. This would allow for de-energizing one section without the loss of essential loads. Note that although the Subchapter J requirement to sectionalize the main bus is not applicable to Mobile Offshore Drilling Units, self-propelled MODU's seeking an IMO MODU Code certificate must meet this requirement (MODU Code Chapter 7, Section 9).

Sectionalized buses increase the ability to provide ship's service power in the event of a casualty to part of the switchboard. On a single voltage level system (i.e., where generated voltage is the ship's service switchboard voltage), the devices used to connect the sections of the buses must be manually operable. In a dual level system, (i.e., in which the generators connect to a medium-voltage bus which in turn supplies the low-voltage ship's service switchboard) at least two transformers or transformer banks are required by 46 CFR 111.10-9. If the medium-voltage bus is required to be sectionalized and the total capacity of these transformers exceeds 3000 KW, the low-voltage ship's service switchboard must also be subdivided. On a dual level system, automatic control of the sectionalizing devices may be permitted when it is part of a load management system allowing for increased system flexibility.

Bus bar sizing. Each bus must be sized so its rating is not less than the capacity required in 46 CFR 111.30-19(a). [NOTE: Bus bars for motor control centers are to be rated per NEC 430-24.] Table A27 of IEEE Standard No. 45 gives minimum bus bar sizes, based on the cross section and spacings required for the bus current rating and the allowable temperature rise.

Bus bar bracing. Bus bars must be braced to withstand the mechanical strains imposed by inrush currents and the maximum available short-circuit current. These currents can generate electromagnetic fields of considerable magnitude. The mechanical forces resulting from these fields can bend the bus bars, shatter insulation, and physically tear the switchboard apart. Switchboard manufacturers should indicate the fault current their boards are designed to withstand. The spacing between bus bars and bare metal parts within the switchboard must meet Section 384-26 of the National Electrical Code.

Aluminum buses. There has been continued interest in the use of aluminum as a bus bar material, due primarily to the relative costs of copper and aluminum. Both marine and shore industrial experience has shown that careful attention must be paid to materials, joint design, and quality of workmanship if unsatisfactory and unsafe aluminum bus bar installations are to be avoided.

The switchboard regulations, in 46 CFR 111.30-19, refer to IEEE Standard No. 45 for bus bar installations. Section 17.11 of IEEE-45 permits aluminum to be used in switchboards. The panelboard regulations, in 46 CFR 111.40-1, require each panelboard to meet UL 67, Standard for Panelboards, and the Marine Supplement. This supplement restricts current-carrying parts to copper or copper alloy. The marine supplement to UL 508 requires aluminum current-carrying parts of motor controllers at 600 volts and less to be "suitably plated or coated to resist marine atmospheres containing salt." Motor controllers for use above 600 volts must meet UL 347, which states only that current-carrying parts "shall be of metal or other material that is acceptable for the particular application." UL 845, Standard for Motor Control Centers, permits the use of aluminum bus bars but requires plating with tin, silver, or cadmium at bolted or plug-in connections. Similarly, UL 857, Standard for Busways and Associated Fittings, allows aluminum bus bars but imposes special conditions on joints and connections. Aluminum must only be used in applications and in a manner permitted by the regulations.

Certain problems and properties associated with aluminum bus bars are discussed below. For vessels operating only in fresh water, the corrosion problem may be minimal; the other three problems are equally applicable to fresh water and salt water service.

A. Corrosion - Aluminum in contact with certain other metals, such as steel, forms a galvanic couple susceptible to accelerated corrosion in the marine environment. Aluminum alloys containing copper are particularly subject to corrosion in a damp salt atmosphere, even when not in contact with a dissimilar metal.

B. Oxide Build-up - Most aluminum alloys form a hard, inert oxide coat whenever a fresh surface is exposed to air. This layer of aluminum oxide has a high electrical resistance and can create a hot spot at connection points.

C. Creep - Aluminum exhibits a phenomenon known as creep, which is a plastic deformation that occurs at stresses below yield strength. Periodic tightening of many types of aluminum connections is required to prevent connections from becoming loose. If connections do become loose, the surface contact area is reduced, permitting the oxide coat to form. This, in turn, causes high-resistance hot spots.

D. Thermal Properties -

(1) As the load increases, the bus bar temperature will increase and the bus bars will expand. The linear coefficient of thermal expansion of aluminum alloys is significantly larger than that for steel or copper. Provisions must be made in the design to account for these different expansion rates. High stresses can occur in aluminum-bodied connectors, especially when used with bolts of a dissimilar metal or which have thermal expansion characteristics different from those of the aluminum device.

(2) The thermal conductivity of aluminum, while alloy dependent, is approximately half that of copper. Heat is not conducted away from a hot spot in aluminum as quickly as with copper.

The use of aluminum bus bars in switchboards, large switchboard-type panelboards, and motor control centers is generally acceptable. The design and practices recommended below, or equivalents, should be considered. Aluminum bus bars are generally not suitable for use in panelboards and motor controllers. The small size and scattered locations of many panelboards and controllers may discourage the periodic inspections which should be made to detect unsafe deterioration of aluminum bus bars and connections.

The following design and assembly recommendations will help ensure a satisfactory installation of aluminum bus bars:

All aluminum current-carrying parts should be made of alloy 6101 or other alloy with a maximum of 0.1 percent copper.

In areas of contact, the bus bars, including any copper bars, should be plated with silver, nickel, or tin after all drilling has been completed. This plating should be performed at the manufacturer's facility and not in the field.

Copper cable or wire should be connected to the aluminum bus using plated compression-type terminal connectors.

Where aluminum-bodied connectors and fittings are used, they should be packed with oxide-inhibitor paste. These fittings should be suitable for use on aluminum.

A shrinkable sleeve should be used to seal the wire to the terminal connector.

A generous amount of joint compound should be applied to all joint surfaces before assembly to seal out air and improve corrosion resistance. A bead of compound should appear all around the edges of each joint when the connection is tightened. Excess compound squeezed out of the joint may be left as is or removed. Abrasive joint compounds should not be used on flat-bar connections.

A plated copper bar or plated copper terminal fitting may be connected to a plated aluminum bar. The connection should be made with a plated steel bolt, plated Belleville spring washers, and wide series plated steel washers. The Belleville washer should be installed with the crown or neck against the nut or bolt head and the concave side bearing on the flat washer. The nut should be tightened until the Belleville washer is just flat.

An aluminum to aluminum connection may be made with either plated aluminum or plated steel bolts. If steel bolts are used, the recommendations of the paragraph above should be followed. Aluminum bolts should be made of a high strength aluminum alloy. Aluminum bolts, nuts, and washers should be made of an alloy containing not more than 0.1 percent copper.

A plug-in type circuit breaker should not be directly connected to an aluminum bus. Circuit breakers or fused switches may be attached to an aluminum bus if a bolt or plug arrangement is used with joint preparation as described above. The plug-in type circuit breaker may be used with a copper bus feeder.

A plated bus bar surface should not be wire brushed or treated with abrasive cleansers prior to assembly.

Medium voltage switchgear. Medium voltage switchboards are required by 46 CFR 111.30-23 to meet ANSI C37.20 for metalclad switchgear. This is not a marine standard, however, and equipment designed to this standard may not be able to withstand prolonged exposure to the inclinations and vibration which are common in the marine environment. It is recommended that switchboards for marine use be designed, constructed, and installed in such a way as to allow successful operation under the environmental conditions listed in 46 CFR 62.25-30.

Equipment. The switchboard equipment listed in 46 CFR 111.30-25 for AC ship's service switchboards, 111.30-27 for DC ship's service switchboards, and 111.30-29 for emergency switchboards is considered to be the minimum necessary to control the electrical plant under normal and manual conditions. Vessels with unique electrical plants should be evaluated to determine the necessary instrumentation.

Automated systems. SOLAS II-1/53.2 requires electrical load shedding arrangements for vessels with periodically unattended machinery spaces. 46 CFR 62.50-30(k) requires that where the electrical power can normally be supplied by one generator, load shedding be provided to maintain the continuity of electrical power to propulsion, steering, and other vital safety systems. In the case of loss of the (one) generator in operation, a standby generator of sufficient capacity to supply the propulsion and steering equipment must be automatically started and connected to the switchboard in not more than 30 seconds. Where the electrical power is normally provided by two or more generators in parallel operation, provision must be made to ensure that, in case of the loss of one operating generator, the remaining generators are kept in operation without overload to maintain propulsion, steering, and the safety of the vessel.

3.6 SCR's

The term SCR refers to the solid state equipment for the conversion of alternating current to direct current which has been called a silicon controlled rectifier, semiconductor controlled rectifier, and semiconductor rectifier. Many electric propulsion systems, thrusters, and pieces of drilling machinery use DC motors in order to obtain more precise speed control. SCR's are the most common means of converting the ship's service AC power to DC. Solid state SCR power converters offer the advantages of high efficiency and low maintenance (compared to motor-generator sets), but are sensitive to heat and humidity and are frequently located in suitably air-conditioned spaces.

Subpart 111.33 is applicable to any SCR used as part of the vessel's electrical power distribution system. Small SCR's which form part of utilization equipment, such as a semiconductor rectifier battery charger, need not meet these regulations.

Requirements. The intent of the regulations is to ensure that the continuity of power to equipment supplied by SCR's is not jeopardized by unsuitable SCR design or installation. An adequate means of heat removal is the primary concern. Due to the criticality of the propulsion system to the safe navigation of the vessel, additional requirements apply to SCR's in electric propulsion systems; see 46 CFR 111.33-11.

Appendix 3 contains a checkoff list which may be useful during the design or plan review of systems using SCR's.

3.7 Transformers

The overcurrent protection for each transformer is required by 46 CFR 111.20-15 to meet Article 450 of the NEC. The transformer overcurrent protection specified in Section 450-3 is intended to protect the transformer alone; the primary and secondary conductors may not be adequately protected. Be careful to ensure that conductor protection is provided. Note that where the primary feeder to the transformer is provided with overcurrent protective devices that are set per Section 450-3, it is not necessary to install an individual overcurrent device at the transformer. The primary conductors must then be sized so that their ampacity is greater than or equal to the rating or setting of the primary overcurrent protective device(s); see 46 CFR 111.50-3(a), (b), and 111.50-5(a). Secondary conductors supplied by a transformer must be protected in accordance with their ampacity. The secondary conductors of a single voltage single-phase transformer which satisfies the requirements of 46 CFR 111.50-5(a)(4) do not require overcurrent protection at the supply (the transformer) to the secondary side conductors.

Aluminum-wound transformers are acceptable. They should be fully encapsulated by the manufacturer and all connections should be made in accordance with the guidelines for aluminum current-carrying parts in section 3.5 of this guide.

See Appendix 4 for full load current ratings for single-phase and three-phase transformers.

3.8 Electric Propulsion

The reference to the ABS "Rules for Building and Classing Steel Vessels" in 46 CFR 111.35-1 is out-of-date. Sections 35.79, 35.81, 35.84, 35.125, 35.127, and 35.129 of the latest revision of the ABS Rules may be used for guidance. In addition, a portion of Table 62.35-50 (Vital System Automation Rules) applies to electric propulsion systems. The general provisions of the SOLAS II-1/31, 49, and 52 are applicable to all propulsion arrangements, including electric propulsion.

3.9 Panelboards

Ratings. The current rating of a panelboard must not be less than the feeder circuit capacity. To meet 46 CFR 111.40-15, the load on any overcurrent device in a panelboard must not exceed 80 percent of that device's rating if the normal load duration is 3 hours or more. This requirement does not apply, however, when the panelboard and the overcurrent device are rated for continuous duty at 100% of the rating.

Number of Circuits. Note that each panelboard must meet UL 67 and the Marine Supplement. This UL Standard states that lighting or appliance panelboards must not have provision for more than 42 overcurrent-protective devices (individual fuseholders or circuit breaker poles), other than those in the mains. The edition of the UL Marine Supplement referenced in the Finding Aids Section requires overcurrent protection in grounded conductors of branch circuits, contrary to present 46 CFR 111.50-3(a). The specific regulation, 111.50-3(a), should be followed. UL 67 has been changed.

3.10 Overcurrent Devices

Purpose. Overcurrent devices, the two most common types being fuses and circuit breakers, offer protection against currents in excess of the rated current of equipment or the current-carrying capacity (ampacity) of a conductor. The purpose of properly coordinated overcurrent protection is to recognize, locate, and isolate faulted portions of the power system in order to minimize the damage to equipment and conductors, danger to personnel, and interruption of electrical power which may result from an overload, short circuit, or ground fault.

Circuit Breakers. Circuit breakers are devices which permit manual opening and closing of a circuit and which open the circuit automatically for a predetermined fault condition (usually overcurrent, but sometimes reverse power flow, undervoltage, or underfrequency) without damage to themselves when applied within their ratings. In effect, they are high current interrupting capacity switches with automatic trip elements. The circuit breakers most commonly found in marine applications respond to overcurrent, tripping when the current magnitude exceeds a specific value for a specific length of time. Low voltage (600 volts AC and below) circuit breakers are usually constructed with an integral overcurrent trip element within the circuit breaker housing.

In medium voltage systems, instrument transformers and protective relays separate from the circuit breakers are often used. Current transformers and voltage transformers are connected to the power system and allow the protective relays to "see" the conditions in the system without exposing them to the high system current and voltage levels. Protective relays interpret the information provided by the instrument transformers to discriminate between tolerable and fault/intolerable conditions. Upon detection of an intolerable condition, the protective relay initiates a tripping impulse to the circuit breaker, which isolates the faulted part of the power system.

When a circuit breaker opens an energized circuit, an arc is drawn between the opening contacts. This arc must be extinguished in order to interrupt the circuit. Circuit breakers are commonly classified according to the medium in which the contacts open. The common designations are air circuit breaker (which includes molded case circuit breakers), vacuum breakers, and SF6 (sulfur hexafluoride) breakers. Air circuit breakers are the most common type found in low voltage, relatively low current circuits for which the air around us serves as a suitable dielectric, preventing continued arcing between the contacts after they have parted. Most air circuit breakers employ a bank of metal fins around the contacts to quickly extinguish arcs. As the arc passes between the fins it is split, cooled, and extinguished.

The Electrical Engineering Regulations require circuit breakers to be the air type (see 46 CFR 111.54-1(a)(4)). Air possesses marginal insulating value to prevent ionization and continued arcing at medium voltage and/or high interrupting current levels. Air circuit breakers for medium voltage applications are large, heavy and expensive. For nearly a decade, trial installations of vacuum circuit breakers have demonstrated satisfactory performance on vessels. Vacuum circuit breakers may now be accepted as providing a level of safety equivalent to air circuit breakers. Similarly, SF6 circuit breakers have demonstrated acceptable performance in medium-voltage industrial and utility service and may also be permitted in a marine electrical system.

The contacts of a vacuum circuit breaker open and close within an evacuated bottle. With very little gas available to ionize, there is essentially no arcing between the contacts. Vacuum circuit breakers can be smaller, lighter, and (usually) less expensive than equivalent air circuit breakers.

Sulfur hexafluoride, is a nonflammable, nontoxic gas with an insulating value 2.5 times that of air at atmospheric pressure. Each SF6 interrupter pole consists of two pairs of contacts sealed in a bottle filled with SF6 gas at slightly more than atmospheric pressure. A puff of gas directed between the parting contacts cools the arc and allows deionization and interruption of the current.

SF-6 and vacuum circuit breakers have been accepted aboard inspected vessels for use in medium voltage metalclad switchgear, and it appears that air circuit breakers may, in the not-too-distant future, be obsolete for this service and become unavailable.

A molded-case circuit breaker is a type of air circuit breaker which is assembled as an integral unit in an insulated housing. Most molded-case breakers are provided with both a thermal trip for sustained overloads and a magnetic trip for instantaneous tripping on high fault currents. The operating mechanism which opens and closes the contacts includes a powerful spring which is charged when the breaker is closed. The trip actuator may have a number of inputs, but it must have a common mechanical output which releases the operating mechanism and uses the spring energy to open the contacts. Traditional circuit breakers have, for each pole, a bimetallic thermal trip element and an electromagnetic (instantaneous) trip unit which initiate the mechanical motion of the trip bar which, in turn, releases the operating mechanism to open the contacts. Note that actuation of the common trip bar opens all the poles of the breaker simultaneously. This is illustrated in Figure 3 below.

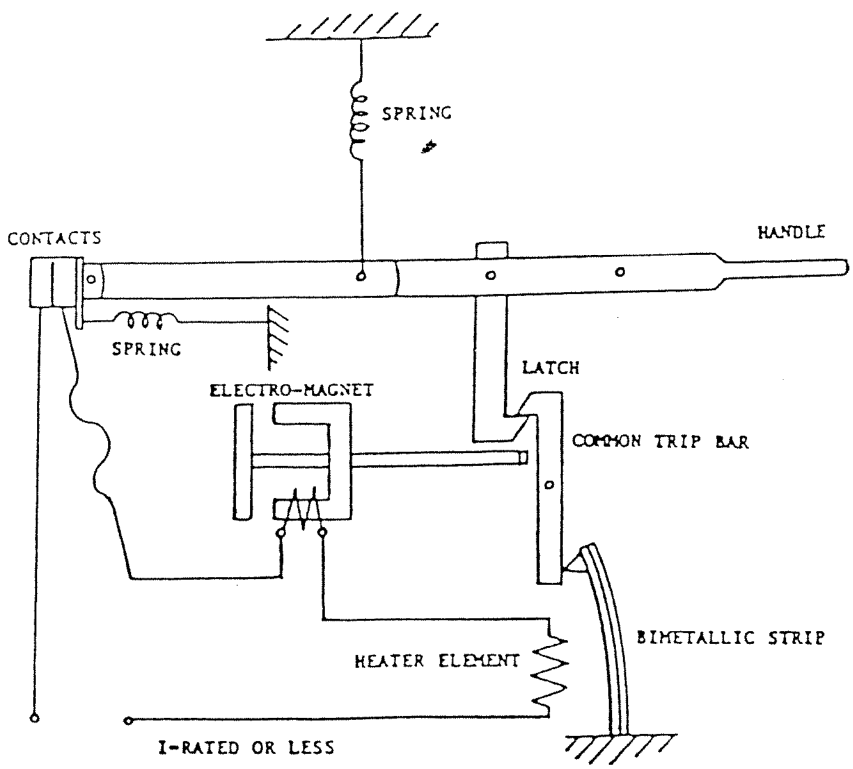


FIGURE 3

Electronic trip systems have been developed which replace the moving thermal-magnetic devices with solid-state electronic sensors and a single trip solenoid. By reducing the number of mechanical moving parts used to release the operating mechanism, electronic trip units can be made inherently more vibration and shock (impact) resistant. In addition, the electronic trip unit can be more closely adjusted and is less sensitive to ambient temperature because no motion of the trip actuator occurs until the trip signal is sent to the solenoid by the electronic circuit. With these advantages and the option for additional protection features, electronic trip units may soon replace thermal-magnetic elements for overcurrent protection.

The interrupting rating of a circuit breaker is the highest rms current at rated voltage which the breaker is intended to interrupt in normal service. In practical circuits containing both resistance and reactance, most short-circuit currents will be asymmetrical during the first few cycles after the short occurs. This asymmetry, due to a DC current component, will decay during the first few cycles until the current becomes symmetrical. The asymmetrical current, although it lasts only a short time, can greatly exceed the corresponding symmetrical fault current and the circuit breaker must be able to withstand the asymmetrical value. Under the ANSI standards presently applicable to low voltage fuses and circuit breakers, interrupting ratings are expressed in terms of the symmetrical rms current to facilitate equipment comparison and selection. Circuit breakers meeting UL 489, although having only a symmetrical rating, are tested under conditions that evaluate their ability to withstand the "worst-case" asymmetrical current. Accordingly, the evaluation of the device for asymmetrical current is not necessary. Medium voltage circuit breakers have a first-cycle asymmetrical rating.

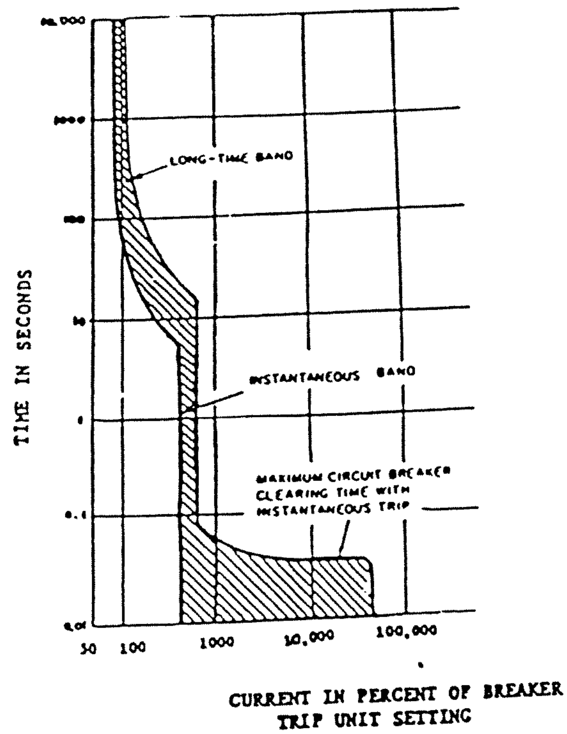
The continuous current rating of a circuit breaker is the continuous current the breaker will carry, without tripping, in the ambient temperature for which it is calibrated. Higher current will initiate tripping, though the current level must be sustained for some minimum length of time in order to actually trip the breaker.

Circuit breakers trip on overcurrent according to a time-current response curve established by the manufacturer. A typical circuit breaker time-current characteristic curve is shown in the Figure 4.

Circuit breakers which respond to overcurrent may have an inverse-time trip, an instantaneous trip, or both. The term "instantaneous" here means only that no intentional time delay has been introduced, although some finite minimum time is required for any circuit breaker to interrupt a circuit. The curves indicate the length of time a particular current level must be sustained in order to trip a particular breaker. These and similar time-current curves for fuses are used in the process of coordinating the various overcurrent devices in the power system.

<u>Fuses</u>. Fuses are overcurrent protective devices containing a circuit-opening fusible element that is heated and severed by the passage of overcurrent. Fuses are among the few components required by the Electrical Engineering Regulations to be <u>listed</u> by UL or other independent laboratory recognized by the Coast Guard (see 46 CFR 111.53-1(a)(3)). Fuses listed or labeled by a "nationally recognized testing laboratory" which has received

FIGURE 4



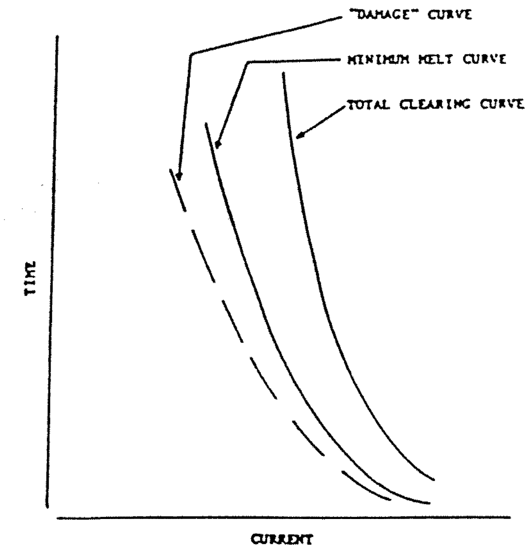
recognition by OSHA are acceptable. Only "one-time" fuses may be used; renewable link cartridge-type fuses and Edison-base fuses (the screw-in type formerly used in residential fuseboxes) must not be used.

The interrupting rating (or capacity) refers to the highest rms alternating current (or direct current depending upon the application) which the fuse is designed to interrupt without charring or cracking of the fuse tube or external arcing. The continuous current rating, or ampere rating, is the current level which the fuse will carry continuously without deterioration or excessive temperature rise.

While fuses are often regarded as instantaneous circuit interrupting devices, they actually follow an extremely inverse time-circuit characteristic curve as shown in the Figure 5.

The total clearing time curve shows the maximum time, including arcing time and manufacturing tolerances, for the fusible element to open the circuit. The minimum melt curve represents the minimum time required for the fusible element to begin to melt. An assumed "fuse damage," curve, approximated at 75% of the minimum melting curve, is used to provide a margin of safety so that applications avoid operation in the time-current band between the minimum melt curve and the total clearing curve, where current levels may cause thermal damage to the fuse without opening the circuit.

FIGURE 5



Current-limiting Devices. Current-limiting fuses are used to limit the magnitude and duration of extremely high fault currents during the total clearing time. Current limiting becomes effective only above a specific threshold current and interrupts the circuit in less than one-half cycle after occurrence of a fault, before the fault current reaches its maximum magnitude. Current-limiting fuses can be used in combination with circuit breakers to provide protection of the circuit breaker against high fault currents while retaining the time delay thermal and instantaneous magnetic trips for overcurrents of lower magnitude. The heat energy developed in a circuit during the fuse's clearing time, expressed in ampere-squared-seconds as I^2t, is used as one measure of a fuse's current-limiting ability.

Applications. Overcurrent devices are generally required to be located at the point of supply of the circuit to be protected. The Electrical Engineering Regulations contain specific exceptions for overcurrent protection for generators, shore power cables, and transformer secondary circuits. Most conductors must be provided with overcurrent protection to protect against thermal damage caused by current in excess of the ampacity rating of the conductor.

This level of overcurrent protection is not desirable in circuits which would hazard vessel operation if unexpectedly opened. Only short-circuit (not overload) protection, set not less than 500% of the expected current, is allowed in electric propulsion control, voltage regulator, and circuit breaker tripping control supply circuits. Exceptions are also made for applications such as motor circuits where a higher trip rating may be necessary to avoid tripping on motor inrush currents. Similarly, the overcurrent protection requirements for transformers contained in Article 450 of the National Electrical Code reflect the need to avoid improper tripping due to magnetizing inrush currents while providing adequate protection against sustained overcurrent.

Due to the vital role of the steering system in the overall safety of a vessel, only limited fault-current protection is permitted in steering gear motor feeder, motor controller, control, and indicating and alarm circuits. It would be dangerous to "protect" a steering gear motor against a moderate overload if, by tripping the motor during a maneuvering situation, steering were lost and the safety of the vessel jeopardized. The fault-current protection required for steering systems is intended to protect against fire; components of the system may be sacrificed in order to maintain control of the vessel for as long as possible in emergency situations. Steering gear and propulsion circuits must meet 46 CFR 111.93 and 111.35, respectively.

The requirements of Article 430 of the National Electrical Code, referenced in 46 CFR 111.70, apply to overcurrent protection for motor circuits other than those for fire pumps, steering gear, or electrical propulsion. Fire pump motor protection must meet the general motor protection requirements of Article 430 in lieu of the requirements contained in the fire pump portions of sections 430-31 and 430-72.

3.11 Fault Current Analysis & Coordination.

Purpose. To provide for an electrical system that minimizes disruption from fault conditions, a fault current analysis and a coordination study must be performed. The fault current analysis is used to determine the magnitude of available fault current throughout the system so that interrupting devices can be selected to safely open that magnitude of current. The coordination study is performed so that the overcurrent devices can be selected or set so that the device immediately upstream from the fault trips before devices further upstream, thereby limiting the power loss to equipment downstream of the fault.

Theory. The available short-circuit current at a given location in the power system is defined as the maximum current which the power system, when operating with the maximum generating capacity that can operate in parallel and the largest "probable" motor load, can deliver to a zero-impedance (bolted) three-phase fault. The sources of short-circuit current are the generators, synchronous motors or synchronous condensors, and induction motors in operation in the system. The connected (spinning) motors function as generators for a short time after a fault occurs, contributing current towards the fault. The subtransient reactance should be used to determine the contribution of induction motors to the fault current during the first few cycles after the occurrence of the fault.

The current which will flow toward the fault depends upon the power available from the source(s), the voltage at the fault (assumed to be zero for a bolted three-phase fault), and the impedance of the circuit components such as transformers, conductors, and other equipment between the fault and the power source(s). Short-circuit currents should be assumed to be asymmetrical during the first few cycles after the short occurs. The asymmetry will be maximum at the instant the short circuit occurs; in practical circuits containing both resistance and reactance, the current generally becomes symmetrical after several cycles. The rms value of the available asymmetrical current must be within the interrupting rating of the overcurrent device. Note that this maximum asymmetrical current is the average of the three phases at a particular instant in time and is not the maximum current in any one phase.

Low-voltage air circuit breakers operate nearly instantaneously for currents near their interrupting ratings. These breakers must be capable of interrupting the maximum current which can flow in the circuit. However, since the interrupting ratings of low voltage circuit breakers are only expressed in terms of symmetrical rms amperes, only the symmetrical fault current needs to be determined. The breaker frame size should be selected to have a (symmetrical) interrupting rating at least equal to the calculated symmetrical short-circuit current.

<u>Calculation Procedures</u>. There are a number of methods, of various degrees of accuracy and simplicity, which can be used to determine the available fault current. The Electrical Engineering Regulations permit the use of the assumptions contained in 46 CFR 111.52-3 in lieu of detailed short-circuit calculations for systems with an aggregate generating capacity below 1500 kilowatts. This refers to the condition where the maximum number of generators which can operate in parallel are operating, generating the maximum power which can be supplied to the system. Detailed calculations may utilize any of the following methods:

1. Exact calculations using actual impedances and reactances of the electrical equipment in the system.

2. Estimated calculations using the Naval Sea Systems Command Design Data Sheet DDS 9620-3, "A.C. Fault Current Calculations."

3. Estimated calculations using the International Electrotechnical Commission (IEC) Publication 363 (1972), "Short-circuit Current Evaluation with Special Regard to Rated Short-Circuit Capacity of Circuit Breakers in Installations in Ships."

4. Estimated calculations using an established, commercially-available fault current analysis procedure for utility or industrial applications, provided sufficient documentation regarding the procedure is submitted to verify its applicability.

