



**I.R.I.S.L TRAINING INSTITUTE**

# **SHIP CONSTRUCTION**

## **CHIEF MATE COURSE**

- **Ship Building Materials**
- **Welding**
- **Bulkhead**
- **Watertight doors**
- **Corrosion & its Prevention**
- **Survey & Dry Docking**
- **SOLAS Requirements**

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## CHAPTER -1 SHIP BUILDING MATERIALS

### Part- A Introduction to Metal

In chemistry, a **metal** is an element that readily forms positive ions and has metallic bonds. In general the metals are classified into **ferrous metals** and **non-ferrous metals**. Irons, carbon steels, alloy steels, stainless steels, tool and die steels are some examples for Ferrous metals and aluminum, copper, magnesium, nickel, titanium, precious metals, refractory metals, for Nonferrous metals and alloys.

**Alloy** is a mixture of two or more elements in solid solution in which the major component is a metal. Most pure metals are either too soft, brittle or chemically reactive for practical use. The aim of making alloys is generally to make them less brittle, harder, resistant to corrosion, or have a more desirable color and luster. Examples of alloys are steel (iron and carbon), brass (copper and zinc), bronze (copper and tin), and duralumin (aluminum and copper).

### 1.1 Chemical property of metals

Properties that describe how a substance changes into a completely different substance are called chemical properties. Flammability and corrosion/oxidation resistance are examples of chemical properties.

Most metals are chemically reactive, reacting with oxygen in the air to form oxides over varying timescales (for example iron rusts over years and potassium burns in seconds). The transition metals take much longer to oxidize (such as iron, copper, zinc, nickel). Others, like palladium, platinum and gold, do not react with the atmosphere at all. Some metals form a barrier layer of oxide on their surface which cannot be penetrated by further oxygen molecules and thus retain their shiny appearance and good conductivity for many decades (like aluminum, some steels, and titanium).

### 1.2 The physical property of metals

Physical properties are those that can be observed without changing the identity of the substance. The general properties of matter such as color, density, hardness, are examples of



physical properties.

The difference between a physical and chemical property is straightforward until the phase of the material is considered. When a material changes from a solid to a liquid to a vapor it seems like they become a different substance. However, when a material melts, solidifies, vaporizes, condenses or sublimates, only the state of the substance changes. Consider ice, liquid water, and water vapor, they are all simply H<sub>2</sub>O. Phase is a physical property of matter and matter can exist in four phases – solid, liquid, gas and plasma.

### 1.3 Mechanical properties of metals

#### 1.3.1 Loading

The application of a force to an object is known as loading. There are five fundamental loading conditions; tension, compression, bending, shear, and torsion.

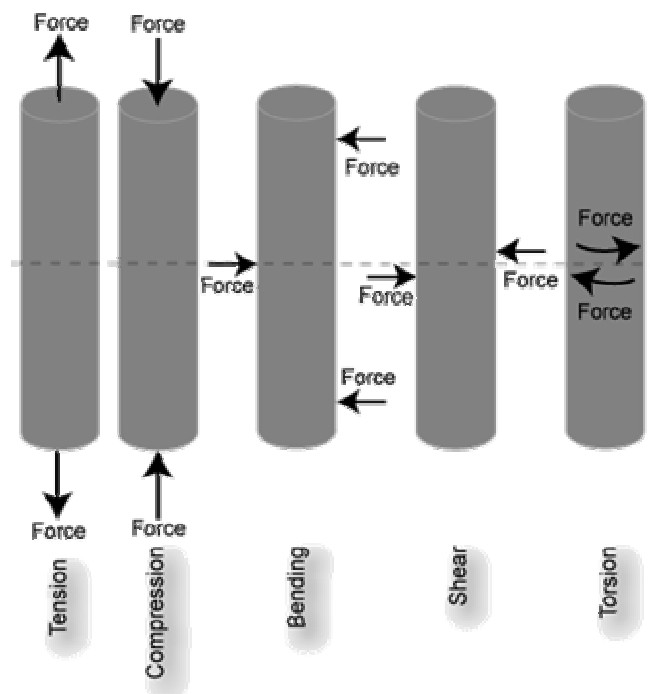
**Tension** is the type of loading in which the two sections of material on either side of a plane tend to be pulled apart or elongated.

**Compression** is the reverse of tensile loading and involves pressing the material together.

Loading by **bending** involves applying a load in a manner that causes a material to curve and results in compressing the material on one side and stretching it on the other.

**Shear** involves applying a load parallel to a plane which caused the material on one side of the plane to want to slide across the material on the other side of the plane.

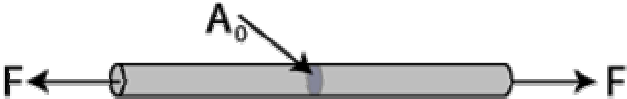
**Torsion** is the application of a force that causes twisting in a material.



### 1.3.2 Stress and Strain

**Stress** is defined as force per unit area. It has the same units as pressure, and in fact pressure is one special variety of stress. Stress is a measure of the ability of a material to transmit a load, and the intensity of stress in the material, which is the load per unit area, is often stated.

Simplifying assumptions are often used to represent stress as a vector quantity for many engineering calculations and for material property determination. The word "**vector**" typically refers to a quantity that has a "magnitude" and a "direction". For example, the stress in an axially loaded bar is simply equal to the applied force divided by the bar's cross-sectional area.




$$\text{Stress, } \sigma = \frac{\text{Force}}{\text{Cross-Sectional Area}} = \frac{F}{A_0}$$

Some common measurements of stress are:

**Psi** = lbs/in<sup>2</sup> (pounds per square inch) , **Pa** = N/m<sup>2</sup> (Pascals or Newtons per square meter)

**kPa** = Kilopascals (one thousand or 10<sup>3</sup> Newtons per square meter) , **GPa** = Gigapascals (one million or 10<sup>6</sup> Newtons per square meter)

**Strain** is defined as the amount of deformation an object experiences compared to its original size and shape. When a material is loaded with a force, it produces a stress, which then causes a material to deform. For example, if a block 10 cm on a side is deformed so that it becomes 9 cm long, the strain is (10-9)/10 or 0.1 (sometimes expressed in percent, in this case 10 percent.) Note that strain is dimensionless.



$$\text{Strain} = \frac{\text{Elongation}}{\text{Original Length}} = \frac{\Delta L}{L_0}$$

