Chapter 2
Electrical Safety

At the end of this chapter you should be able to:

- ★ Comply with regulations governing electrical safety
- ★ Avoid electrical accidents by adopting adequate safety measures
- ★ List the fundamentals requirements for safe installation of equipment
- ★ Identify safe electrical equipment for hazardous areas
- ★ Render fir… …unate event of electrical accidents

2.1 Compliance with Regulations

Practically every ocean-going ship is registered with a Classification Society and is therefore required to comply with the Rules of the relevant Society. These Classification Societies are members of the International Association of Classification Societies (*log on to www.iacs.org.uk for detailed information*). Dedicated to safe ships and clean seas, IACS makes a unique contribution to maritime safety and regulation through technical support, compliance verification, research and development. More than 90% of the world's cargo carrying tonnage is covered by the classification design, construction and through-life compliance Rules and standards set by the ten Member Societies and one Associate of IACS.

Ship Classification, as a minimum, is to be regarded as the development and worldwide implementation of published Rules and/or Regulations which will provide for:

1. the structural strength of (and where necessary the watertight integrity of) all essential parts of the hull and its appendages,
2. the safety and reliability of the propulsion and steering systems, and those other features and auxiliary systems which have been built into the ship in order to establish and maintain basic conditions on board, thereby enabling the ship to operate in its intended service.

The achievement of these goals is conditional upon continued compliance with the Rules and / or Regulations and proper care and conduct on the part of the Owner and Operator (Refer the IACS' Guide to Managing Maintenance in Chapter 26).

A ship built in accordance with a Member Society's Rules and/or Regulations, or in accordance with requirements equivalent thereto, and fulfilling the applicable stability requirements will be assigned a class in the Register Book of the Society. For ships in service, each Member Society maintains the provisions of class by way of periodical visits by its Surveyors to the ship as defined in its Rules and/or Regulations in order to ascertain that the ship currently complies with those Rules and/or Regulations. Should significant defects become apparent or damages be sustained between the relevant visits by the Surveyors, the Owner and Operator are required to inform the Society concerned without delay. Similarly any modification which would affect Class must receive prior approval by the Society.

A ship is said to be in Class when the Rules and/or Regulations which pertain to it have, in the opinion of the Society concerned, been complied with. Individual Societies are to explain by an additional note as to how they deal with items, either statutory or class, beyond the basic definition. The Members and Associates are as follows:

Classification Society	Email	Website
	Members	
American Bureau of Shipping	abs-worldhq@eagle.org	http://www.eagle.org
Bureau Veritas	veristarinfo@bureauveritas.com	http://www.veristar.com
China Classification Society	ccs@ccs.org.cn	http://www.ccs.org.cn
Det Norske Veritas	iacs@dnv.com	http://www.dnv.com
Germanischer Lloyd	headoffice@gl-group.com	http://www.gl-group.com
Korean Register of Shipping	krsiacs@krs.co.kr	http://www.krs.co.kr
Lloyd's Register of Shipping	Lloydsreg@lr.org	http://www.lr.org
Nippon Kaiji Kyokai	xad@classnk.or.jp	http://www.classnk.or.jp
Registro Italiano Navale	info@rina.org	http://www.rina.org
Russian Maritime Register of Shipping	004@rs-head.spb.ru	http://www.rs-head.spb.ru/
	Associate	
Indian Register of Shipping	ho@irclass.org	http://www.irclass.org

Courtesy – International Association of Classification Societies (www.iacs.org.uk)

Table 2.1 – International Association of Classification Societies

The International Electrotechnical Commission (IEC) Publication No. 92, *Recommendations for Electrical Installations in Ships*, gives guidance to national bodies, classification societies and all involved in the marine industry. Increasing adoption of these recommendations will lead to a greater level of international standardisation.

Offshore installations involved in the exploration and / or production of hydrocarbons may not be subject to classification requirements, but will be subject to regulatory requirements of the country within whose waters the operation is being conducted, e.g., Certificate of Fitness. Some vessels are subject to both classification and national offshore regulatory requirements.

In addition to classification requirements, there are statutory international requirements, namely the International Convention for Safety of Life at Sea (usually referred to as SOLAS) which is produced by the International Maritime Organisation and administered by National Governments.

Ships with British registry, for example, are required to comply with the Department of Trade (Marine Division) regulations. Similar is the case for other countries too.

Note: *The International Electrotechnical Commission is the authoritative worldwide body responsible for developing consensus global standards in the electrotechnical field. It is based in Geneva, Switzerland. It writes standards for electrical and electronic equipment practices. It is dedicated to the harmonisation and voluntary adoption of these standards, supporting the transfer of electrotechnology, assisting certification and promoting international trade. Since 1906, it has served the world's electrical industry, developing international standards to promote quality, safety, performance, reproducibility, and environmental compatibility of materials, products, and systems. It has also published standards for the electronics and telecommunications industries. The IEC's present membership of more than 60 participating countries includes most major trading nations with their goals being:*

- *Define requirements for making the global market world wide efficient*
- *Improve efficiency in industrial processes*
- *Improve human health and safety*
- *Protect the environment*

IEC standards are widely adopted as the basis of national or regional electrotechnical standards, and are often quoted in manufacturers' specifications and by users when calling for tenders. Over 2000 standards cover virtually every topic of electrotechnology from acoustics, to medical devices, to insulating materials, to aircraft, to nuclear instruments.

2.1.1 *Other Important International Organisations*

- **Underwriters Laboratories (UL)** is a private company that is nationally recognized as an independent testing laboratory. UL tests products for safety and products that pass UL tests can carry a UL mark.
- The **National Electrical Manufacturers Association (NEMA)** is an organization that, among other things, develops standards for electrical equipment.
- The **National Fire Protection Association (NFPA)** is a nonprofit organization which publishes the *National Electrical Code®* (*NEC®*). The intent of the *NEC®* is to describe safe electrical practices.
- The **American National Standards Institute (ANSI)** is a nongovernmental organization that facilitates the development of standards by establishing a consensus among qualified groups.
- The **Institute of Electrical and Electronic Engineers (IEEE)** is an organization open to individual membership and provides a variety of services for its members. It also develops numerous standards for electrical and electronic equipment and practices.

There are two outstanding considerations in the selection and installation of marine electrical equipment: firstly, outstanding reliability and freedom from breakdown for those services which are essential for safety, navigation (steering, navigation lights, radio services, etc.) and propulsion; secondly, freedom from fire risks. Both these conditions demand a well-found installation with first-class materials and, above all, good workmanship and maintenance. In the following chapters, some of the factors that contribute to these requirements will be dealt with more fully, and a better understanding of installations by the marine engineer and electrical officer will, it is hoped, lead to more efficient maintenance and operation. Some factors are common throughout and to save repetition may be summarised here. All materials should, as far as possible, be non-flammable, but some insulating materials cannot be made to meet this requirement and the nearest approach is that they should be flame-retardant, i.e. they will not continue to burn when the flame is removed.

2.1.2 *Relevant SOLAS Regulations (Chapter II–1)*

Part D – Electrical Installations – Regulation 45 Precautions against shock, fire and other hazards of electrical origin

2.1.2.1 Summary of Regulations

1) Exposed metal parts of electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live shall be earthed unless the machines or equipment are:

   a) Supplied at a voltage not exceeding 50 V direct current or 50 V, root mean square between conductors; auto–transformers shall not be used for the purpose of achieving this voltage; or

   b) Supplied at a voltage not exceeding 250 V by safety isolating transformers supplying only one consuming device; or

   c) Constructed in accordance with the principle of double insulation

   d) Additional precautions for portable electrical equipment for use in confined or exceptionally damp spaces where particular risks due to conductivity may exist.

2) All electrical equipment shall be so constructed and so installed as not to cause injury when handled or touched in the normal manner.

3) Where necessary, non–conducting mats or gratings shall be provided at the front and rear of switchboards

4) No electrical equipment shall be installed in any space where flammable mixtures are liable to collect including those on board tankers or in compartments assigned principally to accumulator batteries, in paint lockers, acetylene stores or similar spaces, unless the Administration is satisfied that such equipment is:

   a) essential for operational purposes;

   b) of a type which will not ignite the mixture concerned;

   c) appropriate to the space concerned; and

   d) appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.

Note: *In addition to the above, relevant safety guidelines have been included in all chapters*

2.2 The Inherent Dangers and Avoidance of Disastrous Consequences

At the outset, it is worth reproducing a few excerpts from "A Guide to Risk Assessment in Ship Operations" (Published by IACS - Date: 26/03/2004 - Revision: 0)

Quote

"The best safeguard against accidents is a genuine safety culture - awareness and constant vigilance on the part of all those involved, and the establishment of safety as a permanent and natural feature of organizational decision-making".

IMO defines risk as:

"The combination of the frequency and the severity of the consequence."

(MSC Circ 1023/MEPC Circ 392)

In other words, risk has two components: likelihood of occurrence and severity of the consequences.

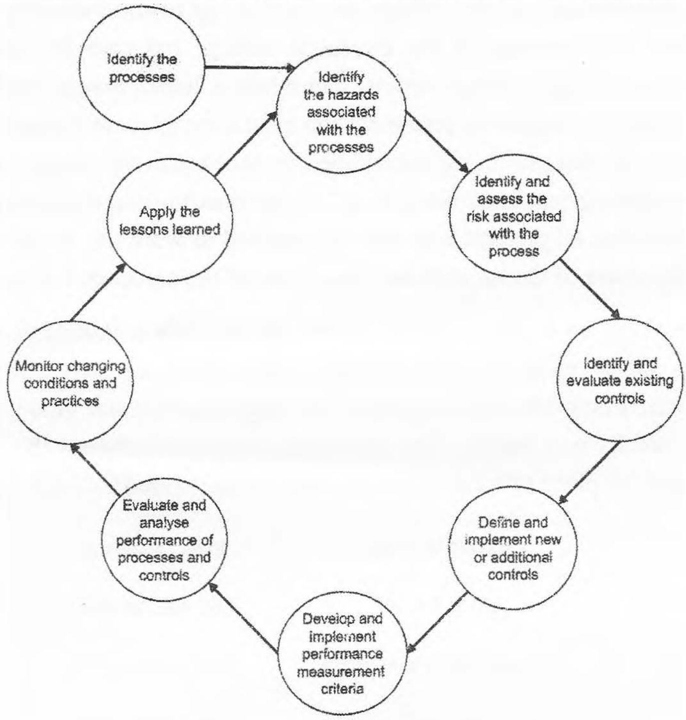
A hazard is a substance, situation or practice that has the potential to cause harm. Briefly, what we are concerned with, therefore, is:

- The identification of hazards
- The assessment of the risks associated with those hazards
- The application of controls to reduce the risks that are deemed intolerable
- The monitoring of the effectiveness of the controls

The controls may be applied either to reduce the likelihood of occurrence of an adverse event, or to reduce the severity of the consequences. The risks we are concerned with are those which are reasonably foreseeable, and relate to:

- The health and safety of all those who are directly or indirectly involved in the activity, or who may be otherwise affected
- The property of the company and others
- The environment

The risk management process may be summarized by the flowchart below.



Unquote

Successful completion of everyday activities depends on safe execution; preparation and conduct during these activities reflects on performance. In no other field is this more significant than in the marine field. Today most marine installations are a.c. based, but there may still be a few operating on d.c., which under certain conditions can be lethal. Generally speaking, the danger of a d.c. shock is not nearly as severe as compared to one from a.c. supplies.

2.2.1 High Voltage Safety

In recent years there has been an increasing use of high-voltage systems on board ships, particularly for cruise liners, some LNG carriers and specialist offshore support vessels.

While working on a high voltage system, we should pay more attention to safety because we know that any voltage above even as low as 55V can also be fatal.

High-voltage circuits (i.e., above 1000 V up to and including 15 kV AC), are potentially more dangerous as compared to low voltage circuits (i.e., up to and including 1000 V AC and 1200 V DC), not only because of the increased voltage but also because under certain common circumstances high-voltage circuits can retain a lethal charge even when they are switched off. In addition, dangerous potentials can exist even at some distance from live high-voltage conductors, the distance being determined by the conductor voltage and the dielectric strength of the insulating materials (including air) surrounding the conductor. It is therefore considered essential that all persons who may be required to work on, or operate high-voltage apparatus are fully aware of the hazards and how to avoid the associated danger.

Personnel working on a high voltage system should follow company safety rules and procedures. They should wear dry, safe clothing, safety shoes, eye protection, hard hat, etc., as even the slightest shock disorients a person who might just fall and injure oneself but more often than not it results in a fatality. The minimum clearances between the nearest exposed, live conductors and the place of work or access way are mentioned in Table 2.2.

Rated Voltage	Safe Distance
Up to 6.6 kV	2.56 metres (8'5")
V > 6.6 kV to V < 11 kV	2.59 metres (8'6")
V > 11 kV to V < 22 kV	2.64 metres (8'8")
V > 22 kV to V < 33 kV	2.74 metres (9')

Table 2.2 – Safe Distances for HV Systems

When work is carried out on a high-voltage system, it is highly desirable that a previously prepared program incorporating a checklist be strictly followed to ensure that the work is correctly performed without mistakes considering their inherent danger. In order to operate a high-voltage system safely, it is necessary to ensure that all persons concerned are suitably qualified for the duties they are to perform. Before attempting any electrical work, there are some basic safety precautions one must bear in mind. The possible dangers arising from the misuse of electrical equipment are well known.

An electric shock or fire can cause loss of life and damage to equipment. Where danger arises it is usually due to an accident, neglect or some other contravention of the regulations. Hence it is important to ensure that appropriate safety measures are always adopted.

2.3 Passive Safety Measures

This is the highest level of safety for personnel, when all systems are in normal operation. Avoiding failure is therefore a primary goal. The basic design philosophy of and electrical system must, when built according to SOLAS Requirements, Classification Rules, Regulations or Standards, have an inherent ability to withstand stresses generated externally and within the system. This ability must give each particular function, for example, a power supply for a pump, a defined quality or reliability level. The level is reached through correct system design, application or use of suitable equipment, correct rating and correct installation procedures. Some of the passive measures are mentioned in the following paragraphs.