The estimated calculation procedure often contain certain "simplifying assumptions" regarding the reactance-to-resistance (X/R) ratios for generators, motors, and transformers, as well as the power factor and efficiency of induction motors. Low voltage systems are generally assumed to experience no voltage drop throughout the system. The maximum fault current is normally calculated at the first half-cycle. Simplifying assumptions may be used, consistent with good engineering judgment. The use of such assumptions must be noted in the calculations.

<u>Coordination</u>. Coordination, sometimes called selectivity, refers to the location of overcurrent protective devices in the system and the selection of proper trip ratings or settings and coordination time intervals so that only the smallest practicable portion of the power system will be isolated following a fault. The protection system can be viewed as a set of overlapping zones of protection with each zone encompassing a segment of the power system including at least one circuit breaker or fuse, as shown in Figure 6.

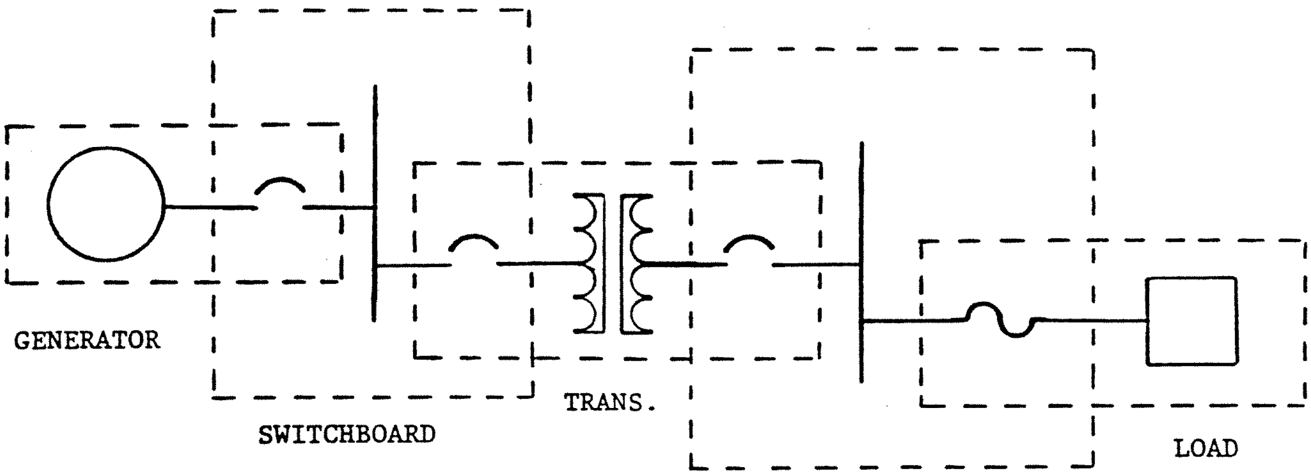


FIGURE 6

In a properly coordinated radial system, the first circuit interrupting device on the source side of the fault should respond (by opening the circuit) the fastest, so that no other interrupting devices open and maximum continuity of power is provided to the remainder of the system. Each circuit interrupting device should provide backup protection for the interrupting devices downstream of it; that is, each interrupting device should be able to open the circuit for any fault which the next downstream device fails to clear, but only after allowing sufficient time for the downstream device to act. The coordination time interval is the time difference between the slowest operating time for the primary protection and the fastest time for the backup protection.

Proper coordination of protective devices requires an analysis of the fault currents available at the various points in the system, selection of the circuit breakers and fuses so that each will clear the anticipated fault currents in an acceptable time, and verification that each breaker or fuse provides adequate backup protection for the circuit interrupters downstream. In general, "instantaneous" or extremely inverse characteristic circuit breakers, or fuses, are used at loads (the farthest downstream devices) with progressively less inverse time-current characteristic breakers employed as one approaches the source(s). An exception is the requirement of 111.12-11(c)(2) for an instantaneous trip on the generator circuit breaker where three or more generators can be paralleled.

Coordination of molded case circuit breakers having thermal-magnetic trips is sometimes difficult. In view of this, non-selective overcurrent protection may be accepted for circuits which supply only non-vital equipment. A fault on such circuits must not affect the continuity of electric power to equipment vital to the propulsion, control, or safety of the vessel.

3.12 Motor Circuits

General. With the exception of steering gear motor circuits, propulsion motor circuits (which must meet 46 CFR Subparts 111.93 and 111.35, respectively) and certain special requirements applicable to fire pump motor circuits, each other motor circuit, controller, and protection must meet Article 430 of ANSI/NFPA 70, the National Electrical Code (NEC). Diagram 430-1 in the NEC is a useful diagram of a motor circuit. The diagram serves as a guide to the applicability of the various sections of Article 430; the NEC does not require all motor circuits to be arranged as shown in the diagram. In fact, the vast majority of shipboard low-voltage motor circuits consist of the motor, a combination motor controller containing overload protection which meets NEC 430 Part C and a disconnecting means which meets 430 Part H, fuses or a circuit breaker which provide branch-circuit short-circuit and ground-fault protection per 430 Part D, and motor branch-circuit conductors meeting 430 Part B.

The nameplate on a motor rated at 0.5 horsepower or larger must list its code letter (see 46 CFR 111.25-5 and NEC 430-7; this information is very seldom available to the plan reviewer). Code letters are listed alphabetically and represent the locked rotor kilovolt-amperes (KVA) per horsepower. The branch circuit protective device chosen must be large enough to allow sufficient time for the motor to start. Higher code letters indicate greater locked rotor currents, requiring larger protective devices. When starting a motor with full voltage, the locked-rotor current does not diminish until the motor is very nearly up to its rated speed. Most motors used have code letters ranging from "F" to "V". For these motors, the maximum rating or setting of the branch circuit protective device, if a fuse, is 300 percent of the motor full-load current; if a circuit breaker, this value must not exceed 250 percent (see 46 CFR 111.70-1 and NEC Table 430-152). The minimum value is not given but must be capable of carrying the starting current of the motor (see NEC 430-52). For vital systems, however, a minimum of 200 percent full-load current is recommended for motors having "F" to "V" code letters, to ensure starting of the motors. The trip setting values listed in the Quick Reference tables of Appendix 6, columns I or J as applicable, may be used to check all motors having code letters "F" through "V".

Branch-circuit conductors supplying a single low-voltage (600 volts and below) motor in a continuous duty application must have an ampacity of at least 125 percent of the rated full-load current of the motor. Motors are assumed to be assigned to continuous duty unless the nature of the equipment driven is such that a motor will not operate continuously with load under any condition of use. Conductors for short-time and intermittent duty motors should be sized per NEC Table 430-22(a). Conductor ampacity of at least 125 percent of the motor full-load rated current is required because the conductors are protected by motor overload protective devices which are set above the motor full-load current.

600 volts and above. The above requirement for conductor sizing applies only to low-voltage applications; Part J of Article 430 adds to or amends the other provisions of the article for motor circuits over 600 volts. Specifically, 430-124 permits motor conductors to have an ampacity not less than the motor overload protective device trip current, which may be 100% of the rated full-load current. This applies to medium-voltage motors for

applications such as thrusters and compressors. Cables for DC motors for drilling equipment (draw-works, rotary table, mud and cement pumps) may be sized in accordance with the International Association of Drilling Contractors "Interim Guidelines for Industrial System DC Cable for Mobile Offshore Drilling Units," IADC-DCCS-1. This standard is attached as Appendix 5.

Motor protection. Motor overload protective devices are required for most motors in order to protect the motors, motor control equipment, and motor branch-circuit conductors against excessive heating due to sustained motor overload, failure to start, or motor stalling. Continuous-duty motors of more than 1 horsepower must generally be provided with a separate overload device set to trip at not more than 115% of the motor rated full-load current. In most cases, overload relays with heater coils responsive to the motor current are included in the motor controller. The Electrical Engineering Regulations generally permit the use of only two motor overload devices for three-phase motors in lieu of the three specified in NEC Table 430-37; see 46 CFR 111.70-1(b). The size of the overload protective device should be based upon the actual nameplate full-load current rating. The values listed in columns "C" and "D" of the Quick Reference tables in Appendix 6 may be used to check the maximum values for running protection.

Part D of Article 430 specifies the protection of motor circuits rated 600 volts or less against overcurrent due to short circuits or grounds. Individual motor circuits must have short-circuit protection rated or set not to exceed the value specified in NEC Table 430-152 and capable of carrying the starting current of the motor. A single protective device may be used to provide both short-circuit/ground-fault and motor overload protection where the overload requirements of 430-32 are met; see NEC 430-55. NEC 430-52 permits a motor short-circuit protector (MCP) to be used in lieu of the protection specified in Table 430-152 where the motor short-circuit protector is a part of a combination controller which has both motor overload protection and short-circuit and ground-fault protection in each conductor and where it will operate at not more than 1300 percent of motor full-load current.

Motor controllers, also called "starters," are used to manually or automatically start electric motors from a local or remote location. Motor controllers basically consist of a relay or "contactor," which is used to connect the motor to the AC line by a pushbutton switch, liquid level switch, pressure switch, temperature switch, etc.. The two types of controllers used are "low voltage release" (LVR) and "low voltage protection" (LVP). Both can appear to be identical, but their electrical circuits will vary.

LVR controllers are required for vital systems to ensure that the equipment will re-start following either a loss of power or a reduction in voltage below the "drop-out" value of the operating coil. These controllers are usually energized by contacts which mechanically remain closed when power is lost.

LVP controllers are energized by momentary contacts, such as a pushbutton. They will not re-start following a power outage until the momentary pushbutton contact is again depressed.

Motor controllers are furnished with the thermal overload elements mentioned above. These elements are used to open (or close) contacts which are used either in the control circuit itself or to provide an overload alarm to another circuit. Some of these elements are adjustable but most often the non-adjustable type is specified. Most motors are stopped by these (normally closed) contacts when an overload occurs. For vital systems, such as steering, these devices are used only to signal the overload condition in a separate circuit.

Safety disconnects. Each motor circuit must have a disconnecting means capable of disconnecting both the motor and the controller from the circuit. The disconnect and the controller may be contained within the same enclosure; the disconnect must, however, open all ungrounded supply conductors to the controller and motor control circuits. Switches and circuit breakers used as disconnecting means for low-voltage motor circuit must have ampere rating of at least 115 percent of the motor full-load current. The use of fuses as disconnects, although permitted by the NEC, is specifically prohibited by 46 CFR 111.70-1(c). Electric heaters in motor controller enclosures should not be excepted from the disconnecting requirements in 46 CFR 111.70-5(a). The purpose of this requirement is to eliminate the shock hazard posed to personnel by an enclosure with more than one source of potential, and is consistent with the intent of NEC 430-113. To allow for safe access during maintenance and inspection shutdown periods, a disconnecting device for an electric heater in a motor controller enclosure, or one of the protection features required by 111.70-7(d) for control, interlock or indicator circuits should be provided.

3.13 Shore Power

Electrical shore power connections are not required by the Electrical Engineering Regulations. Where provisions are made to use shore power, the connection boxes and switchgear must meet 46 CFR 111.83 and 111.30-25(f) for AC switchboards or 111.30-27(f) for DC switchboards. As an alternative to the standard shore power connection box, the use of military specification (MILSPEC) hardware is acceptable. The use of reverse-power or reverse-current relays should be considered when shore power is used extensively. In addition, interlocks are recommended to prevent the paralleling of shore power with the ship's generators.

4. The Emergency Power System

4.1 General. Part 112 of the Electrical Engineering Regulations and SOLAS II-1/42, 43, and 44 contain the requirements for emergency lighting and power systems. The requirements of these two sets of requirements (USCG and SOLAS), are generally in agreement. Vessels in some categories are permitted shorter periods of operation of the emergency power supply by 46 CFR Table 112.05-5(a) than by the SOLAS regulations; these vessels would not normally carry SOLAS certificates due to their size and/or limited operating routes. The Electrical Engineering Regulations permit manually connected emergency power sources only for cargo vessels less than 500 GT or cargo vessels of less than 1600 GT on other than ocean, Great Lakes, or coastwise routes and not on international voyages.

Diesel and gas turbine engines used as emergency generator prime movers must be capable of starting at an ambient temperature of 32 degrees F (0 degrees C). Electric water jacket heaters are permitted to ensure ready starting. Due to the impracticality of testing this capability in warm climates, the manufacturer's certification is generally accepted. A thermostatically controlled electric lubricating oil heater may be provided to reduce the accelerated wear which may result from placing the generator load on a cold engine. Where detached electric motor-driven pumps are provided to circulate warm oil through the engine while it is stopped, a low oil level alarm should be installed to indicate any loss of oil through a leak in the pumps or external piping.

SOLAS II-1/44.2 requires each emergency generating set to be equipped with a starting device with a stored energy capability for at least three starting attempts, with a second source for an additional three starts to be provided within 30 minutes unless manual starting (not just manual initiation of the start per 46 CFR 112.35-5) is practicable. This differs somewhat from the Electrical Engineering Regulations. The requirements for hydraulic, electric, and compressed air starting systems in 46 CFR 112.50 call for a capacity for at least <u>six</u> cranking cycles, with the capacity for three of these cranking cycles to be held in reserve until manually released.

The emergency generator is not intended to be used as an "in port generator"; it may be used to supply necessary electrical power to start the ship's machinery plant from a dead ship condition. When used in this manner, the emergency generator must be sized to provide power to all required emergency loads in addition to any loads on the emergency switchboard (not bus-tie loads) that are used for starting the ship's main propulsion machinery.

<u>4.2 Location</u>. SOLAS II-1/42.1.3 and 43.1.3 and 46 CFR 112.05-5(e) all state that the emergency generator room and a category A machinery space should not be adjoining, except where other arrangement is not practicable. The intent is to maintain the integrity of the emergency electrical distribution system if there is a fire, flooding, or other casualty in the main machinery space. When the arrangement has been shown to be impractical, the installation of an A-60 bulkhead between the emergency generator room and the category A machinery space has been accepted. Although not required, it was recommended that the steel bulkhead be insulated to A-60 on both sides. Casualties such as the recent explosion and fire aboard a U. S. flag tankship, however, demonstrate the vulnerability of an emergency power source located in a space adjacent to the main machinery space. <u>It is preferable to avoid any contiguous boundaries between the emergency generator room and any category A machinery space or space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard.</u>

<u>4.3 Emergency Loads</u>. The temporary and final emergency loads listed in 46 CFR Subpart 112.15 must be supplied by the emergency power source(s). Additional <u>safety</u> devices and systems (i.e., vital) may be connected to the

emergency power system provided the emergency source is sized to supply these loads at 100% load factor. Additional loads which are intended to improve the safety or survivability of the vessel in certain operating modes (i.e., non-vital) and which have not been considered in sizing the emergency generator (such as the addition of a secondary deballasting system on a semisubmersible MODU) may be allowed to be connected to the emergency power supply when arranged to be functionally equivalent to a bus-tie configuration. The following conditions would apply:

1) The non-vital loads must automatically trip off the emergency switchboard (by means of an undervoltage or underfrequency trip or equivalent) when the normal power supply is lost;

2) these loads must only be manually reconnected to the emergency bus, (this may be done remotely); and

3) the non-vital loads must be shed automatically prior to overloading of the emergency generator. Remote load monitoring and manual disconnection of required emergency loads is allowed, but automatic load shedding of the non-vital loads is necessary to maintain the integrity of the emergency power system.

Any bus-tie between a main switchboard and an emergency switchboard must not have automatic feedback of power from the emergency source to the main switchboard. When operating in a feedback mode, the bus-tie must open automatically upon overload before the emergency power source is tripped off line. Each bus-tie should be provided with short-circuit protection by a circuit breaker or fuses at both the main and the emergency switchboards.

Cables from the emergency switchboard, other than those which supply equipment in the machinery spaces, must not be run through the engineroom, boilerroom, or the casings of these spaces. Emergency power cables must not be run along decks or bulkheads which form the boundaries of these spaces. Again, the intent is to maintain the integrity of the emergency power system by protecting emergency power cables from thermal damage should there be a fire in the machinery spaces.

5. COMMUNICATION AND ALARM SYSTEMS

5.1 Fire detecting and alarm systems. An automatic fire detecting and alarm system consists of a power supply, a control unit on which are located visible and audible fire and trouble signalling devices, and fire detector and alarm circuits, as required, originating from the control unit. Detector and alarm circuits consist of initiating and indicating devices and alarms. Initiating devices are smoke, heat or flame detectors and manual fire alarm boxes. Indicating devices are audible and visual alarm devices such as bells and strobe lights.

Systems are approved by the Coast Guard at two separate levels. Manufacturers of systems obtain approval of a type system incorporating all of the components for which they desire Coast Guard approval from Commandant (G-MTH-4). Systems are approved for use on individual vessels by the Marine Safety Center based on compliance with the manufacturer's type system approval. Approved systems are required in designated areas of Passenger Vessels (46 CFR 76.05), Cargo and Miscellaneous Vessels (46 CFR 95.05), and in machinery spaces of inspected vessels where automated systems are provided to replace manual control and observation, such as minimally attended machinery spaces with centralized control rooms or unattended machinery spaces (46 CFR 62.50-20(c) and Table 62.35-50). Approved systems are also required in cargo spaces intended for the carriage of dangerous goods per SOLAS 74, as amended, Regulation II-2/54. NVIC 7-80 "Use of Fire Detection Systems Which Are Not Approved under 161.002" should be consulted for guidance on systems for areas where detectors may be installed but are not required.

Manufacturers of systems may seek approval from Commandant (G-MTH-4), U.S. Coast Guard, 2100 2nd St. S.W., Washington, DC 20593-0001, by submitting system design information and test reports with a letter of request for approval. Plans should be submitted in triplicate and should cover fully the arrangement, construction, and materials of the system and components. Design and testing requirements are found in 46 CFR 161.002.

UL listing of control units is not sufficient evidence of compliance with the approval requirements. Two features not required by UL must be included. They are a power transfer switch and automatic circuit test means. The power transfer switch transfers the energy source from the normal power source to the emergency source upon loss of normal power (46 CFR 161.002-10(g)(1)). Circuit test means must be provided for individually testing each zone circuit by simulating a fire alarm condition and a trouble condition. In addition to the UL required tests, marine related tests must be completed for vibration, humidity, and inclination (46 CFR 161.002-16(c)(3),(4), and (5) respectively). UL listed control units modified to include a UL listed automatic power transfer switch and circuit test means need only be tested for vibration, humidity, and inclination.

UL standards are considered appropriate for all initiating and indicating devices with the exception of detectors for use in exposed locations such as cargo holds, in the weather, or wet spaces including main machinery spaces. Such devices must pass the salt spray tests in the appropriate UL standard. Annunciators are considered to be indicating devices and should meet UL Standard 404, "Audible Signal Appliances", or UL Standard 1638, "Visual Signaling Appliances for Fire Protective Signaling Systems". If the use of annunciators is more complex than indicating devices, they should comply with the requirements for control units.

Approval of systems designed for specific vessels may be obtained from Commanding Officer, Marine Safety Center, U.S. Coast Guard, 400 7th St. S.W., Washington, DC 20590-0001. Arrangements of the systems must be submitted in triplicate and all approved components should be readily identifiable. Only approved components should be used.

The requirements for location of equipment for all systems are found in 46 CFR 76.27 and 35. Additional requirements for vessels requiring SOLAS Certificates are found in SOLAS 74, as amended, Chapter II-2. Further guidance on locating detectors can be found in NFPA 72. Ventilation effects should be considered when locating detectors.

5.2 General Alarm. A general alarm system meeting 46 CFR Subpart 113.25 must be provided on each manned vessel of over 100 gross tons, except barges, scows and similar vessels to alert the crew and passengers to the existence of an emergency situation and the need to report to their muster stations. Components of the general alarm system, including vibrating bells and flashing lights, do not require type approval by the Commandant. The requirement for component approvals was deleted from the regulations by the revision of 46 CFR Subchapter J which became effective 1 June 1982. Only the system design and equipment installation need now be approved.

The general alarm is intended to be sounded only after a deliberate decision by a member of the crew. This position is consistent with SOLAS Chapter II-2 Regulation 13.1.14. The general alarm must only be initiated manually and is intended to be sounded by the person on watch or other responsible member of the crew only after the determination has been made that an emergency situation exists which warrants mustering the crew and passengers (if any). SOLAS permits the general alarm to be sounded automatically by a safety monitoring system, such as a fire detection and alarm system, if an initiating fire alarm is not acknowledged within a reasonable time (two minutes). This is permitted for spaces other than passenger spaces.

An integrated general alarm, fire alarm and public address system may be considered for equivalence to the intent of 46 CFR 113.25 and to satisfy SOLAS chapter II-2, Regulation 40.5 for a public address system. Any such arrangement must give priority to the general alarm function. Such a system would function similarly to the multi-purpose 1MC Emergency Announcing System commonly used on naval vessels. Speakers and electronic tone generators may be used to produce a bell-like signal or tone distinct from any other audible signal on the vessel. The location of speakers and the generated sound level must meet 46 CFR 113.25-9. Either a distinct sound signal or intermittent operation of the general alarm bells (or speakers producing bell-like sounds) may be used to warn of fire. An integrated system must meet the following criteria:

a) The fire alarm activating switch must be in a normally manned space which can receive alarms from the master fire alarm panel and which has a general alarm contact maker.

b) The general alarm signal must have priority over the fire alarm signal.

c) The fire alarm switch should be marked "Fire Alarm" in red letters on a corrosion-resistant plate or sign.

d) Operation of the fire alarm switch may also activate a fire alarm page via the public address system. This must not interfere with the normal operation of the general alarm.

e) If the fire alarm signal is generated external to the general alarm system, loss of power to it must not affect the general alarm system.

f) The fire alarm signal must be distinct from those signals required by 46 CFR 109.503 for MODUs.

The emergency signals required by 46 CFR 109.503 for Mobile Offshore Drilling Units differ considerably from those used on other types of vessels. The intent of this was to recognize and standardize existing industry practice which was different than for vessels. This promotes consistency among offshore rigs, both mobile and fixed, so that an offshore oil worker can recognize the same sound signal and respond in the proper manner to similar emergency situations on either kind of installation. The emergency signals specified in 46 CFR 109.503 should be used for "emergency stations" and "abandon unit" situations on MODU's; other signals, such as fire warnings, must be distinct from these required signals.

Vessels have been allowed, on a case-by-case basis, more than one general alarm contact maker in addition to those required under 46 CFR 113.25-5(a), (b), or (c) where justification was presented. For example, Military Sealift Command vessels have been permitted to use contact makers in weatherproof boxes in the quarterdeck area in order to sound the general alarm in a security/intruder situation. Additional contact makers may be permitted where their installation results in an increase in vessel safety. Any additional contact makers should meet the construction requirements of 46 CFR 113.25-11 and should be labeled per 113.25-20(b). Contact makers in weather locations should be provided with suitable weatherproof enclosures. Where jack boxes are used for these additional contact makers, there must be cut-out switches in the wheelhouse that can isolate the jack boxes from the rest of the general alarm system.

There are no switches available which satisfy the requirements of both 113.25-11 for contact makers and 111.105 for electrical equipment in hazardous areas. For contact makers that must be in hazardous locations, the requirements of 111.105 apply. These switches should be labeled as required for contact makers by 113.25-20(b) and 113.25-11(d), as applicable.

Flashing red lights which augment the general alarm bells must be supplied by the general alarm system power supply, except for flashing red lights in the main machinery space supplied from the emergency source of power through relays operated by the general alarm system. In general, the use of the emergency source of power for all general alarm system flashing red lights meets the intent of 113.25-10(c).

5.3 Sound-Powered Telephones. Section 37.22 of IEEE Standard 45 and military specification MIL-T-15514 may be used as guidance for construction, installation, and performance standards for sound-powered phones.

Sound-powered telephone headsets and jack boxes are not permitted on any telephone system that includes any station required by the regulations, except for use at engineroom local control stations; see 46 CFR 113.30-20(d). The objections to the use of these portable headsets are:

a) Headsets are often not there when needed.

b) Headsets have been more prone to damage than fixed handsets.

c) Headsets introduce noise on the circuit because the earphone is always on and acts as a microphone.

d) Jack boxes frequently corrode and short the circuit contacts, causing unreliable circuit operation.

A hard-wired (no jack) headset with a push-to-talk button, a watertight storage/connection box, and a cut-out switch can overcome these objections and may be accepted for use in locations with high background noise levels, such as steering gear rooms.

5.4 <u>Engine Order Telegraph (EOT)</u>. The engine order telegraph is a communication system that is necessary under temporary emergency conditions. Where an electric EOT is installed, 46 CFR 112.15-1(h) is applicable. Electric EOT systems must either be provided with an independent storage battery source of backup power or be arranged so that they can be energized from the temporary emergency power source.

NVIC 1-69 specifically allowed automated vessels with pilothouse control to use a flush mounted, knob-type transmitter for the EOT on the bridge. This was because the EOT was considered a "standby" device on a vessel with pilothouse throttle control, and its orientation less critical. That NVIC has been superseded by 46 CFR 62, which does not address EOT configuration (there is no longer a conflict). 46 CFR 113.35 requires the EOT transmitter in the wheelhouse to have a "handle." The intent is to provide for rapid visual determination of engine order from throughout the wheelhouse, and if necessary, a determination by feel. This intent should be met by an EOT considered a secondary or standby device, as well as an EOT used as a primary control device. In most instances, this precludes consideration of a flush mounted, knob-type transmitter as an equivalent arrangement. Transmitters that provide rapid visual and tactile determination of orders, such as some push-button type transmitters, may be evaluated for equivalency.

5.5 <u>Emergency Loudspeaker Systems</u>. Subpart 113.50 of the Electrical Engineering Regulations requires an emergency loudspeaker system on each ocean and coastwise passenger vessel certificated to carry 500 or more persons, including officers and crew, and each passenger vessel that has lifeboats stowed more than 100 feet (30.5 meters) from the navigating bridge. The system permits two-way conversation between the navigating bridge and each lifeboat or embarkation station. SOLAS Chapter III, Regulation 6.4.1 requires an emergency means of two-way communication between emergency control stations, muster and embarkation stations, and strategic positions on board as part of the lifesaving arrangements for both passenger <u>and</u> cargo ships.

A combined public address, music distribution, and emergency loudspeaker system may be used for the system required by 113.50, provided the emergency loudspeaker function is given priority. If a separate public address or music system is used, a means to silence that system must be provided at the emergency loudspeaker system control panel.

6. Industrial Systems

6.1 Philosophy. Subpart 111.107 of the Electrical Engineering Regulations states that systems on Mobile Offshore Drilling Units that are used solely for the industrial function of the unit (drilling) may be considered as industrial systems. Industrial systems need not be restricted to MODU's, nor must they be related to petroleum exploration and exploitation functions; the concept of industrial systems can be extended to systems which serve only an industrial function on other types of vessels. Subchapter F, Marine Engineering, 46 CFR 56.01-1(c), provides alternative requirements for piping and pressure vessels in industrial systems on MODUs. However, the Marine Safety Manual indicates that this can be extended to other vessels in individual cases under the general equivalency regulations if the designer prefers to meet the requirements of 58.60. Similarly, 111.107 can be extended to other industrial systems. An example of such an industrial system is the crane power generation and distribution system on a craneship. Unlike the machinery (piping) design, the electrical aspects of industrial systems are not covered by a registered professional engineer's certification. Compliance with 46 CFR 111.107 must be established by plan review and/or inspection.

6.2 Generators. Industrial systems may be provided with dedicated generators or they may be supplied by the ship's service power distribution system. Where any generator, installed or portable is tied to the main switchboard so that it can be used to provide ship's service power, that generator must be considered a ship's service generator. The generator and switchboard regulations contained in 46 CFR Subparts 111.12 and 111.30 would then be applicable, as would the requirements for fault current analysis and (possibly) automatic load shedding. Dedicated industrial system generators, including containerized generator sets which are not tied to the main switchboard and have no provision to supply any ship's service loads, need, from an electrical standpoint, only meet the general safety criteria of the National Electrical Code and 46 CFR Subpart 111.107.

7. Hazardous Locations

7.1 General. Where flammable gases or vapors may be present, such as on the drill floor of a Mobile Offshore Drilling Unit or in the pumproom of a tankship, special precautions must be taken to ensure that electrical equipment is not a source of ignition. Subpart 111.105 of the Electrical Engineering Regulations contains the requirements for electrical equipment and wiring in locations where fire or explosion hazards may exist. In these locations, it is necessary to exercise more than ordinary care with regard to the selection, installation, and maintenance of electrical equipment and wiring. A primary objective of design should be to minimize the amount of electrical equipment installed in hazardous locations. Through the exercise of ingenuity in the layout of electrical installations for hazardous locations, it is frequently possible to locate much of the equipment in less hazardous or in non-hazardous areas and thus reduce the amount of special equipment and installations required.

The Electrical Engineering Regulations incorporate by reference Articles 500 through 503 of the National Electrical Code, with the exceptions listed in 46 CFR 111.105-5(a) through (d). An error is contained in 111.105-5(b), which excepts all of NEC Section 501-4 from incorporation into the regulations. By deleting these sections, it was intended to recognize that shipboard installations use marine cable, not conduit. It was not the intent to delete the statement that "Boxes, fittings and joints shall not be required to be explosionproof except as required by sections 501-3(b)(1), 501-6(b)(1) and 501-14(b)(1)." Non-explosionproof equipment can be allowed in accordance with the NEC.

7.2 Classification. National and international codes and regulations classify materials and locations based upon the experimentally determined properties of flammable vapors, gases, liquids, or combustible dusts or fibers that may be present and the likelihood that a flammable or combustible concentration or quantity is present. North American standards identify hazardous locations by Class and Division using the scheme described in Tables 1 and 2. International standards (such as IEC Standard 79-10) use a different nomenclature, but their classification philosophy is essentially the same.