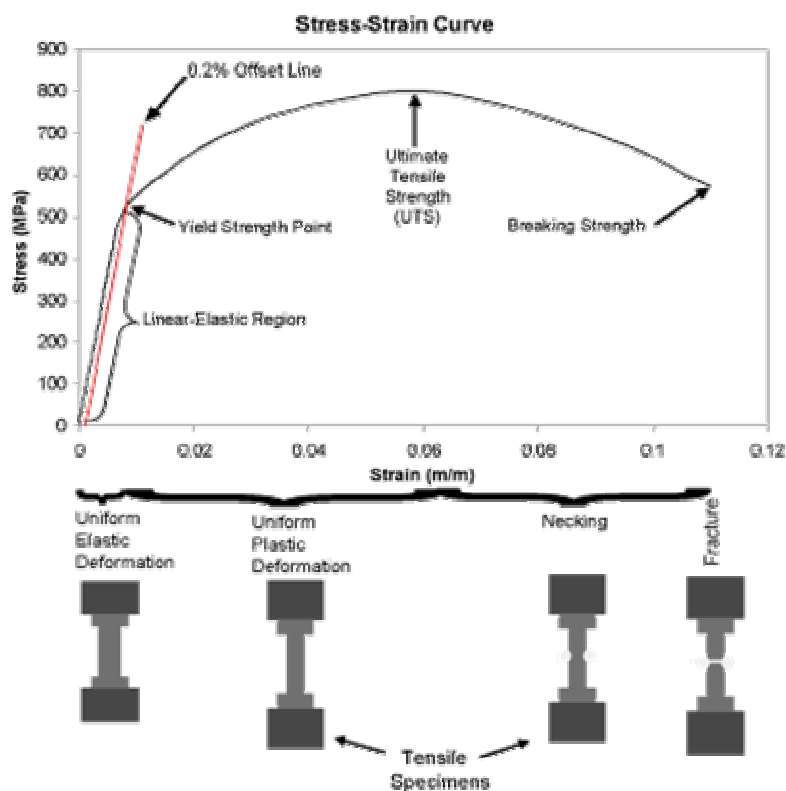


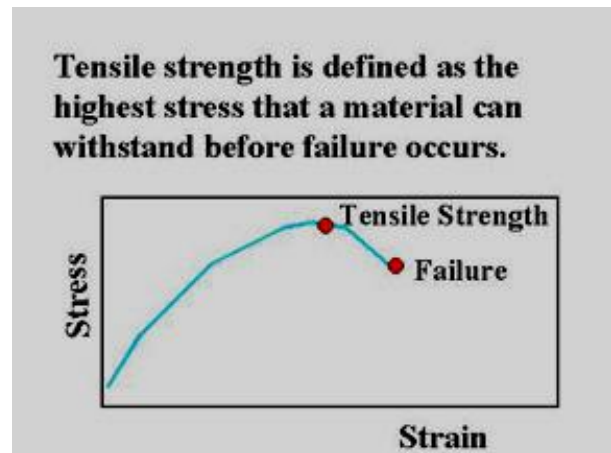
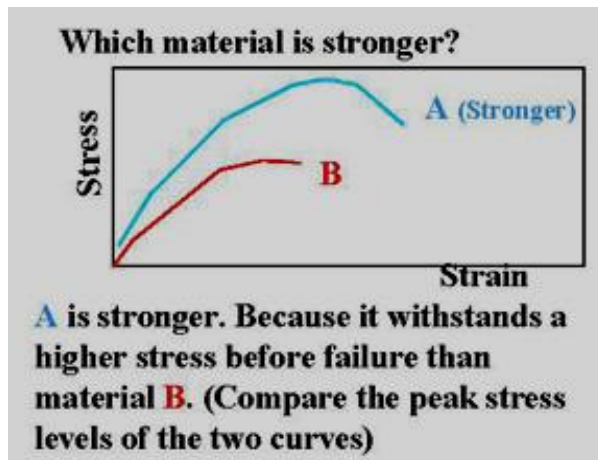
### 1.3.3 Elastic/Plastic Deformation

When a sufficient load is applied to a metal or other structural material, it will cause the material to change shape. This change in shape is called deformation. A temporary shape change that is self-reversing after the force is removed, so that the object returns to its original shape, is called elastic deformation. In other words, elastic deformation is a change in shape of a material at low stress that is recoverable after the stress is removed. When the stress is sufficient to permanently deform the metal, it is called plastic deformation. Plastic deformation involves the breaking of a limited number of atomic bonds by the movement of dislocations.

## 1.4 Tensile Properties

Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, reduction in area, tensile strength, yield point, yield strength and other tensile properties.





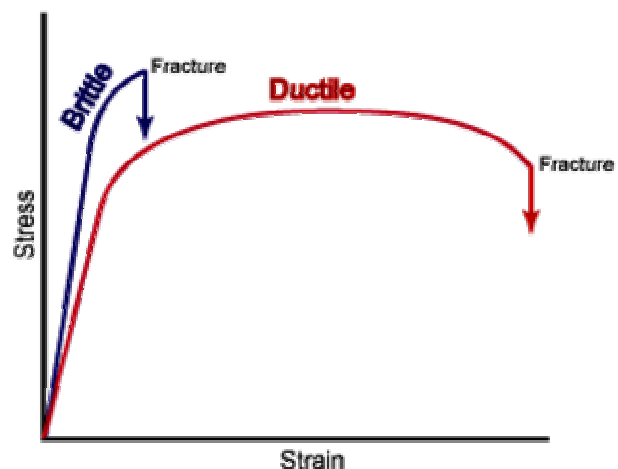
#### 1.4.1- Linear-Elastic Region and Elastic Constants

As can be seen in the figure, the stress and strain initially increase with a linear relationship. This is the linear-elastic portion of the curve and it indicates that no plastic deformation has occurred. In this region of the curve, when the stress is reduced, the material will return to its original shape.

The slope of the line in this region where stress is proportional to strain and is called the modulus of elasticity or Young's modulus. The modulus of elasticity defines the properties of a material as it undergoes stress, deforms, and then returns to its original shape after the stress is removed. It is a measure of the stiffness of a given material. To compute the modulus of elasticity, simply divide the stress by the strain in the material. Since strain is unitless, the modulus will have the same units as the stress, such as kpi or MPa. The modulus of elasticity applies specifically to the situation of a component being stretched with a tensile force. This modulus is of interest when it is necessary to compute how much a rod or wire stretches under a tensile load.

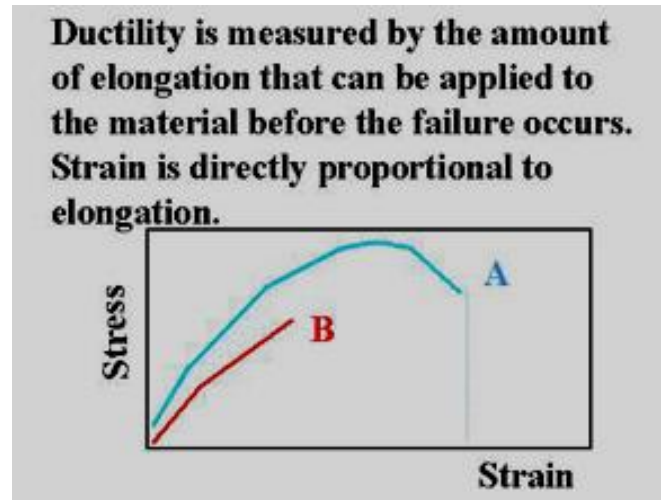
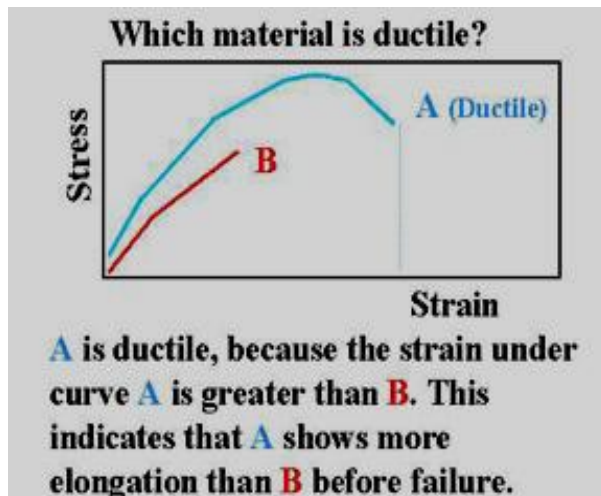
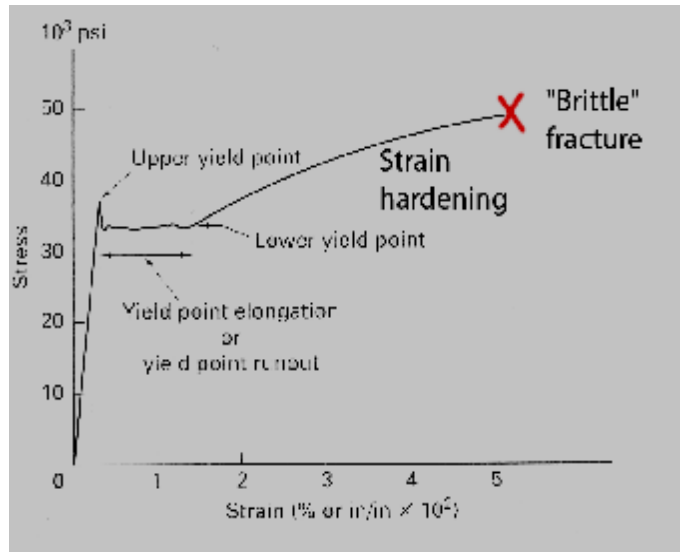
#### 1.4.2- Yield Point