2.3.1 Component Quality or Reliability Level

The following measures must be adopted and adhered to:

i. Components must be selected according to their actual use. The rules mention requirements regarding ambient conditions and design specifications.

ii. The rating must be selected according to the prospective stresses applied on the component by the system at the location where it is installed.

iii. The component must be installed in such a way that its properties as defined above are maintained. The rules specify requirements regarding installation. Some examples are as follows:

   a) Cables are very important in a ship's electrical system's installation. They are usually of specialized construction and incorporate properties in conformity with IEC recommendations such as flame retardant capabilities and a high resistance to humidity, oil, vapour and ageing.

   b) Large switchboards are normally to be divided into several cubicles. One of the reasons is to allow for maintenance work while the rest of the switchboard is in operation and, in high voltage switchboards the equipment in each cubicle is to be interlocked so that no live parts are accessible until they are isolated from the network and solidly earthed. The other reason for adapting to cubicles is that if a mechanical fault were to occur on one of the components, damage can be alleviated to a great extent. They also serve as magnetic shields, thus reducing the effects of electro-magnetic interference.

iv. Enclosures are normally specified according to IEC 529. This standard gives requirements against intrusion of solid objects and against ingress of water. When an electrical component is given a degree of protection, this describes the protection required for personnel and the protection necessary to ensure reliable electrical operation. This is explained in article 15.18. Two examples are mentioned below:

a) Rotating machinery mounted in an engine room is to have protection to at least IP 22. IP gives the reference to IEC 529, the first numeral (2) indicates that the motor must be protected against intrusion of solid objects larger than 12 mm and the second numeral (2) indicates the protection against ingress of dripping water when tilted up to 15 degrees.

b) A machine mounted on an open deck is to have a degree of protection to at least IP 56. The first numeral (5) means dust protected and, the second numeral (6) means protection against heavy seas.

2.3.2 Protection against Erroneous Operation

As far as is possible safeguards are built into the electrical system so that a system, component or machine will be 'fail safe' when operational conditions exceed set limits, in terms of voltage, current, temperature, speed, etc.

2.3.3 Maintenance

There must be an organised system of maintenance applied to the whole electrical installation. This involves inspection and testing at regular intervals, and the repair or replacement of any component or part which is found to be defective or malfunctioning. Only in this way can the electrical installation be relied upon in order to supply electrical energy safely and as demanded by operational requirements.

2.3.4 Personnel Protection

All protective measures applied to eliminate potential failures are in fact elements in a personnel protection scheme, as any abnormal situation will reduce the actual safety level. A number of rules are however, directly aimed at protecting personnel. The most important requirements and their purpose are aimed at the prevention of accidentally touching live parts. Electrical shocks can be lethal, even at voltages as low as 220V. In switchboards the wrong use of tools and other objects can also cause arcs, exposing personnel to short-circuit and similar effects.

Important requirements in the rules are therefore related to:

i. ***Enclosures***

Minimum requirements are given for most electrical equipment, for example, terminal boxes, distribution boards and starter enclosures.

ii. ***Screening***

Screens are often required for equipment which cannot be enclosed, for example, the bus Bars.

iii. ***Warning Signboards***

These must be prominently and permanently displayed at all locations where potential electrical hazards exist for personnel.

iv. ***Limited Accessibility***

For high-voltage equipment, special tools must be available to open, for example, terminal boxes on motors. High voltage transformers are to be installed in locked rooms.

v. ***Accidentally Touching Rotating and Movable Parts***

Minimum enclosures are specified to provide protection against rotating parts in motors and generators.

2.4 Active Safety Measures

When a failure occurs in the electrical installation, the philosophy is that the installation shall only suffer minor operative consequences due to any single system failure. Measures are also to be taken to limit secondary effects from any system failure, to a minimum.

The most important measures adopted to fulfil these requirements are as follows:

2.4.1 Redundancy Requirements

For particular functions where the reliability level is not considered high enough, the level is normally increased by the introduction of redundant systems

Example:

In a lubrication system there are two electrically-powered pumps; where both pumps have sufficient capacity to maintain adequate lubrication alone, and the pumps are supplied from independent power supplies, it is said that the pumps are redundant.

The Classification Rules list a number of users defined as essential and important for the operation of the ship:

a) *Essential users* are for example: steering gear; auxiliary machinery for main and auxiliary engines.

b) *Important users* are, for example, windlasses, bilge and ballast systems and thrusters.

In addition to these users, there are a number of functions which are connected to the emergency system. A typical emergency system arrangement is shown in Figure 4.1. Such functions are emergency lighting, navigation lights, steering gear, fire detection/alarm system and fire pumps. These functions are duplicated.

As an example, normal lighting is supplied from the main system, but in case of a main system blackout, the emergency lighting will be supplied from the emergency system. Based on these considerations, the normal system solution in marine installations, for redundancy, is as follows:

2.4.1.1 Essential Users

Users which need to be in continuous operation are duplicated. These users have separate supplies from the main switchboard. Consequently, a main system blackout will interrupt the operation of these users. Such failures are very rare and if they do occur they are not considered likely to cause major dangers in most installations.

For special installations, for example, on diving vessels where continuous thrust is vital for the safety of the divers, other arrangements must be sought.

With reference to Figure 4.2, this installation can be operated with bus tie breakers open, permitting one section of the system to remain in continuous operation even when a main switchboard failure occurs. Article 1.3.2 also explains the importance of essential users.

2.4.1.2 Important Users

Users which are necessary to maintain the main functions of the installation are very often duplicated or partly duplicated. They are normally supplied directly from the main switchboard or from dedicated distribution switchboards.

Example:

There is a main switchboard failure leading to a main system blackout. There is only a short period where battery-backed systems are alive.

After 5-20 seconds the emergency diesel will start, and users fed from the emergency switchboard will come alive. For most purposes a 5-20 seconds' power interruption will have no consequences, and the power supply is therefore considered "continuous".

If no major damage is present in the main system, the main system can now be re-started and normal operation resumed, provided that functions necessary to start the main system's diesels are supplied from the emergency system or can be activated by other sources.

There are a number of other general redundancy requirements in the Rules:

a) Safety of supply

A ship must be provided with both main and emergency sources of electrical power supply.

b) Main generators and prime movers

There is a requirement for at least 2 (two) generating sets. With any unit out of service the rest of the generators must be capable of supplying all the systems necessary for the operation of the vessel and maintaining a minimum habitable condition.

c) Power transformers

Transformer installations supplying essential and important users must be designed so that with any transformer out of service other transformers will be capable of maintaining normal operation.

d) Cable installation

Cables for redundant users must have separate routing. Cables for the emergency system must be separated from the main system. The intention is that no single incident damaging the cable installation shall cause failures in redundant circuits. The main electrical supply must be independent of the emergency supply in such a way that a fire or other casualty in the spaces containing the main source of supply will not render the emergency source of supply inoperative.

e) Main lighting system

A main lighting system must be provided and supplied from the main source of power. The arrangement of the main lighting system must be such that a fire or other casualty in the spaces containing the main source of power, associated transformer, main switchboards and lighting switchboards will not render the emergency lighting inoperative.

2.4.2 Circuit Protection

We know that a basic circuit consists essentially of two parts:

(a) The *conductor* – which carries current around the circuit; and

(b) The *insulation* – which confines the current to the conductor itself.

Here, only two types of circuit faults can occur, i.e. either a break in the conductor, or a break in the insulation (Refer Figure 2.1). The complexity of other faults is beyond the scope of this chapter. However, Chapter 13 deals with various faults and fault protection devices in detail.

- An *open-circuit fault* is due to a break in the conductor, so that current cannot flow.
- An *earth fault* is due to a break in the insulation, allowing the conductor to touch the hull or an earthed metal enclosure.
- A *short-circuit fault* is due to a double break in the insulation, allowing both conductors (of different potential) to be connected thereby resulting in a very large current that bypasses or short-circuits the load. The magnitude of 'fault current' that will flow depends on the overall impedance left in the circuit under such conditions.

In order to minimize the operational consequences and secondary effects of system failures, the electrical network is equipped with automatic disconnecting devices. The integrity principle as described in IEC Publications and the classification rules is of major importance when selecting protective devices for an installation is 'short-circuits'

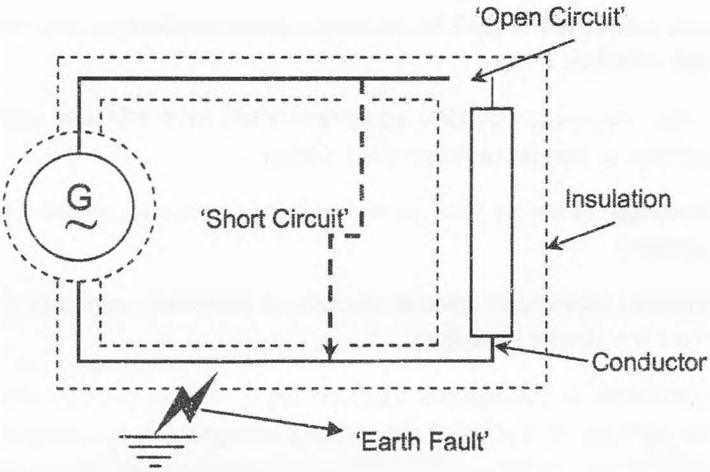


Figure 2.1 - Common Circuit Faults

2.5 Fundamental Requirements for Safe Installation of Equipment

From the very early days of electricity there has been an essential requirement for electrical installations to be installed safely, as well as being suitable for the purpose for which they are designed. Some guidelines are as follows:

- ☞ Good workmanship and proper materials shall be used throughout the installation;
- ☞ The equipment shall be installed in such a way as to be accessible for testing, inspection and maintenance as far as is practical;
- ☞ Joints and connections shall be properly constructed, regarding conductance, insulation, mechanical strength and protection;
- ☞ Wherever necessary, circuits shall have suitably rated automatic protective devices especially for protection against overcurrent;
- ☞ Whenever a prospective earth fault current is insufficient to operate the above, a residual current device shall be fitted;
- ☞ Electrical equipment shall be earthed in such a manner that earth leakage currents will be discharged without danger;
- ☞ If metal parts of other devices can be touched simultaneously with the above, then they should be earthed;

- ☞ Single pole switches shall be inserted in phase conductors, only with the exception of linked switches;
- ☞ Circuits supplying electrical equipment shall have effective means of isolation as necessary, to prevent or remove any danger;
- ☞ Safe means of access shall be ensured for persons to operate or attend to installed equipment;
- ☞ Equipment exposed to adverse weather or corrosive conditions shall be designed to prevent any danger from this;
- ☞ No additions to installations shall be made without ascertaining there is sufficient spare capacity for it and that the earthing arrangements are adequate;
- ☞ Testing shall be carried out on completion of the installation, to the requirements as specified in relevant regulations.

The ships' staff must also operate equipment in a safe manner and maintain them in a safe condition at all times. Failure to do so will cause danger with possible disastrous consequences.

2.6 Dos and Don'ts While Working With Electrical Equipment

Do...

☺ ... get to know the ship's electrical system and equipment. Study the ships' diagrams to pinpoint the location of switches and protection devices, distribution boards and essential items of equipment. Write down this information in a notebook. Note the normal indications on switchboard instruments so that abnormal operation can be quickly detected.

☺ ...operate and maintain equipment according to the manufacturers' recommendations.

☺ ...ensure that all guards, covers and doors are securely fitted and that all bolts and fixings are in place.

☺ ...inform the Officer of the Watch before shutting down equipment for maintenance.

☺ ...remember that it is mandatory to obtain a work permit prior to carrying out any work on equipment that is supplied with voltages greater than 1000 volts. In fact most vessels insist on work permits for electrical equipment that operate at even less than 1000 volts. An example of such a permit is mentioned in article 26.2.1.1.

☺ …switch off and lock all supplies[1], remove fuses and store them in a safe place. It is mandatory to display warning notices before removing covers of equipment for maintenance; refrain from asking others to do this; do this yourself as you are going to work on the equipment.

☺ …confirm that circuits are *dead* (by using a voltage tester[2]) before touching conductors and terminals. Never rely totally on switches, etc, as sometimes they may be defective or could have been wired or labelled wrongly, such that when indicating 'Off', they could actually be 'On' thus completing the power supply to the circuit.

☺ …make contact with the conductor(s) of a supposedly dead power system, first with the back of one hand. Even if a shock should still occur, an involuntary reaction will cause the fist to be clenched, thus moving the fingers *away* from the conductor – rather than involuntarily gripping the live circuit, which has sometimes resulted in many fatalities.

1 Proper and foolproof electrical locking would not merely mean switching off the supply by operating the isolation switch / switch fuse handle but by removing the fuses or by mechanically locking the handle in the "Off" position.

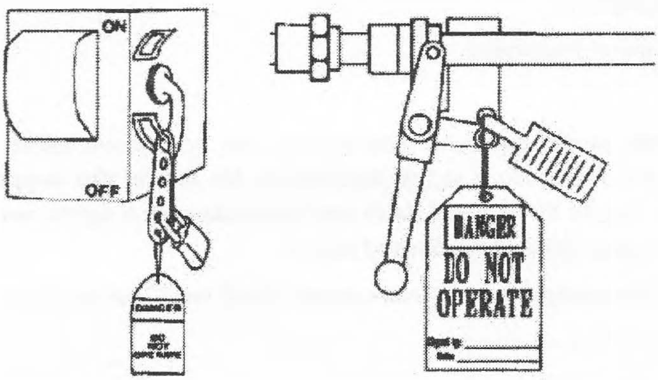


Image Courtesy IACS Rec. No. 72 (2000) Rev 1 (October 2003) Confined Space Safe Practice

Figure 2.2(a) - Foolproof Locking

2 Check the instrument used for testing (to ensure that it is working); next check the equipment which has been made dead (for any presence of electricity); finally check the instrument on a live circuit so as to ensure that it is still working

Don't...

- ☠ ...touch live conductors under any pretext – especially when wearing damp clothing or perspiring.
- ☠ ...remove earth (ground) connectors on power cords and within equipment.
- ☠ ...touch rotating parts as depicted in Figure 2.2(b).

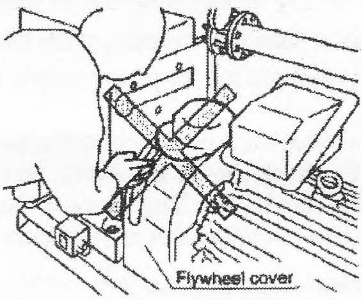


Figure 2.2(b) – Caution for Rotating Machinery

- ☠ ...leave live conductors or rotating parts exposed.
- ☠ ...overload equipment.
- ☠ ...neglect or abuse equipment.