For Class I locations, gases and vapors are divided into groups A, B, C, or D, depending upon experimentally determined maximum explosion pressure, maximum safe clearance between parts of a clamped joint in an enclosure, and the minimum ignition temperature of the atmospheric mixture. For Class II locations, dusts are divided into Groups E, F, and G, depending upon the tightness of the joints of assembly and shaft openings for preventing entrance of dust into the dust/ignition proof enclosure, the blanketing effect of layers of dust on the equipment that may cause overheating, electrical conductivity of the dust and the ignition temperature of the dust. In general, equipment must be approved not only for the Class, but also for the specific Group of the gas, vapor, or dust that may be present. Flammable and combustible liquid cargoes may be further classified according to their vapor pressure and flashpoint. These liquids may be assigned both a Group and a Grade (Grade designation relates to flashpoint). In cases where differing requirements apply or several different hazardous atmospheres may be present, the most hazardous condition is presumed to exist and the most restrictive requirements should be applied. Appendix 7 contains a list of electrical hazard Group classifications for bulk liquid cargoes.

Once a specific location is classified, and specific materials that may be present are identified, the permitted types of electrical equipment are easily determined. For example, an area containing gasoline vapors would require Class I, Group D equipment. Where vapors would be present under normal conditions, the area would be a classified as Division 1, and equipment must be suitable for use in a Class I, Division 1, Group D location.

This classification system requires the use of some individual judgment, especially in the designation of "Division." To promote consistency and ensure safety, standard setting bodies and regulatory agencies have developed detailed standards, recommended practices, codes, and regulations applicable to specific situations.

Table 1

Classification of Properties of Hazard-Producing Materials

Class I -- Locations where flammable gases or vapors may be present, including:

Group A:	Atmospheres containing acetylene.
Group B:	Atmospheres such as butadiene, ethylene oxide, propylene oxide, acrolein, or hydrogen (or gases or vapors equivalent in hazard to hydrogen)
Group C:	Atmospheres such as cyclopropane, ethyl ether, ethylene, or gases or vapors of equivalent hazard.
Group D:	Atmospheres such as acetone, alcohol, ammonia, benzene, benzol, butane, gasoline, hexane, lacquer solvent vapors, naphtha, natural gas, propane, or gases or vapors of equivalent hazard.

Class II -- Locations where combustible dust may be present, including:

Group E:	Atmospheres containing combustible metal dusts or other combustible dusts or similarly hazardous characteristics.
Group F:	Atmospheres containing combustible carbon black, charcoal, coal, or coke dusts.
Group G:	Atmospheres containing combustible agricultural or plastic dusts.

Class III -- Locations where easily ignitable fibers or flyings, such as cotton fibers, sawdust, and wood shavings, may be present.

Table 2

Classification of the Probability that Material May Be Present in Flammable or Combustible Quantities

Division 1: (Zone 1)	Where material can exist under normal operating conditions, or frequently because of repair, maintenance, or leakage.
Division 2: (Zone 2)	Where material can exist under abnormal conditions (accidental rupture or breakdown, abnormal operations, etc.), or locations adjacent to a Division 1 location where material may occasionally be present.

Note: International standards and codes use the term "Zone" instead of "Division" and include a "Zone 0" designation for locations where vapors are assumed to be present, such as inside a tank or in a tankship pumproom. Although North American standards, such as the National Electrical Code (NEC) do not include a comparable "Division 0" designation, the Coast Guard's Electrical Engineering Regulations achieve the same effect by limiting electrical installations in these locations to the type permitted for Zone 0 applications, i.e., intrinsically safe systems.

7.3 Specific Hazardous Areas. Locations where flammable gases or vapors can exist on commercial vessels include battery rooms, paint lockers, pumprooms and weather deck locations above cargo tanks on tank vessels, mud pit rooms and the drill floor of Mobile Offshore Drilling Units, and operating rooms where anesthetics are administered on passenger vessels and hospital ships. Subpart 111.105 defines specific hazardous locations for combustible liquid cargo vessels, flammable liquid cargo vessels, liquid sulphur carriers, inorganic acid tankships, bulk liquefied gas and ammonia carriers, MODU's, vessels carrying coal, and vessels (such as ferries and RO-RO's) with spaces for the carriage of vehicles using gasoline or other highly volatile motor fuels. Typical hazardous location classifications are illustrated in Appendix 8.

The Electrical Engineering Regulations define particular areas to be Division 1 or Division 2 locations; there is no "Division 0" in North American practice comparable to the IEC Zone 0 designation. In the NEC, spaces where the hazard is assumed to be present under normal conditions are classified as Division 1 locations. There is no "higher" classification (i.e., Division 0). Enclosed locations comparable to tank vessel pumprooms typically do not exist in National Electrical Code applications. On shore, such installations are usually located in the weather, and spread-out over a much larger area. In Coast Guard regulations, spaces comparable to "Zone 0" locations such as pumprooms on tank vessels, while not given a Division 0 or Zone 0 designation, are permitted only limited electrical equipment (i.e. explosionproof lights, intrinsically safe systems, and cables) similar to IEC Zone 0 requirements.

Combustible liquids (see definition in 46 CFR 30.10-15) are often referred to as Grade D and Grade E cargoes. Similarly, flammable liquids (defined in 46 CFR 30.10-22) may be classified as Grade A, B, or C cargoes. Due to the high flashpoints of Grade E liquids, vessels carrying only Grade E cargoes need only meet the requirements of 46 CFR 111.105-29 for combustible liquid cargo carriers. The requirements of 111.105-31 apply to vessels carrying Grades A-D cargoes, as well as liquid sulphur and inorganic acids. Flammable hydrogen sulfide gas evolves from liquid sulphur, and many inorganic acids produce hydrogen gas when in contact with a number of common construction metals.

On MODUs, a specific classification for crude oil cannot always be given, since crude is a mixture of widely varying hydrocarbons. Locations are usually, however, designated Group D due to the presence of natural gas. Hydrogen sulfide, which is frequently encountered during drilling operations, has a Group C designation. Drilling operators often utilize electrical equipment that is suitable for both hazard groups C and D, especially when this equipment is readily available, and there is no economic penalty. It should not be inferred from the presence of some Group C equipment that the area has been classified as a Group C area. A Group D classification should be adequate when drilling in a region where the known or suspected mixture of hydrogen sulfide and natural gas is less than 25 percent hydrogen sulfide (by volume). This is in accord with the recommendations of the American Petroleum Institute's "Recommended Practice for Classification of Locations for Electrical Installations at

Drilling Rigs and Production Facilities on Land and on Marine Fixed and Mobile Platforms," API RP 500B, Third Edition, October 1, 1987.

Coal carriers and vessels carrying bulk grain and other agricultural products may be subject to dust explosion hazards. Just as with flammable gas or vapor explosions, the initial ignition source of a dust explosion may be a small spark or flame. However, an initial explosion may dislodge settled dust from the surrounding area which may then be ignited by the residual energy to cause a second and larger explosion. Undispersed dust which has accumulated in layers will not explode but may burn or char, generating heat which may ignite dispersed dust. NEC Article 502 lists the primary hazards which must be avoided as the admission of dusts into electrical equipment enclosures, reaching the heat of ignition due to the insulating characteristics of accumulated dust, and the formation of current paths of conductive dusts.

Explosion hazards due to agricultural dusts are not specifically addressed in the Electrical Engineering Regulations. However, 46 CFR 111.105-17 and 111.105-35 do give the requirements for electrical installations in Class II locations and specific requirements for vessels carrying coal. NVIC 9-84 "Electrical Installations in Agricultural Dust Locations" further defines the classification of hazardous areas due to agricultural dusts. It must be remembered that the enclosure protection method is different for dust than it is for a gas or vapor, and that "dust ignitionproof" and "explosionproof" are two different concepts. For a dust, the enclosure keeps dust out and does not build-up excessive temperatures when blanketed with dust. For a vapor, the enclosure allows vapor to enter and be ignited, yet prevents the internal explosion from propagating to the surrounding atmosphere. Equipment acceptable for use in a dust atmosphere is not generally suitable for use in a gas atmosphere, and vice-versa.

Vessels carrying coal may be subject to the double hazard of explosive gas as well as explosive dust. Freshly mined coal releases methane gas that had been contained within the pores of the coal. Release of methane can continue for days and even weeks after the coal is mined. If freshly mined coal is stored in an enclosed space, such as a bunker or closed hold on a ship, this methane may collect in sufficient quantity to cause an explosion.

Battery rooms and paint stowage or mixing spaces must meet the electrical requirements of 46 CFR 111.15 and 111.105-43, respectively. The regulations do not explicitly state that these spaces are defined as hazardous. However, equipment within these spaces must be suitable for installation in Division 1 locations. The hazardous locations are considered to exist only <u>inside</u> these spaces; the regulations do not define a hazardous area as extending any specific radius from doors, hatches, or other openings into these spaces. The use of only explosionproof or intrinsically safe electrical equipment and the avoidance of open flames and sparking near such openings is, however, strongly recommended.

The Electrical Engineering Regulations require armored or mineral insulated cable for most installations in hazardous locations. Unarmored cable is permitted for intrinsically safe systems, portable equipment, applications requiring flexible cable, and in Division 2 locations.

Industrial systems may use an armored type cable construction, but the cable must also meet the installation and flammability test requirements of 46 CFR 111.107-1(b) if it penetrates a deck or bulkhead. Conduit systems that meet the applicable requirements of the NEC provide an equivalent level of safey and can be permitted.

The minimum safety requirements for electrical equipment located in spaces intended for the stowage of vehicles with gasoline in their tanks and batteries connected are contained in 46 CFR 111.105-39. These requirements apply to spaces designated as "specially suitable for vehicles" on passenger and cargo vessels. A deck, for the purposes of 46 CFR 111.105-39(b), is any deck or platform for vehicles that has sufficient solid surface area to cause the accumulation of petroleum vapors or spilled liquid. Where a vehicle deck or platform is perforated with openings, the next lower space must also comply with 111.105-39. Cable trays, wiring, lighting fixtures, and other electrical equipment must not be located directly under any such openings.

It should be noted that SOLAS II-2/37.1.6, 37.2.2, and 37.3.2 contain somewhat different requirements for ventilation and precautions against ignition of flammable vapors in "special category spaces", which are those vehicle stowage spaces on passenger vessels normally accessible to passengers. Regulations 38.3 and 38.4 address these issues for other vehicle cargo spaces on passenger vessels. Similarly, SOLAS II-2/53.2.3 and 53.2.4 state the ventilation and ignition prevention requirements for vehicle spaces on cargo vessels, including RO/RO spaces. While 46 CFR 111.105-39 is considered to provide sufficient minimum requirements for the prevention of ignition by electrical equipment, closed spaces for fueled vehicles should be provided with ventilation per ABS Section 35.157.1 and SOLAS II-2/53.2.3.

Questions frequently arise concerning the acceptability of electric heat tracing in hazardous locations. Heat tracing is permitted in Division 2 locations by NEC Article 501-10(b)(1). Since the NEC requires wiring in Division 1 locations to be in conduit, it does not recognize heat tracing cable installations in Division 1 locations. However, since shipboard Division 1 installations use cable, not conduit, and Subchapter J does not reference the NEC for Division 1 wiring methods, electric heat tracing may be used in Class I Division 1 locations. The heating cable must not exceed 80% of the autoignition temperature in degrees Celsius of any gas or vapor involved on any surface which is exposed to the gas or vapor, when continuously energized at the maximum rated ambient temperature. Any thermostats, controllers, power supplies, and other associated equipment must be provided with enclosures approved for Class I Division 1 locations or be located outside of the designated hazardous areas.

Hazardous area drawings and a corresponding bill of materials are normally reviewed by the Marine Safety Center, or cognizant OCMI, prior to the installation of any electrical equipment in a hazardous location. Hazardous area drawings and equipment lists should be maintained to reflect the current arrangement and inventory of electrical equipment in those locations.

A proper hazardous area drawing is an arrangement plan showing the boundaries and classification of all hazardous areas, and the location of all electrical equipment in those areas. It should be accompanied by a bill of material or equipment list that identifies each item by manufacturer, model number, and Class and Group for which approved, and should provide evidence of approval by a nationally recognized testing laboratory. In addition, the operating temperature of the electrical equipment must not exceed the autoignition temperature of the gases or vapors likely to be present. Confirmation of equipment temperature is usually beyond plan review capabilities, since it is not usually provided in approval listings. This information is, however, required to be placed on the label of explosionproof equipment in the form of an operating temperature identification code number on the equipment if the temperature exceeds 100 degrees C. (see Table 3). Normally, the only equipment installed in hazardous locations having a temperature code will be incandescent lighting fixtures and motors. When such equipment is used in a machinery space, a 50 degrees C. ambient is assumed. The labeled operating temperature is usually referenced to a 40 degree C. ambient. Unless the equipment has thermally actuated sensors which limit the operating temperature to that specified on the label, equipment used in high ambient temperature locations should be derated.

NVIC 8-84, "Recommendations for the Submittal of Merchant Vessel Plans and Specifications" provided additional guidance on hazardous area submittals. Appendix 8 contains a suggested plan review check-off list for electrical installations in hazardous locations.

7.4 Equipment. Specific requirements for electrical equipment in hazardous locations are contained in 46 CFR 111.105. In that subpart, certain equipment is required to be listed by Underwriters Laboratories Inc. (UL), Factory Mutual Research Corp. (FM), or other independent laboratory recognized by the Commandant (G-MTH-2) for use in the hazardous location in which it is located. "Listed" means equipment included in a list published by an independent test laboratory acceptable to the Commandant and concerned with product evaluation, that maintains periodic inspection of listed equipment and whose listing states either that the equipment meets appropriate standards or has been tested and found suitable for use in a specified manner. The Canadian Standards Association (CSA) is also recognized for explosionproof and intrinsically safe certification. Also acceptable is intrinsically safe equipment tested and labeled by MET Electrical Testing Company.

The following general considerations apply to equipment selection and installation:

a. Division 1 equipment is satisfactory for Division 2 applications with the same Class and Group. Note that the explosionproof equipment label may not say "Division 1." If the label says it is suitable for Class I Group (__) locations, it means it is suitable for both Division 1 and Division 2 locations.

b. NEC Section 501-3(b)(1) requires devices in Class I, Division 2 locations, with make-and-break contacts to be within an enclosure approved for Class I, Division 1 locations or to be in a general-purpose enclosure with the current interrupting contacts either immersed in oil, enclosed in a hermetically sealed chamber, or in only nonincendive circuits. Examples of make-and-break contacts include relays, circuit breakers, servo-potentiometers, adjustable resistors, switches, connectors, and motor brushes. A nonincendive circuit is a circuit in which any arc or thermal effect produced under intended operating conditions of the equipment is not capable of igniting the specified flammable gas or vapor-air mixture. A hermetically sealed device is one which is manufactured so that it is completely sealed against entrance of an external atmosphere and in which the seal is made by soldering, brazing, welding, or fusion of glass, or the like.

c. NEC Section 501-3(b)(2) permits general-purpose enclosures to be used in Class I, Division 2 locations for resistance devices and similar equipment used with meters, instruments, and relays provided such equipment is without make-and-break or sliding contacts <u>and</u> the maximum operating temperature of any exposed surface will not exceed 80% of the ignition temperature of the gas or vapor involved.

d. Belt drives are acceptable if the belt is conductive and the equipment is grounded in accordance with NFPA 77. Acceptable belts have a resistance of approximately 6 megohms or less over an eight inch length, as determined by an industry standard test procedure, and are commonly designated as "static conductive."

e. Cables must not be located in any tanks containing flammable or combustible liquids, except to supply equipment or instrumentation specifically designed for, and compatible with, such location, and whose function requires installation in that location.

f. Vent ducts have the same classification as the space they serve. Fans for ventilating hazardous locations must be nonsparking; see 46 CFR 110.15-1(b)(16) for the definition of nonsparking. Nonsparking construction is not generally indicated by an independent laboratory listing, and must usually be verified by review and/or inspection. Vent fan motors must either be approved for the hazardous location or located outside the duct, 10 feet from the duct termination, in a non-hazardous area.

g. Alloys of aluminum, magnesium, and titanium, when struck by rusty steel, react with the iron oxide to produce a highly exothermic "thermite reaction." Care must be taken to provide adequate physical separation and/or surface coatings where these metals are used in moving components around steel.

7.5 <u>International Standards</u>. Electrical installations in hazardous locations must comply with 46 CFR 111.105, including those portions of the National Electrical Code, NFPA standards, and ISA standards referenced in that subpart. Compliance with recognized international standards, such as those of the International Electrotechnical Commission, may be acceptable for <u>temporary</u> <u>industrial</u> installations aboard MODU's. (See Appendix 11 for guidance.)

7.6 <u>Protection Types</u>. The various methods by which electrical and electronic equipment is made safe for use in hazardous areas may be divided into two major categories: (1) protection by enclosure or other physical separation between the electrical equipment and the hazardous atmosphere; and (2) protection by electrical design (making the circuitry unlikely to produce ignition of the hazardous atmosphere.) Examples of the first category include explosionproof and purged and pressurized enclosures, as well as oil immersion. The second category includes the intrinsically safe and nonincendive safety techniques.

Ignition-protection is another type of protection by design. Ignition-protected devices are intended for use aboard recreational boats and uninspected vessels in enclosed spaces that may occasionally contain gasoline vapors. They meet the testing requirements of UL 1500, which are not as stringent as those for explosionproof or intrinsically safe equipment. Ignition-protected equipment is not suitable for use in hazardous locations on inspected vessels other than oil recovery vessels.

7.7 Intrinsic Safety and Nonincendive Systems. For low power applications, such as instrumentation, control, and operation of solenoid valves, the use of intrinsically safe and nonincendive systems can reduce the likelihood of fire or explosion due to the ignition of flammable gas mixtures by electrical arcs or high temperatures. However, safety depends on their proper application, as these two forms of protection are not equal.

Section 501-3 of the NEC states: In Class 1, Division 2 locations, switches, circuit breakers, and make-and-break contacts ...shall have enclosures approved for Class 1, Division 1 locations...EXCEPTION: General-purpose enclosures shall be permitted, if current-interrupting contacts are...in circuits that under normal conditions (emphasis added) do not release sufficient energy to ignite a specific ignitable atmospheric mixture, i.e., are nonincendive. The word "nonincendive" means that under the conditions specified, there is insufficient energy to cause ignition. Nonincendive systems are only permitted in Division 2 and non-hazardous locations.

Nonincendive circuits are similar to intrinsically safe circuits, but no fault conditions or safety factors are applied, as the existence of a hazardous atmosphere in a Division 2 location is itself considered a fault condition.

In the past, much of the nonincendive circuitry that found its way into Division 2 locations was neither designed nor intended for use in hazardous locations. Only when a Division 2 application arose for a specific item was the circuit examined to see if it was nonincendive. Regulatory bodies typically reviewed manufacturer's analyses to see if voltage and current levels fell below the appropriate ignition curve with a reasonable margin of safety. If they did, the circuit was accepted to be nonincendive.

Today, much of the equipment installed in Division 2 locations has been designed to be nonincendive. This is especially true of sophisticated electronic equipment used in the drilling industry. Furthermore, manufacturers are recognizing the value of independent third-party approvals. In North America, standard setting bodies, such as the Instrument Society of America, Underwriters Laboratories Inc., and the Canadian Standards Association, have published or are presently developing safety standards for nonincendive equipment. Third-party certification agencies are using these standards to evaluate and list or label nonincendive equipment. Listed or labeled equipment provides the end user with a greater degree of confidence that the nonincendive equipment has been properly evaluated and will not present an unnecessary risk of fire or explosion. However, manufacturer certification of nonincendive circuits is acceptable; certification by a third-party testing agency is not required, and many acceptable nonincendive circuits bear no label or other marking by these agencies.

Section 500-2 of the 1987 NEC states: "Equipment and associated wiring approved as intrinsically safe shall be permitted in any hazardous (classified) location for which it is approved...Intrinsically safe equipment and wiring shall not be capable of releasing sufficient electrical or thermal energy under normal or abnormal (emphasis added) conditions to cause ignition of a specific flammable or combustible atmospheric mixture in its most easily ignitable concentration." Additional guidance on intrinsically safe installations is expected to be included in Article 504 of the 1990 NEC.

Intrinsically safe systems are permitted in all hazardous locations (Division 1, Division 2, as well as IEC Zone 0), provided they are approved for the proper hazard group.

Intrinsically safe portable battery-powered equipment, such as walkie-talkies and combustible gas detectors, are evaluated based on their internal circuity. However, equipment that is interconnected to other equipment, such as to the vessel's electrical system, is evaluated on a system basis. Since evaluations for intrinsic safety consider failure modes, faults in connected apparatus such as power supplies, meters, and recorders (regardless of their location, i.e., hazardous or non-hazardous) may affect energy levels in the circuit, and are fully evaluated.

In determining available energy levels, abnormal conditions include opening, shorting, and grounding of wires connected to the enclosures in the intrinsically safe portion of the system. In North America, two "reasonable" simultaneous faults are considered in assessing available electrical and thermal energy. Industry standards give detailed criteria for determining reasonable failure modes. Evaluations usually involve an in-depth circuit analysis, supplemented by actual ignition testing.

Intrinsically safe systems and portable equipment must be tested and approved for the intended application by a nationally recognized testing laboratory (currently UL, FM, CSA, or MET). For installed systems, listing reports should be reviewed to ensure that restrictions placed upon the equipment by the certification agency are recognized in the installation. In general, switches and other simple devices which do not store energy can be in hazardous locations when used with approved intrinsic safety (Zener) barriers that limit the energy in the circuit.

Safety also depends on proper installation. It is necessary to ensure that the system is connected correctly and that unsafe energy levels are not induced in intrinsically safe circuits by nearby non-intrinsically safe circuits. In evaluating intrinsically safe systems, it is important to know the restrictions imposed by the certification agency, and to have the installation information available that verifies that the restrictions, such as installed cable impedance, have been met. The following installation requirements should be followed:

a. Cables for use in intrinsically safe installations should meet the standards of 46 CFR 111.105-15(b). However, since intrinsically safe circuits are inherently power limited, cable constructions other than those specified in 111.60 may be accepted, provided the cable has an adequate voltage rating. Many specialty cable types, which are not constructed to meet the standards referenced in 46 CFR 111.60, are used in intrinsically safe circuits, particularly in industrial systems such as down-hole well testing instrumentation. Flame propagation is a concern with any cable which penetrates a deck or bulkhead. If a particular cable type is self-extinguishing, but cannot comply with the IEEE-45 or IEC 332-3 (Cat. A) fire tests, then it may be run singly (not in or near bundles or cable trays with other cables).

b. Equipment in weather locations must be made watertight.

c. Cable insulation must be compatible with the environment. Some installations may be in cargo tanks.

d. As a general rule, conductors should be no smaller than #18.

e. Cables for intrinsically safe systems must be isolated from other cables to prevent compromise due to induction or insulation breakdown. This is to be accomplished by maintaining two inch spacing, or by using grounded metal barriers or shielded cable.

f. At a termination, intrinsically safe circuits must be isolated from other intrinsically safe circuits, other low-energy level circuits, and all power circuits (see ISA RP 12.6).

g. More than one intrinsically safe circuit of the same system may be run in a multiconductor cable (see ISA RP 12.6).

h. Cables containing conductors for intrinsically safe systems must not contain conductors of non-intrinsically safe systems.

i. In general, an intrinsically safe barrier should be located in a non-hazardous location. If it is in a hazardous location, the barrier itself must be suitable for the location.

j. Energy storing equipment must be explicitly approved by the certification agency when used with a barrier.

k. Passive devices that do not store energy, such as switches, thermocouples, resistances, and LED's may be connected to barriers without further certification, provided they are not part of a unit containing other electrical circuits.

For low power applications, intrinsically safe systems offer advantages over "add-on" protection, such as explosionproof or purged and pressurized enclosures. Intrinsic safety is not jeopardized by a missing or loose bolt, a scratched flange, an unpoured cable seal, a stuck interlock, or mechanical damage. The intrinsically safe circuit is less maintenance dependent and provides a lifetime of protection with relatively little care.

Although the Electrical Engineering Regulations reference the 1976 edition of ISA RP12.6 for cables in intrinsically safe systems, that standard may also be used for other aspects of intrinsically safe installations. The guidelines of the 1987 revision of this standard may also be followed. This later edition contains information on the combination of intrinsically safe apparatus under the entity concept, which allows users to determine acceptable combinations of intrinsically safe apparatus and connected associated apparatus that have not been tested and approved for interconnection in such combination. This approach requires each intrinsically safe apparatus to have a control drawing that specifies parameters for the selection of the associated apparatus. The control drawing is provided by the manufacturer of the intrinsically safe or associated apparatus to specify the allowed interconnections between the intrinsically safe and associated apparatus.

7.8 Purged or Pressurized Equipment. Purged or pressurized equipment and enclosures are permitted by the Electrical Engineering Regulations (46 CFR Subchapter J) for the protection of hazardous area equipment. The regulations require that this type of equipment be constructed to the National Fire Protection Association (NFPA) Standard 496, Purged and Pressurized Enclosures for Electrical Equipment.

Purged or pressurized systems pressurize the atmosphere within an enclosure with a non-hazardous gas (usually air from a non-hazardous location), thereby preventing the hazardous atmosphere from coming in contact with electrical equipment within the enclosure.

The NFPA standard addresses pressurized instrumentation and other small enclosures in Class I locations, power equipment enclosures in Class I locations, pressurized instruments and other small enclosures in Class II locations, and pressurized power equipment in Class II locations.

The standard defines pressurization and purging as follows:

> Pressurization: The process of supplying an enclosure with clean air or an inert gas with or without continuous flow at sufficient pressure to prevent the entrance of combustible dusts.
>
> Purging: The process of supplying an enclosure with clean air or inert gas at sufficient flow and positive pressure to reduce to an acceptably safe level the concentration of any flammable gas or vapor initially present and to maintain this safe level by positive pressure with or without positive flow.

There are three types of purging protection in NFPA 496, Type X, Y, and Z:

> Type Z purging reduces the classification within an enclosure from Division 2 to nonhazardous. With type Z purging, a hazard is created only if the purge system fails at the same time that the normally nonhazardous areas become hazardous. For this reason, it

is not considered essential to remove power from the equipment upon failure of the purge system.

Type Y purging reduces the classification within an enclosure from Division 1 to Division 2. The equipment and devices within the enclosure must be suitable for Division 2. This requires that the enclosure not contain an ignition source under normal conditions. Thus, a hazard is created within the enclosure only upon simultaneous failure of the purge system and of the equipment within the enclosure. For this reason, it is not considered essential to remove power from the equipment upon failure of the purge system.

Type X purging reduces the classification within an enclosure from Division I to nonhazardous. Because the probability of a hazardous atmosphere external to the enclosure is high and the enclosure normally contains a source of ignition, such as a hot element or arcing contact, it is important that any interruption of the purging results in deenergizing the equipment. Also, it is essential that the enclosure be tight enough to prevent the escape of sparks. When type X purging is used in purged power equipment enclosures in Class I locations, power to the equipment should be immediately removed upon loss of pressurization, unless immediate loss of power would result in a more hazardous condition, such as not allowing for the safe shutdown of a process or system.

The NFPA standard presents some diagrams of acceptable installations for Types X, Y and Z purging. These diagrams are shown in Figure 7.

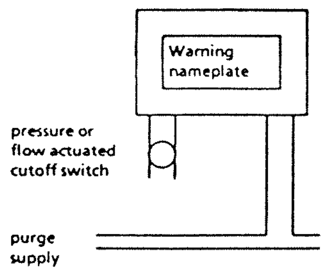
The NFPA standard requires that a nameplate be mounted on the enclosure in a prominent location so that it can be seen before someone opens the enclosure. The nameplate should contain the following statement (or equivalent):

"Enclosure shall not be opened unless the area is known to be nonhazardous or unless all devices within have been deenergized. Power shall not be restored after enclosure has been opened until enclosure has been purged for ______ minutes." (Note: The blank must be filled-in by the manufacturer with the proper purge time.)

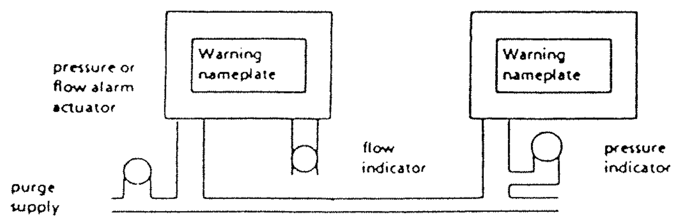
It is apparent from this requirement that purged or pressurized enclosures should be designed in such a manner that normal operation of the equipment does not require that the enclosure be opened. Therefore, openings in the enclosures for inserting computer disks or slots for computer printouts and normal procedures that require the enclosure to be opened to retrieve data or take readings is not acceptable.

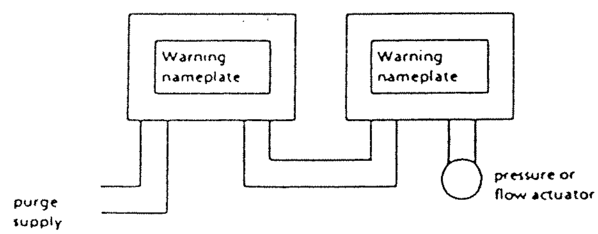
All three types of purging require the warning nameplate. Type X purging generally requires an interlock which immediately deenergizes all circuits which are not suitable for Division 1 areas. Type Y purging does not require an interlock but requires an alarm which operates when the enclosure is opened. Type Y is suitable for Division 1 if the internal components are suitable for Division 2. Type Z purging is suitable for Division 2 and requires an alarm, but does not place restrictions on internal components.