In ductile materials, at some point, the stress-strain curve deviates from the straight-line relationship and Law no longer applies as the strain increases faster than the stress. From this point on in the tensile test, some permanent deformation occurs in the





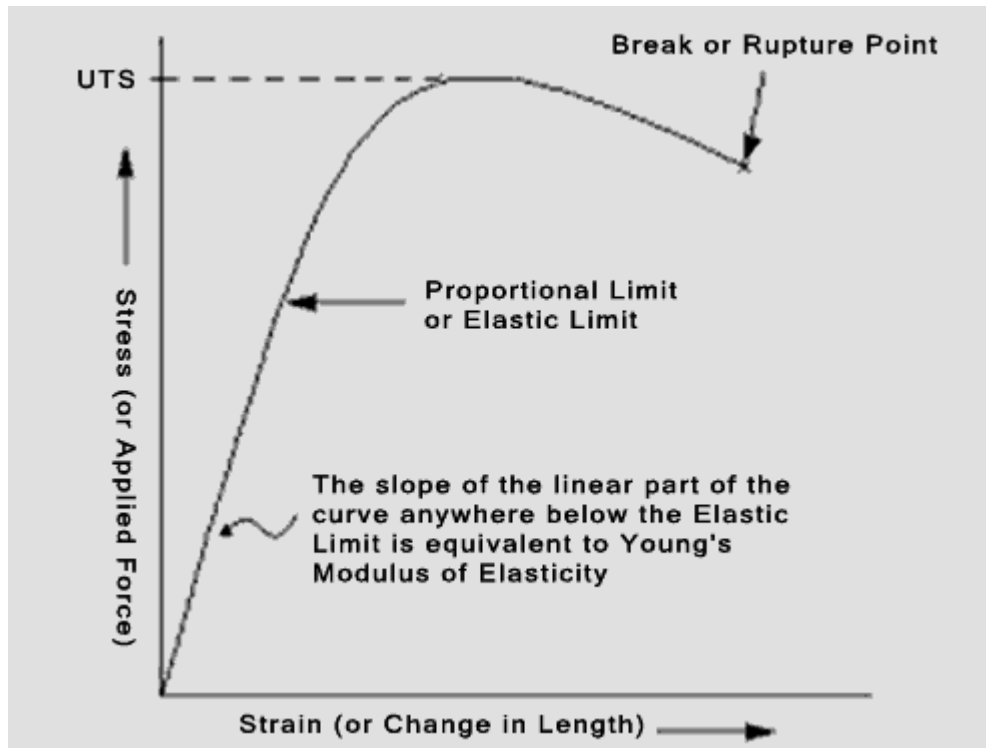
specimen and the material is said to react plastically to any further increase in load or stress. The material will not return to its original, unstressed condition when the load is removed. In brittle materials, little or no plastic deformation occurs and the material fractures near the end of the linear-elastic portion of the curve. The stress required to produce a small-specified amount of plastic deformation is called **Yield strength**.



#### 1.4.3- Ultimate Tensile Strength

The ultimate tensile strength (UTS) or, the tensile strength, is the maximum stress level reached in a tension test. The strength of a material is its ability to withstand external forces without breaking. In brittle materials, the UTS will be at the end of the linear-elastic portion of the stress-strain curve or close to the elastic limit. In ductile materials, the UTS will be well outside of the elastic portion into the plastic portion of the stress-strain curve.





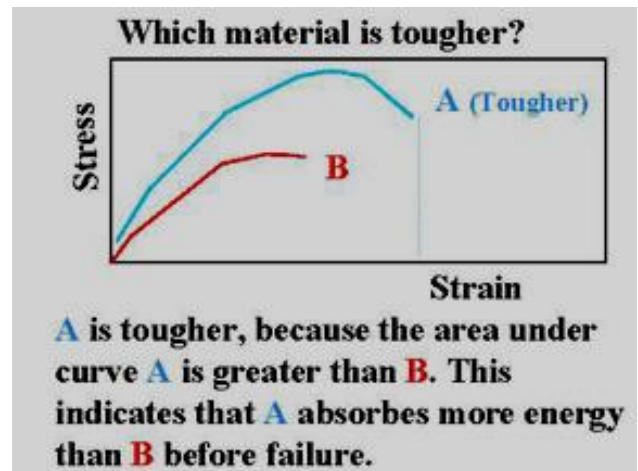
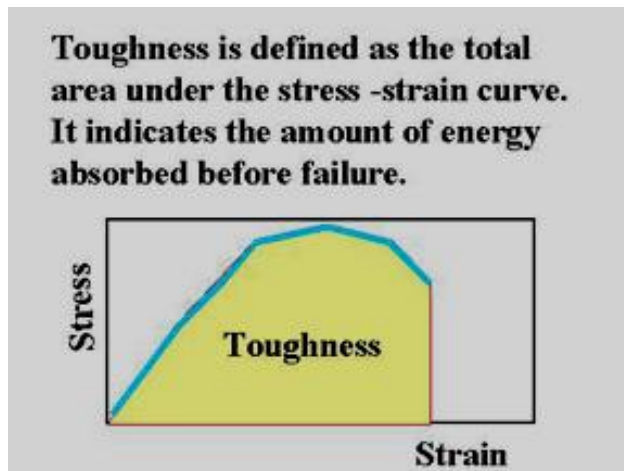
#### 1.4.4- Hardness

Hardness is the resistance of a material to localized deformation. The term can apply to deformation from indentation, scratching, cutting or bending. In metals, ceramics and most polymers, the deformation considered is plastic deformation of the surface. Hardness measurements are widely used for the quality control of materials because they are quick and considered to be nondestructive tests when the marks or indentations produced by the test are in low stress areas

#### 1.4.5- Toughness

The ability of a metal to deform plastically and to absorb energy in the process before fracture is termed toughness. The emphasis of this definition should be placed on the ability to absorb energy before fracture. Recall that **ductility** is a measure of how much something deforms plastically before fracture, but just because a material is ductile does not make it tough. The key to toughness is a good combination of strength and ductility. A material with high strength and high ductility will have more toughness than a material with low strength and high ductility. Therefore, one way to measure toughness is by calculating the area under the stress strain curve from a tensile test. This value is simply called “material toughness” and it has units of energy per volume.