Remember!

Most accidents occur due to a momentary loss of concentration or attempts to overlook or ignore standard safety procedures. Do not let this happen to you! You should think 'Safety First' at all times and hence develop a safety conscious attitude. This will save your life and the lives of others.

2.6.1 Additional Precautions when Commencing Work on Electronic Equipment

1. Switch off the power to equipment
2. Select and use adequately-rated test and measuring devices that are both safe for the environment in which work is to be carried out and for the equipment too.
3. Personnel working on electronic equipment should wear electrostatic discharge straps on the wrist and ensure that the grounding connection (to a good earthing point on the ship) does not hinder safe working procedures.
4. Ensure that the equipment is also grounded at a good earthing point.
5. Electronic components and printed circuit boards, etc, must be stored in anti-static bags and similar storage devices.

2.6.2 Special Protection Scheme for Workshop Machinery

1. A circuit breaker with a no-volt coil for workshop machinery ensures that if the power supply fails, the machine(s) will shut down and will not automatically start once the supply is restored; it has to be manually re-started.
2. The power supply from the Main Switchboard will be routed through a Distribution Board very close to the workshop and its equipment. This contains miniature circuit breakers for various machines; in addition there are overload and short circuit protection circuits; an emergency stop arrangement will also be installed on the machine itself.
3. Lathes have a foot pedal switch to isolate the equipment in case of an emergency

2.7 Danger Signals

Be constantly alert for any signs that might indicate a malfunction of electrical equipment. When any danger signals are noted, report them immediately to the chief engineer or electrical officer. The following are examples of danger signals:

- Fire, smoke, sparks, arcing, or an unusual sound from an electric motor or contactor.
- Frayed and damaged cords or plugs.
- Warm receptacles, plugs, and cords.
- Slight shocks felt when handling electrical equipment.
- Unusually hot, running electric motors and other electrical equipment.
- An odour of burning or overheated insulation.
- Electrical equipment that either fails to operate or operates erratically.
- Electrical equipment that produces excessive vibrations.

2.8 Precautions for Preventing an Electric Shock

Take the following precautions when working on electrical equipment:

- Remain calm and consider the possible consequences before performing any action.
- When work must be done in the immediate vicinity of electrical equipment, check with the senior engineer responsible for maintaining the equipment to avoid any potential hazards. Stand clear of operating radar and navigational equipment.
- Never work alone. Another person could save your life if you receive an electric shock.

- Never enter a flooded compartment that has a generator actively producing power. Transfer the load and secure the generator before entering.
- Never work on electrical equipment while wearing loose-fitting clothing. Be careful of loose sleeves.
- Never work on electrical equipment while wearing rings, watches, identification tags, or other jewellery.
- Wear safety goggles. Sparks could damage your eyes. The sulphuric acid contained in batteries and the oils in electrical components can cause blindness.
- If possible, de-energize the circuit before using test equipment, especially a megger.
- Discharge capacitors before working on de-energized equipment. Take special care to discharge capacitors properly. Injury or damage to equipment could result if improper procedures are used.
- Work on energized circuits only when absolutely necessary. The power source should be tagged out at the nearest source of electricity for the component being serviced.
- Ensure that all tools are adequately insulated when working on energized electrical equipment.
- When working on energized equipment, stand on a rubber mat to insulate yourself from the steel deck.
- When working on an energized circuit, wear approved electrical insulating rubber gloves. Cover as much of your body as practicable with an insulating material, such as shirt sleeves. This is especially important when working in a warm space where you may perspire.
- When working on energized electrical equipment, work with only one hand inside the equipment. Keep the other hand clear of all conductive materials that may provide a path for current flow.
- Keep covers of all fuse boxes, junction boxes, switch boxes, and wiring accessories closed. Report if any cover is not closed or missing, to the senior engineer responsible for its maintenance. Failure to do so may result in injury to personnel or damage to equipment if an accidental contact is made with exposed live circuits.

- Ensure all rotating and reciprocating parts of the electric equipment are adequately protected by guards.
- Secure power to the affected circuits if there is an electrical fire in a compartment. If critical systems are involved that prevent power from being secured (determined by the chief engineer), extinguish the fire using a non-conducting agent, such as dry chemical powder, carbon dioxide ($C0_2$), etc.

WARNING!

- ***The use of water in any form is not permitted***

  Carbon dioxide is the choice for fighting electrical fires. It has a nonconductive extinguishing agent and does not damage equipment. However, the ice that forms on the horn of the extinguisher will conduct electricity.

- ***Personnel exposed to a high concentration of $C0_2$ will suffocate***

  Burning electrical insulation is toxic as sometimes gases like phosgene are also liberated and can kill in a matter of moments. Use an oxygen breathing apparatus (OBA) when fighting electrical fires.

2.8.1 Working on High-voltage Equipment

While carrying out work on high-voltage equipment it is essential that in addition to isolation of the power supply, the system must be earthed (grounded) adequately and all residual charges must be drained; the system must continue to be maintained at zero (ground) potential. While working, a safe distance from other high-voltage equipment, as mentioned in Table 2.2 or as specified, is also to be maintained; this minimises the danger of electric shocks or flash-over burns. Safe working practices also require that while working in such dangerous areas, the zone must be demarcated with proper barriers and warning signs.

2.9 Conditions which Increase Danger to Personnel

The involuntary spasm caused by electric current on some parts of the body sometimes makes the victim jump away. Alternating current that comes into contact with a person's bare hands can cause the muscles to contract; hence contact is (undesirably) prolonged. A current of 12 to 15mA or more through the muscles is sufficient to make relaxation of the grip impossible and 10mA of current can be fatal over a long period. The resistance of dry skin (to current flow) is fairly high, but that of wet skin is much less (the body's internal resistance is very low).

Thus in warm conditions the danger from an electric shock is greater due to sweat on the skin and this has been a feature of some welding accidents. The resistance of wet skin, if taken as 1000Ω, would permit a current flow of 220mA from a 220V supply (220V/1000Ω = 220mA). This is more than enough to be lethal. Obviously a higher voltage would increase the current flow. Other factors, which reduce the resistance of the skin, are poor general health and cuts or other similar injuries.

Current flows into the body through the part in contact with a live conductor and then out through another part which is touching the earth or another live contact at a different potential. The current path may be from one hand to the other, through the chest (resistance between the hands may be 2000Ω depending on the area of skin involved), or from hand to foot etc.

Current flow into the body is less when the skin is dry; and if there is resistance in the current path between the body and the earth this will further reduce or prevent current flow and shock e.g., rubber mats and dry metal-free footwear. There is greater risk when working with electrical equipment in humid or wet conditions; in hot conditions where skin or clothing and even protective leather gloves become soaked with perspiration; and when in contact with metal platforms, railings, machinery or a metal workbench. The effect of electric shock is more serious for someone in poor health with, say, a heart problem.

2.10 Shock Risk with Portable AC Appliances

WARNING! ***An ungrounded portable power tool can kill***

Faulty hand held tools powered by a.c. and with metal casings could impart a lethal shock to the operator where the fault causes the casing to be 'live'. The hand(s) gripping the tool provide a large contact area (possibly damp with perspiration) so that sufficient alternating current might flow to prevent relaxation of one's grip, and such a current could result in fatality.

The risk of shock is increased if the operator is working in damp conditions and standing on metal plates or touching metal structures. There are similar risks with various types of portable or semi portable appliances - particularly lead lamps. Only 24-volts portable hand-lamps are to be used while working in confined spaces like tanks, etc. This minimises the risk of an electric shock. 24V is also considered to be a safe working voltage. The metal casings of portable appliances are connected to the earth through the earth wire in the three core cable and the earth pin in the plug, to ensure protection against a fault which could make the casing live.

Shock risk from portable tools is greatly reduced if the power supply is taken from the secondary winding of a step-down transformer, with the mid-point of its secondary winding earthed. If the secondary voltage is limited to 110V for operation of the single-phase appliance, then the potential shock voltage between the casing and earth is limited to 55V. A case is on record of death as a result of shock at 60V a.c. and the typical 380-440V system can prove fatal.

Several regulatory bodies now require special precautions to be taken on any system where the voltage with respect to the earth exceeds 55V. Secondary voltage can be made lower if required. Nowadays supplies as low as 24V are used for portable grinders, drilling machines, chippers, etc. Double-pole switches are fitted to control single-phase appliances fed in this way. But undoubtedly the safest of all is to resort to adopting the use of pneumatic tools which, more often than not can prove to be intrinsically safe and also enhance life safety in terms of nullifying the effects of electric shock.

Frequently, rough handling of portable equipment not only causes the fault that makes the casing live, but also causes the earth wire to be broken. Thus, when electrical connections and insulation are checked in the course of regular inspection and cleaning, the earth core of the electric cable should also be tested for continuity (i.e. with one terminal of the tester on the metal casing of the appliance and the other on the earth pin of the plug).

Flexible cables for portable tools and equipment are reinforced and given extra protection by a rubber tube where they enter the appliance. Here and at the plug-end, the cable is subject to bending and pulling; it can also be damaged along its length either by being pinched or cut by sharp edges and by touching a hot surface or lying in oil, chemical or water. Sometimes the tool being used cuts the cable. Damage to the cable can cause an electric shock in a number of ways; an earth fault or a short-circuit could also occur.

During cable inspections for damage to the insulation and continuity (particularly in the earth wire), other checks are also made. Live and neutral wires must be correctly fitted to terminal points so that the switch is on the live side and the appliance is isolated from the power supply when it is switched off.

The switch is to be tested for trouble-free operation. Fuses should also be examined to ensure they are of the adequate rating.

Extension leads must be arranged so that when plugged into the power supply, the free end has a socket for the three-pin plug of the power tool. A minor shock from a portable tool can sometimes cause a fall and result in subsequent injury (e.g. to someone working on a ladder).

The following safety tips could save your life:

- Use gloves and appropriate footwear while working with such tools.
- Store them in a dry place when they are not in use.
- Don't use them in wet/damp conditions.
- Keep working areas well lit.
- Ensure that such tools and their accessories do not pose a tripping hazard.
- Don't carry any tool by the electrical cord.
- Don't tug the cord to disconnect it.
- Keep cords away from heat, oil, & sharp edges.
- Disconnect tools when not in use and when changing accessories such as blades / bits.
- Do not use damaged tools.

2.10.1 Safe Practices for Welding Equipment

Merchant Shipping Notice M.752 of the Department of Transport, Marine Division, London (Safety-Electric Shock Hazard in the Use of Electric Arc Welding Plant) points out the risks involved with the use of arc-welding equipment in hot, damp conditions within a restricted space surrounded by the earthed steel structure of the ship. Three fatalities are cited, each resulting from use of a.c. sets with an open circuit (striking) voltage of 70V or so. The notice also states that d.c. welding sets of the same or less voltage are safer (unless derived from a.c. and possessing un-smoothed ripples in which case it is recommended that the idling voltage be limited to 42 volts by provision of voltage reduction safety devices).

These safety devices limit the open-circuit or "idling" voltage to 25V or less until electrode contact is made to strike the arc and then the *full* open-circuit voltage is turned on. The notice also recommends the use of fully insulated electrode holders, adequate protective clothing including non-conducting rubber boots, good lighting and the display of first aid instructions on a wall chart. Some general precautions will help to alleviate any danger:

1) The terminals on the welding machine should be tight and clean.
2) There should not be any wear out on cables and lugs. Replace them in case of damage.
3) There should be good earthing arrangements made closest to the job and at a good conductive strongpoint. Avoid connecting the earth terminal far away from the point being welded as this will lead to currents circulating in the hull and of course catastrophic circumstances!

4) When the vessel is in a dry dock, earthing of the hull must be made at adequate points and these points are to be connected to a certified earth point outside the vessel i.e., on the pier or in the dry dock.
5) Log the open circuit voltage which should match with the specified value.
6) Electrodes should not be inserted into a live holder.
7) After every operation use the vacuum cleaner to remove dust from inside of machine.

Hand tools and welding generators are to be inspected periodically (e.g., once in three months). It is recommended that earth leakage circuit breakers (ELCBs) must be installed in all extension boards used for providing temporary power supply to portable equipment.

Remember safety has no holiday!

2.11 Electrical Accidents

Research has shown that at least 75% of all accidents are the result of carelessness. Hurrying reduces caution and invites accidents.

2.11.1 Arc Flash

An arc fault generates an arc flash, which contains extremely high-temperature conductive plasma and gases. A rough estimate is that around 80% of all electrical injuries are burns resulting from an arc flash contact or ignition of flammable material like clothing. Arc flashes can cause 2^{nd} and 3^{rd} degree burns if skin temperatures rise to 200^0F.

2.11.2 Arc Blast

It is a pressure wave caused by the rapid expansion of gases and conducting material with high-flying molten materials and shrapnel. An arc blast may result in a violent expansion of circuit components. Such blasts can destroy structures, knock personnel from ladders, etc., or just across a room, rupture ear-drums or cause the victim's lungs to collapse.

2.11.3 Shock

Human tissues, such as the skin and the muscles, as well as blood and other body fluids are termed as electrolytes. Consequently, they are electrical conductors that may be characterised based upon their conductivity.

Electric potential differences applied across human tissues, or at two locations on the external skin surface generate response currents. Electric shock can be classified as follows:

2.11.3.1 Microshock

Microshock describes an internal shock that may occur as a consequence of certain medical diagnostic or surgical procedures in which electrically operated sensors are introduced into the human body. The effective current ranges from 10 to 100μA.

2.11.3.2 Macroshock

Macroshock describes simultaneous contact between the body's surface and two electrical conductors at different potentials, and the physiological consequences of this contact.

Electric shock is often from hand to foot or from hand to hand (Refer Figure 2.3). The two conductors may be a hot (live) conductor and the ground or two hot (live) conductors as in two of the phase wires of a three-phase power distribution system. The severity of the consequences of electric shock depends on a variety of factors. The physiological effects of electric shock are not produced by electric potential i.e., voltage, but rather by the electric current that is driven by the potential difference, which is applied externally to the body surface. The combined effective electrical resistance of the body volume involved and the intimacy i.e., the surface area involved and pressure applied during skin-conductor contact, have a major effect on the severity of the electric shock.