Typical Type X Purging



Typical Type Y and Type Z Purging





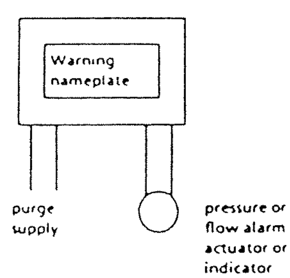


FIGURE 7

Purged or pressurized equipment may be used in lieu of explosionproof equipment for all hazardous locations. Purged or pressurized equipment may not be used as a substitute for intrinsically safe apparatus. Purged or pressurized systems need not be approved by an independent testing agency, but are reviewed and approved for the particular application during vessel plan review.

Special care must be taken to ensure that the protective gas is from a nonhazardous source and cannot be contaminated by a hazardous source. Vent fan operation should be monitored by air flow, not simply by motor operation. Where it is necessary to open a purged or pressurized enclosure, as for maintenance or repair, gas detection equipment may be required to ensure that a flammable atmosphere does not become trapped within the enclosure.

Although the Electrical Engineering Regulations cite the 1974 edition of NFPA 496, the guidelines of the 1982 revision of this standard may be used. The revised standard recognizes the use of purged control rooms in Class I locations and pressurized control rooms in Class II locations. The requirements for control rooms may be used both for spaces which are structurally part of the vessel and for containerized compartments such as may be used for industrial functions aboard a MODU.

Compressed air operated lighting fixtures (turbine lights) are both powered and purged by the air supply. These fixtures are acceptable for use in cargo handling rooms.

7.9 Explosionproof Equipment. When electrical equipment is installed where flammable gases and vapors may be present, an "explosionproof" enclosure may be used to allow the equipment to operate safely. The explosionproof enclosure concept recognizes that flammable gases and vapors may enter the enclosure, and assumes that a source of ignition will create an internal explosion. The enclosure is designed to withstand the explosion and prevent it from propagating to the hazardous atmosphere surrounding the enclosure. Explosionproof enclosures are not designed to be gastight, but are normally intended to "breath." Flammable gases or vapors may enter an enclosure as it breathes due to changes in atmospheric pressure, ambient temperature, or both. Conversely, gastight equipment is not explosionproof.

Explosionproof enclosures usually have covers which can be removed or opened for making connections and adjustments, and for maintenance. The dimension of the gap between an enclosure's flanges and metal-to-metal joints determine its effectiveness. An explosion will propagate through this gap if the gap's width is greater than the maximum experimental safe gap (MESG). If the gap is less than the MESG, the velocity of the emerging jet of hot gases and the velocity of the external gases mixing with the jet are so great that cooling takes place and ignition cannot occur. When the hot gases from an explosion pass through this region, some energy is absorbed by the expansion of gases (refrigeration effect), and some energy is absorbed by hot gases mixing with cool gases outside of the enclosure. A sufficient amount of energy must be transferred from the hot gases to the surrounding air or enclosure; otherwise, an explosion will occur.

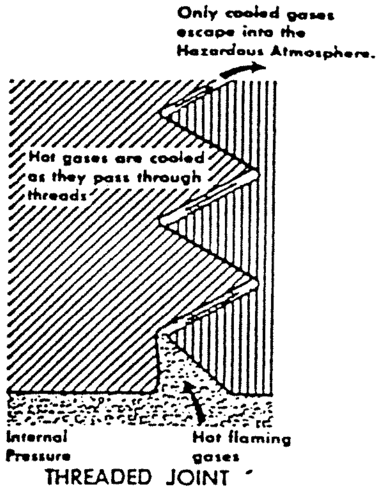


FIGURE 8

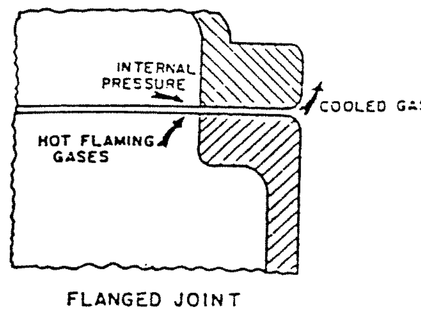


FIGURE 9

Several explosionproof enclosure cover types are used, depending on their application. The most simple and effective cover is a threaded joint (see Figure 8). When an explosion occurs, the cover threads are forced tight against the body threads. Hot gases are cooled as they spiral along these threads. A gasket under the cover's flange is located outside of the cooling region and does not interfere with the metal-to-metal contact of the threads. Other types of enclosure openings or accesses include flanged covers (See Figure 9) and cylindrically shaped openings. These enclosures use precision machined metal-to-metal joints which provide a straight path from inside the enclosure to the outside atmosphere. During an explosion, numerous cover screws prevent flange and enclosure distortion. Explosionproof equipment in weather locations must be made watertight or waterproof. Explosionproof enclosures are not normally designed to be watertight. In making these enclosures watertight, care should be taken that there is not interference with the flame-quenching surfaces and that gaskets are external to these surfaces.

When a flame ignites a gas, it may result in an explosion which causes a large increase in pressure. Due to the rapid increase in pressure, less energy is required for further ignition and flame propagation. An explosion occurs rapidly, causing a front between burned and unburned compressed gas. If the expanding gas is restricted, channeled, or impeded, pressure piling will occur. Pressures can occur which are ten times higher than pressures which occur when there is no impediment to expansion. Pressure piling is particularly serious in pipes and conduit. To reduce the effects of pressure piling, cable seal fittings must be installed within eighteen inches of the enclosure for each conduit. Where two explosionproof enclosures are connected and located less than 36 inches apart, only one seal is necessary in the conduit between them.

Equipment which is required by the Electrical Engineering Regulations to be explosionproof must be specifically tested and approved by a nationally recognized testing laboratory (UL, FM, and CSA are presently acceptable) for use in a Class I Division 1 location and the group of the hazard present, and be labeled as such.

In typical test programs, the enclosure is placed in a test chamber which has explosion pressure-recording devices attached to it. Both the enclosure and the chamber are charged with a specified gas. The gas inside the enclosure is ignited, and the resulting explosion is observed for propagation to the surrounding chamber's atmosphere. The explosion tests are repeated over the entire explosive range of the gas or vapor's fuel-air mixture. The enclosure must withstand the internal pressure from the explosion without bursting or loosening its joints. Explosion damage to equipment inside the enclosure must not occur during testing unless the damaged equipment can readily be replaced. All tests are conducted using maximum loads, short circuit, or worst case conditions. Typically, ten tests are conducted over the entire flammable range for each device. Enclosures are usually tested for a period of one (1) minute using a hydrostatic pressure based on the maximum observed internal explosion pressure. Seals must withstand for one (1) minute a hydrostatic test pressure of four times the maximum explosion pressure.

Equipment which generates heat is evaluated to ensure that its surface temperature is not high enough to cause autoignition of the surrounding hazardous atmosphere. North American practice recognizes 14 temperature ratings for Class I locations. The Class I temperature ratings are listed in NEC Table 500-3(b) and the Class II temperature limits are in NEC Section 500-3(d). The Class I temperature ratings are included in Table 3 for convenience.

TABLE 3

NEC ART. 500 - **TABLE 500-3(b)**

MAX. TEMP. °C	°F	MARKING
450	842	T 1
300	572	T 2
280	536	T 2 A
260	500	T 2 B
230	446	T 2 C
215	419	T 2 D
200	392	T 3
180	356	T 3 A
165	329	T 3 B
160	320	T 3 C
135	275	T 4
120	248	T 4 A
100	212	T 5 *
85	185	T 6 *

Marking shall not exceed auto ignition temp. of the atmosphere encountered.

*** Non-heat producing equipment, and that with a temp. of 100°C or less, need not be marked.**

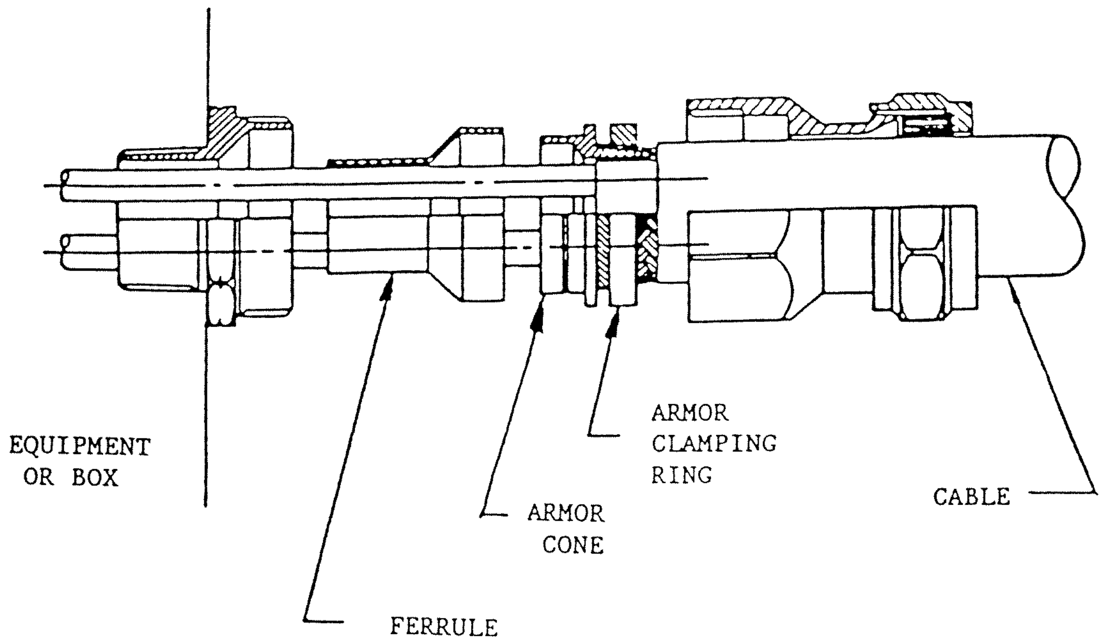
Flame arresters are sometimes used in explosionproof enclosures to reduce maximum explosion pressure and to protect any incoming air lines. Types of flame arresters include porous metal plugs made of sintered metal, a baffle-type breather similar to an automobile muffler, a special fitting with a loosely fitted thread, and a spiral wound corrugated metal fitting. These configurations causes the flame to spread through paths which cool the gases by heat transfer to the metal from the atmosphere or make the escaping explosion's hot gases turn sharp corners, allowing them to cool.

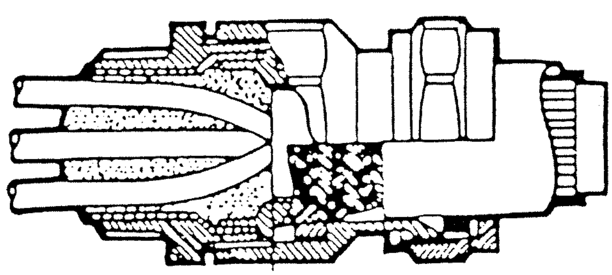
Explosionproof receptacles and plugs are designed as a pair. Mechanical interlocking is used between the plug and receptacle. When a plug is inserted, electrical contact cannot be made until the mated plug and receptacle assembly has established its explosionproof integrity. To prevent explosions from propagating, many threads are usually engaged before electrical contact is made or broken.

An explosionproof enclosure is not effective without sealed conductor entrances. Seal fittings allow an explosion to be contained within an enclosure, prevent pressure piling, and prevent the transmission of gases or vapors between enclosed electrical systems installed in Division 1, Division 2, and ordinary locations. Seal fittings are usually attached by a short piece of rigid conduit to an enclosure for switches, circuit breakers, fuses, relays, resistors, or other apparatus which may produce arcs, sparks, or a high temperature. Not more than eighteen (18) inches of pipe or rigid conduit may be used, and at least five (5) full nipple threads must be engaged at each end. Explosionproof unions, couplings, elbows, capped elbows, and conduit bodies are the only permitted fittings between the sealing fitting and the enclosure. All such components, including the seal fitting and seal compound, must be approved by the testing laboratory for the intended purpose. Seal fittings are either shop fabricated or poured in the field. The cable gland (shown in Figure 10) is a relatively new type of seal. Use of a cable gland allows for a cable to be assembled in a clean shop environment and for simple field connection and installation. A more traditional sealing method uses a "poured" seal (See Figure 11) which is completed in the field. The seal is poured after the cables have been brought into the enclosure. Mineral insulated cables require a different type of explosionproof seal fitting than shipboard marine cables.

Alterations to explosionproof equipment may destroy explosionproof protection. Explosionproof <u>enclosures</u> are approved for certain applications, such as the installation of terminal strips, relays, etc., and may be internally modified to meet these intended applications within the limits specified in the approval. Explosionproof <u>assemblies</u> may not be modified in any way. Enclosure modifications must are limited so that they do not affect piling from internal volume changes, impair flame-quenching paths and surfaces, or reduce enclosure structural strength. Alterations different from the configuration as tested by UL, FM, CSA, or other approved laboratories, void the approval.

Equipment which is certified for a hazardous location should usually be repaired by a qualified facility. Product certification agencies usually qualify repair facilities that have demonstrated their knowledge, expertise, and capability to repair explosionproof equipment. Each facility is qualified to repair specific types of equipment such as motors, generators, telephones, etc.





CABLE GLAND

FIGURE 10

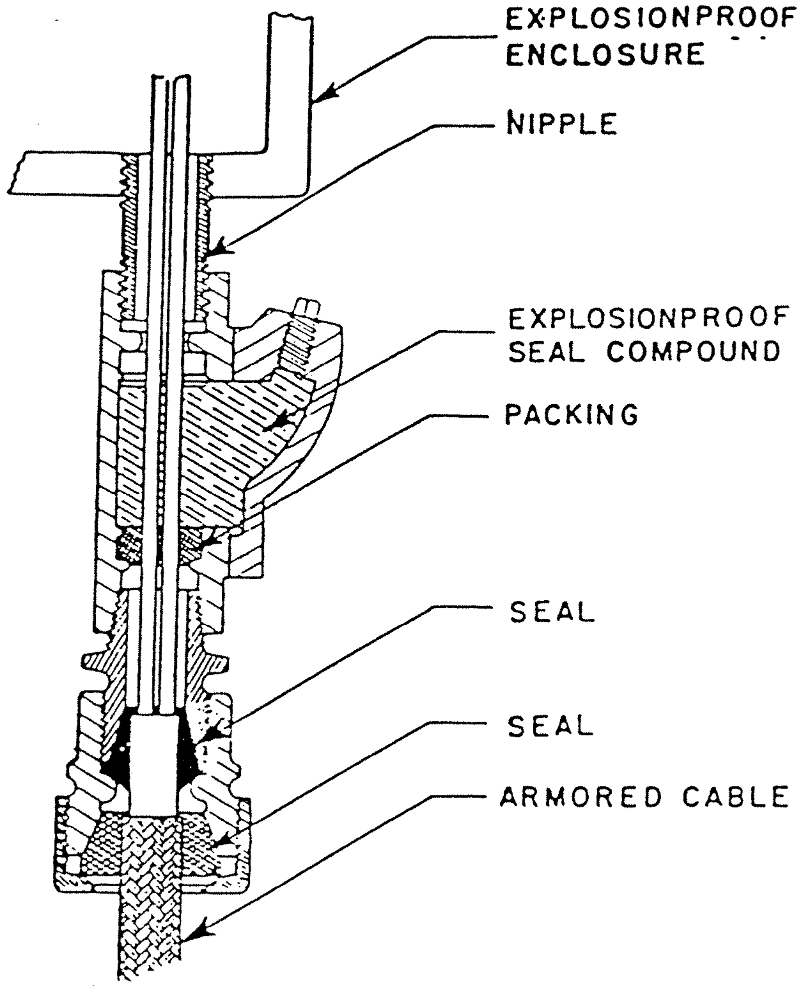


FIGURE 11

When the explosionproof equipment is repaired, a label is usually affixed to indicate that the equipment conforms to the same rules which applied when it was new. The following guidelines can be used to maintain explosionproof equipment:

1. All cover screws and bolts must always be tight while circuits are alive. Leaving one screw or bolt loose can render equipment unsafe. Bolts or screw types other than those provided with the equipment should not be used.

2. Hammers and other tools must not be allowed to damage threaded joints or flat machined surfaces of flanged joints. All surfaces that form part of a flame path must be protected from scratches and other mechanical defects.

3. Flange surfaces and threaded joints should be cleaned free of old grease and other foreign materials. A light oil film or lubricant should be applied to both sides of the joint immediately before assembly. When reassembling, there should be no foreign particles on joint surfaces.

4. Threaded covers, flat joints, surfaces, rotating shafts, bearings, and operating shafts should be lubricated to protect against corrosion. Abrasives or files should never be used to remove corrosion products from threaded or flanged joints. Equipment which is corroded should be replaced.

5. Explosionproof equipment must not be modified, except as allowed by the approval laboratory, and the equipment nameplate should not be obscured.

It should be mentioned that encapsulation, often called "potting," is not considered equivalent to explosionproof protection and is not a recognized method of protection for electrical equipment in hazardous locations. While embedding a component in a solid or semi-solid material such as plastic, epoxy, ceramic, or wax may effectively isolate an ignition source from the surrounding flammable atmosphere, there are currently no recognized standards for encapsulation for safety purposes. In some circumstances, potting can increase the risk of ignition.

8. Wire and Cable

8.1 General. A wire is a conductor with functional insulation only, for use inside an enclosure. A cable consists of one or more insulated conductors provided with a protective covering of either a watertight metallic sheath or an impervious non-metallic sheath compatible with the insulation. Most shipboard wiring is accomplished using multiconductor cable.

Wire and conduit may be used for shipboard wiring. However, Due to the high cost, labor-intensive installation, susceptibility to corrosion, and problems with flexing hull structures, conduit is rarely used. Where it is used, the installation requirements of the NEC should be followed (i.e., requirements for sizes and fill, bends and bending methods, couplings and connectors, and support methods and locations), and the additional aspects of a marine installation (corrosion, moisture, watertight bulkhead penetrations, and flexing) should be addressed. Additionally, the wire must meet the requirements of 46 CFR Subpart 111.60 for insulated conductors.

8.2 Types of Cable. The regulations for the construction of shipboard electrical cable are contained in 46 CFR 111.60. These regulations require shipboard cable to be constructed in accordance with one of the following:

(1) Cable constructed in accordance with Section 18 of IEEE Standard 45 (46 CFR 111.60-1);

(2) Cable constructed in accordance with MIL-C-915 and of a type that meets the flammability tests of Section 18.13.5 of IEEE Standard 45 (46 CRF 111.60-1(a));

(3) A cable with polyvinyl chloride (PVC) insulation with a nylon jacket that meets 46 CFR 111.60-1(b) (Type N Cable); or

(4) Cable constructed to another standard if accepted for specific application by Commandant (G-MTH-2).

It should be noted that some types of cable constructed in accordance with MIL-C-915 are not required to meet the flame propagation requirements of IEEE Standard 45. Therefore, it may be necessary to verify that a MIL-C-915 cable type meets the flammability test of IEEE-45. At this time, there is little MIL-C-915 cable available; most has been replaced with the new low smoke mil-spec cable.

Type N cable will have embossed or printed on the cable either information required by Section 18.8 of IEEE-45, or information required by Section 310-11 of the NEC, the manufacturer's name, identification code, voltage rating, number of conductors, and conductor size. Since this information is not unique to shipboard cable, the manufacturer may need to provide certification that the cable meets 111.60-1(b) including the flammability test of IEEE-45.

The design emphasis for merchant vessel cable has historically been placed on the harsh ship construction environment (nearby welding, pulling cable through bulkheads, and subjecting cable to constant mechanical abuse), as well as on the shipboard operating environment (clamped assemblies, large cable bundles, and exposure to a wide range of temperatures, high humidity, and oil). Additional considerations for naval vessels have included longitudinal water propagation resistance, overload conditions, and circuit integrity under fire conditions. The U.S. Navy has also had to explore smaller diameter, lighter weight cable constructions in order to conserve space and reduce topside weight. Only in recent years, however, have several disastrous shipboard fires focused attention on the damage to health and property caused by fire propagated by cables. In fires aboard ships, cableways have been blamed for spreading relatively small and confined fires and generating dense smoke and toxic and corrosive products of combustion, compounding the firefighting problem.

These issues have led to significant changes in design and approval procedures affecting both commercial and Navy shipboard cable which are not addressed in the Electrical Engineering Regulations. Underwriters Laboratories Inc. (UL) has developed a listing program for shipboard electrical cable. There are two types of acceptances under this program. The first lists cable which has been manufactured in accordance with the IEEE-45 standards and bears the IEEE designation on the cable. The second acknowledges cable that does not meet the specific construction requirements of IEEE-45 but has been shown by a comprehensive test program to meet the intent of that standard. Such cable will not have an IEEE designation. It will have a temperature marking which indicates the appropriate IEEE-45 ampacity ratings to be used for that cable. The ampacities of cables having a UL shipboard listing may be found in Tables A6, A24, and A25 of IEEE-45. All UL cable listings for shipboard applications must be for a maximum conductor temperature of 100°C or less. For cables listed by UL for 100°C conductor temperature, use the (S, GTV) column ampacities of Tables A6 and A24 of IEEE Standard 45. For cables listed by UL for 90°C, use the (E,X) column ampacities. If UL listed for 75°C, use the (T) column ampacities. These ampacities should be used regardless of the actual insulation composition of the cables. Where UL cable temperature ratings exceed 100°C, the ampacities for 100°C rated (S, GTV) IEEE cable should be used.

The 100°C limitation does not apply to DC cable utilized in MODU industrial systems. As an alternative to the cable construction and sizing requirements of 46 CFR 111.60, DC cables on MODUs may meet the requirements of the International Association of Drilling Contractors (IADC) Standard DCCS-1, "Interim Guidelines for Industrial System DC Cable for Mobile Offshore Drilling Units", attached as Appendix 5. In accordance with this standard, marine cables may be listed by UL for up to 110°C. The current-carrying capacity of 110°C rated cables is 1.14 times the 90°C (E,X) rating column in IEEE-45. If the UL listing is for 100°C or less, however, the cable cannot be used at the 110°C rating. Industrial system cable rated and utilized (sized) at 110°C may be run with other cables, without maintained spacing (i.e., banked) if derated in accordance with Note 6 of Table A6 of IEEE-45.

The Naval Sea Systems Command (NAVSEA) has published two new military specifications on the construction of shipboard electrical cable. The first, MIL-C-24640 (Cable, Electrical, Lightweight, for Shipboard Use), addresses lightweight power, lighting, and communication cable with a crosslinked polyolefin jacket. The second, MIL-C-24643 (Cable and Cord, Electrical, Low Smoke, for Shipboard Use), addresses electrical cable which exhibits low smoke generation characteristics when subjected to specific smoke and flame tests. The ampacities for these Navy cables may be found in "Cable Comparison Handbook, HDBK-299, issued 3 April 1989." Although this handbook addresses standard Navy cable size designations, it should also be used for the AWG sized cables of MIL-C-24640 having similar (not necessarily identical) cross-sectional areas.

Industry needs have led to modifications to acceptable cable construction on vessels. In most cases, these modifications are superior to the minimum requirements and should be permitted. For example, MODUs operating in the North Sea are often required by local authorities to have an additional jacket over cable armor. The addition of such a jacket on an already acceptable cable construction can be accepted, provided that the finished cable meets the pertinent cable test requirements of IEEE Std. 45 (i.e. bending, drip test, flammability). Another example of an acceptable alteration would be the replacement of the PVC outer jacket on an IEEE cable with a low smoke jacket meeting MIL-C-24643.

The first standard in the United States that included testing typical cable installations for flame propagation resistance was IEEE Standard 383-1974, developed as a test standard for cabling in nuclear power plants. The IEEE Marine Transportation Committee subsequently adopted a similar method for fire testing in IEEE Standard 45-1977. The Electrical Engineering Regulations require shipboard cable to meet these IEEE-45 flammability requirements. The IEEE-45 test attempts to simulate a realistic cableway fire situation in evaluating flame propagation parameters of a bunched vertical cable installation. At this time, the IEEE-45 procedure does not address toxicity, smoke evolution, or corrosive gas generation. The procedure of the International Electrotechnical Commission (IEC) Report 332 Part 3 is another practical method of testing the flame propagation characteristics of cables in a bunched configuration. The test is similar to the IEEE-45 procedure, but is more specific in defining the chamber size and heat input and is basically concerned with the total volume of combustible material in a cable run. Category A of this test uses a sufficient number of 3.5 meter lengths of cable to obtain 7 liters/meter of total combustible material, with the cables touching and mounted vertically on a steel ladder. Cables constructed in accordance with IEC 92-3 (Electrical Installations in Ships, Part 3: Cables (Construction, Testing, and Installations)) may be accepted as equivalent to those required by 46 CFR 111.60 provided they meet the flame propagation test requirements of IEC Report 332 Part 3, Category A. Flame proagation resistance should be verified by an independent third party testing organization. The ampacities tabulated in the ABS Rules, Table 35.2, should be used for cables constructed to IEC 92-3, except that notes 2 and 3 to that table should not be used, as they are not comparable to IEEE-45. The values shown in the table may be used for a single bank installation. For double-bank installations, the correction factor of IEEE-46 table A6 applies. The IEC is in the process of replacing IEC 92-3 with significantly revised requirements in 92-350 series documents. While completion of this task is several years away, at this time it appears that the newer standards will not be comparable to present marine cable standards and will not be equivalent to the cable standards referenced in Subchapter J.

Type N cable (PVC-insulated cable with a nylon jacket over each conductor, and an outer cable jacket) is based upon shoreside type T building wire construction, the use of which is addressed in NEC Table 310-13. Shipboard Type N cable is required by 46 CFR 111.60-1(b)(1) and (3) to meet the PVC insulation and nylon insulation covering thickness requirements of UL 83 for type THWN wire, and the other requirements of IEEE-45 for a Type T cable, such as outer jacket requirements and conductor stranding. The nylon jacket material must meet the requirements of ASTM D789 Type VIII.

Although NEC Article 310-3 permits solid conductors for size No. 10 AWG and smaller, solid conductors are unacceptable for shipboard power cables. Nicks on solid conductors from insulation removal are likely to lead to conductor breakage with shipboard vibration.

The problem of shipboard cable flammability was addressed internationally in IMCO Resolution A.325 (IX), which was adopted on November 12, 1975. Paragraph (e)(ii) of Regulation 23 of that Resolution requires that all electric cables be at least of a flame retardant type and installed in a manner that does not impair their original flame retarding properties. This requirement was subsequently adopted in the 1981 Amendments to SOLAS 1974 which became effective September 1, 1984. Attempting to provide guidance on how to meet the SOLAS Amendments, IEC Technical Committee 18 developed guidelines which stated that cables should either be qualified using a flame propagation test procedure for bunched cables (such as IEC Report 332 Part 3), or that special precautions be taken. These special precautions can be achieved by the use of fire barriers as follows:

(1) Fire stops having at least B-0 penetrations are to be fitted:

(A) At cable entries at the main and emergency switchboard,

(B) Where cables enter engine control rooms,

(C) At cable entries at centralized control panels for propulsion machinery and essential auxiliaries,

(D) At each end of totally enclosed cable trunks.

(2) In enclosed and semi-enclosed spaces, cable runs are to:

(A) have either a fire protection coating applied:

(i) to at least 1 meter in every 14 meters for horizontal runs; and,

(ii) to the entire length of vertical runs; or,

(B) be fitted with fire stops having at least B-0 penetrations every second deck or approximately 6 meters for vertical runs and at every 14 meters for horizontal runs.

The cable penetrations are to be installed in steel pipes of at least 3 mm thickness extending all around to twice the largest dimension of the cable run for vertical runs and once for horizontal runs, but need not extend through ceilings, decks, bulkheads or solid sides of trunks. In cargo areas, fire stops need only be fitted at the boundaries of the spaces.

In addition to the standards referenced in 46 CFR 111.60-1, cable constructed in accordance with one of the following can be accepted:

(1) Cable having a UL shipboard cable listing;

(2) Cable constructed and labeled in accordance with MIL-C-24640;

(3) Cable constructed and labeled in accordance with MIL-C-24643;

(4) Cable constructed in accordance with IEC 92-3 and meeting IEC Report 332-3 Category A (independent test laboratory certification should be provided);

(5) For DC industrial systems on MODUs, cable meeting the requirements of IADC Standard DCCS-1;

(6) Cable constructed in general accordance with an above standard but modified in a manner clearly superior to the minimum requirements specified. Examples of such modifications have been discussed above.

8.3 Unique Applications. Special purpose cables may be used for unique applications where there is a compelling reason for deviating from the cable construction standards discussed above in order to satisfy system requirements. Such special purpose cables may include coaxial, triaxial, and low noise signal cables. Exceptions to the construction and testing requirements for such cables exist in both Section 19.1 of IEEE-45 and SOLAS II-1/45.5.2. The primary concern with these cables is flame propagation. If a particular cable type cannot be shown to comply with the IEEE-45 or IEC 332-3 (Cat A) fire tests, then the special precautions discussed earlier should be used to achieve a flame propagation resistant installation. If special purpose cables are run singly (not in or near bundles or cable trays with other cables), then self-extinguishing construction is acceptable.

As discussed in Section 7 of this guide, cables in intrinsically safe circuits need not meet the cable construction requirements of 46 CFR 111.60. These cables must have sufficient dielectric strength for the maximum voltage in the circuit, and must be of self-extinguishing construction and run singly, comply with the IEEE-45 or IEC 332-3 (Cat. A) fire tests, or be installed using the special precautions to achieve a flame propagation resistant installation.

Fiber optic cable is not currently addressed in 46 CFR Subchapter J or in IEEE-45. Since fiber optic cables present no shock or ignition hazards, concern is limited to the flame propagation issue. Fiber optic cables should meet the flammability test of Section 18 of IEEE-45, or be installed in accordance with the special installation precautions discussed earlier.