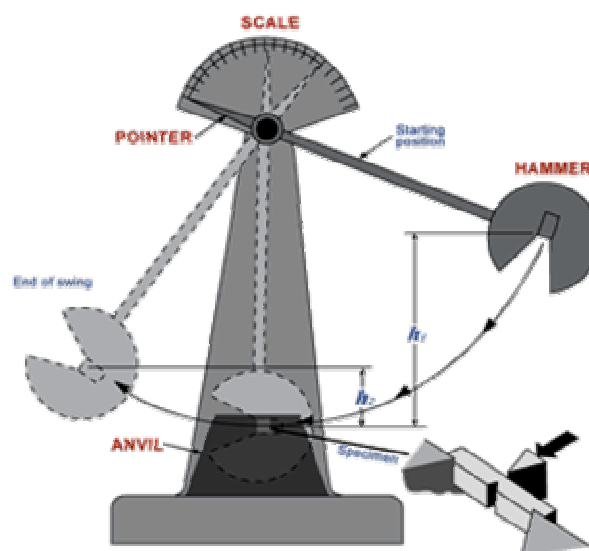




There are several standard types of toughness test that generate data for specific loading conditions and/or component design approaches. Three of the toughness properties that will be discussed in more detail are 1) impact toughness, 2) notch toughness and 3) fracture toughness

#### 1.4.5.1 Impact Toughness

The impact toughness of a material can be determined with a Charpy or Izod test. Impact properties are not directly used in fracture mechanics calculations, but the economical impact tests continue to be used as a quality control method to assess notch sensitivity and for comparing the relative toughness of engineering materials.



The test makes use of a pendulum-testing machine. The specimen is broken by a single overload event due to the impact of the pendulum. A stop pointer is used to record how far the pendulum swings back up after fracturing the specimen. The impact toughness of a metal is determined by measuring the energy absorbed in the fracture of the specimen. This is simply obtained by noting the height at which the pendulum is released and the height to which the pendulum swings after it has struck the specimen. The height of the pendulum times the weight of the pendulum produces the potential energy and the difference in potential energy of the pendulum at the start and the end of the test is equal to the absorbed energy. At low temperatures the material is more brittle and impact toughness is low. At high temperatures the material is more ductile and impact toughness is higher.

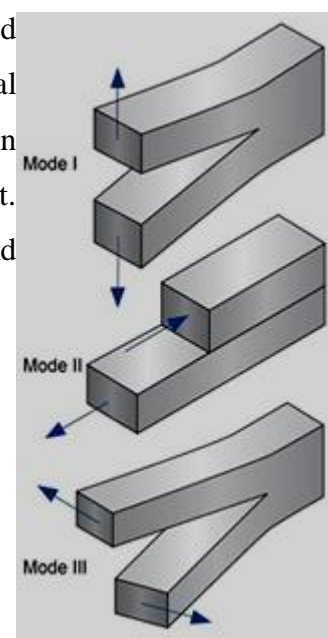
#### 1.4.5.2 Notch-Toughness

Notch toughness is the ability that a material possesses to absorb energy in the presence of a flaw. In the presence of a flaw, such as a notch or crack, a material will likely exhibit a lower level of toughness. When a flaw is present in a material, loading induces a triaxial tension stress state adjacent to the flaw. The material develops plastic strains as the yield stress is exceeded in the region near the crack tip. However, the amount of plastic deformation is restricted by the surrounding material, which remains elastic. When a material is prevented from deforming plastically, it fails in a brittle manner.

#### 1.4.5.3 Fracture Toughness

Fracture toughness is an indication of the amount of stress required to propagate a preexisting flaw. It is a very important material property since the occurrence of flaws is not completely avoidable in the processing, fabrication, or service of a material/component. Flaws may appear as cracks, voids, metallurgical inclusions, weld defects, design discontinuities, or some combination thereof.

The three modes of fracture are illustrated in the image to the right.

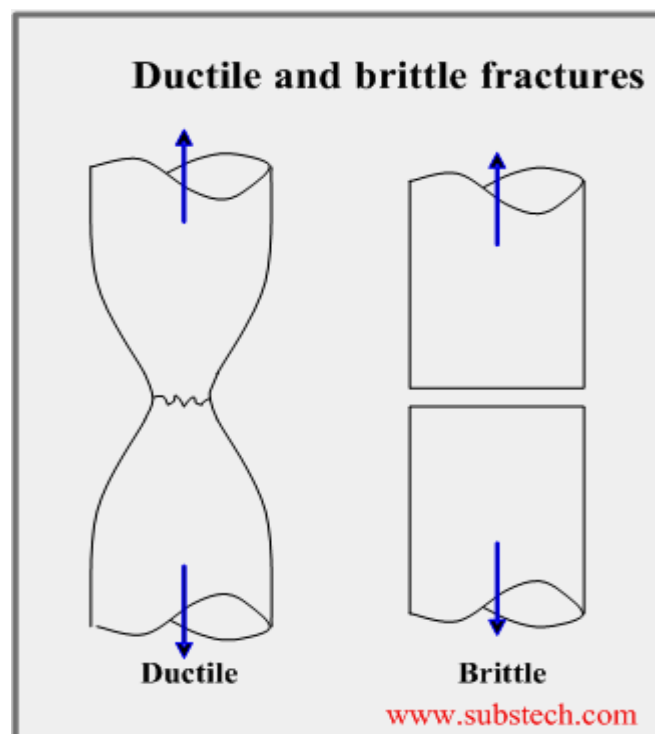


### 1.4.6 Brittle Fracture

A **fracture** is the local separation of an object or material into two, or more, pieces under the action of stress.

**Brittle fracture** is characterized by rapid crack propagation with low energy release and without significant plastic deformation. The fracture may have a bright granular appearance. The fractures are generally of the flat type and chevron patterns may be present. Brittle fracture occurs when an otherwise elastic material fractures without any apparent sign or little evidence of material deformation prior to failure.

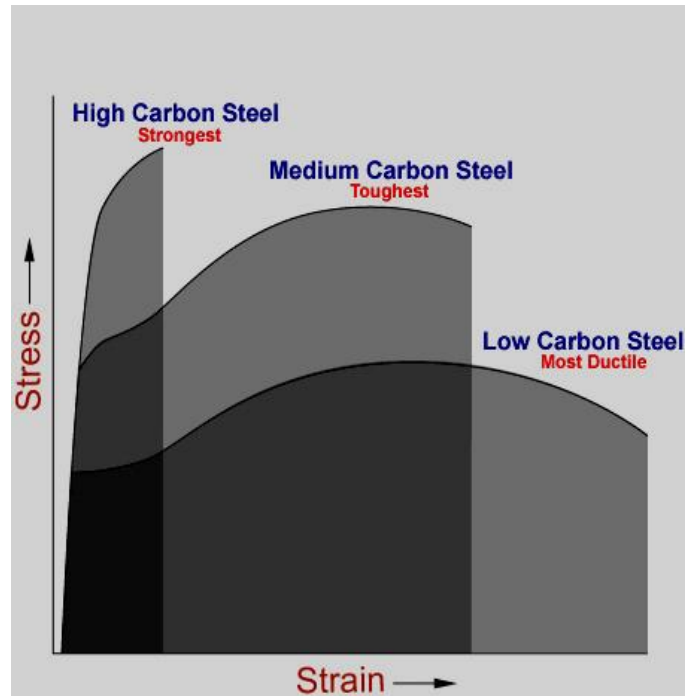
**Ductile fracture** is characterized by tearing of metal and significant plastic deformation. The ductile fracture may have a gray, fibrous appearance. Ductile fractures are associated with overload of the structure or large discontinuities.



