United States
Coast Guard

COMDTPUB P16700.4
NVIC 2-89
14 August 1989

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 2-89

Electronic Version for Distribution on the World Wide Web

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. IMPIEMENITATION. 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

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

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

TABLE OF CONTENTS

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 Qfficer in Charge, Marine Inspection (OGMI) 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 lubrica~on.

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. 0 General Provisions of the Electrical En~ineering Regulations

The existing Subchapter J applies to vessels contracted for after May 31, 1982, where Subchapters D, H, I, IA, 0, 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 Snecifications. 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 bv UL is not reQuired. While evidence of such listing may be the most expeditious method to determine compliance, it is not the onlv 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; Themanufacturer'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 (lEG) 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 svstem 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 overall level ~ safetv 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 anDlications, 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 eguiDment 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 OGMI 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 Epuinment Reciuired 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 a~proved 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 GSA 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.

Temoerature. 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 ~n 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 Eauioment Ground. Grounded Systenis. 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 groundin~ 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 device~. 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.

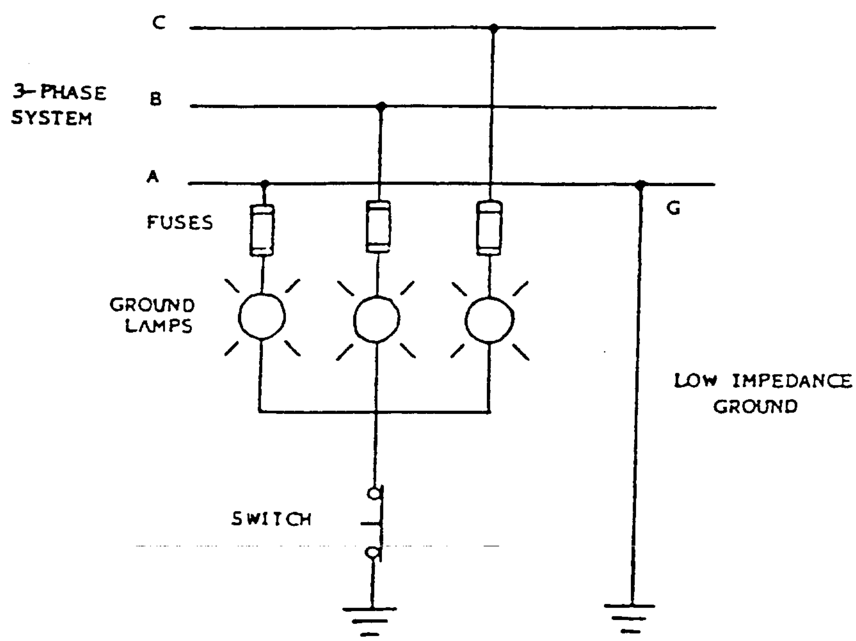


FIGURE 1

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 ~etween 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.