8.4 Ampacity. The ampacity of a cable is the maximum current-carrying capacity of the cable, based on the cross-sectional area of the conductors, maximum allowable conductor temperature for the insulation used, and the ambient temperature. The temperature rating of a conductor is the maximum temperature, anywhere along its length, that the conductor can withstand for a prolonged period without serious degradation of its insulation. Ampacities for many common conductor sizes and insulation types have been calculated, using procedures such as the Neher-McGrath method, and tabulated for ease of reference and consistency. Conductors with a temperature rating above the maximum ambient temperature must be used. Tabulated ampacities should be corrected for the anticipated ambient temperature and method of cable installation (banking of cables) using the ampacity correction factors applicable to that table. Adjacent or closely-spaced cables both raise the ambient temperature and impede heat dissipation.

The ampacities of IEEE-45 type distribution, control, signal, and mineral insulated cables are tabulated in Tables A6, A24, A25, and A21 of IEEE-45, respectively. It is important to read the notes for each table to know the ambient temperature and method of cable installation upon which the tabulated ampacities are based, so that the proper correction factors may be applied. Ampacities should be adjusted as noted to suit the ambient temperature in which the cable is installed if it differs from 45°C for Tables A6, A24, and A25 or from 50°C for Table A21. IEEE-45 restricts type T conductor insulation to a maximum ambient temperature of 50°C, types E and X to 60°C, and types S and GTV to 70°C.

The distribution type cable ampacities in Table A6 are for marine installations with cables arranged in a single bank per hanger. These values are 85% of the Insulated Cable Engineers Association (ICEA) calculated ampacities, which are based on cables installed in free air, that is, with at least one cable diameter spacing between adjacent cables. Distribution cables that are double banked must be derated to 80% of the tabulated current.

The ampacity of a four-conductor cable, where one conductor is the neutral which carries only the unbalanced current (normally small) from the other conductors, is the same as that of a three-conductor cable as listed in Table A6 of IEEE-45 or a 3-4 conductor cable as listed in Table 35.2 of the ABS Rules, as appropriate. Where four or more current-carrying power conductors are used in a cable, as in a MODU topdrive system, the maximum current carrying capacity of each conductor must be reduced in accordance with the number of power conductors in a cable (not in a tray). Derating factors can be found in Note 8 to Tables 310-16 through 310-31 of the NEC.

The tabulated ampacities of IEEE-45 Table A6 are used for UL listed shipboard distribution type cables, according to the procedure described previously in this NVIC. The tabulated ampacities in NAVSEA HDBK-299 are used for cables constructed in accordance with MIL-C-915, MIL-C-24640, or MIL-C-24643.

8.5 Minimum Conductor Size. The Electrical Engineering Regulations specify minimum cable conductor sizes of 22 AWG for thermocouple and pyrometer cables, 14 AWG for lighting and power cables, and 18 AWG for other cable conductors. The regulations also require each wire to be at least 18 AWG, and wires in switchboards to be at least 14 AWG. These minimum sizes are considerably larger than the conductors commonly found in ribbon cables, used to interconnect printed circuit boards and computer system components.

Where ribbon cables or similar small conductor size cables are recommended for use in low-power instrumentation, monitoring, and control circuits by the equipment manufacturer(s), the use of such cables may be permitted. Additional mechanical protection may be required to protect the conductors from parting due to mechanical damage or flexing. Ribbon cables are usually found within equipment or consoles. However, they are sometimes used externally to interconnect modules. The location of the cable aboard the vessel and the function of the circuit will determine the extent of mechanical protection required, if any.

The requirement for 14 AWG minimum wire in switchboards was written with full voltage, field-wired switchboard equipment in mind. Wire smaller than 14 AWG may be considered for low voltage, low-power circuits within switchboards.

8.6 Flexible Cord. Flexible electric cords and cables may be used only as allowed by Table 400-4 and Sections 400-7 and 400-8 of the NEC, per 46 CFR 111.60-13. They must not be used for fixed wiring, unless they are dual rated as both flexible cable or cord and shipboard cable listed by UL. No. 18 AWG conductors are permitted in power and lighting circuits only for portable applications. The IADC Standard DCCS-1 for DC cables on MODU's accepts high-flex single conductor cables constructed to the requirements of the American Association of Railroads (AAR) Specifications S-501 and 591. Certain high-flex strandings for large conductor sizes (such as 535,000 circular mils.), originally developed for locomotive use, have been incorporated (with flame propagation resistance) into the IEEE-45 cable construction standards.

8.7 Color Coding. The Electrical Engineering Regulations do not require the use of any particular conductor color coding scheme. The only requirement is that an insulated equipment grounding conductor in a cable must have green braid or insulation, per 46 CFR 111.05-33(b). Different color codes for circuit conductors may be found in IEEE-45 Section 18.5 and NEC Sections 210-5 and 310.12. Although the regulations do not require the use of a specific color scheme for the ungrounded conductors of a circuit, it is recommended that some consistent coloring or marking practice be used for multiwire circuits in order to provide positive identification of circuit conductors and facilitate troubleshooting and repair.

8.8 Cable Installation. Each cable installation must meet the general requirements of IEEE-45 Sections 20 and 22, with the exception of 20.11 which is superseded by 46 CFR 111.60-19. The use of nylon or plastic cable straps is explicitly recognized in 20.5 for horizontal runs where the cable will not fall if the strap fails. They are permitted where the cable strap is used to maintain spacing and not for support of the cables.

Section 20.5 of the IEEE Standard requires metallic band strapping to be a minimum of 5/8 inch wide. Deviations from this dimension may be permitted where the width of the strap provides sufficient mechanical strength to support the cables and does not cause chafing of the cable jacket when the strap is tightened.

Twist-on wire connectors, or "wire nuts," (TM) are pressure-type connectors which may be used per 46 CFR 111.60-17(a)(1). Connections using twist-on connectors must be made within an enclosure. The use of insulating electrical tape over connectors is recommended. Twist-on connectors are not recommended for use on small vessels due to the pounding motions frequently encountered. Additionally, they are not recommended for use in vital circuits, such as those powered from the emergency switchboard. Pressure connectors are typically designed for non-marine-stranded conductors. This may present a problem, especially with smaller conductors. Some twist-on connectors have sharp metallic inserts that could sever individual wires as they cut their way into the copper. Installations must be carefully examined to ensure that connections are tight, and that conductors have not been damaged. Although twist-on wire connectors are acceptable as pressure-type connectors, they are no longer covered under the latest edition of UL 486A, the standard referenced in 46 CFR 111.60-17(d). (They are covered by the edition of UL 486A referenced in the Finding Aids section.) UL Standard 486C is presently used to evaluate these connectors.

When pressure type connectors are used, the proper size is important. The connection must be tight, yet it must not be necessary to remove strands to fit the connector body to the conductor. This can sometimes present problems since marine cable has a different conductor diameter than NEC constructions.

Methods of connection of conductors to terminal parts, other than those listed in 46 CFR 111.60-17, may be accepted provided they insure a sound mechanical and electrical connection without damaging the conductors. A twisted, soldered loop may be used to connect a stranded conductor to a terminal screw on receptacles and lampholders. Where supplied by a circuit having a grounded conductor, a lampholder of the screw-shell type should have the grounded conductor connected to the screw-shell.

Splicing may be used to connect cables in one subassembly to cables in another subassembly; 46 CFR 111.60-19(a)(1) permits the use of cable splicing to facilitate modular construction techniques. The safety and reliability of a spliced cable is dependent upon the careful selection of the proper connectors, insulation and jacket replacement material, installation tools, and installation procedures. It is most important that the right size connector be used for the cable, with no trimming of the conductors. Selection of the proper connector for the conductor, the proper compression die for the connector, and the proper compression tool for the die is critical to the mechanical and electrical integrity of the splice. The type of crimp is not really important, as long as it does not leave sharp edges which may damage insulation. Manufacturer's certification of material compatibility is generally acceptable. The replacement insulation material need not match the cable jacket material as long as the temperature characteristics and materials are compatible.

In addition to the heat shrinkable or pre-stretched tubing required by 46 CFR 111.60-19(b)(3), poured epoxy, polyurethane, and vulcanized replacement jackets may be accepted. Flame propagation is not a major concern for the short lengths of cable splices. While splices made in the open are prohibited in hazardous locations, cables may be connected in hazardous locations in junction boxes (explosionproof in Divison 1 and Zone 0). Note that flexible cables or cords with conductors of 12 AWG or larger may be spliced for repairs, per 46 CFR 111.60-13(e).

8.9 Cable Armor. The requirement for armored cable is limited to installations in Class I Division 1 hazardous locations and in the other hazardous locations for cargoes of Grade A and lower, and for bulk liquefied gasses or ammonia per 111.105-31 and 32. The purpose of the requirement for armor is to give added mechanical protection to avoid possible arcing from an accidentally severed cable and to enable quicker detection, via the ground detection system, of damaged cable insulation. With intrinsically safe systems used in hazardous locations, the armor is unnecessary for this purpose since the energy available in the system is insufficient to constitute an ignition hazard. However, if there is insufficient cable separation, or there is no grounded partition, then a metal weave or shield around the cable is required to prevent the possible induction of current within the intrinsically safe circuit.. This metallic covering may be inside an outer cable jacket. See 111.105-11(b)(3) on the use of shielded cables.

An exception to the requirement for armored cable in hazardous locations is when flexible cord or cable must be used to connect electrical equipment. This flexible cable need not be joined to armored cable immediately beyond the section which requires flexing service. Rather than make such a connection in an explosionproof junction box within the hazardous location, it is generally preferable to extend the flexible cable to its point of supply outside the hazardous area. However, if a run of flexible cable is particularly vulnerable to mechanical damage, connection to armored cable or some other means of mechanical protection may be required.

Where single-conductor cables are used for AC circuits or DC circuits with a high ripple content, the following precautions should be observed in order to avoid undesirable induced currents and generated heat:

1. cable armor, if any, should be of non-magnetic material;

2. there should be no closed magnetic circuit around any conductor unless it encircles all conductors of the circuit; where installed in steel conduits, pipes, or casings, the cables should be bunched so that all conductors and the neutral, if any, are enclosed by the same conduit, pipe, or casing;

3. no magnetic material should be located between single-conductor cables of a circuit; where such cables pass through a steel deck or bulkhead, all the conductors of the circuit should pass through a non-ferrous plate or gland so that no magnetic material is located between the conductors.

Cable routing and segregation requirements are contained in 46 CFR 111.60-9 and 111.60-5, which references IEEE-45 Sections 20 and 22, except 20.11. Section 20.3 requires cables to be so routed as to avoid, so far as practicable, galleys, firerooms, and other spaces where excessive heat and high risk of fire may be encountered. SOLAS II-1/45.5.3 includes laundries in this category of spaces to be avoided.

9. Components and Equipment

9.1 Miscellaneous Equipment: The procedure by which miscellaneous items of electrical equipment may be reviewed to alternate design standards has been discussed in "Meeting Reference Standards," section 2.2 of this NVIC. That approach may be used to evaluate, for example, an inside decorative lighting fixture for use on a passenger vessel. Fixtures which are designed to a recognized electrical safety standard such as UL 57, Standard for Electric Lighting Fixtures, may be reviewed to the general marine requirements of UL 595. These requirements include vibration clamps on fluorescent tubes longer than 40 inches, secure mounting of glassware, and rigid mounting of fixtures (suspension by a chain and loose glass globes would be unacceptable). These requirements reflect concerns about the vibration and motion that a vessel may experience.

Appendix 9 contains additional information regarding electrical equipment requiring "approval" under Subchapter Q.

9.2 Navigation Lights. The requirements for navigation light systems are contained in 46 CFR 111.75-17. Note that dual light sources are required for certain lights. Annex I of the International Regulations for Preventing Collisions at Sea, 1972, (72 COLREGS) and the 1980 Inland Navigation Rules, (80 RULES), specify navigation light requirements in terms of color, arcs, range of visibility, and position.

Fixtures. The regulations applicable to electric navigation light fixtures are also contained in 46 CFR 111.75-17. There are no regulations that specifically prohibit the use of non-electric lights, except where the use of open flames is prohibited. However, the requirement for a navigation light indicator panel generally precludes the use of non-electric lights on vessels subject to the requirements of Subchapter J.

Ranges. Compared to the 1960 Rules, the range requirements of the 72 COLREGS, for most lights, have increased. The relationship between range of visibility and luminous intensity has also changed. However, many lights on vessels built to the 1960 Rules were much brighter than required and may meet the present Rules. It should be noted that with the change in the value of assumed atmospheric transmissivity, the old 5-mile lights were required to be brighter than the COLREGS 6-mile lights.

Color. Compared to the 1960 Rules, color coordinates for green lights have narrowed. This has resulted in a shift toward a bluish tint in the manufacturing of "green" dyes for navigation light lenses. The most commonly manufactured green plastic dyes have not had good ultraviolet stabilization; constant exposure to solar ultraviolet radiation will alter the green tint in a few years. This may be beneficial, in that it moves the color coordinates of an older light lens into the region required by the present Rules. However, it may also move them beyond the acceptable region. [NOTE: Tests can determine the color coordinates of the lens only at the time of testing; these coordinates continually change as navigation lights are exposed to ultraviolet radiation].

Horizontal Sector. Annex I of both sets of Rules gives specific arcs in which certain intensities of light are required. For example, sidelights as fitted on the vessel must, in the forward direction, reach "practical cut-off" (i.e., one-eighth of the minimum required sector intensity) between 1 and 3 degrees outside the prescribed sector. Prior to adoption of the 72 COLREGS and the Inland Rules, lights were "eyeballed" for a "reasonable decrease" in intensity in the cut-off region.

The 72 COLREGS have been interpreted as requiring the intensity between 0 and 1 degrees outside the prescribed sector to be greater than the practical cut-off value. This allows both sidelights to be visible dead ahead of the vessel, at a distance dependent upon their separation. This may present a problem for some vessels. For example, containers stacked forward of the sidelights could act as large screens, preventing the 1 degree "spillover." A Certificate of Alternative Compliance (CAC) is not appropriate in such cases; the lights should be relocated or the obstruction removed.

Vertical Sectors. Annex I of both sets of Rules also establishes requirements for vertical sectors of navigation lights. Previously, this parameter was not even considered.

Masthead Separation. Masthead lights must be separated by a horizontal distance of one-half the length of the vessel but need not be more than 100 meters (Annex I 2.(b)). Most vessels with a midship house were built with the after mast located amidships and will not meet this separation requirement without moving the mast(s). Also, moving the after mast from the midship house to the after house generally requires the after mast to be higher than original to meet height separation requirements. For this reason, Rule 38 permanently exempted vessels under 150 meters (492.1 ft..) and gave larger vessels 9 years to comply. This extension was made with two-house vessels in mind and in consideration of the economic hardships involved with moving/raising masts. Therefore, CAC's would not be appropriate for masthead separation unless moving the masts would interfere with the special purpose of the vessel.

Sidelight Placement. Sidelights must not be "in front" of the forward masthead light (Annex I 2.(g), 3.(b)). This rule also applies to single masted vessels and will require sidelight repositioning on many vessels in the 20-50 meter range. Some vessels (i.e., tugboats, workboats, or fishing vessels) may qualify for CAC's due to the special purpose of the vessel.

Acceptance and Conformance. Underwriters Laboratories Inc. standard UL 1104 is based on the requirements of the 72 COLREGS and construction requirements that address lighting fixtures in weather locations. The regulations do not require UL listing of navigation light fixtures; they require that the fixtures meet the UL standard. This allows the manufacturer to do his own testing and submit the reports for acceptance.

Premature Bulb Failure. On vessels such as tugs and barges, problems with vibration and shock (impact) have been reported. Although navigation lights are subjected to stringent vibration testing, with bulb failure as a rejection factor (evidenced by one manufacturer failing this test and having to re-design the fixtures), the accepted fixtures are not tested for impact shock. When shock or vibration is a problem, shock mounting the fixture is recommended. This shock mounting can take two forms. The first is internal isolation of the bulb. This is a manufacturer's modification and could involve retesting of the fixture. The second is to isolation mount the fixture on the vessel.

Another factor that has contributed to premature failure of lamps is inadequate voltage regulation. A 10% increase in voltage will reduce bulb life to approximately 25% of its rated life. Thus, any action to ensure proper voltage at the fixture will help to extend bulb life.

Screens. Annex I of the International Regulations for Preventing Collision at Sea, 1972 (72 COLREGS) and Annex I of the 1980 Inland Navigation Rules require sidelights on vessels over 20 meters in length to have external screens. These screens are to be painted matte black. Therefore, all sidelight fixtures on U.S. Coast Guard certificated vessels greater than 20 meters in length must have screens painted matte black for the sidelights.

The sidelight screens may be utilized to obtain the required cut-off angles for the sidelights as required by Section 9 of Annex I to the 72 COLREGS and section §84.17 of the 1980 Inland Rules. If the sidelight fixtures are fitted with internal screens that provide the proper cut-off angles, an external screen must still be provided to meet the 72 COLREGS as well as the Inland Rules. The installation of an internally screened sidelight in conjunction with an inboard external screen, if properly aligned, would meet the requirements.

In addition to sidelights, other navigation lights (such as masthead and anchor) have horizontal sector cut-off requirements. Most manufacturers have used internal screens to achieve the required cut-off, but external screens would also be acceptable, although they are not required. These fixtures would be required to be marked with an indication that they are to be installed with external screens.

Barge Lights (Battery Powered) Exemptions. COMDTINST M16672.3 has exempted battery powered barge lights from the vertical sector cut-off requirements of the 72 COLREGS. This exemption is good until July 1, 1989, at which time it will be re-evaluated. The COMDTINST is only applicable to unmanned barges without machinery for the generation of electricity or with such machinery intended for operation only while moored.

The 1980 Inland Rules permanently exempt electric navigation lights on unmanned barges from the vertical sector requirements.

Navigation Light Fixture Marking. Navigation light fixture markings generally indicate compliance with the 72 COLREGS.

10. SOURCES OF ADDITIONAL INFORMATION

The following references contain electrical information of general interest and are in addition to those specifically mentioned throughout this NVIC.

10.1 The Federal Register preambles to the 27 June 1977 Notice of Proposed Rulemaking, 3 March 1980 Supplemental Notice of Proposed Rulemaking, and 8 April 1982 Final Rules for Subchapter J contain discussions of the philosophy and intent of the Electrical Engineering Regulations. These discussions can provide amplifying and clarifying information on a number of the regulations.

10.2 The National Electrical Code Handbook, published by the National Fire Protection Association, is a valuable reference for those parts of the NEC which are incorporated by reference into the Electrical Engineering Regulations as well as for other areas of general interest such as Article 700 on emergency power systems.

10.3 Electrical Instruments in Hazardous Locations, by Ernest C. Magison, published by the Instrument Society of America.

10.4 Hazardous Locations, A Guide for the Design, Construction and Installation of Electrical Equipment, by John Bossert and Randolph Hurst, published by the Canadian Standards Association, 1986.

10.5 NFPA 493, "Intrinsically Safe Process Control Equipment".

10.6 COMDTINST M16465.11, Chemical Hazard Response Information System (CHRIS).

10.7 IEEE Std.. 141, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, (the IEEE "Red Book").

10.8 IEEE Std.. 142, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems, (the IEEE "Green Book").

10.9 IEEE Std.. 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, (the IEEE "Buff Book").

10.10 Instrument Society of America (ISA)-RP12.1 -- Electrical Instruments in Hazardous Atmospheres.

10.11 ISA-S12.4 -- Instrument Purging for Reduction of Hazardous Area Classification.

10.12 ANSI/ISA-RP12.6 -- Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations.

10.13 ISA-S12.10 -- Area Classification in Hazardous Dust Locations.

10.14 ISA-S12.11 -- Electrical Instruments in Hazardous Dust Locations.

10.15 ANSI/ISA-S12.12 -- Electrical Equipment for Use in Class I, Division 2 Hazardous (Classified) Locations.

10.16 ANSI/ISA-S12.13 Part I -- Performance Requirements, Combustible Gas Detectors.

10.17 ISA-RP12.13 Part II -- Installation, Operation, and Maintenance of Combustible Gas Detection Instruments.

10.18 Appendices 10 - 13: Appendices 10 and 11 contain guidance on the inspection for certification of vessel electrical installations and electrical requirements particular to special vessel types, respectively.

10.19 Appendix 12 provides guidance concerning the submittal and review of electrical plans for certificated vessels other than Subchapter T small passenger vessels.

10.20 Appendix 13 contains a list of abbreviations commonly used on marine electrical plans, including NEMA enclosure symbols.

APPENDIX 1

INDEX FOR REFERENCE DRAWING TO TITLE 46 CFR, NATIONAL ELECTRICAL CODE (NEC), INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE) STD. 45-1983, UNDERWRITERS LABORATORIES (UL), ETC.

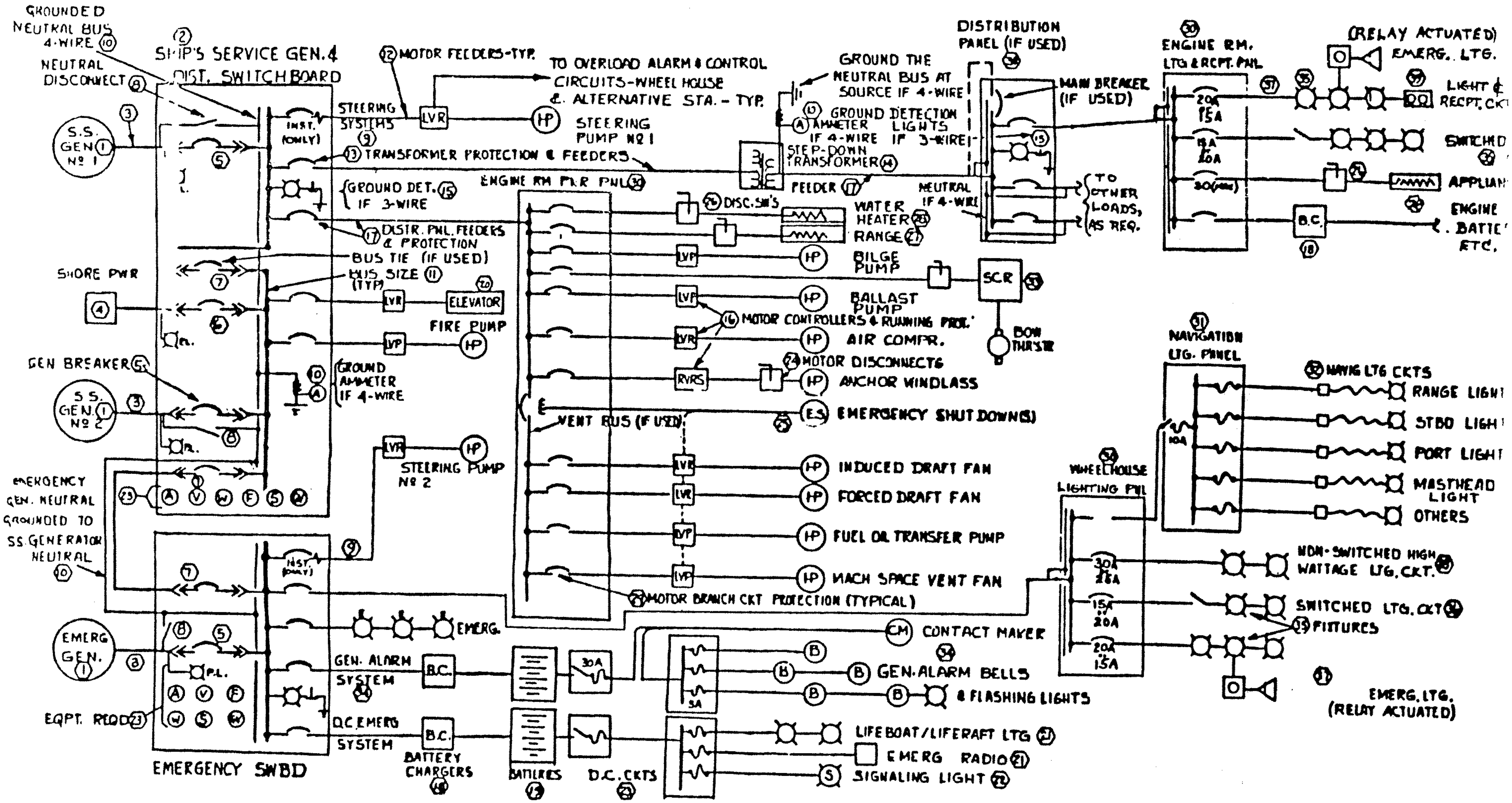
ITEM	TITLE	REFERENCE*	SPECIFIC AREAS
1	Generators	111.12	Ship's service
		112.50	Emergency
		111.12-7, -11	Parallel operation
2	Generator & Distribution Switchboards	111.30	General
3	Generator Cables	111.60-3	Application
		111.60-7	Demand load
		111.60-5 & 111.12-9	Installation
4	Shore Ties & Connection Boxes	111.83	Construction
5	Generator Circuit Breaker	111.30-25	Switchboard-mounted
		111.50-7	Enclosures
		111.50-5(a)	Location
		111.12-11	Circuits & Protection
		111.54-1(a)(3)	Interrupting capacity
6	Shore Tie Circuit Breakers	111.30-25(f)	Switchboard-mounted
		111.50-5(a)(2)	Switchboard-mounted
		111.54-1(a)(3)	Interrupting capacity
7	Bus Tie Circuit Breakers	111.60-7	Demand load
8	Generator Neutral Disconnects or Links	111.30-25(b)	Switchboard-mounted
9	Steering Systems	58.25	Steering apparatus
		111.93	Electric steering gear
		112.15-5(o)	Tankships
		33 CFR 164.39	
10	Generator Neutral Grounding	111.05-17	Ship's service and emergency generator
11	Bus Sizes	IEEE STD 45-1983	Table A-27 & 111.30-19
12	Motor Feeders	111.60-7	

APPENDIX 1 (cont'd)

ITEM	TITLE	REFERENCE*	SPECIFIC AREAS
13	Transformers, Feeders, and Protection	111.20-15 and NEC 450	
14	Transformers, General	111.20	
15	Ground Detection	111.30-25(e)(1) 111.30-27(e) 111.05	
16	Motor Controllers	NEC 430-86 111.70-3 111.70-3(f)&(g) 111.70-3(d)	Location Enclosures Low voltage protection (LVP) and low voltage release (LVR) types Group control panels
17	Distribution Panel Feeders & Circuit Breakers	111.60-7 111.54-1(a)(3) 111.51	Demand loads Interrupting rating Selective operation
18	Battery Chargers	UL 1236 & 111.15-30 111.15-25	Acceptable types Reverse current protection
19	Storage Batteries	111.15-1 111.15-5 111.15-10 111.15-5(g)-(h) 111.15-20 112.55	General Installation and arrangement Ventilation Corrosion protection Conductors Emergency power and lighting systems
20	Electric Elevators & Dumb Waiters	ANSI A17.1 111.91	Safety Code
21	Emergency Lights & Loads	112.43 112.01-10 112.15 UL 595	Emergency lighting systems Automatic systems Emergency loads Light fixtures standard
22	Signaling Lights	111.75-18	
23	Switchboard Instrumentation & Control Equipment Required	111.30-25	AC switchboards ship's service and emergency

APPENDIX 1 (cont'd)

ITEM	TITLE	REFERENCE*	SPECIFIC AREAS
24	Disconnects (Motors)	111.70-1 NEC 430	
25	Emergency Shut Down	111.103	
26	Disconnects (Switching Means)	111.55	
27	Electric Ranges	111.60-7 111.77-3	Demand loads Standard
28	Electric Water Heaters	63.15	
29	Motor Circuit Protection	111.70-1 NEC 430	
30	Distribution Panelboards	111.40 111.50-5,-7	
31	Navigation Light Indicator Panels	111.75-17	
32	Navigation Lighting Circuits	111.75-17	
33	Semiconductor-Controlled Rectifier (SCR) Circuits	111.33	Electric propulsion
34	General Alarm Systems	113.25	
35	Lighting Fixtures	111.75-20 UL 595 111.05-3	Marine type Construction Grounding
36	15- or 20-Ampere Lighting Branch Circuits	111.75-5(e)(1) & (2)	"Switched" lights and receptacles
37	15- or 20-Ampere Lighting Branch Circuits	111.75-5(e)(1) & (2)	"Non-Switched" lights and receptacles
38	25- or 30-Ampere Lighting Branch Circuits	111.75-5(f)	Non-Switched light wattage lighting ckt.
39	Receptacle Circuits	111.79-1 111.05-3 UL 498 UL 514 UL 50	General Grounding Attachment plugs and receptacles Outlet boxes and fittings Cabinets and boxes



APPENDIX 1

SHIPBOARD ELECTRICAL SYSTEM
TYPICAL ONE-LINE DIAGRAM

APPENDIX 2

LOAD ANALYSIS

(1) General Requirements. Ship's service generating plants must be sized for the anticipated operating load as required by 46 CFR 111.10-4. To determine if the generators are adequate, a load analysis is necessary and is required to be submitted for review by 110.25-1(b). Demand factors (d.f.) are essential to the load analysis but often can vary, as can be seen from the typical values in Table 1 of this Appendix. The individual characteristics of the vessel should be considered in the determination of demand factors. The load analysis should document that:

(a) Individual load factors used are reasonable.

(b) Application of the load factors is reasonable and thorough.

(c) Generating plant is adequate and in accordance with the applicable regulations.

(2) Considerations. The load analysis should be prepared and evaluated with the following considerations in mind:

(a) Loads can be classified by various operating conditions such as port, anchor, sea, functional, emergency, maneuvering, or cold start. The load analysis will normally address only the normal sea load, maneuvering load and emergency load, unless special considerations for the safety of the ship require otherwise (e.g., at sea cargo transfer (functional)).