#### **Factors affecting brittle fracture:**

- n A sharp notch is present in the structure from which the fracture initiates.
- n A tensile stress is present.
- n There is a temperature above which brittle fracture will not occur.
- n The metallurgical properties of the steel plate.
- n Thick plate is more prone.





## Part- B Ship Building Materials

The materials used for the construction of ship's structure, hull and machinery are steels, cast iron, non-ferrous metals, non-ferrous alloys, polymers etc. These materials have different properties such as tensile strength, ductility, toughness, hardness, resistance to corrosion etc. and are used appropriately for the construction of the ships and machinery. The most widely used material is steel, which is essentially an alloy of iron and carbon, containing up to 2% carbon. By varying the carbon content and heat treatment of the resulting steel a wide range of mechanical properties can be obtained.

Most cast irons contain 2% to 3.5% carbon and are widely used for the construction of machinery due to their good casting properties and strength. The range of mechanical properties can be further widened by adding alloying elements such as nickel, chromium and molybdenum. Non ferrous metals such as aluminium, copper and their alloys are also widely used as a result of their ability to resist corrosion, good mechanical strength, easy casting and machinability. There is an increasing use of polymers in the marine industry in recent years.



## 1.1 Common Metallic Materials

- Iron/Steel - Steel alloys are used for strength critical applications
- Aluminum - Aluminum and its alloys are used because they are easy to form, readily available, inexpensive, and recyclable.
- Copper - Copper and copper alloys have a number of properties that make them useful, including high electrical and thermal conductivity, high ductility, and good corrosion resistance.
- Titanium - Titanium alloys are used for strength in higher temperature (~1000° F) application, when component weight is a concern, or when good corrosion resistance is required
- Nickel - Nickel alloys are used for still higher temperatures (~1500-2000° F) applications or when good corrosion resistance is required.
- Refractory materials are used for the highest temperature (> 2000° F) applications.

## 1.2- STEEL

**Steel** is an alloy consisting mostly of iron, with carbon content between 0.2% and 2.14% by weight, depending on grade. Carbon is the most cost-effective alloying material for iron, but various other alloying elements are used such as manganese, chromium, vanadium, and tungsten. Carbon and other elements act as a hardening agent, preventing dislocations in the iron atom crystal lattice from sliding past one another. Varying the amount of alloying elements and form of their presence in the steel controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel with increased carbon content can be made harder and stronger than iron, but is also more brittle.

The production of all steels used for shipbuilding involves the smelting of iron ore and the making of pig iron. Pig-iron is 92 to 97 per cent iron, the remainder being carbon, silicon, manganese, sulphur and phosphorus. Wrought iron is a form of iron made by rolling or forging, while cast iron is the name given to molten steel made in an open hearth process, which is poured into a mould of a required shape and then allowed to solidify.

### 1.2.1 Steel production

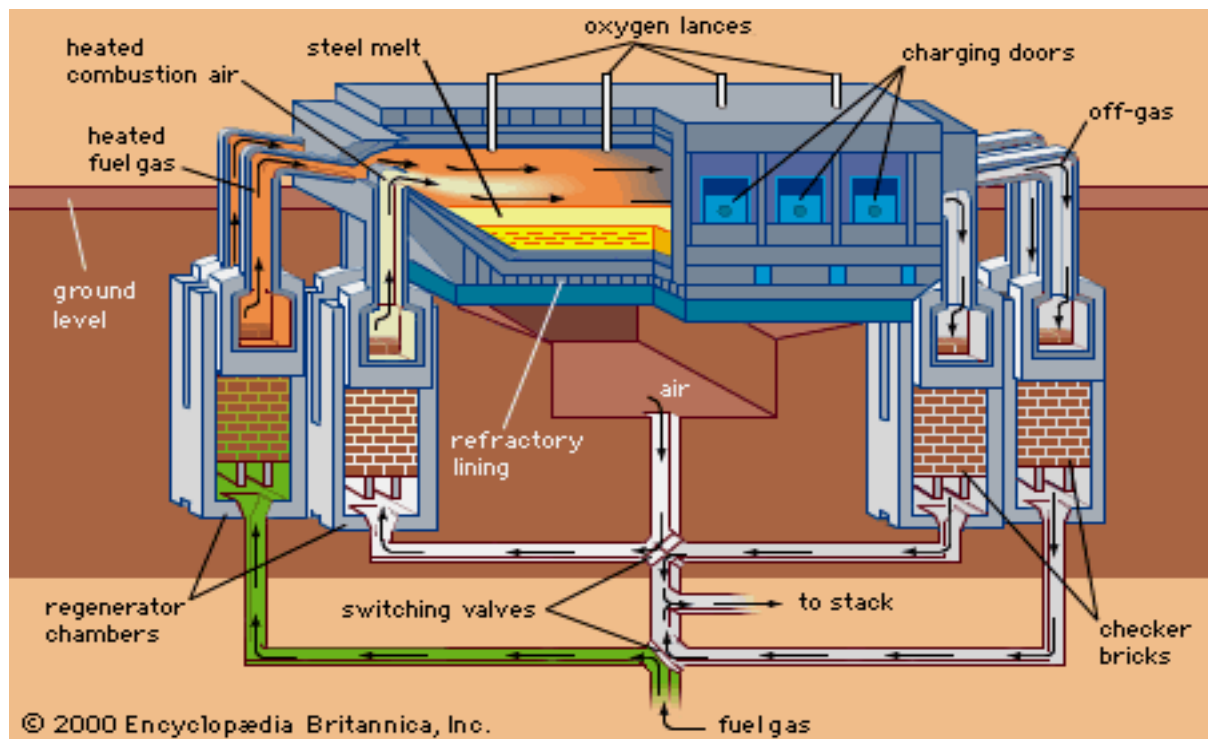
Steel is manufactured by the purification of pig iron. It is to be made by the open hearth, electric furnace. Oxygen process or other approved processes. The manufacturing process is to be such as to minimize the non-metallic content of the steel.





### 1.2.1.1 Open Hearth Process

In the furnace, which has a wide, saucer-shaped hearth and a low roof, molten pig iron and scrap are packed into the shallow hearth and heated by overhead gas burners using preheated air. This method is capable of producing large quantities of steel, handling 150 to 300 tonnes in a single melt. A mixture of pig-iron and steel scrap is melted in the furnace, carbon and the impurities being oxidized. The carbon, manganese, and other elements are added to eliminate iron oxides and give the required chemical composition.