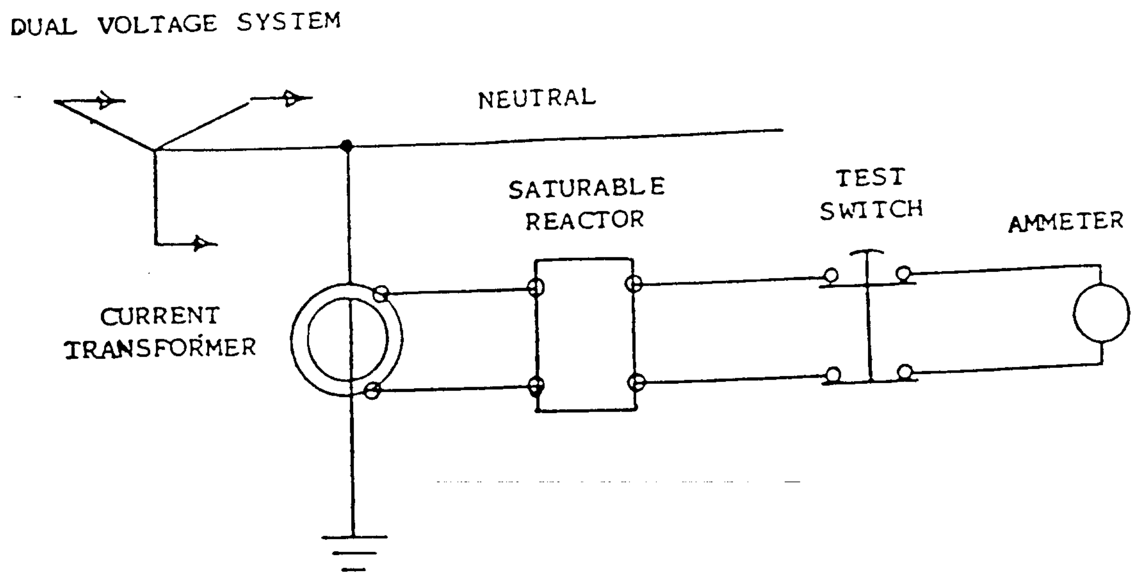


FIGURE 2

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.

Main engine denendent generators. 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 maintained 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 shin's service 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 yariable 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 all 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 suppleme~tal 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 Qhange 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.

Ship's Service SuDDlv Transformers 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 11-1/45, that automatic transformer tranq.fer is required by the SOLAS 11-1/53 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 inore 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 Batterv 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.

Batterv tvoes & 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 lll.30-l(a)(4) to be located in a machinery space that contains at least one 5hip~5 service generator. This requirement is consistent with the SOLAS Amendments, Chapter 11-1, 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 frqm 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 b~rs 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 switch~ear. Medium voltage switchboards are required by 46 CFR 111.30-23 to meet ANSI C37.20 for metaldad 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 11-1/53.2 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 ProDulsion

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 11-1/31, 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

<u>Purnose</u>. 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.

<u>Circuit Breakers</u>. 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 metaldad 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.

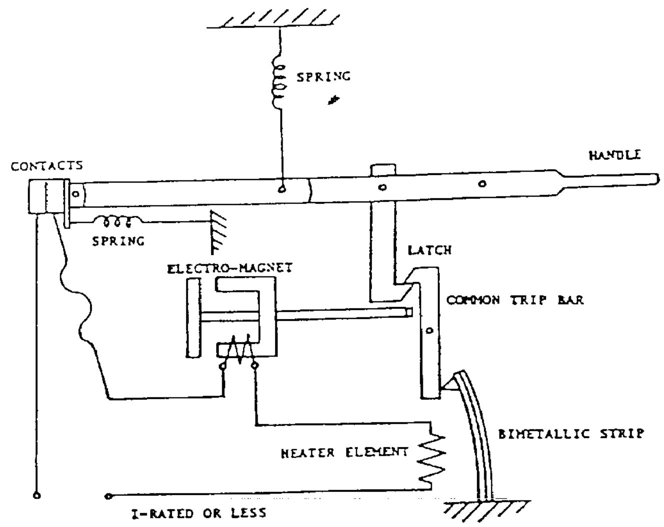


FIGURE 3

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 numb r of mechanical moving parts used to release the operating mechanism, ele~tronic 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 uHtil 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.

Fuses. 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 listedby 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 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.