(b) A motor may be oversized for its attached load and thus not operate at its rated capacity.

(c) Formulas for the determination of load factors for major steam propulsion vessels may be found in SNAME T&R Bulletin 3-11, "Marine Steam Power Plant Heat Balance Practices", Section 3.2.15.

(d) Load factors for individual loads, in general:

$$\text{Load factor} = \frac{\text{Operating bhp}}{\text{Rated bhp}} \times \frac{\text{No. hours operation}}{\text{24 hours}}$$

or

$$\text{Load factor} = \frac{\text{Operating KW}}{\text{Rated KW}} \times \frac{\text{No. hours operation}}{\text{24 hours}}$$

Often, operating load information is not provided and load factors become $\frac{\text{No. hours operation}}{\text{24 hours}}$

(e) A single load factor for group loads may be assigned if they meet one of the following criteria:

(i) Two or more loads operate with a definite relationship to each other (e.g., heating and air conditioning);

(ii) When the relationship described in (i) above is not clear, but is known to exist (e.g., galley equipment);

(iii) When low power loads in the same space can be assigned roughly the same load factors (e.g., radios and electronics).

(f) Known load use data should always be used in lieu of demand factors, if available.

(g) Power conversions and their efficiency should be considered (e.g. power factors, transformers, semiconductor controlled rectifiers (SCR's). Due to efficiency below 1.0, apparent connected loads may be increased due to the conversion equipment).

(h) Loads that are provided individual factors in the analysis should not be additionally assigned a group factor, and vice versa (e.g., 0.3 (individual factor) x 0.4 (group factor) = 0.12 (final factor) (either 0.3 or 0.4 could be used, but not 0.12)).

(i) Factors of zero (0) are assigned to equipment that is seldom used.

(j) Factors of 0.9 and 1.0 are used where motors operate at full load for an extended period of time.

(k) Any standby or duplicate units should be listed and assigned a factor of zero unless they are continuously idling. The primary unit should be assigned an appropriate factor, e.g., Steering pump #1, d.f.=0.9; Steering pump #2, d.f.=0.0 (Stby).

(l) The development of standard load factors for given classes of vessels is encouraged, as time and experience permit.

(m) Large equipment -- unusually large loads, as compared to the generating capacity -- should be assigned appropriate factors assuming that other non-essential loads are not operated simultaneously.

(n) The load analysis should show that the generating plant is adequate to simultaneously carry the loads vital to the survival of the vessel in an emergency such as fire or flooding. These loads should include:

(i) Steering;

(ii) Vital propulsion auxiliaries;

(iii) Ventilation;

(iv) Communications;

(v) Fire pumps;

(vi) Alarms;

(vii) Bilge pumps;

(viii) Emergency lighting;

(ix) Radar; and

(x) Controls.

(o) For unmanned machinery spaces, remotely operated emergency loads, such as bridge started fire pumps should be assigned a load factor of 1.0.

(p) Automatically started equipment should be provided a load factor of 1.0 without regard for spinning reserve.

(q) Special functional operations of the vessel, such as underway replenishment (a Military Sealift Command (MSC) ship), dredging (a hopper dredge), and at-rig offloading (an offshore supply vessel) do not require one generator in reserve. Normal at sea operations such as cargo cooling (refrigerated ships) and liquid cargo recirculation (offshore supply vessels) do require one ship's service generator in reserve.

APPENDIX 2

TABLE 1

TYPICAL OPERATING LOAD FACTORS

LOAD DESCRIPTION	NAVY FACTORS		MAR. ENG. FACTORS		SNAME
	Sea	Emerg.	Sea	Emerg.	Sea
Main Steering gear pump	.3	.3	.1		.2
Stby. steering gear pump	0	0			
Steering gear servo. pump	.5	.5			
Steering control	.5	.5	.1		
Steering aux. heater	0	0			
Shaft turning gear	0	0			
Stern tube bearing lube oil pump			.5		
Main cond. pump	.9	0	.4		.75
Main circ. pump	.9	0	1.0		.9
Aux. cond. pump					.9
Aux. circ. pump	.6	0			.9
Main feed pump					.8
Main feed boost pump	.9	.5			
Emer. feed boost & transfer pump	0	0			0
Reserve feed transfer pump	.2	0			.5
Aux. condenser condensate pump			0		
Atm. clean drain tank pump			.6		
L.P. Heater drain pump					.65
L.P. Steam gen. feed pump			.9		
Aux. boiler	0	0			
Main turb. gland exhauster	.9	0	.9		.9
Aux. turb. gland exhauster	.5	0			
F.W. Drain coll. tank pump	.6	0			.6
Main L.O. purifier	.3	0	.9		.35
Main feed L.O. pump	.9	0	.9	.3	.9
Stby. L.O. serv. pump	0	.2		1	
L.O. transfer pump	.1	0			0
L.O. cooler circ. pump					.9
L.O. heater					.1
F.O. service pump	.9	0	.4		.85
F.O. transfer pump	.1	0	.1		.1
F.O. stripping pump	0	0			
F.O. stripping drain and transfer pump	.3	0			
Red. gear L.O. stby. pump	0	0			
Prop. hyd. stby. pump	0	0			
Elec. prop. exciter	.9	0			
Elec. prop. equip. heater	0	0			
Prop. motor vent fan	.9	0			
Prop. motor L.O. service pump	.9	0			

TABLE 1 (cont'd)

LOAD DESCRIPTION	NAVY FACTORS		MAR. ENG. FACTORS		SNAME
	Sea	Emerg.	Sea	Emerg.	Sea
T/G circ. pump	.5	0			
T/G cond. pump	.5	0			
T/G start L.O. pump	0	.9		.9	
Sea valves	0	0			
Emer. gen. S.W. booster	0	.9			
S.W. boost pump	.3	0			
Air preheater					.9
S.W. service pump	.1	0	.6		.8
Bilge and fuel stripping pump	.1	0	.1		
Bilge pump	.1	0	.1		.1
Flushing pump	.1	0			.4
Fire pump	.2	.4	0		0
Bilge & ballast priming pump		0	.1		
Fire & bilge pump					0
Fire & general service pump			0		
Bilge & ballast pump					.2
Ballast pump					.2
Fog/Foam sys. pump	0		0		
Forced draft blower			.5		
H.W. circ. pump	.6	0	.1		.7
H.W. heater	.5	.1			.5
Cargo stripping pump	0	0			
Liq. cargo transfer pump	0	0	0		0
Cargo brine circ. pump			.7		
Cargo air coolers			.9		
Cargo dehumidifier					.5
Window defrosters and wipers	0	0			
Generator space heaters	0	0		1	
Anchor windlass	0	0			
Capstan	.0	0			
Personnel elevators	.2	0			
Cranes	0	0			
Cargo elevators	0	0			
Shop tools	.1	0	.1		.1
Welder	.1	0			
Test board	.1	0	0	0	.2
Battery charger	.2	0			.2
I.C. battery charger				1	
Ventilation	.9	.4	.9		.85
Duct & space heaters	.4	0			.4
Deck mach. heaters					1
I.C. system	.4	.4		1	.4
Radar	.5	.5		1	
Gyro				.5	.4

TABLE 1 (cont'd)

LOAD DESCRIPTION	NAVY FACTORS		MAR. ENG. FACTORS		SNAME
	Sea	Emerg.	Sea	Emerg.	Sea
Radio	.4	.4			
Searchlights	0	0			
Mach. space ltg.	.9	.9			.9
General ltg.	.6	.4	.4		.6
Emergency ltg.	.6	.4		.9	
Navigation ltg.	.6	.2		.4	.5
Service area ltg			.4		.35
SS. reefer circ. pump					.4
SS. reefer compressor	.3	0	.1		.4
Cargo reefer cmp.	.3	0	.6		
A.C. compressor	.7	.4	.8		.75
A.C. chill wtr. pump	.7	.4	.9		.75
A.C. S.W. circ. pump	.7	.4			.75
A.C. Fan					.75
A.C. H.W. circ. pump			.6		.75
Unit coolers	.2	0			
Oven/range	.4	0			
Galley equip.	.3	0			.3
Refrig/freezer	.5	0			
Refrig. small	.3				.3
Pantry equip.	.2	0			.3
Laundry equip.	.2	0			.2
Hospital equip.	.1	.1			.2
Electronics	.5	.2	.5		.45
Distiller plant	.7	0			
Distiller brine ovbd.			.8		.75
Distiller cond. pump			.3		.6
Distiller feed pump			.8		.75
F.W. transfer pump			0		
Ice water circ. pump			1		.7
Potable water pump	.3		.2		
Drinking fountain	.4				
H.P. air compressor	.1				
S.S. air compressor	.1		.1		.3
Control air compressor	.6		.2		.4
Sewage pump	.1		1.0		.2
Sewage macerator	.1		1.0		
Sewage blower			1		
Cathodic protection			.7		
Ice water circ. pump			1.0		.7
Brine circ. pump			1.0		
Reefer container recept.			.9		
Winches					
Bow thruster					
Main control console			.6		
Boiler console			.6		
R.A.I., E.O.T., alarms			1		

APPENDIX 2

TABLE 2

SAMPLE LOAD ANALYSIS

NOTE: All figures used are purely hypothetical.

DISTRIBUTION A	ATTACHED LOAD	DEMAND FACTOR	DEMAND LOAD
Bilge Pump	5 KW	0	0
Ballast Pump	10 KW	0.1	1 KW
A/C - Heater	10/20 KW	0.8	8/16 KW *
Cargo Circ. Pump	15 KW	0.6	9 KW
	Dist. A Total	0 + 1 + 16 + 9 =	26 KW
DISTRIBUTION B			
Steering Pump #1	10 KW	0.9	9 KW
Steering Pump #2	10 KW	0	0 **
Steering Control	1 KW	0.9	.9 KW
Bow Thruster	40 KW	0.4	16 KW
	Dist. B Total	9 + 0 + .9 + 1' =	25.9 KW
DISTRIBUTION C			
Main Deck Ltg. Fwd.	4 KW	0.5 ***	4 KW
Main Deck Ltg. Aft	4 KW	0.5	
Eng. Rm. Ltg. Port	2 KW	0.9 ***	3.6 KW
Eng. Rm. Ltg. Stbd.	2 KW	0.9	
	Dist. C Total	4 + 3.6 =	7.6 KW
DISTRIBUTION D			
Range	12 KW	0.4	4.8 KW
Water Heater	15 KW	0.6	9.0 KW
	Dist. D Total	4.8 + 9.0 =	13.8 KW

TRANSFORMER #1

Dist. C	7.6 KW	1.0 @ .95
Dist. D	13.8 KW	Efficiency ****

Transformer 1 Total is 1.05 (1.0)(7.6 + 13.8) = 26.9 KW

TABLE 2 (cont'd)

SAMPLE LOAD ANALYSIS

MAIN SWBD

Dist. A		26 KW
Dist. B		25.9 KW
Transformer #1		26.9 KW
	Generator Demand Load	78.8 KW
	Full Load Gen. Capacity	85 KW

* Relationship exists, take larger load.
** One pump is the standby.

*** Similar loads given group factor.
**** Reduced efficiency increases demand load. typ. transformer eff .96-.99

APPENDIX 3

<u>SCR System Check-Off List.</u>

(a) Meets the requirements of 46 CFR 111.33, and for a switchboard and/or electric propulsion installation, 46 CFR 111.30-11, -19, -21.

(b) Name plate data.

(c) Heat removal system.

(d) Cooling.

(e) Immersed type with non-flammable liquid and no leakage with vessel inclined.

(f) Located away from heat sources.

(g) Temperature rating and operating range.

(h) Unrestricted air circulation if naturally cooled.

(i) Inlet air temperature within design limits.

(j) Loss of cooling shutdown.

(k) Inlet cooling water temperature.

(l) Watertight or dripproof rectifier stack.

(m) Vent exhaust does not terminate in a hazardous area.

(n) Vent exhaust does not impinge on electrical equipment in enclosure.

(o) High temperature alarm or shutdown.

(p) SCR propulsion systems:

- (i) Meet ABS Section 35.84.4 (1983).
- (ii) Current and current rate limiting circuit.
- (iii) Overcurrent protection.
- (iv) High temperature alarm set below shutdown temperature.
- (v) Internal overcurrent device coordination.
- (vi) Blown fuse detection system.
- (vii) In dry place.

(q) SCR motor control:

- (i) Overspeed trip; loss of load (series); loss of field (shunt).
- (ii) Shunt motor field excitation interlock.

APPENDIX 4

Miscellaneous Tables.

CURRENT RATING, RECTANGULAR BUS BARS ON EDGE, 50°C AMB., 50°C RISE, IEEE 45-1983, A27 SINGLE BARS IN PARALLEL, COPPER

SIZE (inches)	DC	AC, 60HZ
3/4 x 1/8	250	250
1 x 1/8	330	330
1-1/2x 1/8	500	500
1-1/2x 3/16	580	570
2 x 3/16	760	745
1 x 1/4	490	480
1-1/2x 1/4	685	675
2 x 1/4	920	900
3 x 1/4	1380	1280
4 x 1/4	1730	1650
5 x 1/4	2125	2000
6 x 1/4	2475	2300
8 x 1/4	3175	2875

MINIMUM SWITCHBOARD SPACINGS (inches)

VOLTAGE	LIVE PARTS, OPP. POLARITY, OVER SURFACE	THRU AIR	BETWEEN LIVE PARTS & GROUNDED DEAD METAL
125V or Less	3/4	1/2	1/2
126V - 250V	1-1/4	3/4	1/2
251V - 600V	2	1	1

From NEC Table 384-26

NEUTRAL GROUNDING CONDUCTORS, AC SYSTEMS

A.W.G. OF LARGEST GENERATOR CONDUCTOR OR EQUIVALENT FOR PARALLEL GENS.	A.W.G. OF GROUND CONDUCTOR
up to #2	#8
#2 - #0	#6
#0 - 3/0	#4
3/0 - 350 MCM	#2
350 MCM - 600 MCM	#0
600 MCM - 1100 MCM	2/0
greater than 1100 MCM	3/0

See 46 CFR 111.05-31(b).

<u>Generator Continuous Full Load Ampere Ratings.</u>

3-PHASE 0.8 POWER FACTOR

		115%		115%		115%		115%		115%		115%	
W	KVA	208V	FLA	230V	FLA	240V	FLA	460V	FLA	480V	FLA	600V	FLA
.0	6.3	17.5	20	15.8	18	15.2	17	7.9	9	7.6	9	6.1	7
.5	9.4	26.1	30	23.6	27	22.6	26	11.8	14	11.3	13	9.0	10
0.0	12.5	34.7	40	31.4	36	30.1	35	15.7	18	15.0	17	12.0	14
5.0	18.7	52.0	60	47.0	54	45.0	52	23.5	27	22.5	26	18.0	21
0.0	25.0	69.4	80	62.8	72	60.1	69	31.4	36	30.1	35	24.1	28
5.0	31.3	87.0	100	78.6	90	75.3	87	39.1	45	37.6	43	30.1	35
0.0	37.5	104.1	120	94.1	108	90.2	104	47.1	54	45.1	52	36.1	42
0.0	50.0	138.8	160	125.5	144	120.3	138	62.7	72	60.1	69	48.1	55
0.0	62.5	173.5	200	156.9	180	150.3	173	78.4	90	75.2	86	61.1	70
0.0	75.0	208.2	239	188.3	217	180.4	207	94.1	108	90.2	104	72.2	83
5.0	93.8	260.4	300	235.4	271	225.6	259	117.7	135	112.8	130	90.3	104
00.0	125.0	347.0	399	313.8	361	300.7	346	156.9	180	150.4	173	120.3	138
25.0	156.0	433.0	498	391.6	450	375.3	432	195.8	225	187.6	216	150.1	173
50.0	187.0	519.1	597	469.4	540	449.8	517	234.7	270	224.9	259	179.9	207
75.0	219.0	607.9	699	549.6	632	526.7	606	274.8	316	263.3	303	210.7	242
00.0	250.0	694.0	798	627.6	722	601.4	692	313.8	361	300.7	346	240.6	277
50.0	312.0	866.1	996	783.2	900	750.5	863	391.6	450	375.3	432	300.2	345
00.0	375.0	1040.1	1196	941.3	1082	902.1	1037	470.7	541	451.1	519	361.0	415

NOTES:

(1) Generator cables shall be capable of carrying at least 115 percent generator continuous F.L.A. (see 46 CFR 111.60-7).

(2) Generator circuit breaker long time overcurrent trip shall not exceed 115 percent generator continuous F.L.A. (see 46 CFR 111.12-11).

Transformer Full Load Currents.

FULL LOAD CURRENTS
3-PHASE TRANSFORMERS
Voltage (Line to Line)

KVA Rating	208	240	480	800	2400	4180
3	8.3	7.2	3.6	2.9	.72	.415
6	16.6	14.4	7.2	5.8	1.44	.83
9	25	21.6	10.8	8.7	2.16	1.25
15	41.6	36.0	18.0	14.4	3.6	2.1
30	83	72	36	29	7.2	4.15
45	125	108	54	43	10.8	5.25
75	208	180	90	72	18	10.4
100	278	241	120	96	24	13.9
150	416	360	180	144	36	20.8
225	625	542	271	217	54	31.2
300	830	720	360	290	72	41.5
500	1390	1200	600	480	120	69.4
750	2080	1800	900	720	180	104
1000	2775	2400	1200	960	240	139
1500	4150	3600	1800	1440	360	208
2000	5550	4800	2400	1930	480	277
2500	6950	6000	3000	2400	600	346
5000	13900	12000	8000	4800	1200	694
7500	20800	18000	9000	7200	1800	1040
10000	27750	24000	12000	9600	2400	1366

For other KVA Ratings or Voltages:

$$\text{Amperes} = \frac{\text{KVA} \times 1000}{\text{Volts} \times 1.732}$$

FULL LOAD CURRENTS
SINGLE PHASE TRANSFORMERS
Voltage

KVA Rating	120	208	240	480	600	2400
1	8.34	4.8	4.16	2.08	1.67	.42
3	25	14.4	12.5	6.25	5.0	1.25
5	41.7	24.0	20.8	10.4	8.35	2.08
7.5	62.5	36.1	31.2	15.6	12.5	3.12
10	83.4	48	41.6	20.8	16.7	4.16
15	125	72	62.5	31.2	25.0	6.25
25	208	120	104	52	41.7	10.4
37.5	312	180	156	78	62.5	15.6
50	417	240	208	104	83.5	20.8
75	625	361	312	156	125	31.2
100	834	480	416	208	167	41.6
125	1042	800	520	260	208	52.0
167.5	1396	805	698	349	279	70.0
200	1666	960	833	416	333	83.3
250	2080	1200	1040	520	417	104
333	2776	1600	1388	694	555	139
500	4170	2400	2080	1040	836	208

For other KVA Ratings or Voltages:

$$\text{Amperes} = \frac{\text{KVA X 1000}}{\text{Volts}}$$

INTERNATIONAL ASSOCIATION OF DRILLING CONTRACTORS

Street Address: 15810 Park Ten Place, Suite 242
Houston, Texas 77084-5134
Phone 713-578-7171
Telex # 516985
Telefax 713-578-0589

Mailing Address: P.O. Box 4287
Houston, Texas 77210-4287

INTERIM GUIDELINES
FOR INDUSTRIAL SYSTEM DC CABLE
FOR MOBILE OFFSHORE DRILLING UNITS
IADC-DCCS-1

I. Purpose

These interim guidelines have been prepared to establish a method for the selection, installation and acceptance of DC electrical cables used on industrial drilling systems on mobile offshore drilling units. These systems are drawworks, pumps and rotary table. These interim guidelines will provide the necessary guidelines for DC cable on MODUs until a final standard has been prepared and issued.

II. Single Conductor Cable Selection

For all cable types, the following shall apply:

A. The interim guidelines shall apply to DC motors nominally rated 750 volts DC armature voltage.

B. The cable size per polarity shall have a current-carrying capacity determined by multiplying the duty factor times the lesser of:

1. The continuous current rating of the motor; or

2. The continuous current limit setting of the power supply.

C. The duty factors to be used are:

1. Mud pumps, cement pumps: 0.80;

2. Drawworks, rotary table: 0.65.

D. The cable need only be sized for a maximum ambient temperature of 45°C in machinery spaces as determined by the U.S. Coast Guard, the American Bureau of Shipping and the Marine Transportation Committee of the Institute of Electrical and Electronic Engineers.

E. The cable shall meet the flame retardancy requirements of IEEE-383-1974 or IEEE-45-1977. Manufacturer shall supply to the owner of the vessel a certificate of compliance with this requirement.

F. The voltage rating of the cable shall be 1000 volts minimum.

G. For this specification, the cable insulation and jacket shall meet or exceed the requirements of the latest edition of one or more of the following standards as it applies to the construction of a single conductor power cable. Where the following standards do not specifically list AAR-sized cable, the insulation and jacket thicknesses shall conform to the next larger size cable listed.

1. Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-19-81);

2. Cross-linked Thermosetting Polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-66-524);

3. Ethylene-Propylene Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-68-516);

4. Specification for Single Conductor Cleaning-stripping Ethylene-propylene Rubber-insulated 0-600 Volt (see A and E of this interim guideline) Chlorosulfonated Polyethylene-jacketed Cable for Locomotive and Care Equipment (AAR Specification 591). NOTE: The insulation and jacket thickness of AAR 591 are suitable for 1000 volts based on comparison with ICEA S-68-516 for 0-2000 volt rating. The manufacturer shall test, certify and label the cable with appropriate voltage ratings.

5. American Association of Railroads (AAR) Wiring and Cable Specification S-501.

6. IEEE Recommended Practice for Electrical Installations on Switchboards (IEEE-45).

7. General Specifications for Cable and Cord Electrical for Shipboard Use (Military Specification MIL-C-915E).

8. Any UL-listed Marine Shipboard Cable.

APPENDIX 6

MOTOR CIRCUIT INFORMATION

FIGURE 1

3-PHASE, 208 VAC MOTOR BRANCH CIRCUIT QUICK-REFERENCE TABLE FOR SINGLE BANKED CABLES

A	B	C	D	E	F	G	H	I	J
HP	FLA	Running Prot. 115% FLA.		Starter Size	Discon-nect Size	Max. Prot. Device Full Volt Start			
		Adj.	Non-Adj.			Code B-E		Code F-V	
						C.B. 200%	Fuse 250%	C.B. 250%	Fuse 300%
.25	1.23	1.41	2	00	30	15	15	15	15
.33	1.48	1.7	2	00	30	15	15	15	15
.5	2.0	2.3	3	00	30	15	15	15	15
.75	2.8	3.22	4	00	30	15	15	15	15
1	3.6	4.14	4	00	30	15	15	15	15
1.5	5.7	6.56	8	00	30	15	15	15	20
2	7.8	8.97	10	0	30	20	20	20	25
3	10	11.5	12	0	30	20	30	30	30
5	17	19.6	20	1	60	35	40	50	60
7.5	24	27.6	30	1	60/100	50	50	70	80
10	31	35.7	40	2	100	70	70	90	100
15	46	52.9	60	3	100/200	100	100	125	150
20	59	67.9	70	3	200	125	125	150	200
25	75	86.3	100	3	200/400	175	175	200	250
30	88	101	110	3	200/400	200	200	125	300
40	114	131	150	4	400	250	250	300	350
50	143	164	200	4	400/600	300	300	400	450
60	170	196	225	5	400/600	350	350	500	500
75	212	243	250	5	600	500	500	600	-
100	273	314	350	5	600	600	600	-	-
125	343	394	450	6	-	-	-	-	-
150	396	455	500	6	-	-	-	-	-
200	528	607	800	6	-	-	-	-	-

FIGURE 1 (cont'd)

3-PHASE, 208 VAC MOTOR BRANCH CIRCUIT QUICK-REFERENCE TABLE

HP	K	L	M	N	O	P
	125% FLA	THREE CONDUCTOR BRANCH CABLE				
		AWG (IEEE 45, 50°C)			TSGA - ( )	
		T	E,X	AVS	40°C	50°C
.25	1.54	14	14	14	4	4
.33	1.85	14	14	14	4	4
.5	2.51	14	14	14	4	4
.75	3.5	14	14	14	4	4
1	4.5	14	14	14	4	4
1.5	7.13	14	14	14	4	4
2	9.75	14	14	14	4	4
3	12.5	14	14	14	4	4
5	21.3	12	14	14	9	9
7.5	30.0	10	10	12	9	9
10	38.8	7	8	10	9	14
15	57.5	5	6	7	23	23
20	73.8	3	4	5	30	30
25	93.8	1	2	3	40	50
30	110.0	1/0	1	2	50	60
40	142.5	3/0	2/0	1/0	75	100
50	178.8	4/0	3/0	2/0	125	125
60	212.5	300	250	4/0	150	150
75	265.0	400	350	250	200	250
100	341.3	600	500	400	300	400
125	428.8	-	-	-	400	-
150	495.0	-	-	-	-	-
200	660.0	-	-	-	-	-

APPENDIX 6

FIGURE 2

3-PHASE, 460 VAC MOTOR BRANCH CIRCUIT QUICK-REFERENCE TABLE

A	B	C	D	E	F	G	H	I	J
HP	FLA	Running Prot. 115% FLA		Starter size	Disconnect size	Max. Prot. Device Full Volt Start			
		Adj.	Non-Adj.			Code B-E		Code F-V	
						C.B. 200%	Fuse 250%	C.B. 250%	Fuse 300%
.5	1	1.15	2	00	30	15	15	15	15
.75	1.4	1.61	2	00	30	15	15	15	15
1	1.8	2.07	3	00	30	15	15	15	15
1.5	2.6	2.99	3	00	30	15	15	15	15
2	3.4	3.91	4	00	30	15	15	15	15
3	4.8	5.52	6	0	30	15	15	15	15
5	7.6	8.74	10	0	30	20	20	20	25
7.5	11	12.65	15	1	30/60	25	30	30	35
10	14	16.1	20	1	30/60	30	35	35	45
15	21	24.15	25	2	60/100	45	60	60	70
20	27	31.05	35	2	60/100	60	70	70	90
25	34	39.1	40	2	100/200	70	90	90	110
30	40	46	50	3	100/200	90	100	100	125
40	52	59	60	3	200	125	150	150	175
50	65	74.75	80	3	200	150	175	175	200
60	77	88.55	90	4	200/400	175	200	200	250
75	96	110.4	125	4	400	200	250	250	300
100	124	142.6	150	4	400	250	350	350	400
125	156	179.4	200	5	400/600	350	400	400	500
150	180	207	225	5	600	400	450	450	600
200	240	276	300	5	600	500	600	600	–

FIGURE 2 (cont'd)

HP	K	L		M	N	O	P
	125% FLA	THREE CONDUCTOR BRANCH CABLE					
		AWG (IEEE 45, 50°C)				TSGA-( )	
		T		E,X	AVS	40°C	50°C
.5	1.25 14		14	14	4	4	
.75	1.75 14		14	14	4	4	
1	2.25 14		14	14	4	4	
1.5	3.25 14		14	14	4	4	
2	4.25 14		14	14	4	4	
3	6	14		14	14	4	4
5	9.5	14		14	14	4	4
7.5	13.75	14		14	14	4	4
10	17.5 14		14	14	4	9	
15	26.25	10		10	12	9	9
20	33.75	8		10	10	9	9
25	42.5 7		8	8	14	14	
30	50	6		7	7	14	23
40	65	4		5	6	23	23
50	81.25	2		3	4	30	40
60	96.25	1		2	3	40	50
75	120	2/0		1/0	1	60	75
100	155	3/0		2/0	1/0	100	100
125	195	250		4/0	3/0	125	150
150	225	300		250	4/0	150	200
200	300	500		400	300	250	300

APPENDIX 6

MOTOR CIRCUIT INFORMATION

Examples Of 3-Phase AC Motor Circuits. Use Quick-Reference Columns, Figure 1:

(a) Example No. 1. Single motor, 25 horsepower, 460V, code letter J, full voltage start, non-vital, non-adjustable overloads, branch circuit protected by circuit breaker, Type T, IEEE 45 Cable, in 50°C ambient temperature space.

From Quick-Reference Columns, Figure 1:

D - Standard overload size nearest 115 percent full load; current is 40 amperes.

E - Starter size is 2.

F - If a disconnect is used near the motor, a 100 ampere size is sufficient, provided it is not fused above 100 amperes (if fusible). If part of a combination starter, the complete unit must be rated to handle the 25-horsepower motor.

I - The maximum standard size for the branch circuit protective device is a 90 ampere breaker.

L - The cable used to power the motor must be rated for at least 42.5 amperes. For Type T cable in a 50°C ambient location Type T-7 is required.

(b) Example No. 2. A 460 volt Motor Control Center (MCC) supplying one 30 HP, one 15 HP, and two 5 HP motors in 50°C ambient space. One 5 HP motor is a steering system pump. All are full-voltage starting; the 30 HP motor starter has adjustable overloads. The unit has branch circuit protection with circuit breakers. Navy-type cable TSGA is used. First get data for each motor load; assume code letters F-V.

From Quick-Reference Columns, Figure 2:

Col. A	Col. B	Col. C	Col. E	Col. F	Col. I	Col. K	Col. P
Horse-Power	Full Load Amps	Adj. Over Load Size	Starter Size	Std. Disc. Size, If Used	Max. Branch Circ. Bkr. (250%)	125% F.L.A.	50°C TSGA-( )
30	40	46	3	100	100	50	23
15	21	24.2	2	60	60	26.3	9
5	7.6	8.7	0	30	N/A	9.5	4

Subchapter J does not address motor control centers directly; one must refer to NEC 430-24 and 430-62(a). Per 430-24, bus or cable in MCC must be sized for 125 percent of the largest plus 100 percent of the remaining motor full load currents, 50 + 21 + 7.6 + 7.6 = 86.2 amperes. If the MCC has spare sections, allowance shall be made for future growth. Breaker protecting entire MCC must not be larger than the largest rating or setting of the branch-circuit short-circuit and ground fault protection (based on Table 430-152) for any motor in the group, plus the sum of the full load currents of the other motors in the group, or 100 + 21 + 7.6 + 7.6 = 136.2 amperes.