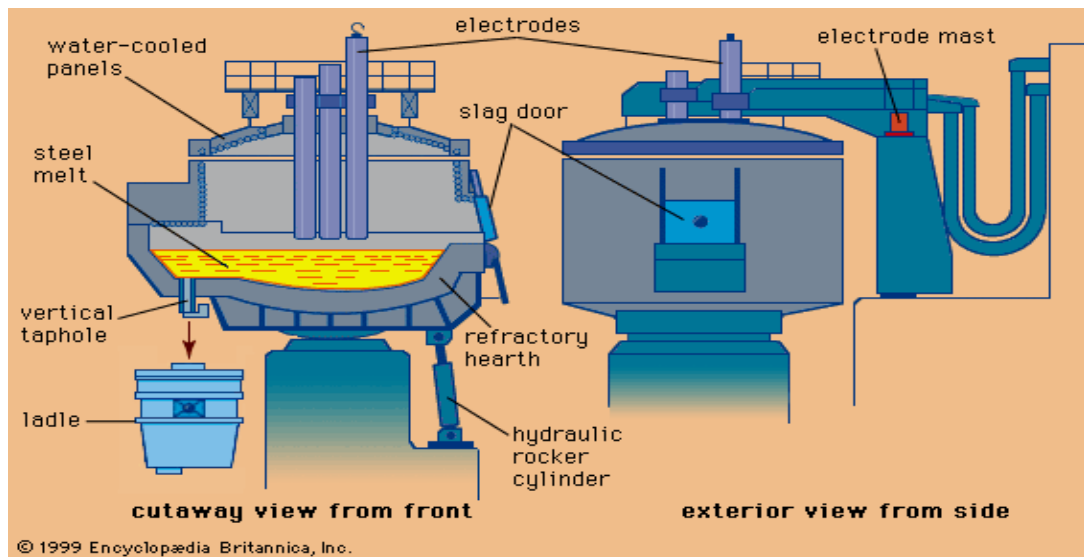


### 1.2.1.2 Electric Arc Furnace

In this method, melting is produced by striking an arc between electrodes suspended from the roof of the furnace and the charge itself in the hearth of the furnace. A charge consists of pig-iron and steel scrap and the process enable consistent results to be obtained and the final composition of the steel can be accurately controlled. Electric Arc used to heat and remove impurities. This method used for making stainless steel, carbon tool steel, and high alloy steels and for recycling scrap. Time for each heat determined by the amount of scrap included in the charge.

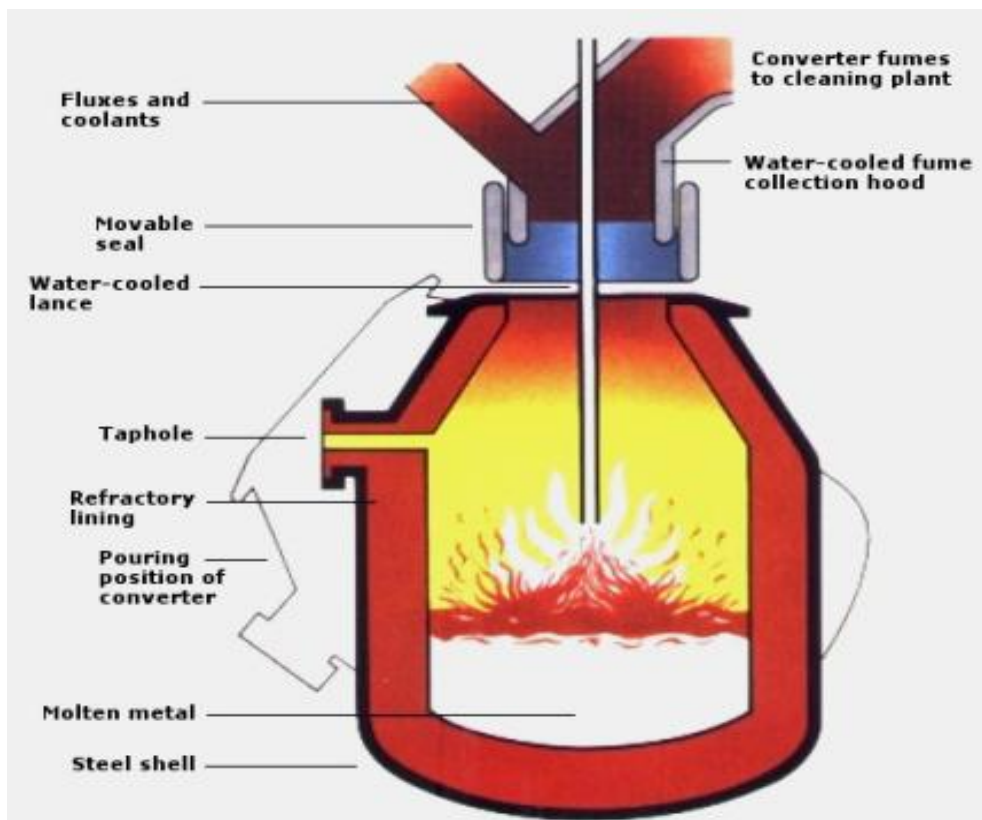






### 1.2.1.3- Basic Oxygen Process

A molten charge of pig-iron and steel scrap with alloying elements is contained in a basic lined converter. A jet of high purity gaseous oxygen is then directed onto the surface of the liquid metal in order to refine it. The oxygen initiates a series of intensively exothermic (heat-releasing) reactions, including the oxidation of such impurities as carbon, silicon, phosphorus, and manganese. No heating required Up to 200 tons per heat Automatic process controlled by a computer Results in clean product with very tight specifications.



### 1.2.2 Classes of steel based on their use

Carbon steels can be classed into four main groups in terms of their specific uses.

Dead-mild steels: Steels containing up to 0.15% carbon which are generally used for presswork and other applications where high ductility is necessary in forming, e.g. motor car bodies, tin cans, nails and wires.

Mild steels: Steels containing 0.15% to 0.3% carbon. Higher tensile strength and hardness when compared with dead- mild steels. Used for structural members, shafting, levers and various forging. Steels used for castings usually contain 0.3% to 0.35% carbon.

Medium carbon steels: Steels containing 0.4% to 0.6% carbon. Widely used for components such as axles, connecting rods, gears, wire ropes, rails, etc. which require higher tensile strength, toughness and hardness. Can be hardened by heat treatment process.

High carbon steels: Steels containing 0.6% to 1.5% carbon. Used to make cutting tools

### 1.2.3 Shipbuilding Steels and steel grads

Steel for hull construction purposes is usually mild steel containing 0.15 per cent to 0.23 per cent carbon, and a reasonably high manganese content. Both sulphur and phosphorus in mild steel are kept to a minimum. The effects of the elements are, basically

- i) Carbon increases hardness and tensile strength but reduces ductility
- ii) Manganese increases tensile strength, ductility and notch-toughness
- iii) Silicon in small quantities increases hardness and tensile strength without making welding difficult
- iv) Sulphur, an impurity which tends to produce hot shortness when steel is stressed during welding
- v) Phosphorus an impurity which reduces ductility and toughness and may create faults when welding

There are now five different qualities of steel employed in merchant ship construction. These are graded A, B, C, D and E.

Grade- A being ordinary mild steel, Grade- B is a better quality mild steel than Grade- A and is specified where thicker quality plates are required in the more critical regions. Grades- C, D and



E possess increasing notch-tough characteristics.

All steel are subjected to tests, these being tensile, (41-50 kg/mm<sup>2</sup>, elongation 22%), bend and impact tests. The impact test is only carried out on the higher grades of steel and the temperature at which the test is to be carried out is given i.e. Grade E steel, Steel is subjected to heat treatment depending on the grade, i.e, normalizing or annealing. The purpose is to produce steel having a fine grained structure; it improves its tensile strength, ductility and resistance to shock.

#### **1.2.4- Classification society and shipbuilding steel**

Most of the classification societies require that certain essential items of materials, machinery, equipment and components are procured by the shipyards from only those manufacturers whose works have been approved by the classification societies. Such items include steel plates and sections, important forgings and castings, anchors, chain cables, electrical cables etc. Such works approval is normally accorded to those manufacturers who can demonstrate to the society their capability to meet the Rule requirements of the Society and have certain minimum facilities and procedures for in house quality control so as to consistently produce items meeting the Rule requirement.