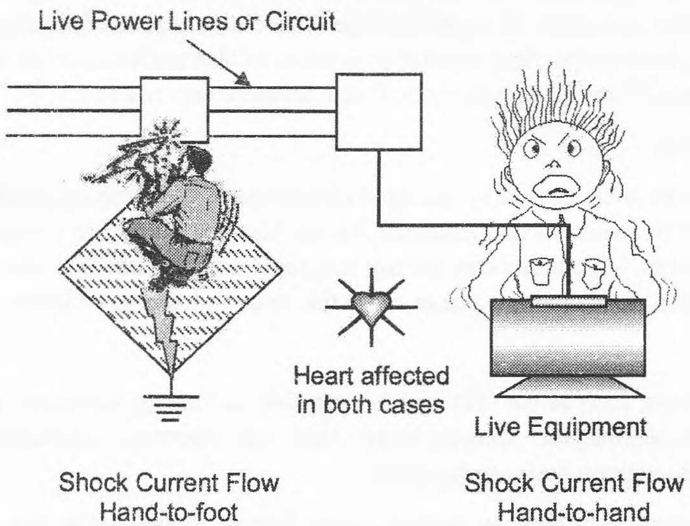


Figure 2.3 – Current Paths in General

Due to the damp, saline conditions generally encountered in the marine environment, quite low a.c. voltages can result in a fatal electric shock. The passage of even a very small current through a vital part of the human body can kill. Nearly everyone has experienced an electric shock at some time in their lives.

Electric shock is a jarring, shaking sensation. Usually it feels like receiving a sudden blow. At best, it is an unpleasant experience; at worst it is fatal. Anyone who has access to live electrical equipment must be fully aware of first aid and safety procedures related to electric shock as described in relevant Safety Acts. Copies of these safety procedures should be displayed on board a ship.

Posters on display at high-risk areas such as the switchboard, generally portray the effects of severe electric shock and immediate first aid required for its victims. Resuscitation techniques are also taught in the mandatory first aid courses.

Certain conditions increase the dangers from electric shock, and risks are greater when using portable a.c. appliances than with fixed electrical installations. Unfortunately, body resistance goes down as the applied voltage goes up. This means that the shock current is further increased at high voltages.

The value of body resistance also depends on other factors such as the state of one's health, the degree of contact with live wires, and the perspiration or dampness on the skin, the condition of the skin surfaces coming in contact with the electrical conductors being an important factor. Personnel who use their hands in occupations that build up calluses (hardened areas of skin), will tend to possess more resistance to electric shock, while those with soft hands would be more susceptible to the same current levels.

Typical dry full-contact body resistance is about 5000Ω at 25V, falling to about 2000Ω at 250V. Hand-to-hand resistance of a wet body may also be as low as 1,000Ω and as high as 10,000Ω for a dry body. Fatalities have resulted from voltages as low as 30 volts.

Table 2.3 explains the general effectiveness of various levels of current in a 60 Hz circuit. To explain briefly, a shock current as low as 15mA a.c. or 50mA d.c. may be fatal. *At about 100mA (0.1 ampere), the shock is fatal if it lasts for one second or more.* Obviously the magnitude of shock current is related to the applied voltage and body resistance; however, the effects widely vary depending upon the person involved. Current from a steady d.c. source, in passing through the skin, will tend to cause muscular contraction at the initial contact and as contact is broken.

Alternating current produces a continuing spasm in the muscles through which current passes, with its change from forward to reverse flow at the rate of 50 or 60 cycles per second. Alternating current has the ability to stimulate nerves directly. It finally results in the unfortunate victim tightening his / her grip. Most victims of 'serious shock' will have been in contact with a.c. Serious shock results in unconsciousness or worse conditions, requiring resuscitation and medical care.

Alternating current, which takes a path through the chest area, can, by contraction of the chest and diaphragm muscles, stop the breathing directly and possibly also indirectly by interfering with the functioning of the respiratory control nerves. Similarly, shock in the region of the chest can have direct consequences for the heart, causing stoppage of contraction of the heart's muscles. Lesser alternating currents can upset the heart's pumping action by destroying the co-ordination between the walls of the ventricles (ventricular fibrillation).

It must be remembered that fibrillation is unlikely to occur if the current in mA is less than 116/t where t is the shock duration in seconds; thus even though the current may be lower it may lead to this unpleasant condition if the victim is exposed for a longer time.

Current Level	Effect on Victim
1 mA	Sensation that shock is occurring
5 mA	Upper limit of safe or harmless range
10 to 20 mA	Let-go threshold – the victim cannot shake loose from the source of shock and perspires
30 to 40 mA	Sustained muscle contraction and cramping
50 to 70 mA	Extreme pain, physical exhaustion, fainting, irreversible nerve damage; possibility of ventricular fibrillation (shocking of the heart into a useless flutter); respiratory arrest with possible asphyxiation
100 mA	Ventricular fibrillation (of the heart) and death if the current passes through the body trunk
>100 mA	Fibrillation, amnesia (memory loss), burns, severe electrolysis at contact sites
>5A	Little likelihood of survival

Table 2.3 – Electric Shock Currents and Physiological Effects

Current flowing through the body can also cause clotting within blood vessels so that tissues are starved of blood. Various nerves may be affected. The brain or other vital organs could also be injured. Serious shock as a consequence of the above can kill instantly, in so far as stoppage of the heart and breathing are equated with death. However, with the power shut off, or with the person safely removed from contact, the prompt and continuing application of first aid has a 75% chance of saving life. With shock, arrest of breathing and heartbeat are not the result of physical defect but of a temporary condition induced by the electric current, and with only brief contact there may not be serious damage from the current.

Resuscitation to overcome loss of heartbeat and breathing requires both heart massage and artificial respiration to be employed. An unconscious person who is not breathing must be given artificial respiration. After recovery, victims of shock are to be kept under close observation because of the likelihood of a relapse. Unconsciousness and other forms of distress may be delayed and not follow immediately after a shock, which has apparently left the victim only shaken.

2.11.4 First Aid

2.11.4.1 The Basic Procedure

The following will help to alleviate the danger in any situation:

1. Act quickly!
2. Survey the situation
3. Develop a plan
4. Assess the victim's condition
5. Summon help if needed
6. Administer the required First Aid

This type if injury is an emergency that calls for prompt and intelligent action - prompt action if the casualty's life is to be saved; intelligent action if two casualties instead of one are to be avoided. Studies prove that only about 20% of victims survive if there is a delay of up to 3 minutes in rendering the right aid! The following are the basic steps to be initiated in case of an electric shock:

+ ***Switch off the current***

If the switch cannot be found immediately and the supply is through a flexible cable, removing the plug, wrenching it free or even severing the cable may cut off the current.

DO NOT attempt to cut the cable with a knife or un-insulated cutters / scissors. *In case it is impossible to switch off or break the current's circuit, then...*

...Remove the casualty from contact with the current

The greatest care is necessary; insulating materials must be used and they must be dry. With ordinary domestic equipment, gloves are good. In case this is not available, a dry cap, coat, garment or even cardboard / folded newspaper gives fair protection.

If possible the rescuer should stand on some dry insulating material such as rubber-soled shoes or boots, a rubber mat or piles of cardboard / news papers. It must be remembered that if the rescuer comes in contact with the casualty, even he will get a shock!

With very high voltages, danger may exist even if the casualty is not actually in contact because the current may jump across the gap (arcing may occur). In these cases the rescue should be approached with great caution and the rescuer must keep as far as possible from any part of the electrical equipment. The casualty may be dragged away with a dry wooden pole or rope.

- ***Lower the casualty to the floor taking care not to damage the head***
- ***If the casualty is conscious, make him comfortable***
- ***Should the casualty be unconscious but breathing...***

  ...loosen the clothing around the neck and waist and place the casualty in the recovery position; Keep a constant check on his pulse; improvise a suitable method to keep him warm.

- ***When the casualty is found unconscious, but not breathing...***

  ...take immediate action and apply emergency resuscitation techniques that one must be aware of:

  Mouth-to-mouth (or mouth-to-nose) resuscitation is by far the most commonly used form of resuscitation and is most effective in the event of an electric shock. However if the face has sustained injury, it may be more practical to use the Holger-Neilson method. Both methods are explained in articles 2.11.4.2 and 2.11.4.3. Once the person is stabilized, attend to the physical injuries as they would normally be treated. Lay the victim face up in a prone position. The feet should be about 12 inches higher than the head. Chest or head injuries require the head to be slightly elevated. If there is vomiting or if there are facial injuries that cause bleeding into the throat, place the victim on his stomach with his head turned to one side. The head should be 6 to 12 inches lower than the feet.

✚ ***Keep the victim warm***

The injured person's body heat must be conserved. Cover the victim with one or more blankets, depending on the weather and the person's exposure to the elements. Avoid artificial means of warming, such as hot water bottles.

✚ ***Treat any burns***

Damage from electrical burns may not appear to be extensive from the surface mark (sometimes just a small whitened area), but the penetration may be deep; the injury would be slow to heal and subject to infection if it is not treated immediately.

In some cases both thermal and electrochemical burns can occur simultaneously if the victim accidentally touched an electrically energised hot conductor such as an electric oven's heating coil.

Current flow can cause clotting of the blood and destruction of tissue. Most cases of severe burning result from contact with a direct current supply.

- Maintain a neutral position of the head and neck by applying a cervical collar or improvised (towel) collar.
- Establish and maintain the airway, breathing, and circulation (ABCs).
- Elevate burned limbs; place some firm, soft support under the affected limbs to elevate them. This helps to reduce swelling to a great extent and increases the comfort level of the victim.
- Cover burns with a moist, preferably sterile dressing.

✚ ***Control the victim's intake***

Do not give drugs, food and liquids if medical attention will be available within a short time. If necessary, liquids may be administered. Use small amounts of water, tea, or coffee. Never give alcohol, opiates*, and other depressant substances.

* *An opiate is: (i) a sedative drug containing opium or (ii) a thing that soothes the feelings or dulls activity.*

✚ ***Transfer to hospital or seek medical aid***

Send for medical personnel (a doctor, if available) at once, but do not, under any circumstances leave the victim until medical help arrives.

2.11.4.2 *Mouth-to-Mouth Resuscitation*

- Lay the casualty on his or her back and check the mouth for blockages. If possible raise the casualty's shoulders with a padding of some sort.
- Make sure the head is well back and the air-way is clear.
- Pinch the casualty's nose. Take a deep breath and seal your lips around the open mouth of the casualty.
- Blow gently and firmly into the casualty's mouth; the chest should rise slightly as the lungs fill with air. Repeat this until the casualty shows signs of recovery.

2.11.4.3 *Holger-Neilson Resuscitation*

- Place the casualty face downwards with the head to one side; check that the casualty's mouth is clear.
- Kneel down by the head-side of the casualty and place both your hands flat on the upper-part of the back.
- Rock forward applying pressure with your hands.
- Rock backward sliding your hands under the casualty's arm-pits.
- Grasp the upper-arms and lift the casualty gently off the floor to bring air into the lungs.
- Lower the casualty gently down again.
- Repeat the sequence until there is a sign of recovery and place in the recovery position.

2.12 Tanker Installations

To differentiate the types of tankers, their cargoes are tested for flash point.There is generally four types of tankers namely for the carriage of the following:

1. Type "A" - cargoes with a flash point not exceeding 60^0C (closed cup test) e.g. crude oil and gasoline.
2. Type "B" - Cargoes with a flash point (closed cup test) in excess of 60^0C e.g. fuel or diesel oils.
3. Type "C" - Liquefied Natural Gas (LNG) or Liquefied petroleum gas (LPG); such vessels are commonly referred to as "Gas Carries".
4. Type "D" - Other flammable cargoes; these are potentially more hazardous than those described above.

2.12.1 Awareness of Hazardous Areas

When a ship is involved in its normal operational functions there will be some areas and zones where flammable or explosive vapour, gas or, dust may normally be expected to accumulate and present a hazard to the ship, its crew and other personnel who may be onboard. Such areas are defined as hazardous and classified in terms of the risks involved. For example, IEC Publication 79-10 defines three such categories:

Zone 0: The flammable mixture is continuously present or present for long periods (>1000 Hours per year). These areas include the interiors of cargo tanks, slop tanks, any pipe work of pressure-relief or other venting systems of cargo and slop tanks, pipes and equipment containing the cargo or developing flammable gases or vapour. Only equipment with Ex i(a) standard protection is permitted where there is a continuous hazard and Ex s that is specially certified for use in Zone 0.

Zone 1: The flammable mixture is not continuously present, but will be present during normal operations (10 hours ... 100 hours ... 1000 hours per year). These areas include void spaces adjacent to, above or below integral cargo tanks, cofferdams, cargo pump rooms, etc. Only equipment with Ex (i)a or b; Ex d; Ex e; Ex p or Ex s protection is allowed in these areas.

Zone 2: The flammable mixture would not normally be present, but if it is, it would be present for a short period only (<10 hours per year). All safe-type of equipment are permitted provided they conform to the stipulated requirements.

Note:

1. *In the case of combustible dusts, the zones are identified as 20, 21 and 22 respectively.*
2. *The terms 'gas-dangerous area' or 'gas-safe area' may also be mentioned on ships. The general ship's operation manual, or other similar documents, must be referred to in order to determine the number and extent of the hazardous areas for any given ship.*
3. *An Explosive atmosphere is referred to as "Hazardous area" in IEC countries and "HAZLOC" in North America.*
4. *The IMO definition for a dangerous area is "an area on a tanker, which for the purposes of the installation and use of electrical equipment is regarded as dangerous".*
5. *There are variations in zone classification due to different codes of practice - some countries have identified just two zones, one being hazardous and the other – non-hazardous.*

Regulations and practices applied to the installation of electrical equipment in tankers specify the types of safe equipment that can be fitted in the areas where flammable gas and air mixtures may be present. The degree of risk is not the same throughout the hazardous areas, which include cargo tanks and the spaces above them, pump rooms, cofferdams and closed or semi-enclosed spaces with direct access to a dangerous zone (Refer Figure 2.4).