A 125 amp circuit breaker would be adequate.

The 5 HP steering pump motor should be protected with a circuit breaker having adjustable, instantaneous (magnetic) type tripping only. This breaker must be set to open the motor circuit at 175 to 200 percent of the locked rotor current. As will be shown below, this setting should be 79 to 90 amperes.

NEMA AC General Purpose, Class A Full Voltage Controllers, Single-Speed Squirrel Cage Motors.

3-PHASE NON-JOGGING DUTY

SIZE	CONTINUOUS DUTY AMPS	HORSEPOWER 200 VAC	HORSEPOWER 230 VAC	HORSEPOWER 460 VAC	LIMIT AMPS
00	9	1.5	1.5	2	11
0	18	3	3	5	21
1	27	7.5	7.5	10	32
2	45	10	15	25	52
3	90	25	30	50	104
4	135	40	50	100	156
5	270	75	100	200	311
6	540	150	200	400	621
7	810		300	600	932

3-PHASE JOGGING DUTY

0	18	1.5	1.5	2	21
1	27	3	3	5	32
2	45	7.5	10	15	52
3	90	15	20	30	104
4	135	25	30	60	156
5	270	60	75	150	311
6	540	125	150	300	621

NOTE: From NEMA ICS 2-321 B

Motor Conversion Formulas.

TO FIND	DC	AC-Single Phase	AC 3 Phase
AMPS when HP is known	$\frac{\text{HP} \times 746}{\text{Volts} \times \text{Eff}}$	$\frac{\text{HP} \times 746}{\text{Volts} \times \text{Eff} \times \text{PF}}$	$\frac{\text{HP} \times 746}{\text{Volts} \times 1.73 \times \text{Eff} \times \text{PF}}$
AMPS when KW is known	$\frac{\text{KW} \times 1000}{\text{Volts}}$	$\frac{\text{KW} \times 1000}{\text{Volts} \times \text{PF}}$	$\frac{\text{KW} \times 1000}{\text{Volts} \times 1.73 \times \text{PF}}$
AMPS when KVA is known		$\frac{\text{KVA} \times 1000}{\text{Volts}}$	$\frac{\text{KVA} \times 1000}{\text{Volts} \times 1.73}$

TO FIND	DC	AC-Single Phase	AC 3 Phase
Kilowatts KW	$\frac{\text{AMPS x Volts}}{1000}$	$\frac{\text{AMPS x Volts x PF}}{1000}$	$\frac{\text{AMPS x Volts x 1.73 x PF}}{1000}$
KVA		AMPS x Volts	AMPS x Volts x 1.73
Power Factor PF		KW/KVA	KW/KVA
HP Output	$\frac{\text{AMPS x Volts x Eff}}{746}$	$\frac{\text{AMPS x Volts x Eff x PF}}{746}$	$\frac{\text{AMPS x Volts x 1.73 x Eff x PF}}{746}$

NOTES: (1) Power Factor and Efficiency should be expressed in decimals.

(2) If Power Factor is not given, assume 0.8.

(3) If Efficiency is not given, assume 0.8.

Single Phase Motor: Approximate Full Load Current.

HP	115V	HP	115V
.33	7.2	2	24.0
.5	9.8	3	34.0
.75	13.8	5	56.0
1.0	16.0	7.5	80.0
1.5	20.0	10	100.0

NOTES: (1) Values are for motors of normal speed and torque.

(2) For additional values, see NEC Table 430-148.

(3) For other KW ratings, voltages, and power factors:

$$\text{AMPS} = \frac{\text{KW x 1000}}{\text{1.732 x Volts x PF}}$$

Motor Locked Rotor Current.

Max. HP	115VAC 1 Phase			208VAC 3 Phase			230VAC 3 Phase			460VAC 3 Phase		
	100%	175%	200%	100%	175%	200%	100%	175%	200%	100%	175%	200%
2	144	252	288	43	75	86	39	68	78	20	35	40
3	204	357	408	59	103	118	54	95	108	27	47	54
5	336	588	672	99	173	198	90	158	180	45	79	90

Motor Locked Rotor Current (cont.)

Max. HP	115VAC 1 Phase			208VAC 3 Phase			230VAC 3 Phase			460VAC 3 Phase		
	100%	175%	200%	100%	175%	200%	100%	175%	200%	100%	175%	200%
7.5	480	840	960	145	254	290	132	231	264	66	116	132
10	600	1050	1200	178	312	356	162	284	324	84	147	168
15				264	462	528	240	420	480	120	210	240
20				343	599	686	312	546	624	156	273	312
25				422	739	844	384	672	768	192	336	384
30				515	901	1030	468	819	936	234	410	468
40				686	1201	1372	624	1092	1248	312	546	624
50				825	1444	1650	750	1313	1500	378	662	756
75				1221	2137	2442	110	1943	2220	558	977	1116
100				1624	2874	3248	1476	2583	2952	738	1292	1476

NOTES:

(1) These values are to be used only if motor code letter is not provided.

(2) Values above calculated from NEC Tables 430-150, 430-151.

(3) If motor nameplate code letter is provided, the following applies:

(a) See NEC Table 430-7(b) for code letter KVA/HP; and

(b) Locked rotor current, IL:

$$\text{3-phase motors IL} = \frac{\text{HP x (KVA/HP) x 1000}}{\text{1.73 x Volts}}$$

$$= \frac{\text{577 x HP x (KVA/HP)}}{\text{Volts}}$$

$$\text{1-phase motors IL} = \frac{\text{HP x (KVA/HP) x 1000}}{\text{Volts}}$$

Continuous-Duty, 3-Phase Motor Approximate F.L.A.

HP	Squirrel Cage			Wound Rotor		
	208V	220V	440V	208V	220V	440V
.5	2.1	1.9	.95			1.0
1	3.7	3.4	1.7	5.9	5.4	2.7
1.5	5.5	5.0	2.5	7.5	6.8	3.4
2.0	6.9	6.3	3.1	8.8	8.0	4.0
2.5	8.4	7.6	3.8	9.7	8.8	4.4
3.0	9.9	9.0	4.5	11.5	10.5	5.3
5.0	16.0	14.5	7.2	17.6	16.0	8.0
6.0	18.9	17.2	8.6	19.8	18.0	9.0

3-Phase Motor Approximate F.L.A. (cont.)

HP	Squirrel Cage 208V	Squirrel Cage 220V	Squirrel Cage 440V	Wound Rotor 208V	Wound Rotor 220V	Wound Rotor 440V
7.5	23	21	10.5	25.3	23	11.5
9.0	27.3	24.8	12.4	28.6	26	13
10	28.6	26	13.5	31.9	29	14.5
20	57.2	52	26	59	54	27
25	71.5	65	32	75	68	34
30	86	78	39	88	80	40
35	101	92	46	103	94	47
40	112	102	51	114	104	52
45	128	116	58	128	116	58
50	139	126	63	141	128	64
60	167	152	76	169	154	77
75	207	188	94	207	188	94
100	275	250	125	275	250	125
125	341	310	155	341	310	155
150	407	370	185	407	370	185
200	539	490	245	539	490	245

NOTES:

(1) To be used in lieu of nameplate data (see NEC 430-6).

(2) Not to be used to size motor running overloads; use nameplate data.

(3) For multi-speed, low speed, special motors, use nameplate data.

(4) For additional information, see NEC Table 430-150.

(5) Ranges: 220V 220-240VAC
440V 440-480VAC

APPENDIX 7

LIST OF ELECTRICAL HAZARD GROUP CLASSIFICATIONS FOR BULK DANGEROUS CARGOES

NOTES:

1. This table is the National Academy of Sciences' (NAS) "Classification of Gases, Liquids, and Volatile Solids Relative to Explosion-proof Electrical Equipment," NMAB 353-5 (1982). This information is is updated as necessary in the Federal Register.

2. "H" indicates a high flash point (in excess of 150^{o}F.), a Grade E combustible liquid; less stringent electrical requirements apply per 46 CFR 111.105-29.

3. "N" indicates non-flammable; however, when the non-flammable evolves hydrogen in contact with mild steel or otherwise results in the liberation of another flammable gas, an appropriate electrical group is assigned instead of an "N" being shown.

4. "NA" indicates that no electrical hazard group is applicable; no electrical restrictions apply.

5. Note that Grade E combustible liquids do have hazardous areas (in tanks) and that intrinsically safe (IS) equipment (level indicators, etc.) must be for the proper group.

LIST OF ELECTRICAL HAZARD GROUP
CLASSIFICATIONS FOR BULK DANGEROUS CARGOES

C Acetaldehyde
D Acetic acid
D Acetic anhydride
H Acetone cyanohydrin
D Acetonitrile
D Acrylic acid
D Acrylonitrile
H Adiponitrile
C Allyl alcohol
D Allyl chloride
NA Aluminum sulfate solution
H Aminoethyl ethanolamine
D Ammonia, anhydrous (press.)
D Ammonia, anhydrous (atmosphere)
NA Ammonium bisulfite solution (70% or less)
D Ammonium hydroxide (28% or less NH3)
H Aniline
D Anthracene oil (coal tar fraction)
NA Argon, liquified
D Benzene
D Benzene-hydrocarbon mixtures
B Butadiene
B Butadiene, butene mixtures
D n-Butyl acrylate
D iso-Butyl acrylate
D Butylamine
C Butylmethacrylate
C Butyraldehydes (crude)
C n-Butyraldehyde
C iso-Butyraldehyde
D Camphor oil (light)
H Carbolic oil
A Carbon disulfide
NA Carbon dioxide (liquefied)
N Carbon tetrachloride
N Caustic potash solution
N Caustic soda solution
N Chlorine
D Chlorobenzene
N Chloroform
D Chlorohydrins (crude)
B Chlorosulfonic acid
D Coal tar
D Coal tar naphtha solvent
D Coal tar pitch (molten)
H Creosote
H Cresols
N Cresylate spent caustic
C Crotonaldehyde
D Cyclohexanone
D Cyclohexylamine
H iso-Decyl acrylate
D Dichlorobenzene (all isomers)

N Dichlorodifluoromethane
D 1,1-Dichloroethane
D 2,2-Dichloroethyl ether
N Dichloromethane
NA 2,4-Dichlorophenoxyacetic acid, diethanolamine salt solution
NA 2,4-Dichlorophenoxyacetic acid, dimethylamine salt solution
NA 2,4-Dichlorophenoxyacetic acid, triisopropanol-amine salt solution
D Dichloropropane
D Dichloropropene, Dichloropropane mixtures
NA 2,2-Dichloropropionic acid
H Diethanolamine
C Diethylamine
H Diethylenetriamine
C Diisobutylamine
H Diisopropanolamine
C Diisopropylamine
D N,N-Dimethylacetamide
C Dimethylamine
C Dimethylethanolamine
D Dimethyl Formamide
C 1,4-Dioxane
C Di-n-propylamine
NA Diphenylmethane Diisocyanate
C Epichlorohydrin
H Ethanolamine
D Ethyl acrylate
D Ethylamine (72% or less)
C Ethyl n-butylamine
D Ethyl chloride
C Ethyl cyclohexylamine
D Ethylene chlorohydrin
H Ethylene cyanohydrin
D Ethylene diamine
N Ethylene dibromide
D Ethylene dichloride
NA Ethylene glycol propyl ether
B Ethylene oxide
C Ethyl ether
H 2-Ethyl hexyl acrylate
C Ethylidene norbornene
D Ethyl methacrylate
C 2-Ethyl-3-proply acrolein
B Ferric chloride solutions
H Formaldehyde solution (37%-50%)
D Formic acid
C Furfural
NA Glutaraldehyde solution (50% or less)
D Hexamethylenediamine solutions
C Hexamethyleneimine
B Hydrochloric acid
B Hydrochloric acid, spent (15% or less)
B Hydrofluorosilicic acid (25% or less)

B Hydrogen chloride
B Hydrogen fluoride
H 2-Hydroxyethyl acrylate
D Isoprene
NA Kraft pulping liquors (free alkali content 3% or more)
D Mesityl oxide
C Methylacetylene Propadiene mixture
D Methyl acrylate
D Methylamine (anhydrous)
D Methylamine solution (42% or less)
D Methyl bromide
D Methyl chloride
B Methylcyclopentadiene dimer
C Methyldiethanolamine
H 2-Methyl-5-ethyl pyridine
D Methyl methacrylate
D 2-Methyl pyridine
D alpha-Methyl styrene
N Monochlorodifluoromethane
H Ethanolamine
C Morpholine
D Motorfuel antiknock compounds
B Nitric acid (70% or less)
D Nitrobenzene
NA Nitrogen, Liquified
C 1- or 2- Nitropropane
NA Octyl nitrates (all isomers)
B Oleum
NA Pentachloroethane
D 1,3-Pentadiene
N Perchloroethylene
H Phenol
H Phosphorous, elemental
B Phosphoric acid
H Phthalic anhydride
H Polyethylene polyamine
H Polymethylene polyphenylisocyanate
H iso-Propanolamine
D Propionic acid
D iso-Propylamine
B Propylene oxide
D iso-Propyl ether
D Pyridine
NA Sodium aluminate solution
N Sodium chlorate solution (50% or less)
NA Sodium dichromate solution (70% or less)
NA Sodium hypochlorite solution (15% or less)
N Sodium sulfide, hydrosulfide solutions (H2S 15ppm or less)
N Sodium sulfide, hydrosulfide solutions (H2S greater than 15ppm but less than 200ppm)
N Sodium sulfide, hydrosulfide solutions (H2S greater than 200ppm)
NA Sodium thiocyanate solution (56% or less)
D Styrene monomer
C Sulfur (molten)
N Sulfur dioxide

B Sulfuric acid
B Sulfuric acid, spent
NA 1,1,2,2-Tetrachloroethane
H Tetraethylene pentamine
C Tetrahydrofuran
H Toluene diisocyanate
D 1,1,2,-Trichloroethane
D Trichloroethylene
H 1,2,3-Trichloropropane
H Triethanolamine
C Triethylamine
H Triethylene tetramine
H Triisopropanolamine
C Velaraldehyde (iso-,n-)
NA Vanillan black liquor (free alkali content 3% or more)
D Vinyl acetate
D Vinyl chloride
D Vinylidene chloride
D Vinyl toluene
D Urea, Ammonium nitrate (containing more than 2% NH3)

APPENDIX 8

RECOMMENDED PLAN REVIEW CHECK-OFF FOR HAZARDOUS LOCATIONS

1. Has sufficient information been provided?

____(a) Hazardous cargoes;

____(b) An arrangement plan identifying hazardous and non-hazardous areas, cargo system or hazards, electrical equipment type and locations;

____(c) A complete and detailed Bill of Materials;

____(d) Elementary and one-line wiring diagrams, showing all wiring;

____(e) Electrical installation details;

____(f) Nationally Recognized Testing Laboratory (NRTL) label or listing for explosionproof (EP) and intrinsically safe (IS) equipment and systems; and

____(g) Maximum temperature ratings of electrical equipment in hazardous areas.

2. Identify hazardous characteristics:

____(a) Class and group;

____(b) Flashpoint and grade;

____(c) Minimum ignition temperatures; and

____(d) Special requirements, including material compatibility.

3. Confirm boundaries of hazardous locations and suitability of equipment installed.

4. Confirm that the installation meets:

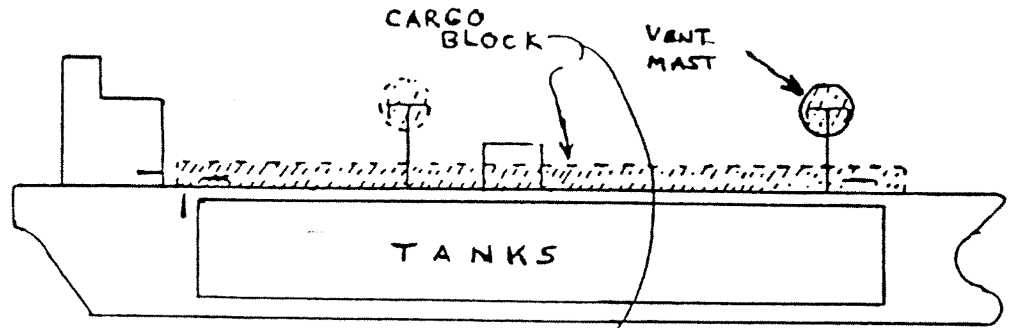
____(a) Subchapter J;

____(b) Intended application by a NRTL (currently UL, FM, CSA, and MET are acceptable to the Coast Guard);

____(c) Specific requirements for the cargo/material; and

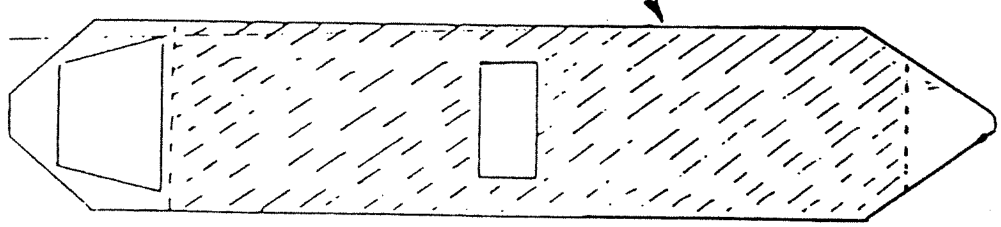
____(d) General considerations of this NVIC.

TANKSHIP WEATHERDECK CRITERIA



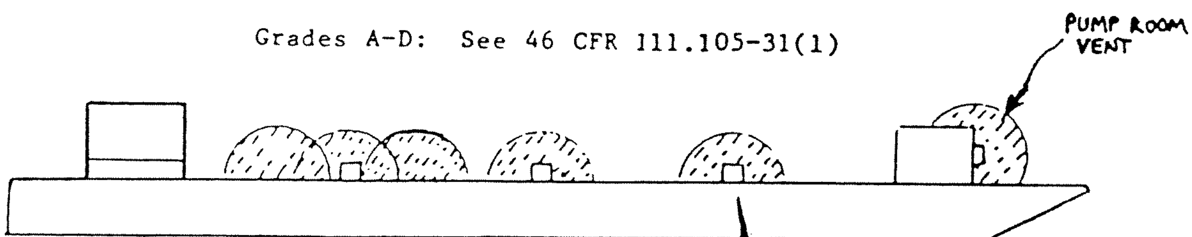
:quipment in cross-hatched areas must be
xplosionproof, watertight, Class 1, Division 1

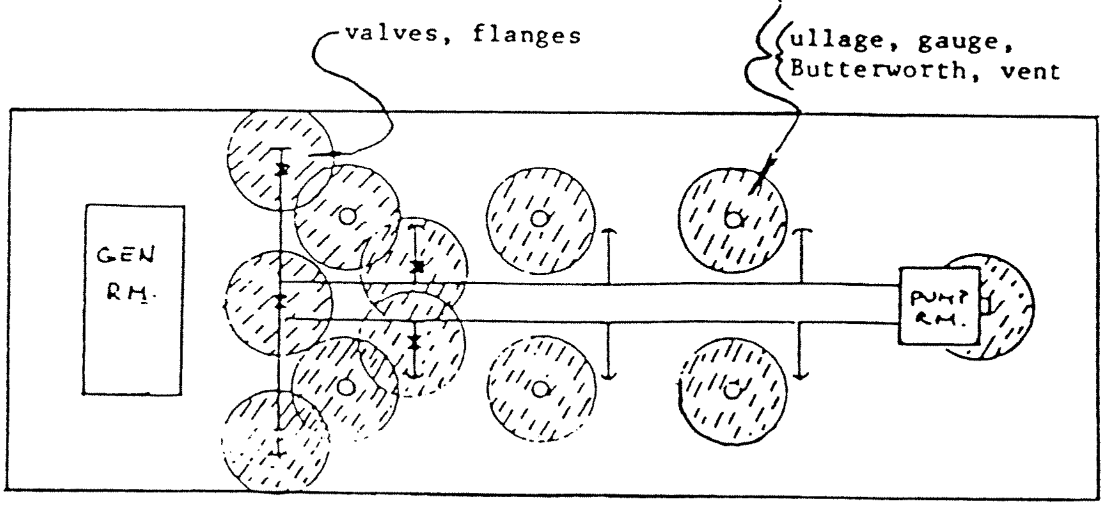
See 46 CFR 111.105-31(1)



TANK BARGE WEATHERDECK CRITERIA

Grades A-D: See 46 CFR 111.105-31(1)





)-foot rule: Equipment in cross-hatched areas must be explosionproof, watertight
Class 1, Division 1

SPECIFIED HAZARDOUS LOCATIONS

LOCATION	CLASS I DIV. 1	CLASS I DIV. 2	CLASS II	CLASS III
CARGO TANKS*	NA	NA	NA	NA
CARGO HANDLING ROOMS*	NA	NA	NA	NA
COFFERDAMS*	NA	NA	NA	NA
BATTERY ROOMS	X	NA	NA	NA
PAINT STORAGE ROOMS	X	NA	NA	NA
PAINT MIXING ROOMS	X	NA	NA	NA
OIL STORAGE ROOMS	X	NA	NA	NA
ANESTHETIC HANDLING AREA	X	NA	NA	NA
TANK VESSEL WEATHERDECK 10 FT. RULE	X	NA	NA	NA
TANK VESSEL WEATHERDECK CARGO BLOCK	X	NA	NA	NA
FLAMMABLE GAS HANDLING ROOM*	NA	NA	NA	NA
FLAMMABLE LIQUID HANDLING ROOM*	NA	NA	NA	NA
ADJACENT TO CLASS I, DIV. 1 W/COMMUNICATION	X	NA	NA	NA
TANK VESSEL ENCLOSED SPACES ADJACENT TO CARGO TANK*	NA	NA	NA	NA
GRAIN HANDLING AREA	NA	NA	X	NA
COAL HANDLING AREA	NA	NA	X	NA
COAL PULVERIZING AREA	NA	NA	X	NA
CARPENTER SHOP	NA	NA	NA	X
FIBER HANDLING AREA	NA	NA	NA	X
VENT DUCT		SAME AS SPACE SERVED		
TANK VESSEL CARGO HOSE STOWAGE SPACE*	NA	NA	NA	NA
SPACE CONTAINING CARGO PIPING ONLY, ON TANK VESSELS*	NA	NA	NA	NA
LFG BARRIER SPACE*	NA	NA	NA	NA
ENCLOSED SPACE OPENING TO WEATHER DECK HAZ. AREA	X	NA	NA	NA
TANK VESSELS WITHIN 8' OF CARGO CONTAINMENT SYSTEM	X	NA	NA	NA
TANK VESSELS, WITHIN 10' OF CARGO HANDLING ROOM DOOR OR VENT	X	NA	NA	NA
VESSEL FUEL OIL TANKS, 10' RULE DOES NOT APPLY	X	NA	NA	NA
TANK VESSEL, A-D CARGOES, AREA FROM 3m TO 5m OF PV VALVES (see SOLAS II-2/59.1.7.2)	NA	X	NA	NA
TANK VESSEL, A-D CARGOES, AREA FROM 3m TO 10m OF VENT OUTLETS FOR FREE FLOW OF VAPORS AND H.V. VENTS FOR LOADING OR DISCHARGE (see SOLAS II-2/59.1.9.3)	NA	X	NA	NA

* These areas are considered more hazardous than Class I, Division 1 and therefore carry specific requirements in 46 CFR 111.105-29, 111.105-31, and 111.105-32.

APPENDIX 9

Approvals Under Subchapter Q

Subchapter Q electrical equipment (see 46 CFR 161) is required to be "approved" by the Commandant and is listed in Equipment Lists. For the most part, the specifications in Subchapter Q have not been updated since 1959 and, therefore, do not reflect changes in the state of the art. The following electrical equipment receives approval under Subchapter Q:

a. 161.004 - Emergency Loudspeaker Systems. Although this specification is in need of revision, there have been no new submittals for type approval of emergency loudspeaker systems in the past several years. The Coast Guard intends to propose deletion of this Subchapter Q specification in regulatory project CGD85-043, Miscellaneous Changes to the Electrical Engineering Regulations. The Coast Guard intends to incorporate performance requirements in Subchapter J for public address systems on all vessels subject to Subchapter J.

b. 161.006 - Searchlights, Motor Lifeboat For Merchant Vessels. The Coast Guard intends to delete the Subchapter Q specification and incorporate an industry concensus standard, ASTM F1003-1986 "Searchlights for Motor Lifeboats," in regulatory project CGD84-049.

c. 161.008 - Hand Electric Flashlights For Merchant Vessels. Until recently, approved flashlights were required in lifeboats and liferafts. The Federal Register, Vol. 53, No. 96, dated May 18, 1988 published the final rule which deletes 46 CFR 161.008. This rule, effective August 16, 1988, requires flashlights for lifeboats and liferafts to be constructed to ASTM F1014-1986, "Standard Specification for Flashlights on Vessels", as a Type I or Type III flashlight. It also requires flashlights in emergency lockers, fireman's outfits, and as part of the safety equipment on self-propelled vessels carrying bulk liquefied gases to be constructed to ASTM F1014-1986 as a Type II or Type III flashlight. Manufacturers of flashlights who have current Certificates of Approval for their flashlights may continue to label their flashlights with the appropriate U.S. Coast Guard approval number up to the expiration date of the Certificate of Approval. These Certificates will not be re-issued after their expiration date. Coast Guard approved flashlights in lifeboats presently installed on U.S. flag vessels need not be replaced as long as they are in serviceable condition.

d. 161.010 - Floating Electric Waterlights. Many of these lights have had their approvals superseded by new approvals. Waterlights that are approved at the time of installation and then have their approvals superseded may continue in service as long as they are operational. The Coast Guard intends to adopt the construction requirements of UL 1196, "Floating Electric Waterlights," to replace the detailed requirements in the Subchapter Q specification. The UL standard addresses the present international requirements of SOLAS 74 and the 1983 ammendments.

APPENDIX 10

INSPECTION OF ELECTRICAL INSTALLATIONS FOR VESSEL CERTIFICATION

1. Introduction. (NOTE: The material in this Appendix has been taken substantially from MSM II/6.L.) At each inspection for certification, the inspector shall examine the vessel's electrical equipment and apparatus, the arrangement and materials of the installation, and the operating condition of the installation as required by the regulations. The primary purposes of electrical inspections are to ensure the adequacy and reliability of shipboard electrical systems, to maximize safety to personnel from electrical shock, and to minimize the danger of fire originating within the electrical system.

2. Scope of Inspection. The scope of the electrical inspections for vessels other than small passenger vessels is detailed in the vessel CFR subchapters and is supplemented by 46 CFR 110.30. The inspection includes the examination and testing, when necessary, of all electric generators, motors, wiring circuits, junction boxes, fixtures, and other electric installations. No electrical repairs or alterations affecting the safety of the vessel, its equipment, and crew should be made without the knowledge and approval of the OCMI. Drawings must be approved before work is started when the repairs will involve alterations.

3. References. The standards for the inspection of electrical installations on all vessels except small passenger vessels (Subchapter T vessels) are contained in 46 CFR Subchapter J. As indicated in 46 CFR 110.10, they are supplemented by recognized specifications, standards, and codes. Subchapter J applies to small passenger vessels only insofar as it is made applicable by 46 CFR 183. Vessels contracted for prior to November 19, 1952 are not fully subject to the requirements in Subchapter J. The electrical installations on these older vessels may be maintained as long as their condition is satisfactory to the OCMI, unless amended regulations specifically apply to these vessels. However, major alterations or extensions to such electrical installations shall be made to the requirements of Subchapter J.

4. Initial Electrical Inspections.

a. Introduction. In carrying out tests and inspections prescribed in the vessel subchapters and in 46 CFR 110.30, the inspector shall pay particular attention to the items listed below. These tests and inspections are intended as guides to the inspector; they are not mandatory unless the OCMI judges them to be necessary. Extreme caution shall be exercised during all inspections and tests. Tests and inspections will be done by the shipbuilder, the owner, or the owners representative. They should be observed by the inspector and the recorded data obtained for checking and reference purposes.

b. Electrical Cable. Electrical cable shall be checked during installation for size and type as shown on the approved plans. The adequacy of cable supports shall also be checked. It shall be ascertained that cables are not located near pipes and hot objects, and that they have not been damaged during installation by excessive pulling, sharp bends, sharp or rough edges of cable supports or bulkhead penetrations, or similar conditions. Cable penetrations required to be watertight shall be checked for proper packing of terminal or stuffing tubes, including areas provided for future takeup of gland units. Cable penetrations through Class A and Class B bulkheads and decks shall be checked for compliance with approved methods.

c. Insulation Resistance. All electric power, lighting cables, generators, and vital systems motors shall be checked for proper insulation to ground and between conductors. The insulation resistance measuring instrument (megger) used should be of the 500 volt, direct-current type, except for equipment where the normal operating voltage is less than 100 volts in which case a direct reading ohmmeter of the appropriate voltage should be used. Insulation resistance varies considerably with humidity, amount of exposed copper, etc. Therefore, it is difficult to establish firm rules to guide the inspector. Generally, Figure A-4 should be used as a guide in determining minimum acceptable values of insulation resistance. Ordinarily, on a dry day and with new, clean equipment, resistance should not be less than the values indicated in the figure. The insulation resistance in megohms shall be at least equal to that determined by the formula in Figure A-4.