FIGURE 4

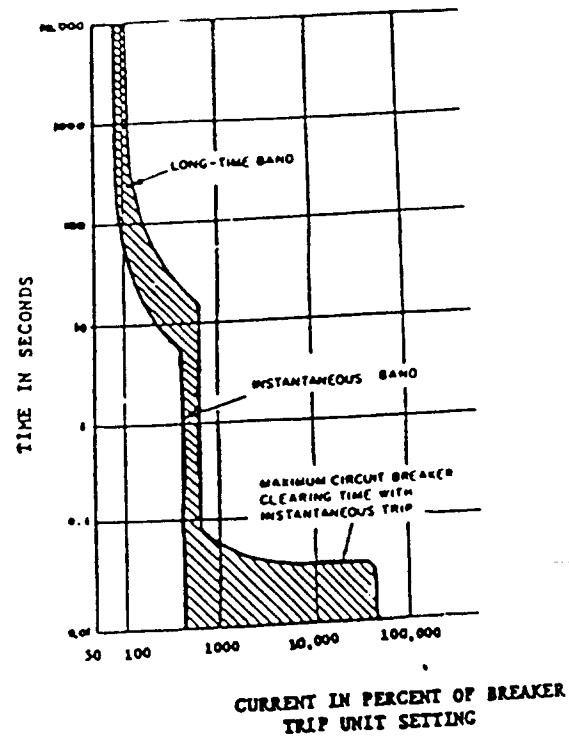
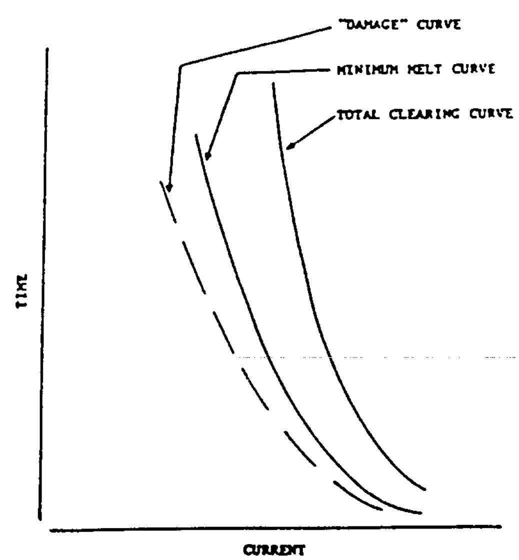


FIGURE 5



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.
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.

Aoolications. 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 steeringgear 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 Analvsis & 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 o~eration 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 o~ly 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.

Calculation Procedures. 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.

Coordination. 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.

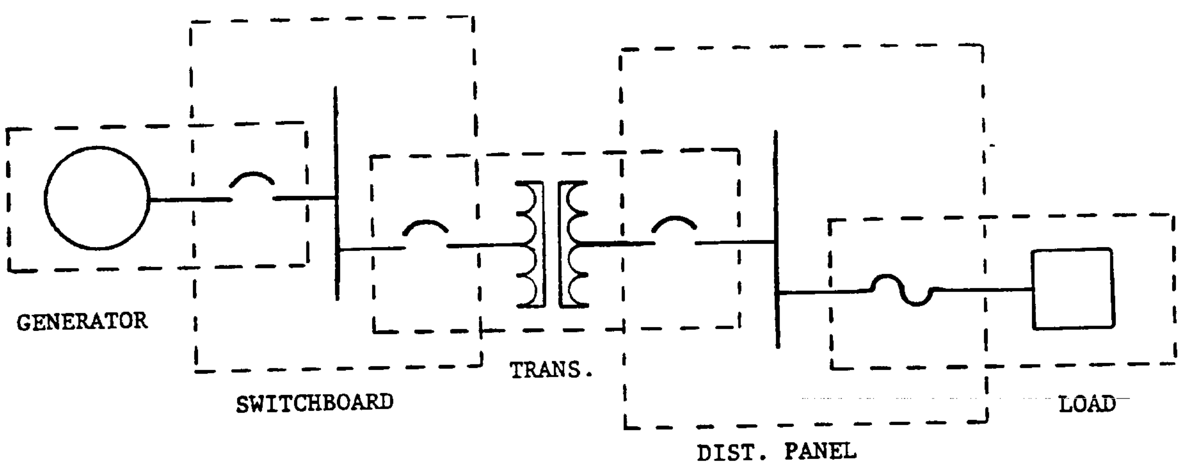


FIGURE 6

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 diag~am 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 continu6usly 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-l. This standard is attached as Appendix 5.

Motor orotection. 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, overlQad 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 vQlts 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 5~0~t~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.

Safetv 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 enclo.-~ures 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 11-1/42, 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 CT 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 11-1/44.2 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 six 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.

4.2 Location. SOLAS 11-1/42.1.3 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. It is ~referable to avoid anv conti~uous boundaries between the emer~ency ~enerator room and any cate~orv A machinerv s~ace or s~ace containing the main source of electrical nower associated transformin~ egui~ment if anv. and the main switchboard.