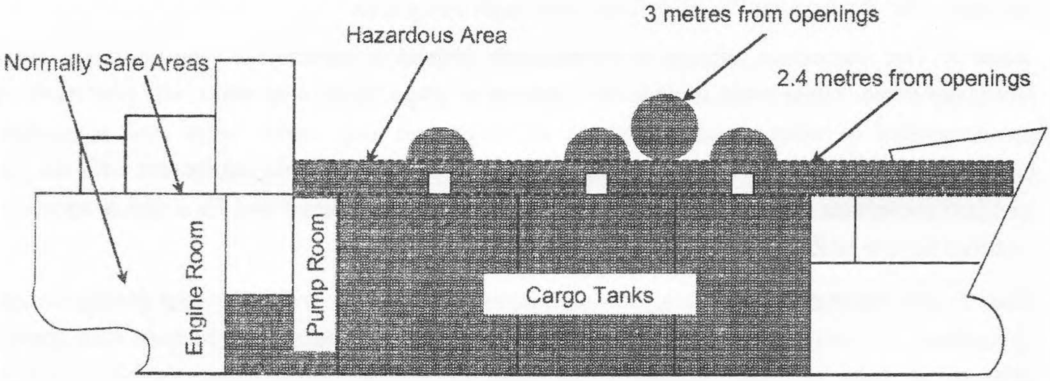


Figure 2.4 – General Tanker Arrangement
Showing Hazardous Areas and Normally Safe Areas

Cargo tanks are permitted to have only intrinsically safe apparatus which is certified to the higher Ex i(a) standard. Pump room lighting must be flameproof (Ex d) and arranged with two separate and independent circuits. Intrinsically safe apparatus to Ex i(a) standard is also allowed. Cofferdams adjacent to cargo tanks can be fitted with intrinsically safe equipment.

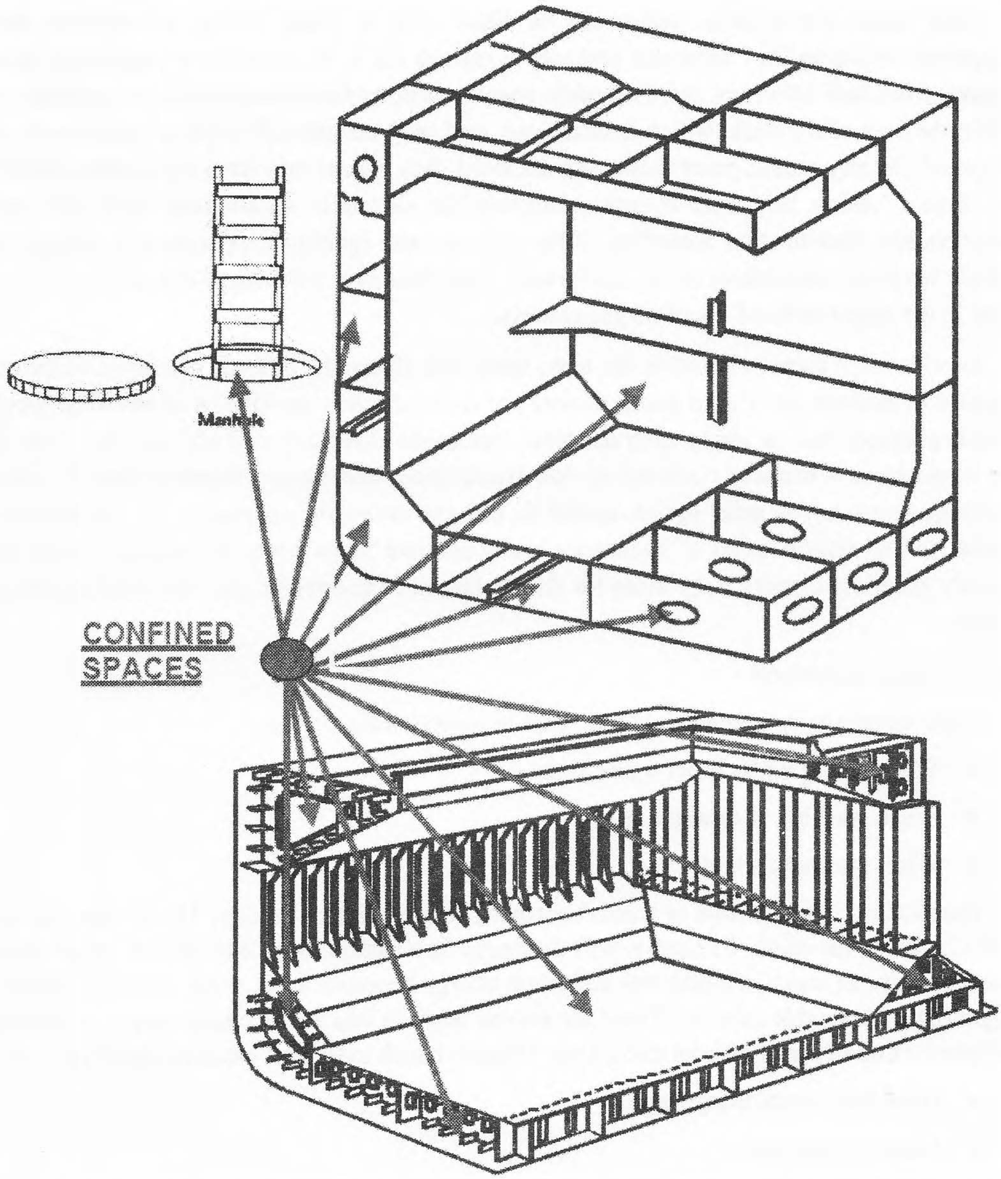


Image Courtesy IACS Rec. No. 72 (2000) Rev 1(October 2003) Confined Space Safe Practice

Figure 2.5 - Examples of Confined Spaces

Deck areas above cargo tanks can be fitted with a wider variety of certified safe equipment including Ex i apparatus and others such as Ex d, Ex e and Ex p depending upon distance from tank openings, etc. Forecastle spaces are considered hazardous if the entrance is within the area of the deck, which is hazardous, and only certain safe types of equipment are permitted. Battery rooms, paint rooms and enclosed deck spaces may have equipment suitable for "zone 1" areas. Selection of safe equipment for all tanker installations must take into consideration classification according to the gas-type and ignition temperature in relation to surface working temperature of the equipment. Exceptionally, submerged electric motors are fitted in the cargo tanks of liquefied gas carriers.

Provided that there is liquid in the tank, there will always be boil-off vapour at sufficient pressure to exclude air. Cargo pump motors are isolated when gas-free or at any time when there is a danger that air might enter the tank. Automatic shut down and alarm in the event of low liquid level is required (initiated by low liquid level, low motor current or drop in pump discharge pressure). A safer option would be to have steam-driven pumps for the purpose. Similar to the classification of hazardous areas onboard ships codes of practice in the oil industry generally classify risky areas for the likelihood of flammable gas / air mixtures being present

2.12.2 Static Electricity

Static electricity is generated within tanks in several ways such as:

- When filling with clean oil products
- When washing with water jets
- When steaming a tank

The product or water mist or steam becomes charged with electricity. The charge will try to discharge to the earth. In time it will discharge itself harmlessly through the ship's hull. There are several ways in which this sufficient charge becomes a hot spark which is capable of igniting a flammable mixture. There are several ways in which this might happen involving the introduction of metal objects into a tank. Objects which may have caused a spark include:

- Hand-held metal ullage tapes
- Metal sample cans
- Metal sounding rods
- Ungrounded portable washing machines

A static charge and spark may also be caused by carbon dioxide or steam being discharged at a high rate from a nozzle. Flammable gas remains in a tank after it is discharged. This presents a hazard particularly during washing, unless appropriate steps are taken. When tank washing is in progress, the following points must be remembered:

- Keep tank openings closed as much as possible.
- Do not introduce metal objects into the tank, other than a grounded washing machine.
- Do not disconnect tank cleaning hoses from their hydrants until they have been removed from the tank.

Note: *In addition to the above, electronic printed circuit boards are to be handled as follows:*

1. *They must be stored in antistatic bags (to prevent them from either being affected by static charges or in rare cases, affecting any other devices) and then wrapped in bubble-wrap or similar material to avoid damage to components*
2. *In order to avoid any pollution, they must not be discarded with the garbage or incinerated. Instead, they must be handed over to authorised handlers ashore for repairs / recycling.*

2.13 Safe Electrical Equipment for Hazardous Areas

2.13.1 International Electrotechnical Committee Ex Scheme

The IECEx Scheme is an International Conformity Assessment Scheme covering Apparatus for Explosive Atmospheres, as the Internationally accepted means of demonstrating claimed compliance with IEC Standards prepared by IEC TC31(Technical Committee for Explosive equipment). The IECEx Scheme was created in September 1999 to cover Equipment for use in Explosive Atmospheres in order to reduce and ultimately eliminate the wasteful duplication of Ex testing and certification that has occurred worldwide for some time.

The IECEx scheme caters for 25 countries whose national standards are either identical to those of the IEC or else very close to IEC standards. The goal is to help manufacturers reduce costs and time while developing and maintaining uniform product evaluation to protect users against products that are inadequate to the required level of safety. The IECEx is a voluntary scheme that provides an internationally accepted means of proving compliance of products and services with an IEC standard.

The other measures are safety earthing and fire prevention. While the former is covered in Chapter 5, the latter is an independent subject. However the precautions against a fire onboard are also mentioned in several other chapters of this book.

2.13.2 Effect of Added Oxygen on a Mixture of Oil Vapour and Inert Gas

Hydrocarbon gases or vapours from crude oil form highly flammable mixtures with air when they are present in a proportion between 1% and 10% hydrocarbon with 99% down to 90% normal air (this is also known as the flammable range). Below the lower explosive limit (LEL) the mixture is too lean to burn rapidly, although a lean mixture will burn slowly in the presence of a naked flame or a spark, as is proved by the operation of explosimeters in this range. The LEL is also referred to as the lower flammable limit (LFL) and it is the minimum concentration of hydrocarbon gas in air to support and propagate combustion. Over-rich mixtures exist when the level of the hydrocarbon exceeds 10%.

The risk of explosion or fire within the cargo tanks, pump rooms and other enclosed areas of an oil tanker are high as a consequence of the very small quantity of hydrocarbon gas or vapour that makes up an explosive mixture.

Within tanks, vapour is readily evolved from cargo; immediately above the surface of the liquid there tends to be a layer of undiluted hydrocarbon vapour. Further above the surface of the liquid, dilution by air (if present) increases towards the top of the tank, to give a mixture with decreasing hydrocarbon vapour content (Refer Figure 2.6).

At the top of the tank, the larger quantity of air is likely to produce a lean mixture. Thus the free space within the tanks above any liquid petroleum cargo, or in an empty tank from which the cargo has been discharged, is likely to contain a middle flammable layer sandwiched between lower over-rich and upper lean layers. Leakage of crude oil or products from pump glands would produce the same effect in pump rooms.

Inert gas is delivered to the cargo tanks of crude oil tankers, for example, to maintain a slightly higher than atmospheric pressure and so exclude air during operations. The inert gas can also be used to displace any air present in a tank after inspection.

The Inert Gas System cannot be used for pump rooms or other spaces in which crude oil vapours can collect and therefore form a flammable mixture with air. In these areas and on deck, precautions to avoid the possibility are necessary.

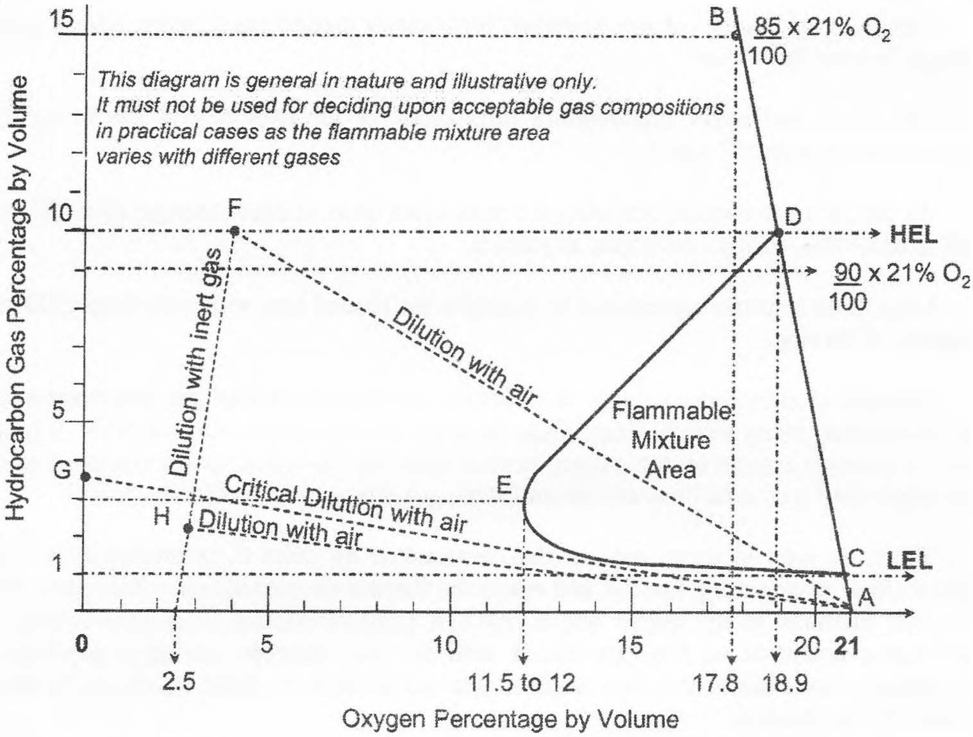


Figure 2.6 – Flammability Composition for Hydrocarbon Gas

- When an inert gas is added to a hydrocarbon gas / air mixture, the result is an increase in the lower flammable limit concentration and a decrease in the upper flammable limit concentration. Figure 2.6 illustrates these effects which should be regarded only as a guide to the principles involved.

- Any point on the diagram represents a hydrocarbon gas/air/inert gas mixture, specified in terms of its hydrocarbon and oxygen content.

- Hydrocarbon/air mixtures, without inert gas, lie on the line AB, the slope of which shows the reduction in oxygen content as the hydrocarbon content increases. Points to the left of AB represent mixtures whose oxygen content is further reduced by the addition of inert gas.

- As indicated in Figure 2.6 above, as inert gas is added to hydrocarbon/air mixtures, the flammable range progressively decreases, until the oxygen content reaches a level generally taken to be about 11% by volume, at which no mixture can burn.