FIGURE A-4

INSULATION RESISTANCE

1. GENERAL INSULATION RESISTANCE FORMULA FOR VITAL MOTORS AND GENERATORS

$$R \text{ (In Megohms)} = \frac{E}{\frac{KVA}{100} + 1{,}000}$$

Where: E = Rated line to line voltage of the machine.
KVA = Rated kilovolt amperes.

2. GENERAL RESISTANCE TABLE FOR CABLE[1]

CIRCUIT		MINIMUM INSULATION RESISTANCE
0-5	amperes, inclusive	2.0 megohms
6-10	amperes, inclusive	1.0 megohms
11-25	amperes, inclusive	400,000 ohms
26-50	amperes, inclusive	250,000 ohms
51-100	amperes, inclusive	100,000 ohms
101-200	amperes, inclusive	50,000 ohms
Over 200	amperes	25,000 ohms

[1] The values for a circuit should be determined with the circuit de-energized, with all switches or circuit breakers connected in the circuit closed, and with all panelboards, controllers, fuses, and fuseholders in place.

d. Group Control Panels. When two or more motor controllers are grouped into a central panel and supplied by a common feeder, the panel shall be checked for compliance with the requirements of 46 CFR 111.70. Each controller, its associated motor overcurrent protective device, its motor branch circuit overcurrent protective device, and disconnecting mechanism shall be mounted in a common enclosure with a disconnect device that prevents the door being opened when the circuit is energized. The enclosure shall be either dripproof or watertight, depending on its location. Adequate working space should also be provided. This generally should be no less than 36 inches in front, and in no case less than 24 inches in the rear, when access to the rear may be necessary.

e. Generators. Generators shall be checked for general condition (both electrical and mechanical), voltage regulation, parallel operation, operation of safety devices such as reverse-current or reverse-power trips, overcurrent trips, overspeed trips, low-oil pressure trips, and similar devices (see 46 CFR 111.12).

f. Rotating Electric Machinery. This equipment shall be checked to ensure that rotating and uninsulated electric parts are adequately shielded from accidental contact by personnel. Nameplate data shall be examined for correct ratings for the particular application (see 46 CFR 111.01 and 111.25).

g. Switchboards. Switchboards shall be checked for nonconducting handrails, guardrails, working spaces, insulating floor coverings, drip covers, and shields. Switchboard enclosures shall be checked for proper construction in accordance with 46 CFR 111.30. Switchboard mounted apparatus shall be checked for identifying nameplates. Circuit nameplates shall be compared with the rating or setting of the overcurrent devices and with approved plans. The accessibility of items requiring maintenance or adjustment shall be checked. Meters shall be checked for proper operation. The operation of automatic switchgear and interlocks shall be observed (see 46 CFR 111.30).

h. Panelboards. The rating or setting of the overcurrent devices shall be compared with the values given on the circuit directory and the approved plans. The accuracy of the directory description of loads served by each circuit shall also be checked (see 46 CFR 111.40).

i. Motor Starters. Motor starters shall be checked to ensure proper starting under service conditions with properly rated, motor running, overcurrent protective devices. Enclosures shall be checked to ensure that they are dripproof or watertight, and that required door positioners are installed on doors with a height of more than 45 inches or a width greater than 24 inches. A fixed heat-resistant wiring diagram for each motor starter must be on the inside of its enclosure door. Each motor starter not disconnected from all sources of potential when the disconnect switch is opened, due to electrically interlocked circuits that are necessary for proper operation of the apparatus or for other valid reasons, shall have attention directed to these conditions by a warning sign (see 46 CFR 111.70).

j. Disconnect Switches. The presence and location of disconnect switches required for motor starters, fuses, etc., shall be checked. When a switch, circuit breaker, switchboard, or distribution panel is intended to serve as a motor and controller disconnect switch, the inspector shall ensure that the applicable requirements have been met (see 46 CFR 111.55 and 111.70).

k. Accessibility. The accessibility of electrical apparatus for inspection and maintenance shall be observed. The accessibility of junction boxes and similar apparatus in way of paneling shall also be noted. Hinged doors of motor starters and similar apparatus shall be checked for interference with adjacent structural parts or apparatus.

l. General Alarm Systems. The general alarm system shall be checked with a sound level meter, the sound level of the bells being measured in each stateroom with the doors closed. Where the background noise level is questionable, the sound level should be measured while the vessel is underway (see 46 CFR 113.25-9).

m. Emergency Loudspeaker Systems. During the initial inspection for certification, the emergency loudspeaker system shall be checked with a sound level meter at each lifeboat handling station, each lifeboat embarkation station, each passenger assembly station, and throughout the crew's quarters. Where the background noise level is questionable, the sound level should be measured while the vessel is underway (see 46 CFR Table 113.50 for the required sound levels).

n. Electric Installations In Hazardous Locations. Electric equipment and wiring in hazardous locations shall be checked for compliance with 46 CFR 111.105. Intrinsically safe systems shall be checked to ensure that they are installed in accordance with the plans and instructions required by 46 CFR 111.105-11. Equipment required to be explosionproof or intrinsically safe shall also be checked for proper Underwriters Laboratories, Inc. (UL), Factory Mutual Research Corporation (FM), Canadian Standards Association (CSA), MET Electrical Testing Company (MET), or other "nationally recognized testing laboratory" label or other evidence of listing. Purged or pressurized equipment shall be checked for adequate air supply and required interlocks.

o. Steering Gear Circuits. Steering gear circuits shall be separated to meet the requirements of 46 CFR 111.93. Steering gear motor controllers shall be located in the steering gear room.

p. Emergency Circuits. Circuits connected to the emergency switchboard must not pass through the engineroom or boiler room (except for circuits supplying equipment in those spaces).

q. Low Voltage Release Tests. It shall be determined that motor controllers required by 46 CFR 111.70-3(f) and (g) to have low voltage release, do so, and that motor controllers prohibited from having low voltage release have low voltage protection. All motors should be run simultaneously and all generators then tripped off the line. One generator should be placed back on the line; it should not trip because of the oncoming load. Motor controllers requiring low voltage release should start their motors automatically; those prohibited from having low voltage release should not start their motors automatically. If the motor load exceeds the total ship's service generating capacity, this test should be conducted with all motors that have low voltage release and sufficient motors with low voltage protection, adding up to the total generating capacity running. A

q. (cont'd) second test shall then be conducted with the remaining motors; none of the motors in this second test should start automatically.

r. Miscellaneous Electrical Equipment. The Coast Guard no longer grants type approvals for miscellaneous electrical equipment. Electrical equipment can basically be divided into the following categories:

(1) Equipment Required To Be Approved By The Commandant. This equipment is listed in Subchapter Q and will have an approval number assigned.

(2) Equipment Required To Meet Various Standards. This equipment is contained in Subchapter J. It is important to note that the requirement is to meet the standard, not to be listed by a listing service. The burden of proof that the standard is met rests with the manufacturer.

(3) Equipment Required To Be Explosionproof Or Intrinsically Safe. This equipment must be listed by a nationally recognized testing laboratory (initially UL, FM, CSA, or MET).

[NOTE: Some equipment approvals may require combination of the above factors.]

5. Subsequent Electrical Inspections.

a. Introduction. In subsequent tests and inspections, inspectors shall pay particular attention to the items listed in this section of the manual. The inspector shall determine mechanical and electrical conditions, performance, safety of personnel against shock hazards, and safety of the vessel from fire hazards.

b. New And Modified Circuits. Circuits and equipment added or modified since the last inspection shall be given special attention to determine that they comply with the regulations.

c. Navigation Lights. Navigation lights shall be examined for corrosion of materials and for satisfactory condition of portable cable and receptacles. Navigation light panels shall be tested for satisfactory operation and proper functioning of alarms.

d. Lifeboat Winch Electrical Equipment. All enclosures for electrical lifeboat winch control equipment, such as limit switches, master switches, and emergency disconnect switches, shall be opened and examined for evidence of water or corrosion. In particular, attention shall be given to the proper functioning of limit switches and emergency disconnect switches in the control circuits of lifeboat

d. (cont'd) winches. Casualty investigations have indicated the need to specifically examine the clutch interlock switches on dual winches, such as those on Victory-type cargo ships. It is essential that satisfactory limit switches and emergency disconnect switches be used with gravity davits and power-operated winches. Therefore, a test operation of the lifeboat winch controls, including limit switches, emergency disconnects, and clutch interlocks where employed, shall be conducted at each reinspection and as the inspector may require.

e. Watertight Doors. The inspector shall thoroughly check the watertight door systems to verify that they are in satisfactory operating condition. The enclosures for all local control door switches and controllers should be examined for evidence of water or corrosion. It has been found that faulty operation of electrically operated watertight doors may be caused by seawater entering the local control switch located at the watertight door. If seawater has entered the switch enclosure, it may short circuit the motor starter and motor so that the door opens even with the wheelhouse control indicating the "closed" position. To the extent practical, the inspector shall also be satisfied that the ship's personnel are familiar with the watertight door system, location of disconnect switches, etc.

f. Electrical Cables. The condition of cables should be determined by insulation resistance readings (see subparagraph 4.c. above) and by visual examination. Deterioration of armor should not generally require replacement. Deteriorated armor may be removed, except where required in hazardous locations. Where deteriorated armor segments are not grounded, they must be connected to ground. Deteriorated armor in hazardous areas must be replaced or repaired.

g. Ground Detection Systems. Ground detection systems should function properly. Where lamps are used, they should be of the proper wattage with the connections between the lamps grounded. Ground faults shall be cleared.

h. Temporary Wiring And Installations. Long extension cords, "juryrigs," or temporary modifications are not satisfactory installations.

i. Portable Electrical Equipment. Portable electrical equipment may be accepted in several ways. Portable cargo lights are covered under the Underwriters Laboratories Inc. "Standards for Marine-Type Electric Lighting Fixtures." These lights are labeled to indicate UL approval as "marine types"; portable items covered by this category are considered satisfactory. Portable items not labeled by UL must be checked to ensure compliance with 46 CFR Subchapter J. Portable fixtures should be referred to the Marine Safety Center for determination. Approval of portable lighting devices by inspectors is not advisable. Portable tools can be accepted if the design appears to be commercially sound. This can be verified by a UL listing under the classification "Tools -- Commercial Type."

Existing equipment shall be serviceable and free from potential shock or fire hazards. Metal bodies of these items shall be grounded through grounding leads in the portable cord. To be effective, the grounding conductor on a tool or light must be connected to a grounding terminal. This conductor must be electrically continuous (the wire must not be broken anywhere along its length), this can be checked with an ohmmeter or megger. Portable devices which are double insulated need not be furnished with the grounding conductor in the portable cord and the grounding pole in the attachment plug. No splices or patching should be permitted in portable leads smaller than No. 12 AWG. Splices shall be in accordance with 46 CFR 111.60-19. Careful checks shall be made of the condition of the cord where it enters the light or tool. This is a location of severe stress and bending fatigue, especially on items such as portable cargo lights. Cracking, brittleness, and heat discoloration of the cord at this point are sufficient reasons for rejection. If the device is to be rewired, only cords indicated in 46 CFR Table 111.60-13 for hard or extra-hard service should be used. Lighting fixtures should be examined to see that the interior insulation is satisfactory, particularly the lamp holder. Cracked porcelain or plastic lamp holders should be replaced. Devices in which the exterior case is cracked or damaged should be replaced or repaired.

j. Fire and Smoke Detection Systems. Fire and smoke detection systems shall be checked regularly, and faulty detectors shall be recalibrated or replaced. The following test methods may be used:

(1) Thermal detectors may be tested by replacing the guard and globe with a sheet metal shield and using a portable light as the heat source; this will not cause damage to the adjacent paintwork. The activation temperature range should be as specified in 46 CFR 161.002-11.

(2) Photoelectric and ionization smoke detectors may be tested by holding "pink sticks" or other smoke sources near the detector.

(3) Infrared detectors may be tested with a candle or other flame source. (NOTE: These detectors often have a response delay.)

k. Vital Machinery. Motors, motor starters, and control switches used with machinery vital to the safety or propulsion of the vessel shall be visually examined for condition and suitable nameplate ratings. When there is evidence of deterioration, they shall be opened for closer inspection.

l. Electric Cooking Equipment. Electric cooking equipment shall be maintained in good condition. There should be no evidence of grease or dirt buildup nor deterioration of the equipment.

m. Leakage onto Propulsion Control Circuits, Switchboards, Etc. A 1974 casualty to a U.S. tank vessel was caused by water spraying onto the main propulsion control area from a failed cooling water gauge nipple for the vessel's air conditioning system. In a similar casualty, water leaked onto a vessel's main switchboard from an exterior electrical junction box that had filled with water. The conduit and wire provided the path to the switchboard. These casualties demonstrate clearly that shielding or other measures must be used to guard against accidental discharge of water onto electrical installations. All water lines must be located clear of control circuits, electrical equipment, and areas of high voltage whenever possible. Cables to switchboards, controllers, etc., should be connected so as to prevent water from entering connectors, through use of drip loops, joining cables to the bottom side of the installation, or similar methods.

n. Emergency Lighting And Power Systems. Casualty reports indicate that in some instances emergency diesel generators and associated equipment were not maintained in a satisfactory state of readiness for emergency use. Periodic testing by vessel personnel of the emergency lighting and power systems installed, and the recording of such tests in official logbooks, are required by 46 CFR 35.10-15, 78.17-45, and 97.15-30. The regulations for tank vessels, passenger vessels, cargo and miscellaneous vessels, and the electrical engineering requirements intend that emergency lighting and power installations are tested in the presence of an inspector. Testing of a properly functioning emergency plant can be accomplished quickly with little or no interruption of normal service. 46 CFR Table 112.05-5(a) notes vessels required to have an emergency source of power meeting the requirements of 46 CFR 112. At each inspection, and whenever emergency drills are conducted, light and power emergency systems shall be tested as follows:

(1) Automatic Starting and Connecting Power Systems. These systems should be tested by using the test switch required in 46 CFR 112.45-5. When the switch is put in the test position, the following should occur in less than 45 seconds:

(a) Bus-tie breaker opens;

(b) Power source should automatically start (if the power source is a battery, this step will be skipped); and

(c) Required loads will be transferred to the emergency power source when the voltage reaches 85-95 percent of the final (nominal) value, i.e., the generator circuit breaker closes. This will happen immediately for a battery source.

Upon completion of the test, loads should be transferred back to the normal source and the emergency system set up for automatic operation.

(2) Manual Transfer System. Test as indicated above, except that step (b) will occur as the result of a manual action. All other functions remain automatic.

(3) Alternatives. Some passenger vessels contracted for prior to 19 November 1952 may not be arranged for testing as outlined above. Tests of such vessels should be performed in a manner compatible with their arrangements. Many older vessels have an inport or standby generator (and no "emergency plant" as such). These are usually arranged to feed directly to the main switchboard, and cannot be tested in the manner outlined above. The testing of such standby units shall be prescribed by the OCMI.

6. Vessel Reinspections.

a. Introduction. Vessel inspections occurring between those required periodically for certification by the vessel inspection laws are intended to focus more on the vessel's equipment and operating practices than on basic hull and machinery conditions.

b. Tank, Cargo and Miscellaneous Vessels. A general examination of the machinery spaces with particualr attention to the propulsion system, auxiliary machinery, and the fire and explosion hazards should be performed. This includes:

(1) Testing of all the means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternate steering position, if fitted;

(2) Visual and operational examination, as far as feasible, of electrical machinery, switchgear, and other electrical equipment; and

(3) Confirmation, as far as practical, of the operation of all emergency sources of power and, if they are automatic, in the automatic mode.

(4) On tankers, confirmation that all electrical equipment in hazardous locations is in good condition and has been properly maintained.

c. Tankers Over Ten Years Old. Regulation 10(a)(ii), Chapter 1 of the 1978 SOLAS Protocol, contains additional inspection requirements at intermediate inspections for tankers over ten years old. Such inspections should include a general examination of the electrical equipment and cables in hazardous locations, such as cargo pumprooms and areas adjacent to cargo tanks, for defective explosionproof lights and fixtures, improperly installed wiring, non-approved lighting and fixtures and dead-ended wiring, and testing the insulation resistance of the circuits. Except in cases where a proper record of testing is maintained, consideration should be given to accepting recent readings by the crew. If any of the readings are marginal, or if the condition of the cables, fixtures, or equipment appears defective in any way, verification measurements may be required. These measurements should not be attempted until the ship is in a gas-free or inerted condition and should be carried out within an acceptable time period.

APPENDIX 11

SPECIAL VESSEL TYPES AND REQUIREMENTS

1. Oil Recovery Vessels. Vessels built for the purpose of cleaning up spilled oil are of special interest to the Coast Guard. They are usually designed to carry various grades of oil (generally mixed with water) as cargo, and must be able to operate safely in areas where flammable vapors may be present. The primary safety concern for oil recovery vessels is the possibility of ignition of flammable vapors from oil spilled on the water and collected oil stored aboard. The following criteria should be applied to reduce the likelihood of vapor ignition on oil recovery vessels:

a. Electrical equipment installations should be kept to a minimum. Hydraulically-powered equipment should be used when available (e.g., hydraulically-powered cargo pumps).

b. Where electrical equipment is employed (switches, lights, solenoid valves, etc.), it must be one of the following types:

(1) Spark ignitionproof (per Underwriters Laboratories Inc. (UL) 1500);

(2) Explosionproof; or

(3) Intrinsically safe.

[NOTE: The UL listing "spark ignitionproof" (UL 1500) employs a standard that is based on part of the explosionproof test. Those electrical devices that do not create sparks in normal operation (lights, solenoids, etc.) are inherently "spark ignitionproof" and should obtain UL listing as such.]

c. Enclosed machinery spaces must be ventilated at a rate of at least 20 changes of air per hour by fans designated as "nonsparking" under the provisions of 46 CFR 110.15-1(b)(16).

d. Belt drives must use conducting belts, pulleys, and shafts to prevent the buildup of static electrical charges.

e. Machinery exhausts must be fitted with spark arrestors.

f. All exposed surfaces (machinery, light lenses, etc.) must be maintained at a temperature below 400°F. When these surfaces are normally accessible to personnel they must be maintained below 150°F for personnel protection.

g. Oil tank vents must be fitted with flame screens and must have a cross sectional area at least as large as the fill lines.

Most oil recovery vessels are designed for use with Grades D and E liquids. If use with more flammable grades or with hazardous chemicals is desired, Commandant (G-MTH) should be consulted. Vessels engaged in other service when not operating as oil recovery vessels must meet normal requirements for that service.

2. Non-Self-Propelled Harbor Dredges and Barges That Change Places of Employment.

   a. General. Non-self-propelled harbor dredges and barges of 100 or more gross tons, when voyaging on the high seas to change places of employment, are subject to inspection and certification. 46 CFR 91.01-10(c) provides for a limited or short-term certificate, by which the vessel may be operated manned or unmanned. In those cases when the vessel is manned, the intent is to require a more thorough inspection than if it were unmanned.

   b. Wiring. Only the electrical wiring that will be energized during any part of the voyage shall be subject to inspection. Any unsafe or unsatisfactory condition detected shall be made a matter of record and the owner of the vessel so advised in writing by the OCMI.

3. U.S. Flag MODU's Operating In Foreign Waters.

   a. Introduction. Full compliance with the U.S. regulations may be difficult for units operating in foreign waters and subject to coastal state requirements. When another country's requirements conflict with ours, U.S. Coast Guard regulations shall take precedence unless specifically authorized by the cognizant OCMI.

   b. Electrical Installations In Hazardous Locations. 46 CFR 111.105 will require explosionproof and intrinsically safe systems to be listed or labeled by a "nationally recognized testing laboratory" which has been recognized by OSHA. The Coast Guard currently accepts approvals by Underwriters Laboratories, Inc., Factory Mutual Research Corp., Canadian Standards Association, and, for intrinsically safe equipment only, MET Electrical Testing Company. However, requiring electrical equipment to be listed by North American laboratories is not always reasonable in foreign waters because such equipment may not be available, or it may not meet coastal state equipment listing requirements. For subcontractor equipment or other temporary installations, other independent laboratories are acceptable for listing explosionproof equipment and intrinsically safe systems, or flameproof equipment.

      (1) Subcontractor Services. Drilling operations aboard MODU's often require subcontractor services. Subcontracted services include, among others, well logging, cementing, and casing perforation. Typically, these services are obtained locally by the leaseholder without regard to vessel flag. Contractor electrical equipment usually meets the certification requirements of the coastal administration. These installations are considered "temporary" although they may be installed for a few days or a few years.

(2) Temporary Installations. For temporary installations, equipment approved by an independent laboratory acceptable to the coastal state may be permitted by the OCMI in whose zone the vessel is operating. Where the coastal state has no certification requirements, equipment must be listed by one of the North American "nationally recognized testing laboratories", by one of the agencies listed at the end of this section, or by another agency acceptable to Commandant (G-MTH-2). In no case should equipment required by 46 CFR 111.105 to be listed, i.e., explosionproof equipment or intrinsically safe systems, be permitted based on manufacturer or classification society certification. Upon return to U.S. waters and prior to engaging in OCS activities, MODU's must utilize equipment listed by one of the North American laboratories. Listed below are independent laboratories that are acceptable, provided they are recognized by the coastal state. This list is not intended to be all-inclusive; other laboratories acceptable to the coastal state may be acceptable.

Belgium	INIEX	Institut Nationale des Industries Extractives
Denmark	DEMKO	Danmarks elektriske materielkontrol
France	LCIE	Laboratoire centrale des industries electriques
	CERCHAR	Centre d'Etudes Recherches des Charbonnages de France
Italy	CESI	Centro Elettrotecnico Sperimentale Italiano
Norway	NEMKO	Norges Elektriske Materiallkontroll
U.K.	BASEEFA	British Approvals Service for Electrical Equipment in Flammable Atmospheres
West Germany	PTB	Physikalisch-Technische Bundesanstalt
	BVS	Berggewerkschaftliche Versuchsstrecke

Equipment labeled by one of the laboratories above will usually be marked in accordance with, or in a manner similar to the IEC designation. This marking provides information on the method of protection, the hazard group designation, and the temperature class, and is illustrated in the following example:

Ex d IIA T2

Equipment marked as such is flameproof , suitable for use in Class I, Group D locations, and has a maximum operating temperature of 300 degrees Centigrade.

"Ex" is the IEC symbol meaning protected for use in flammable atmospheres. It is followed by a small letter indicating the type of protection as follows:

Letter	Protection Type
d	Flameproof (explosionproof)
e	Increased Safety
ia	Intrinsically Safe for Zone 0
ib	Intrinsically Safe for Zone 1
o	Oil-immersion
p	Pressurization
q	Sand Filling
s	Special Protection

A comparison of IEC Group/Zone designations to North American designations is as follows:

IEC	North American
Group I	Gaseous Mines
Group II-A	Class I, Group D
Group II-B	Class I, Group C
Group II-C	Class I, Groups A and B
Zone 0	---
Zone 1	Division 1
Zone 2	Division 2

The Temperature class is indicated as follows:

Temperature Class	Max. Surface Temp.
T1	450 degrees C.
T2	300 degrees C.
T3	200 degrees C.
T4	135 degrees C.
T5	100 degrees C.
T6	85 degrees C.

APPENDIX 12

Plan Review of Electrical Systems

1. Introduction

a. Objectives. Plan review is performed to ensure that the electrical arrangement, materials, and installation as shown on the plans comply with the applicable laws and regulations for the vessel or unit. The primary purposes of the electrical requirements are to arrive at adequate and reliable shipboard electrical systems, the components of which provide safety to personnel from electrical shock, and to minimize the danger of fire originating from within the electrical system. After the initial certification of a vessel or unit by the Coast Guard, subsequent plan review may be required due to electrical repairs or alterations affecting the safety of the vessel, its equipment, and crew. If considered necessary by the Officer in Charge, Marine Inspection (OCMI), drawings must be approved before work is started. Repairs to existing installations must meet the regulations in effect on the date of the original installation or the regulations in effect on the date of the repair.

b. General Procedures. Prior to a vessel's construction, those plans listed in 46 CFR 110.25 are reviewed. The plans listed are general in character, but include all plans that normally show construction and safety features coming under the cognizance of the Coast Guard. In the case of a particular vessel, all of the plans enumerated may not be applicable; it is intended that only those plans and specifications be submitted as will clearly show the vessel's arrangement, construction, and required equipment. Because the regulations give only a general listing of the plans and specifications that require review by the Coast Guard, NVIC 8-84, "Recommendations For the Submittal of Merchant Vessel Plans and Specifications", was published to provide further clarification. This circular is a detailed guide on recommended plan submittal procedures. Some of the plans and specifications required by the Coast Guard are also necessary for the approval of construction by the American Bureau of Shipping (ABS) for vessels classed by that organization. In this regard, NVIC 10-82, "Acceptance of Plan Review and Inspection Tasks Performed by American Bureau of Shipping for New Construction or Major Modifications of U.S. Flag Vessels", was published to provide information on ABS plan approval procedures intended to facilitate industry activities and reduce duplication of effort between the ABS and the Coast Guard.

c. Handling of "Existing" Vessels. The regulations do not include requirements for vessels existing before the effective date of the regulation. Persons must refer to the regulations in effect for older existing vessels in order to determine electrical construction requirements for those vessels.

2. Plan Review Guidance

a. This NVIC includes:

(1) Check-off lists for review of typical electrical plans;

(2) A reference for technical data, formulas, and principles used in routine plan review;

(3) Some items of policy; and

(4) An index for detailed reference information not contained in the NVIC or regulations.

This NVIC may be used as a guide by the plan reviewer, and should not be considered as containing hard-and-fast requirements. The user's discretion should be applied during its application.

3. Submittal of Electrical Plans. For uniform administration of 46 CFR Subchapter J (Electrical Engineering Regulations), certain basic plans for electrical installations, when submitted to the OCMI, should be acted upon only by the MSC. Following examination, the plans and an accompanying action letter are returned to the cognizant OCMI. Therefore, when electrical plans are submitted to the OCMI, the following procedures shall be followed:

a. Initial copies of the plans required by 46 CFR 110.25 should be forwarded to the MSC for action.

b. Subsequent revisions may be acted upon directly by the OCMI, or they may be forwarded to the MSC for action. When major changes or revisions are made on these plans, they should be forwarded to the MSC for review.

APPENDIX 13

SYMBOLS AND ABBREVIATIONS

(1) NEMA Enclosures. ICS 1-110, NEMA STDS.

TYPE	DESCRIPTION	PROTECTION
	General Purpose, Indoor	Personnel and Falling Dirt
2	Dripproof, Indoor	Personnel, Dirt, Non-Corrosive Falling Liquids
3	Dust- and Raintight, Sleet- and Ice-Resistant, Outdoor	Personnel, Outdoor Windblown Dirt and Water
3R	Rainproof, Sleet and Ice	Personnel, Self-Explanatory
3S	Dusttight, Raintight, Sleet- and Ice-Proof, Outdoor	Personnel, Self-Explanatory
4	Watertight and Dusttight, Indoor and Outdoor	Personnel, Falling and Splashing Dirt and Water, Sleet-Resistant
4X	Watertight, Dusttight, Corrosion-Resistant, Indoor and Outdoor	Personnel, Self-Explanatory
70	Submersible, Watertight, Dusttight, Sleet- and Ice-Resistant, Indoor and Outdoor	Personnel, Self-Explanatory
7	Class I, Groups A - D Air Break	Hazardous Locations, Indoor
8	Class I, Groups A - D Oil-Immersed	Hazardous Locations, Indoor
9	Class II, Groups E - G Air Break	Hazardous Locations, Indoor
10	Bureau of Mines	
11	Corrosion-Resistant and Drip-proof, Oil-Immersed, Indoor	Corrosive Liquids
12	Industrial Use, Dusttight and Driptight, Indoor	Dirt and Non-Corrosive Dripping Liquids
13	Oiltight and Dusttight, Indoors	Self-Explanatory

(2) Common Abbreviations.

a	amperes
AC	alternating current
Al	aluminum
alt	alteration
amb	ambient
AVC	asbestos-varnished, cambric-insulated cable
AWG	American Wire Gage
bhd	bulkhead-mounted
B/M	bill of material
C	degrees Centigrade
chg	change
Class I, Class II, etc.	(see NEC 500)
cond	conductor
corr	corrosive
CSA	Canadian Standards Association
Cu	copper

Cu in	cubic inches
cy	cycles
DC	direct current
D/G	diesel generator
dp	double pole
dp	dripproof
dpdt	double pole, double throw
dpst	double pole, single throw
dwg	drawing
EP	explosionproof
F	degrees Fahrenheit
fig	figure
FM	Factory Mutual
gnd	ground
Group A, Group B, etc.	(see NEC 500)
haz	hazardous
HP	horsepower
IC	interrupting capacity
incand	incandescent
incl	inclusive
inst	instantaneous
IS	intrinsically safe
KVA	kilo volt amperes
KW	kilowatt
L.C.L.	light center length
LVP	low voltage protection
LVR	low voltage release
max.	maximum
M.I.	mineral insulated, metal sheathed
min	minimum
mod	model
mtg	mounting
NEC	National Electrical Code
nwt	non-watertight
p	pole
ped	pedestal
pend	pendant
PF	power factor
ph	phase
port	portable
psi	pounds per square inch
pt	point
PYRO	pyrometer
R	rubber-insulated cable
refl	reflector
rev	revision
SCR	semiconductor controlled rectifier
sp	single pole
spdt	single pole, double throw
S.P. Phone	sound-powered phone
SS	ship service
SWBD	switchboard
sym	symbol

T	thermoplastic insulated cable
term	terminal
Temp	Temperature
T/G	turbine generator
UL	Underwriters Laboratories, Inc.
uv	under voltage
v	volts
VC	varnished cambric-insulated cable
w	watts or wire
wt	watertight
w/	with
#	catalog number(s)
&	and
@	at