4.3 Emergencv Loads. The temporary and final emergency loads listed in 46 CFR Subpart 112.15 must be supplied by the emergency power source(s). Additional safetv 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 detectin~ 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 Ves6els (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 11-2/54. 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 trensfer 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)(l)). 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 cot:ipleted 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 appropria~e UL standard. Annunciators are considered to be indicating devices and should meet UL Standard 404, "Audible Signal Appliances", or UL Standard 1638, "Visual Sig~aling 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. 5.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 11-2. 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 11-2 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 11-2, 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 Teleohones. 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 Engine Order Telegraph (EOT). 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 Emergencv Loudsneaker Systems. 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 and 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 Philosonhv. 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)(l), 501-6(b)(l) and 501-14(b)(l)." 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 ptessure, 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 C, 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.

7.3 ST,ecific 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.

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.

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 SOOB, 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 nspecially 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 11-2/37.1.6, 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 11-2/53.2.3 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 11-2/53.2.3.

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 a~d 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 Equinment. 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 I." 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)(l) 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 and 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 International Standards 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 temnorarv industrial installations aboard MODU's. (See Appendix 11 for guidance.)

7.6 Protection Types. 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 re~uired, 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 abnorinal (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

> 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.

<u>Type</u> X 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 condit{ons. 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.

<u>Type</u> 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.

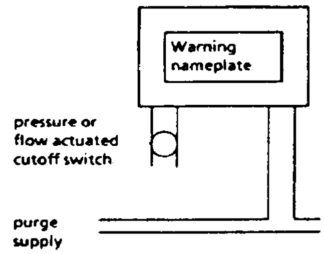
The NFPA standard requires that a nameplate be mounted on the enclosure in a prominent location so that it can be seen before someone opens the enclosure. The nameplate should contain the following statement (or equivalent):

"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 <u>normal o~eration</u> 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

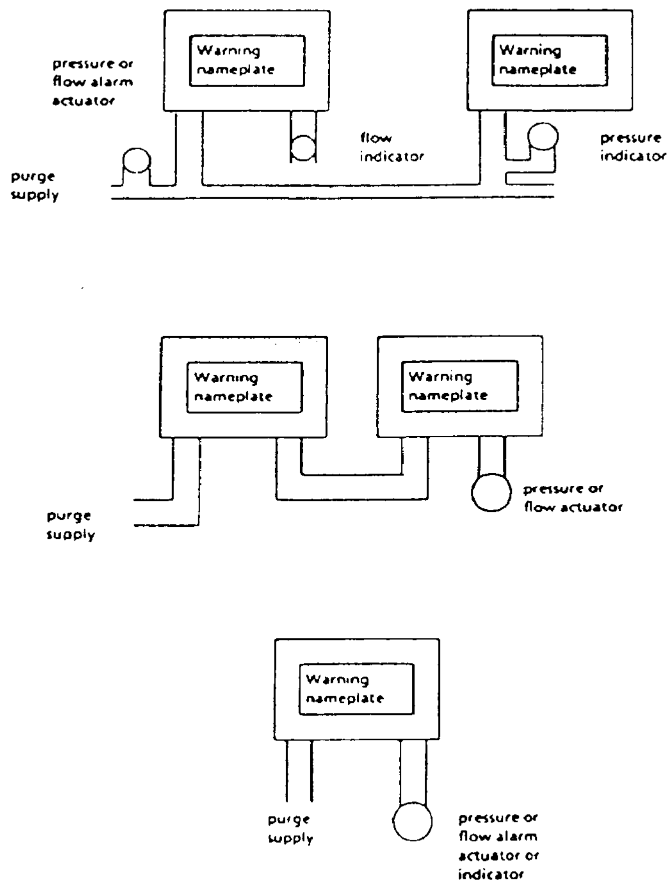


FIGURE 7

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 pressuri~ed 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.

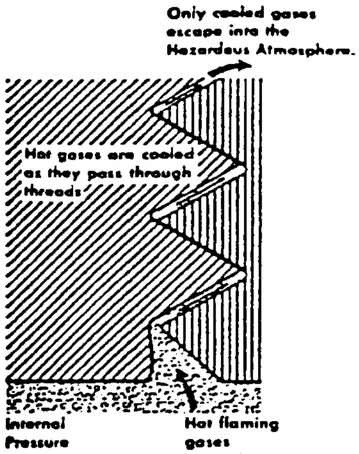
Although the Electrical Engineering Regulations cite the 1974 edition of NFPA 496, the guidelines of the 1982 revision of this standard may be used. The revised standard recognizes the use of purged control rooms in Class I locations and pressurized control rooms in Class II locations. The requirements 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 ExDlosion~roof Equi~ment. 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.