- The value of 8% by volume, specified for a safely inerted gas mixture, allows some margin beyond this value.
- The lower and upper flammability limit mixtures for hydrocarbon gas in air are represented by points C and D.
- As the inert gas content increases, the flammable limit mixtures change; lines CE and DE indicate this, finally converging at point E.
- Only those mixtures represented by points in the shaded area within the loop CED are capable of burning.
- Changes of composition, due to the addition of either air or inert gas, are represented by movements along straight lines; these lines are directed either towards point A (pure air), or towards a point on the oxygen content axis corresponding to the composition of the added inert gas; such lines are shown for the gas mixture represented by point F.
- When an inert mixture, such as that represented by point F, is diluted by air, its composition moves along line FA and enters the flammable mixture area; this means that all inert mixtures in the region above line GA (critical dilution line) pass through a flammable condition as they are mixed with air (for example, during a gas-freeing operation); those below line GA, such as that represented by point H, do not become flammable on dilution.
- It will be noted that dilution with additional inert gas, i.e. purging, makes it possible to move from a mixture, such as that represented by F, to one such as that represented by H, by dilution with additional inert gas, i.e. purging.

2.13.3 Reasons for Specially-designed Equipment

1. There are no special measures taken in ordinary electrical equipment to encapsulate contacts, which arc as they close or open. Thus light switches, torches, sockets and plugs, push button contacts, relays, electric bells, starters, circuit breakers, and open fuses are all potential sources of ignition should there be a flammable gas, vapour or dust in the atmosphere.
2. The danger from arcing contacts in a starter box or switch is not obvious because the arc is hidden. Sparks from an electric motor, particularly of the commutator-type, the momentary glow of a broken light bulb filament, and arcing from a broken or damaged power cable are more apparent as sources of ignition.

3. An unusual condition (as with a gas leak at home) can make a safe area potentially dangerous so that all machinery and equipment must be shut down after ensuring it is safe to do so.

4. Conventional equipment and cables are suitable for areas that are considered safe. Special regulations apply to hazardous zones requiring only safe equipment or none at all. Examples of mandatory design features for some items to be used in hazardous areas are as follows:

2.13.3.1 Lighting

1. Care should be taken to ensure that the integrity of the approved lighting system is maintained. Additional lighting if any should also be approved prior to installation.

2. If there is any reason to doubt the integrity of the pump-room's lighting system, it should be switched on only after thorough ventilation of the pump-room. However, new regulations require that the pump-room lighting should be interlocked with the pump-room ventilation and will come on only after the ventilation system is switched on.

2.13.3.2 Pulley Drives

Each pulley drive in a hazardous location must have:

a. A conductive belt, i.e. anti-static; and

b. Pulleys, shafts and driving equipment that are grounded. The grounding leads and other arrangements must satisfy Class Requirements and requisite International Standards.

2.13.3.3 Miscellaneous Equipment

Small battery-powered personal items such as watches, miniature hearing aids and heart pacemakers are not expected to be significant sources of ignition. But unless approved for use in flammable atmospheres, portable radios, tape decks, recorders, calculators, cameras containing batteries, photographic flash units, portable telephones, radio pagers and similar equipment must not be permitted on the tank deck or in areas where flammable gas may be present.

2.14 International Safety Standards

The information needed when selecting suitable safe apparatus for use in hazardous areas is shown below as on a nameplate. The data consists of letter codes and references, which in the example apply to flame proof equipment (Refer Figure 2.7). Other types of protection also use the marking for gas grouping and temperature.

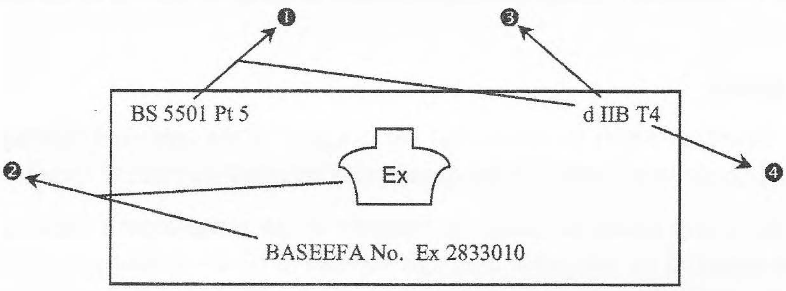


Figure 2.7 - Nameplate for Equipment Used in Hazardous Areas

The standard to which the safe apparatus is made may be British Standard BS 5501 or an equivalent from the IEC (International Electrotechnical Commission), or another standard. For flameproof equipment, details of the construction method can be found in Part 5 of BS 5501.This item is indicated on the nameplate by ❶ together with the code letter for flameproof apparatus (d). The crown with inscribed letters 'Ex' is the European Union's symbol of the testing and certifying authority and this indicated here by ❷, is the British Approvals Service for Electrical Equipment in Flammable Atmospheres (BASEEFA).

There are others too; is the European Union's symbol of the testing and certifying authority. 'Ex' represents the general term 'Explosion Proof', which is used in Europe for the safe practices of electrical equipment. Reference ❸ shows the IEC grouping of apparatus with respect to certain gases. Explosive gases are also classified under group numbers as follows (the full list is given in BS 229). These are also applicable in North America CEC Section 18, NEC Article 500:

- Group I is gas encountered in coal mining where methane and coal dust constitute the risks.
- Group II comprises gases such as cellulose vapour, petrol, benzene, amyl acetate. Group II may be further sub-divided into:
  - IIA – Methane, which requires a higher ignition energy of 180 micro joules; Butane, Methanol, Petroleum, Propane and Styrene are also included in this group.

  - IIB – Ethylene, which requires an ignition energy of 69 micro joules; Diethyl ether and Tetrafluoroethylene are also included in this group.
  - IIC – Hydrogen, which requires an ignition energy of 29 micro joules; Acetylene and Carbon Disulphide are also included in this group.
- Group III is coal and coke gas and ethylene oxide.

Further details of gas classification can be found from the IEC publication or from BS 5435 Pt I (1976). Some countries have maintained their own grouping systems, which are slightly different. For example, in North America acetylene is a type A gas, hydrogen is type B, ethylene is type C, propane and methane are type D gases. The energy for ignition can be derived from a spark or from contact with a hot surface. Protection against sparks is necessary whenever flammable gas and air mixtures are present. Hot surfaces, however will not cause combustion unless their temperature reaches the ignition temperature of the gas (ignition temperature is higher than flash point. A spark can cause combustion at flash point, but a hot surface will only cause combustion at a higher ignition temperature). The letter T, reference❹, indicates the maximum surface temperature. Temperature indications are shown in IEC Publication 79, Electrical Apparatus for Explosive Gas Atmospheres. Table 2.4 below gives the relationship between class number and maximum surface temperature:

<table>
<tr><th>North America
(CEC / NEC)</th><th>Maximum Surface
Temperature (^{o}C)</th><th>Europe
(CENELEC)</th></tr>
<tr><td>T1</td><td>450</td><td>T1</td></tr>
<tr><td>T2</td><td>300</td><td rowspan="5">T2</td></tr>
<tr><td>T2A</td><td>280</td></tr>
<tr><td>T2B</td><td>260</td></tr>
<tr><td>T2C</td><td>230</td></tr>
<tr><td>T2D</td><td>215</td></tr>
<tr><td>T3</td><td>200</td><td rowspan="4">T3</td></tr>
<tr><td>T3A</td><td>180</td></tr>
<tr><td>T3B</td><td>165</td></tr>
<tr><td>T3C</td><td>160</td></tr>
<tr><td>T4</td><td>135</td><td rowspan="2">T4</td></tr>
<tr><td>T4A</td><td>120</td></tr>
<tr><td>T5</td><td>100</td><td>T5</td></tr>
<tr><td>T6</td><td>85</td><td>T6</td></tr>
</table>

Table 2.4 – Surface Temperature Classification

Equipment for hazardous areas are selected so that their maximum surface working temperature is less than the ignition temperature of any gas or vapour likely to be found in its hazardous environment. Details of gas ignition temperatures and the T classifications can be found in BS 5345 Part I (1976) *Basic Requirements*, which is the UK code of practice for safe electrical installations in hazardous areas. With most types of electrical equipment, a choice can be made as to the particular method of protection that is most suitable and economical.

The methods of explosion protection suitable for equipment machines are described below, together with any limitations. These are based on IEC, European and North American standards. Electric motors or other rotating machines without these types of protection are not permitted in pump rooms or other similar hazardous enclosed areas of ships, or in the most hazardous areas (Zone 0) of any offshore or onshore installation. Equipment with non-sparking Ex n / N protection can, in fact, only be positioned in Zone 2 or least hazardous areas.

2.14.1 Flameproof (Ex d) Equipment

If electrical equipment could be made with perfectly gas-tight casings, the possibility of gas seeping in and being ignited by a spark would not be a problem. Unfortunately, seals on the rotating shafts and motors or on the operating rods of solenoids are not gas-tight. Hermetic sealing of covers is not guaranteed; gaskets or jointing can deteriorate and face-to-face joints depend on the quality of the machined surfaces and tightness of fastenings. Inaccurate threads on screwed cover joints or conduits can allow leakage of gas; so too can deteriorating cement or sealant on inspection glasses or windows. The designers of flameproof equipment recognise that there is a risk of ignition and explosion of gas within some enclosures and counter this by making casings strong enough to withstand such an explosion. Also potential flame paths to the outside of the casing through joints or seals are made so as to extinguish any flame. Normally this is done in joints by making them face-to-face with a limited gap.

The possible flame path between the surfaces is made long enough to prevent flame emission and packing or jointing is not used in the actual flameproof joint. Using a labyrinth design elongates the flame path through shaft seals. Special consideration is given to cover fastenings which must be strong enough to withstand internal explosion and, as far as possible, gas-tight. Screws of special material must have a unique design so that ordinary screws cannot be used to replace them. Their heads are patterned for special keys. The screw holes must not pierce the casing (Refer Figure 2.8). The glass of inspection windows must be held against the casing by an internal clamping ring. Flame paths are incorporated and sealing cement must be durable.

Flameproof enclosures ('explosion proof' is the term in the US) are used for equipment where sparking or arcing occurs during normal operation, as in a switch or a starter. The spark is contained and likewise any flame or explosion (of gas which might enter the casing), preventing the ignition of a surrounding explosive atmosphere. The maintenance of light fittings, switch boxes or other equipment that are designed and type-tested as flame proof must be thorough to preserve the 'as tested' condition.

Inspection may reveal the impairment of a structure which would permit gas to enter, and also allow flames from the gas that is ignited inside, to reach the surrounding atmosphere without being cooled or extinguished.

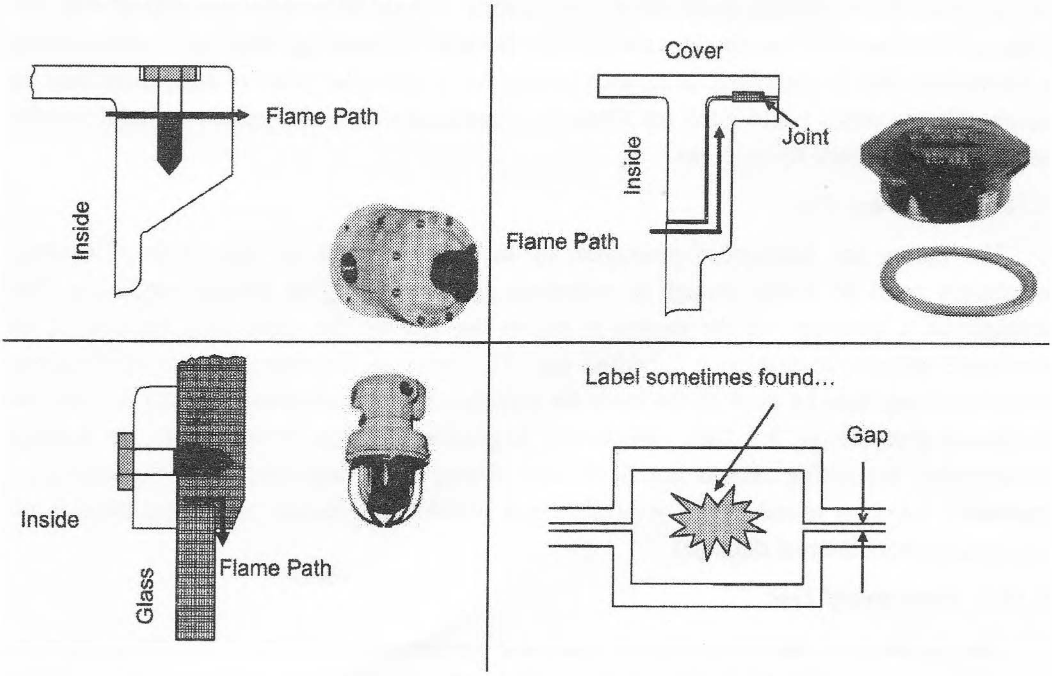


Figure 2.8 - Flameproof (Explosion proof) Enclosures

Casings or terminal equipment (boxes, etc.) may be corroded, cracked, broken or not properly closed due to missing nuts or slack screws. The glass windows may be cracked, broken, not properly closed or not adequately cement-sealed. Deterioration of conduits, cables and cable boxes, or glands may be evident; also friction between fans or couplings and guards.

Deterioration, wear or damage must be made good by replacement or repair followed by correct assembly procedures. Feeler gauges are used to ascertain that there is no gap in flanges greater than the specified limits (approx. 0.15-mm). Any weatherproofing must be done as specified; paint is applied with care to protect against corrosion without affecting the flame proofing (incendive aluminium paint must not be used).

2.14.2 Flameproof (Ex d) Equipment Protection

This type of protection can be applied to any type of rotating electrical machine but is intended for those where the ignition of a flammable atmosphere is likely because sparks or arcing occur during normal operation of the machine. Wound rotor induction motors with slip rings and brushes, also commutator motors, are, because of sparking, likely to be protected by a flameproof (Ex d) enclosure. With such protection, a particular piece of equipment may be acceptable for zones 1 and 2 but the flameproof protection does not make it suitable for the most hazardous (zone 0) locations.

2.14.3 Explosion Test

The casing for flameproof protection of an electric motor or other type of rotating machinery must be strong enough to withstand pressure during an internal explosion. The strength of a prototype of the casing is put to the test by the spark plug ignition of an explosive mixture containing a specified gas. The pressure developed by the explosion is found and may then be used as the basis for a further static or dynamic test at 1.5 times the explosion pressure or 3.5 bars, whichever is greater. For the protection to be deemed satisfactory, the casing should not have been damaged or deformed (it is the casing or enclosure which is tested by the explosion and which must remain intact, but there is no stipulation about internal damage).