Steels for a ship classed with any of the classification societies are produced by approved manufacturers, inspection and prescribed tests are carried out at the steel mill before despatch. All test pieces are stamped by a surveyor or his authorised deputy. Every finished item is also marked with the society's brand where it complies with the societies requirements. The class Rules state the particular grade of steel to be used; where greater strength is required a higher grade is used. Vessels over 200m in length are to have grade E steel used for the sheer strake, bilge strake and keel for a distance of 0.4L amidships.

In large oil tankers, ore carriers, etc., high tensile steels are used. These are special steels which in addition to having an increased strength over mild steel retain this strength at low temperatures. The use of high tensile steel in large vessels permits of a reduction in plate thickness and hence a saving in weight, The high tensile steel used in ship construction is capable of being fabricated and welded under shipyard conditions.



**1.2.5 High tensile steels**

**High tensile** (HT) steel is one with a greater ultimate tensile strength (UTS) than mild steel. High tensile steels have been in use for many years in large passenger ship structures and are now being used to an increasing extent in all types of cargo ships, but most especially in the larger tankers, bulk carriers of various types, container ships and the 'open' or 'multiple hatch' type cargo liners. The high tensile steels in common use have an ultimate tensile strength of about 55-56 kg mm<sup>2</sup> which is about 20% higher than the value for mild steel. The corresponding yield strength is about 35 kg mm<sup>2</sup>. (Steels with lesser or greater strength values than these can be encountered). The Modulus of Elasticity is practically the same as that of mild steel.

The increased strength of high tensile steels can be obtained in several different ways. The amounts of carbon and manganese may be increased, or various alloying elements may be introduced; the alloys which may be used include silicon, copper, chromium, nickel, molybdenum, aluminium, niobium and vanadium. (Heat treatment by quenching and tempering is also a possible method of raising the strength). Lloyds Rules specify the chemical composition, method of manufacture, heat-treatment and tests required for various grades. Each grade is identified by suffix H and grades AH, DH, and EH are those commonly encountered.

**Advantages:**

- 1-Saving structural weight.
- 2- Saving of weld metal.
- 3- Ease of handling.
- 4-The possibility of building up bigger fabricated units.

**Disadvantages:**

- 1-The smaller allowable amount of wastage by corrosion
- 2-The possibility of increased vibration, because of reduction of mass
- 3-The greater care required when burning and welding
- 4-The increased bending (or deflection) - either hogging or sagging - which arises from the reduced moment of inertia

Higher tensile steels used for hull construction purposes are manufactured and tested in accordance with Lloyd's Register requirements. Full specifications of the methods of manufacture, chemical composition, heat treatment, and mechanical properties required for the higher tensile steels are given in Chapter 3 of Lloyd's Rules for the Manufacture, Testing and Certification of Materials.



### 1.2.6- Steel casting and Forging

Most steel components start as **castings**: metal that has been melted, poured into a mold and solidified. In the casting process at the foundry, because the mold has the shape of the desired component, all that remains to be done after casting are the various finishing operations. In the casting process the metal starts as a liquid and flows into the desired shape. Therefore, it is practical to cast components of large sizes and section thicknesses. For extremely large components, cast/weld construction is generally preferable to forged/weld construction. The reason is that fewer parts are typically involved, and because steel castings tend to have better weld ability than steel forgings.

With **forgings**, the first shape is an ingot or continuously cast billet. Ingots are large, usually rectangular in form and weigh up to several tons. Ingots or continuously cast billets are forged into shapes by hammers or presses. Extensive machining to final configuration usually is required, and welding also may be necessary before finishing operations can begin. In forging, metal is moved while it is still in the solid state. Because the forging billet is solid, substantial force is required to change its shape to the desired configuration. Because of this, the required force increases as section size increases. In practical terms, there is a limit on size and section thicknesses produced by forging.

### 1.2.7 Types of Steel according to de-oxidation practice

During steel-manufacturing processes, combination of carbon and oxygen takes place to form a gas. If the oxygen is not removed before or during casting (by adding silicon or other deoxidizer) the gaseous products continue to evolve during solidification. The type of steel produced is determined by the control of the amount of gas evolved during solidification. If no gas is evolved, the steel is called "**killed**" because it lies quietly in moulds. Increasing degree of gas evolution results in **semi-killed**, **capped** or **rimmed steels**. Some carbon steels and high strength low-alloy steels can be supplied in all four types. Alloy steels and stainless and heat resisting steels are normally manufactured as killed steel.

#### a) Killed steel:

- It is produced by involving the use of several deoxidizing elements which act with varying intensities.
- The common of these are silicon and aluminum.
- Killed steel, because of greater uniformity in chemical composition and soundness is



used for forging, carburizing, heat treatment and other applications.

- They are strongly deoxidised and are characterized by high composition and property uniformity.
- All forging steels and in general, all steels containing more than 0.25% carbon are killed.
- These types of steels are free from blow holes and segregation.

**b) Rimmed Steel:**

In rimmed steel, the aim is to produce a clean surface low in carbon content. Rimmed steel is also known as drawing quality steel.

- The typical structure results for a marked gas evolution during solidification of outer rim.
- They exhibit greatest difference in chemical composition across sections and from top to bottom of the ingot.
- They have an outer rim that is lower in carbon, phosphorus, and sulphur than the average composition of the whole ingot and an inner portion or core that is higher the average in those elements.
- In rimming, the steel is partially deoxidized. Carbon content is less than 0.25% and manganese content is less than 0.6%.
- They do not retain any significant percentage of highly oxidizable elements such as Aluminum, silicon or titanium.
- A wide variety of steels for deep drawing is made by the rimming process, especially where ease of forming and surface finish are major considerations.
- These steel are, therefore ideal for rolling, large number of applications, and is adapted to cold-bending, cold-forming and cold header applications.

**1.2.8 Heat Treatments**

These are operation, or series of operations, involving the heating and cooling of steel in the solid state that brings about a change in the mechanical properties principally by modifying the steel's structure. This is related to the crystalline structure of carbon and iron. When steel is heated or cooled, then at certain temperatures, the temperature remains constant although heat is applied or lost. Such points are called 'arrest points' or 'critical points'. At these points the structure of the material changes. Heat treatments which concern shipbuilding materials are:



1. Annealing
2. Normalizing
3. Hardening or Quenching
4. Tempering
5. Stress Relieving

**Annealing:** This consists of heating the steel at a slow rate to a temperature of say 850°C to 950°C, and then cooling it in the furnace at very slow rate. The objects of annealing are to relieve any internal stresses, to soften the steel, or to bring the steel to a condition suitable for a subsequent heat treatment.

**Normalizing:** The steel is heated to a determined temperature above the critical range (850°C to 950°C) Cooled to below that range in still air. The results are;

- Promotes uniformity of the structure and alters mechanical properties.
- Molecular structure changes.
- Results in higher strength, hardness, and less ductility.
- Cools faster than stress relieving or annealing

**Hardening or Quenching:** Steel is heated to temperatures similar to that for annealing and normalizing, and then quenched in water or oil. The fast cooling rate produces a very hard structure with a higher tensile strength.

**Tempering:** Quenched steels may be further heated to a temperature somewhat between atmospheric and 680 °C, and some alloy steels are then cooled fairly rapidly by quenching in oil or water. The object of this treatment is to relieve the severe internal stresses produced by the original hardening process and to make the material less brittle but retain the higher tensile stress.