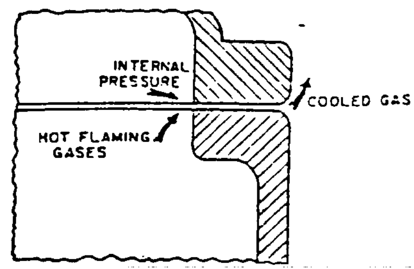
Explosionproof enclosures usually have covers which can be removed or opened for making connections and adjustments, and for maintenance. The dimension of the gap between an enclosure's flanges and metal-to-metal joints determine its effectiveness. An explosion will propagate through this gap if the 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 fr6m 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. sufficient amount of energy must be transferred from the hot gases to the surrounding air or enclosure; otherwise, an explosion will occur.

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.



THREADED JOINT

FIGURE 8



FLANGED JOINT

FIGURE 9

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 oecurs 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 hazardDus 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

^{0}C	^{0}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	256	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 ahall not exceed auto ignition temp. of the atmosphere eucouutered.

* Mon-heat producing equipment, and that vith a temp. of 100^{0}C or 1ess, 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 a~tomobile 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 enclosures 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 assemblies 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.

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:

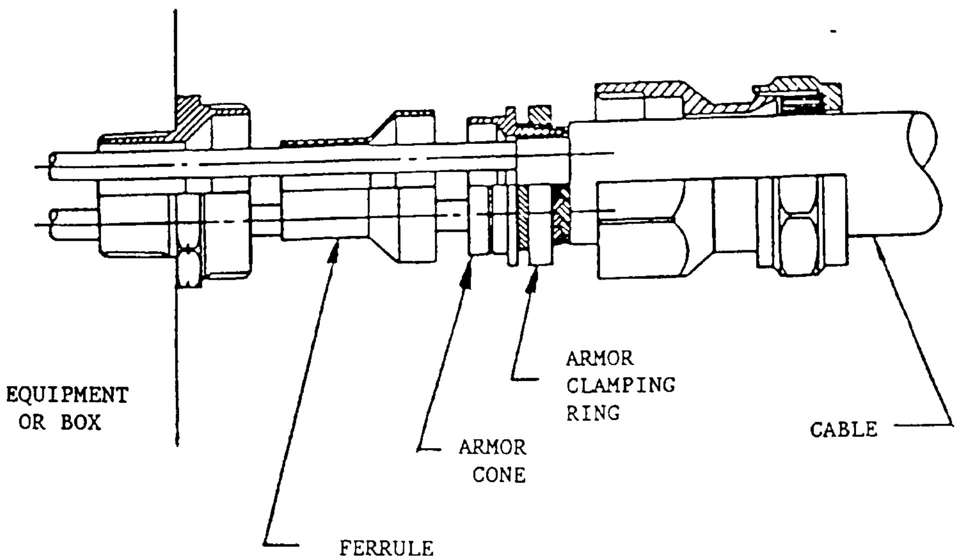
1. All cover screws and bolts must always be tight while circuits are alive. Leaving one screw or bolt loose can render equipment unsafe. Bolts or screw types other than those provided with the equipment should not be used.

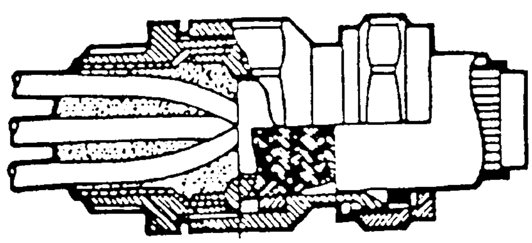
2. Hammers and other tools must not be allowed to damage threaded joints or flat machined surfaces of flanged joints. All surfaces that form part of a flame path must be protected from scratches and other mechanical defects.

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.





CABLE GLAND

FIGURE 10