2.14.4 Flameproof Test

The requirement that the enclosure must also prevent transmission of any flame from an internal explosion to any explosive atmosphere surrounding the enclosure is tested by repeating the explosion test at least five times with the machine in a chamber, which is filled with the same explosive mixture. If the mixture in the chamber is not ignited, then the second set of tests is considered to have been passed and a Flameproof Ex d certificate is granted.

Re-certification is needed for any modification of the casing. Explosive mixtures vary in their ability to force flame through a gap of given dimensions; machines are grouped according to the design of the joint with respect to the length of the flame path, maximum gap and dimensions (Refer Figure 2.6 in article 2.13.1). Gases are generally listed for a given enclosure group.

2.14.5 General Comments

A flameproof enclosure need not be hermetically sealed. Emphasis is placed on the design of potential flame paths for effectiveness in preventing passage of the flame, rather than providing a seal between any covers and the casing.

With no jointing material permitted between covers and casing, the face-to-face gap, although limited in size, will allow the entry of small amounts of flammable gas or vapour to the enclosure.

As in a Davy lamp*, where a small quantity of gas burns in the presence of a flame, so in a flameproof enclosure for a machine with arcing contacts, the gas will normally burn at a slow rate where arcing occurs. If a large quantity (within the explosive limits) accumulates, there may be a contained explosion.

The lamp was invented by Sir Humphry Davy in 1815. The lamp used naphtha for fuel and was 10-12 inches tall. He had discovered that, to explode, the gas must be heated to its ignition temperature and that if such heating is prevented, combustion cannot occur. If the flame in a lamp is surrounded by a metal gauze cylinder about 1½ inch in diameter and 7 inches in length to distribute the heat over a large area, the maximum temperature of the screen is below the ignition temperature of the gas.

It consisted of a glass cylinder, within which the flame was further encased in wire gauze so as to permit air to enter but prevent the flame escaping to ignite any inflammable gases which might be present in the air of a mine shaft.

Davy's invention has stood the test of time and has been the means of saving innumerable lives. The modern flame safety-lamp, although superior in illuminating power, still owes its safety to the basic principle discovered by him.

There is no limit imposed for the flameproof (Ex d) requirements on the rating of a machine or its internal temperature other than what may be involved in limiting the surface temperature of the enclosure or may be imposed by the rating of the insulation material.

2.14.6 Increased Safety (Ex e) Equipment

This type of protection is applied to electrical apparatus that does not produce arcs or sparks in normal service. Such equipment can be made safe for operation in areas that are hazardous by the likelihood of flammable vapour, by the application of increased safety techniques. Additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arc and sparks. See IEC Publication 79-7.

A squirrel-cage induction motor is a type of electrical apparatus, which does not normally have any associated arcing and sparking during operation and where the running temperature is not excessive.

The General features for design of motors for gas protection types are as follows:

1. Power supply terminals are of the non-loosening type and well separated to prevent tracking (i.e., excessive leakage of current between their insulated points, also called creepage) and the cables are firmly supported.
2. Insulation for windings and cables is of a high quality and protection against ingress of water or solids, which would cause a breakdown (often resulting in tracking), is ensured.
3. Breakdown of insulation due to overheating from overload is prevented by overload devices, which are an essential part of the increased safety technique. The overload devices also prevent excessive external or internal pressure.
4. They have a minimum ingress protection of IP 54 or IP55
5. The clearance between the fan and fan cover must be at least 1% of the maximum diameter of fan with a minimum value of 1 mm and maximum of 5 mm
6. The insulation resistance of fans, fan cover and ventilation screen should not exceed 1GΩ if the peripheral speed of the fan is equal or more than 50 m/s for gas environment
7. The fan, fan cover or ventilation screen should not contain mass of more than 6% of magnesium. Adequate clearance is given to the fan and rotor to avoid mechanical sparks from friction and the casing is made impact-resistant.
8. All surfaces, which can charge electrically, should be earthed or equipotential bonded.
9. Temperature of the relevant surface for determining the temperature class (external or internal surface) is determined by measuring the maximum temperature rise in worst conditions of voltage supply including the voltage tolerances required according to the standard *(in both cases with an additional margin of 5 K (T3, T4, T5 and T6) and 10 K (T1 and T2) below the temperature class)*
   a. +/- 5% of nominal voltage if the motor is stamped according to IEC 60034-1
   b. +/- 10% of nominal voltage if the motor is stamped according to IEC 60038 (or IEC 60079-0).

2.14.7 Pressurised (Ex p) Equipment

Pressurized equipment consists of separately ventilated enclosures supplied with positive-pressure ventilation from a closed-loop system or from a source outside the hazardous areas, and provision is to be made such that the equipment cannot be energised until the enclosure has been purged with a minimum of ten air changes and the required pressure is obtained.

Ventilating pipes have a minimum wall thickness of 3mm (0.12" or "11 gauge"). In the case of loss of pressurization, power is to be automatically removed from the equipment, unless this would result in a condition more hazardous than the one created by failure to de-energise the equipment. In this case, in lieu of removal of power, an audible and visual alarm is to be provided at a normally manned control station. Pressurized equipment in compliance with IEC Publication 79-2, NFPA 496 or other recognized standard will also be acceptable.

Pressurisation has been used for control cabinets and enclosed spaces for safe containment of sparking electrical equipment. It must be remembered that an enclosed space is one which cannot be assumed to contain oxygen. These are spaces like cofferdams, duct keel, double-bottom tanks, etc. All pressurised spaces must be thoroughly purged before the equipment is switched on.

Some deck lights used for tankers are operated by compressed air turbines, which drive small individual generators within the fitting (to provide power for the lamp). The exhaust air pressurises and purges the fitting, thus expelling any flammable gas, which might be present in the external atmosphere.

Failure of air supply automatically causes the power to be switched off. The technique of pressurising is also used in straightforward types of electrical apparatus, particularly where it is necessary to install a non-standard piece of equipment in a hazardous area. Ex p equipment is not permitted to be installed in very hazardous areas. Alarms and automatic shutdown at a loss of pressurisation are required if normally sparking Ex p type of apparatus is installed where flammable atmosphere is likely to occur.

2.14.8 Pressurised (Ex p) Equipment Protection

This is acceptable for all types of rotating machinery including motors with commutators or slip rings. Requirement of protection by pressurising is that the casing is purged or scavenged; any gas that may be present is completely displaced before the power is switched on. Nitrogen, carbon dioxide or argon may be used for pressurising the equipment. (Refer Figures 2.9, 2.10 and 2.11).

Connecting a manometer (e.g. a glass U-tube in which water is displaced by the internal pressure) tests the adequacy of pressurisation. Efficiency of scavenging is also tested. The procedure involves displacing the atmosphere (air) within the enclosure with a safe, easily available test gas which has an appropriate vapour density and then, in turn, using the intended purging / pressurising gas to displace the test gas. A "before and after" gas analysis is carried out. This type of protection also involves a surface temperature classification.

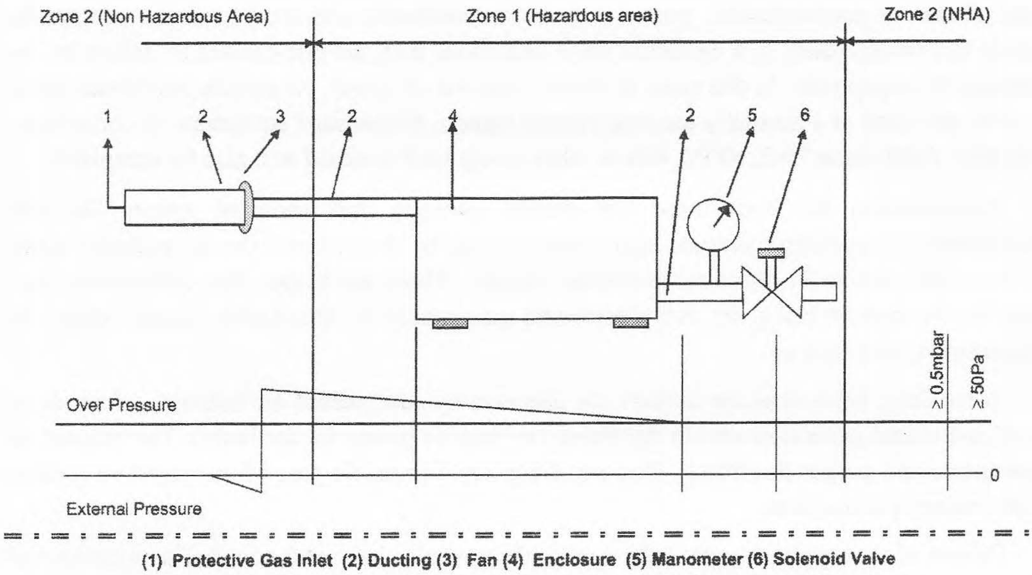
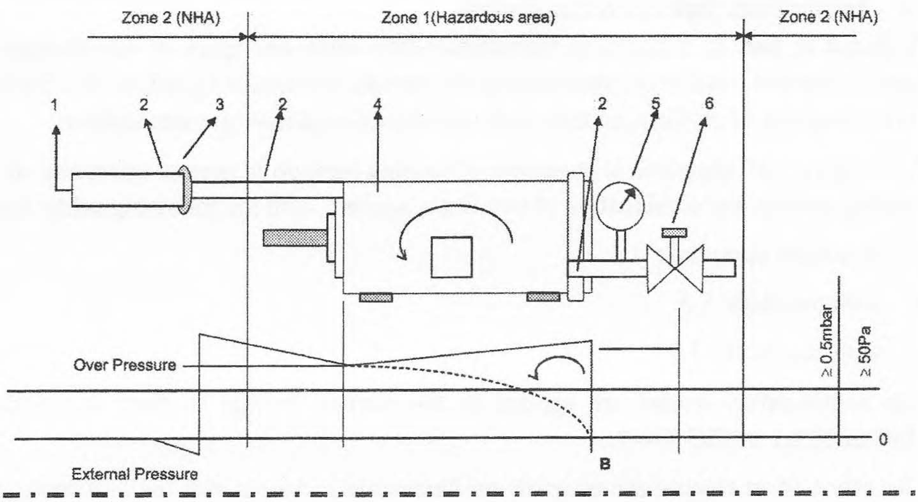
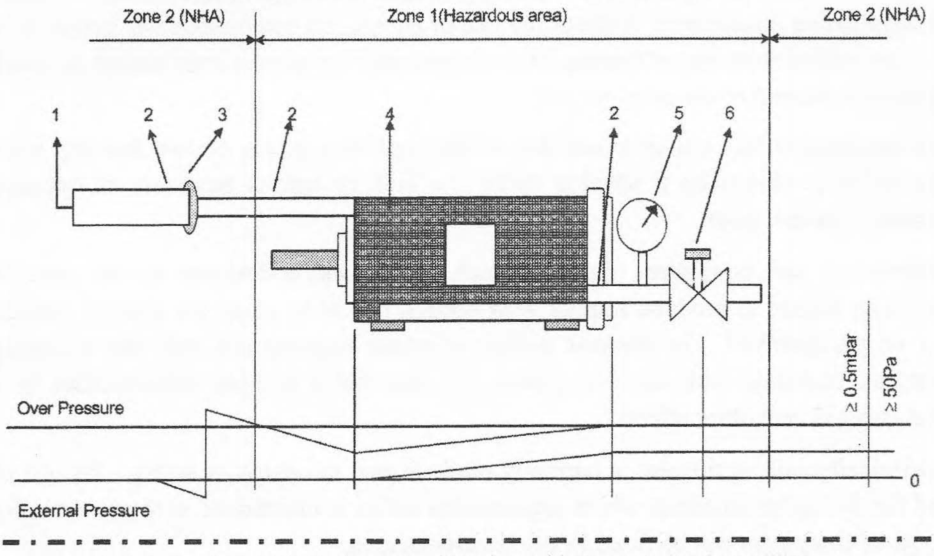


Figure 2.9 – Pressurised Apparatus with Leakage Compensation Enclosure without Rotating Parts



(1) Protective Gas Inlet (2) Ducting (3) Fan (4) Enclosure (5) Manometer (6) Solenoid Valve

Figure 2.10 – Pressurised Apparatus with Leakage Compensation Rotating Electrical Machine with an Internal Fan



(1) Protective Gas Inlet (2) Ducting (3) Fan (4) Enclosure (5) Manometer (6) Solenoid Valve

Figure 2.11 – Pressurised Apparatus with Leakage Compensation Rotating Electrical Machine with an External Fan

2.14.9 *Intrinsically Safe (Ex i) Equipment*

A circuit or part of a circuit is intrinsically-safe when any spark or any thermal effect produced in the test conditions prescribed in the recognized standard (such as IEC Publication 79-11) is incapable of causing ignition of the prescribed explosive gas atmosphere.

A Category "ia" apparatus is incapable of causing ignition in normal operation, or with a single fault, or with any combination of two faults applied, with the following safety factors:

a. in normal operation: 1.5

b. with one fault: 1.5

c. with two faults: 1.0

The above safety factors are applied to the current, voltage or their combination as specified in 10.4.1 of IEC 79-11.

The effect of an electric arc or spark on flammable vapour is that the heat increases the energy of the vapour and air locally so that particles are activated and made ready for chemical combination. The energisation reaches a sufficient pitch after a very small time delay so that combustion results. A weak spark or arc may not have sufficient thermal energy to heat the local flammable mixture at a rate faster than that at which the energy is dissipated to the surrounding atmosphere. Without the rise of energy, no combustion will occur. A weak spark or arc with a slow rate of heating (the mixture) may not persist long enough to complete the ignition at the end of the delay period.

An intrinsically safe circuit is one that is designed for a power so low that any spark or thermal effect produced by it whether there is a fault or not, is incapable of igniting the surrounding gas or vapour.

Intrinsically safe equipment is used in such circuits and is designed on the same basis, i.e., of being unable to produce a spark with enough power to ignite the specific flammable vapour or gas involved. The intrinsic safety technique requires not only that a system be designed for operation with very low power, but also that it is made indestructible by high external energies and other effects.

Intrinsically safe equipment is currently made to two standards of safety - Ex i(a) is the symbol for the higher standard, which requires that safety is maintained with up to two faults. This type of equipment can be fitted in any hazardous area.

The other standard is given by the symbol Ex i(b) and apparatus made to this specification is safe with up to one fault. Ex i(b) products are not used in most hazardous areas.

Manufacturers state that this method of protection is suitable for electrical supplies at less than 30V and 50mA (in some cases the maximum current may be 30mA). It is extensively used for instrumentation and some control functions. Care is exercised in design, that capacitance and inductance within the electrical installation is kept to a minimum in order to prevent storage of energy, which in the event of a fault could generate an incendive spark.

Ex i systems are isolated from other electrical supplies even to the extent that the cables are not permitted to be in the same trays as those of other cables (to prevent induction effects); most of the time they cross over perpendicularly in order to prevent any mutual induction. Systems are earthed and protection is provided by inclusion of shunt diode safety barriers between hazardous and non-hazardous areas. The safety barriers have (current-limiting) resistors and (voltage-bypassing) zener diodes that prevent excessive electrical energies from reaching the hazardous areas (Refer Figure 2.12).

Neither certification nor marking is necessary if none of the following values are exceeded in a device: 1.2 volts, 0.1A, 20 microjoules, 25mW. However, great caution is needed when deciding whether the apparatus will operate within all these limits and any associated system would have to be certified as intrinsically safe. An example of equipment marking in this case is "Ex ia IIC T4" (North America / IEC) or E EN ia IIC T4 (Europe).

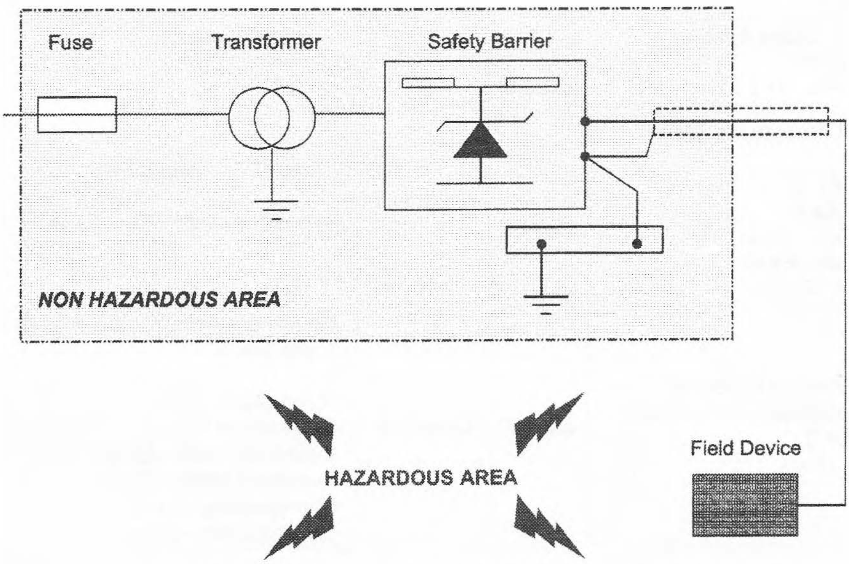


Figure 2.12 – An Intrinsically-safe Circuit

2.14.10 Non-incendive (Ex n or N) Equipment

The difficulty of absolutely sealing casings against the slow inward seepage of hazardous vapour, which is permanently present in the surrounding atmosphere, has been mentioned in the section for flameproof equipment. In an area where gas might only be present for a limited duration, if at all, the problem of accumulation of vapour within the casing is not so serious. Thus Ex n protection that can be used with lights in such slightly hazardous areas, for example, would incorporate a convenient casing seal, a surface temperature limit and protection against ignition by operational sparks of any vapour which reaches inside the enclosure.

2.14.11 Non-incendive (Ex n or N) Equipment Protection

A spark risk is negated by an enclosed-arc spark break device, or by ensuring that the spark is of low energy, or by hermetic sealing of the spark location. Sometimes an AFCI (Arc Fault Current Interrupter) is used for this purpose. This type can be used for squirrel cage or brushless synchronous machines. The features are similar to those of Ex e protection but less demanding. The criteria for Ex n protection may well be met by standard machines. Certification is required, however, but the type of protection only makes the machine suitable for zone 2 areas.

2.14.12 Class I Certified Equipment Comparison Chart (IEC, CENELEC, NEC, CEC)

<table>
<tr><th colspan="2">Zone System</th><th colspan="2">Division System</th></tr>
<tr><td>Intrinsically safe, Ex i, Ex ia</td><td>Zone 0</td><td rowspan="2">Division 1</td><td rowspan="2">Class I Div. 1 Equipment

Intrinsically safe Ex i, Ex ia</td></tr>
<tr><td>All Equipment accepted in Zone 0

Flameproof - Ex d
Pressurized - Ex p
Increased safety - Ex e
Intrinsically safe - Ex ib
Encapsulation - Ex m</td><td>Zone 1</td></tr>
<tr><td>Equipment accepted in Zone 0
Equipment accepted in Zone 1 and Class I Division 2
Non sparking - Ex n</td><td>Zone 2</td><td>Division 2</td><td>Equipment Acceptable for Class I Div. 1 and Div. II
+
Flameproof - Ex d
Pressurized - Ex p
Intrinsically safe - Ex ib
Increased safety - Ex e
Non-sparking - Ex n
Encapsulated - Ex m</td></tr>
</table>

2.14.13 Other Methods of Protection

Equipment can also be protected by:

- Oil immersion (Ex o),
- Using powder, sand or quartz filling (Ex q),
- Being encapsulated (Ex m), or
- Having a special method of protection (Ex s)

2.15 Ventilation when using Volatile Varnishes, Paints, etc., containing Solvents

Paints with solvents, varnishes and electro-cleaners are volatile i.e., they have very low ignition and evapouration temperatures. If they are left uncovered or when they are used, they contaminate the atmosphere of enclosed spaces with flammable vapours. Fumes also pose a fire hazard as they can be ignited with an electric arc or any rise in ambient temperature above their flash points. Such vapours are also extremely harmful to personnel as most of them have an intoxicating or suffocating effect. Apart from these, some vapours are corrosive in nature too. Hence it is mandatory to ensure adequate ventilation to exhaust the flammable vapours and fumes out of such enclosed spaces. Fans whose impellers and housings are made of anti-static non-metals or alloys (preferably of non-ferrous metals) that are recognised as being spark-proof (by means of appropriate test procedures) are used in these areas. It is also mandatory to bond them to the hull. Protection screens of not more that 13mm (0.5") square mesh must be fitted in the inlet and outlet of ventilation openings on the open deck in order to prevent any ingress of foreign objects into their casings. When such measures are adopted, they are unlikely to produce any sparks by static electricity or by entry of foreign objects in both normal and abnormal conditions. Most classification societies also insist that the air gap between the impeller and the casing is to be not less than 10% of the shaft diameter in way of the impeller bearing but in any case not to be less than 2mm (0.08"). It need not be more than 13mm (0.5"). Figure 2.13 is that of a non-sparking type of fan used in hazardous areas.

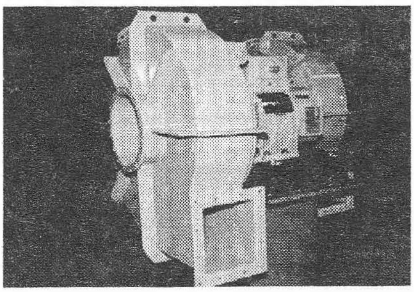


Image Courtesy: www.piller.com

Figure 2.13 – A Non-Sparking Fan used in Hazardous Areas

2.16 Maintenance of Records

Maintenance of records forms an important part of the system that is to be adopted for achieving electrical safety. The records could include the following:

a) Single line diagrams of systems

b) Layout plans of equipment

c) Record of inspections, work permits and a list of authorised personnel (permitted to carry out electrical work)

d) Equipment history sheets

e) Accident investigation reports

f) Training records

Finally, we must remember that safety in the use of electrical energy is a subject of paramount importance. It is very essential to adhere to the various requirements and practices as laid down in various safety standards and codes of practices to ensure a safe and healthy electrical system while complying with the statutory rules.

Find the Answers

1) Ex stands for _______.

2) Ex i(a) means _______.

3) Ex i(b) means _______.

4) Equipment in the Flameproof category is classified as ________.

5) Equipment in the Increased Safety category is classified as ________.

6) Equipment in the Pressurised category is classified as ________.

7) Equipment in the Non-incendive category is classified as ________.

8) Equipment in the Intrinsically Safe category is classified as ________.

9) Only equipment with Ex i(a) standard (and Ex s that is specially certified) equipment are permitted for use in ________ areas.

10) To indicate the probability of an explosive gas-air mixture being present in hazardous areas they are classified into zones as ________.

11) Only equipment with Ex (i) a or b; Ex d; Ex e; Ex m, Ex p, or Ex s protection are allowed in ________ areas.

12) If a motor is to be installed in a flammable (hazardous) area the Ex rating should be __.

13) An example of Zone 0 on a tanker is _______.

14) ________ areas are hazardous only under abnormal conditions and are usually freely ventilated and all safe-type of equipment are permitted to operate provided they conform to the stipulated requirement.

15) Explosive gas-air mixture continuously present or present for long periods ________.
Explosive gas-air mixture likely to occur during normal operation ________.

16) Explosive gas-air mixture is not likely to occur and any occurrence would generally be for a short time in ________ areas.

17) In terms of electric current, there is a sensation that shock is occurring when the value is about________ mA / A / kA.

18) The upper limit of safe or harmless range of electric current is ________ mA / A / kA.

19) In terms of electric current at the let-go threshold, the victim cannot shake loose from the source of shock and perspires; this is approximately at ________ mA / A / kA.

20) There is sustained muscle contraction and cramping when the value of electric (shock) current is ________.

21) There is extreme pain, physical exhaustion, fainting, irreversible nerve damage; possibility of ventricular fibrillation (heart); respiratory arrest with possible asphyxiation when the value of electric (shock) current is ________.

22) There is ventricular fibrillation (heart) and death if the current in excess of _________ mA / A / kA passes through the body trunk.

23) There is fibrillation, amnesia (memory loss), burns, and severe electrolysis at contact sites when the value of electric (shock) current is ________.

24) There is little likelihood of survival when the value of electric (shock) current is _____.

25) Typical dry full contact body resistance is about _______ Ω / kΩ / M Ω.

26) Zone, 0 Zone 1 and Zone 2 mean ______ , ______ and ______ respectively.

27) The recognised standard frequencies onboard ships are _______ and _______ Hz.

28) A shock current as low as ______ mA / A / kA can be fatal.

29) In terms of shock current, d.c. is _______ effective as compared to a.c.

30) BASEEFA stands for_______.

31) IEC stands for _______.

32) The typical body resistance can fall to about ________ at 250 V.

33) Risk assessment is carried out to ________.

34) Fumes released by volatile solvents are ________.

35) To differentiate the types of tankers, their cargoes are tested for ________.

36) As per BS and IEC standards, the high voltages are defined as ____ a.c. and ____d.c.

37) At what location the sign "Men at work" should be placed while working on electrical equipment?

38) What is the significance of earthing of electrical equipment.

39) What is generally the Ex protection for an electric motor?

40) What precaution is to be taken to ensure that the electrical equipment is not switched on while working?

41) What must be done to ascertain complete isolation of supply in Electrical installations?

42) What is to be checked to confirm safe working practice is followed in ship?

43) While working within the scavenging manifold in the main engine, the hand lamp should be rated at ________.

44) What is the minimum amount of electric current that can cause death to a human being?

45) What is the factor that can increase the risk of shock in case there is an earth fault in the electrical installation?

46) What is the minimum safe insulation in an electrical Installation?

47) What factor can increase the potential risk when working in a battery room?

48) When work is to be carried out on an electrical installation, what extra precautions must be taken to prevent against an electric shock after isolation of the power supply?

49) What precautions must be taken for portable electrical hand tools in order to avoid a lethal shock as its hand gripping area is large?

50) What is the safe voltage (in the case of a dry human body condition) to prevent an electric shock?

51) What precaution must be taken to prevent against an explosion while changing lamps in the pump room lighting in a tanker?

52) What would be the consequences if work on the electrical installation commences without taking Safety precautions?

53) What is the optimum location for earthing a welding machine in order to avoid circulation current?

54) What is the voltage applicable for welding in a ship?

55) Does current flow through the hull during welding? If so, why don't you get a shock?

56) Describe the precautions before commencing work on electrical equipment.

57) What safety are precautions associated with the operation of a HV (High Voltage) system?

58) What are the fundamental requirements for the safe installation of electrical equipment onboard a ship?

59) What is the maximum voltage regarded as reasonably safe for portable power tools? Justify your answer.

60) State the maximum safe current a human body can tolerate.

61) What is the maximum shock voltage to earth for a centre-tapped 110V tool transformer?

62) What are the two types of Electric shock? What is the first thing that must be done when finding a victim of electric shock? Give two methods of how this is done.

63) State the first aid to be administered to a person exposed to electric shock

64) Why are high voltage systems more dangerous than low/medium systems?

65) List the various type of Explosion Proof Equipment and explain each type in one or two lines.

66) What do you understand about the Do's and Don'ts of Electrical safety? Explain.

67) While ensuring Electrical Safety, certain Active and Passive measures are adopted. List them and briefly explain each measure.

68) Identify the hazardous areas on a ship and with the help of a table / chart determine what type of equipment should be installed in each location.

69) Demonstrate safe methods to test and use portable electrical tools.

70) State the type pulley belt specified for use in hazardous zones.

71) Why is special lighting used in battery rooms?

72) Describe the precautions for storing, replacing and repairing electronic PCBs.

73) With the help of simple sketches explain the basic design features of Ex d equipment.

74) State the essential features of switches certified for use in hazardous zones.

75) Using suitable diagrams, explain the role of zener barrier devices in Ex i equipment.

76) State the essential features of fittings for illumination in hazardous zones.

77) In your own words explain safe installations for tankers.

78) Differentiate the tankers by the cargo they carry?

79) State the importance of proper ventilation when using volatile electro-cleaners, varnishes and paints having solvents.

80) Describe the hazardous zones, classification of type, classification pertinent to different class of vessels and constructional and operational details.

81) With reference to electrical equipment in areas aboard ship having potentially flammable atmospheres:

    a) Explain the hazards involved.

    b) State the design features that render the equipment safe.

    c) Explain the precautions necessary when maintenance work is being carried out.