**Stress Relieving:** Reduces internal stresses that may have been caused by machining, cold working or welding. Heat the metal to a temperature below the critical range (600°C), hold until temperature is reached throughout the piece and allow it to cool slowly.



### 1.3 Aluminium alloys

The pure aluminium obtained from bauxite ore is very soft and has little strength. It must be alloyed with small percentages of other metals to obtain a reasonable strength. Alloying metals used include magnesium, silicon, copper, nickel and manganese. Some aluminium alloys have a tensile strength as high as mild steel; to achieve this requires very expensive heat treatment. The aluminium alloys used in shipbuilding industry have a lower tensile strength, about  $27 \text{ kg mm}^2$  which is obtained without heat treatment and the alloy is referred to as non-heat-treatable alloy. This type of alloy may be welded and a limited amount of controlled heating may be used during forming. The tensile strength depends greatly upon the proportion of magnesium - this is often 5% or 6% - and aluminium forms about 93½% of the total.

Advantages of using aluminium alloys arise from:

1. Weight saving. The density is little more than one third of the density of steel ( $2.73 \text{ gm cm}^3$  compared with  $7.85 \text{ gm cm}^3$ ).

For practical reasons a larger volume of aluminium is required to replace a given volume of steel in any part of the ship structure and the weight saved will be roughly half. An aluminium superstructure on a large passenger ship may save about 1000 tonnes.

2. Corrosion resistance
3. The non-magnetic property
4. High thermal conductivity
5. The fact that it is very notch tough at low temperatures

Disadvantages arise from:

1. The much higher capital cost
2. The lower melting point
3. The galvanic corrosion which arises if aluminium is in contact with steel (or some other metals)
4. Vibration and 'drumming' of decks due to lack of mass, unless these are adequately sheathed.





Amongst the more common uses for aluminium alloy in ship construction are the following:

Superstructures, (external plating, decks and internal bulkheads) deckhouses, funnels, masts, permanent awnings, stanchions, guard rails, lifeboats, window frames, skylights, accommodation ladders, overside lifts, vent trunks, cable trays, shifting boards, car platform decks, engine-room gratings and platform plates, heating coils, and as sheathing in refrigerated spaces or for the construction of methane tanks in LNG carriers.

The saving of top weight when aluminium alloy is used for the superstructure of a passenger ship can be utilised in one of several ways. Most often it is used to improve the stability (by giving the ship a lower centre of gravity) or the ship acquires the required stability with less breadth; or the ship can be given an extra deck without making the stability any worse than the stability of the 'all steel' ship. Any saving of structural weight reduces the light displacement and may be used to increase the load deadweight. A narrower ship permits the required speed to be attained with a smaller, lighter engine and reduced fuel consumption. The gross and net tonnages will be smaller.

Passenger ships must be able to withstand a certain amount of flooding after fairly extensive hull damage, and must still possess positive stability after this flooding. This is often only possible with a particular ship design if an aluminium superstructure is incorporated, although cost will be greatly increased.

Cargo ships may have deck houses of aluminium alloy to minimise the maintenance required, and at the same time to allow a greater weight of cargo to be carried.

The non-manganese property is valuable when the wheelhouse, funnel and other items close to the compass are made of aluminium. Many small items such as gangways, ladders, shifting boards, gratings etc are made of aluminium because they are portable.

The resistance to corrosion arises from the inert layer of oxide which forms naturally on the surface. Painting is only required to improve the dull unattractive appearance of the film, and is required at long intervals. Paints containing lead, mercury or copper cannot be used because of the reactions that they set up. Usually zinc chromates or zinc oxide based paints are used, especially as primers.



Young's modulus of elasticity (the constant ratio of stress to strain, up to the limit of proportionality) for aluminium is about 7030 kg mm<sup>-2</sup>. For mild steel it is roughly three times this figure. Consequently if equal values of steel and aluminium are subjected to the same load or stress the aluminium will yield or 'give' three times as much. In practice the volume of aluminium used is greater than the volume of steel it replaces (possibly 50% more) to cut down the stress imposed in the aluminium. The strain imposed in the metal is reduced in the same proportion as the stress is reduced. The result is that the strain imposed in aluminium then compares more closely with the strain in the steel.

The low melting point of aluminium, -600°C compared with about 1600°C for steel requires better fire resisting insulation to be fitted to the aluminium to comply with the Passenger Ship Construction Rules and the Cargo Ship Safety Construction Rules. Serious trouble could arise if, for example, boat davits were supported wholly or partly by an aluminium housing which collapsed because of fire and made it impossible to launch boats. The failure of insufficiently insulated internal bulkheads would allow a quicker spread of fire. When aluminium is connected to steel sections, special connections are required. These are shown in the sketches below



## Sample questions

- 1- Explain steel forging & casting & give two examples.
- 2- List the alloying elements of aluminum alloy also states the advantages and disadvantages of aluminum.
- 3- State the heat treatment of steel, name the types used in shipbuilding's & explain one in detail.
- 4- Explains the followings:
  - a- Steel casting
  - b- Steel forging
  - c- Advantages of aluminum alloy over mild steel.
- 5- State the various methods of manufacturing steel & define one.
- 6- How the normalizing carried out?
- 7- Define the following terms:
  - a- Yield point
  - b- Elastic limit
- 8- State the acid & basic process in steel production.
- 9- What is the effect of alloying techniques used in production of HTS in comparison with mild steel used in ship building?
- 10- Define the followings;
  - a\_ stress and strain.
  - b\_ toughness and brittle fracture.
- 11- Explain 4 methods of heat treatment.
- 12-
  - a) what is the yield.
  - b) Explain the factors that influence brittle fracture.



## CHAPTER- 2 WELDING

### 2.1 Welding and its Advantages

Welding is the fusion of two metals together by the application of heat resulting in a joint which is as strong, or stronger, than the metals being joined. Welded joints may be obtained with any metal although some are more difficult to weld than others. The heat required to produce the weld may be generated in a number of ways, examples are:

- A) Electric Arc Welding.
- B) Gas Heating by Oxygen and Acetylene.
- C) Resistance Welding.
- D) Thermit Welding.

#### Advantages of welding over riveting:

For the shipbuilder the advantages are:

- (a) Welding lends itself to the adoption of prefabrication techniques.
- (b) It is easier to obtain water tightness and oil tightness with welded joints.
- (c) Joints are produced more quickly.
- (d) Less skilled labour is required.

For the ship owner the advantages are:

- (a) Reduced hull steel weight; therefore more deadweight.
- (b) Less maintenance, from slack rivets, etc.
- (c) The smoother hull with the elimination of laps leads to a reduced skin friction resistance which can reduce fuel costs.

### 2.2 Flux and its function

**Flux** is a material that covers the electrode. Its composition varies with different electrodes but it normally consists of:

- A combustible material like wood pulp, this burns to provide carbon monoxide and hydrogen gases. This cloud of gas called the 'gas shield' keeps out the air during welding.
- An 'arc stabiliser' which helps maintains a steady electric arc and to produce a hard brittle slag, which can be easily chipped of, Rutile is the most common and is a natural ore of titanium oxide.



- ‘Fluxing materials usually silicates, such as asbestos. These combine with oxides and other impurities in the molten steel and float them out into a slag.
- ‘Alloying elements, like manganese and carbon which help replenish important constituents that may be burned out during welding.

2.2.1 The main purpose of fluxes: is to prevent nitrogen and oxygen from attacking the hot weld-metal and to combine with and float out any impurities in the molten metal.

- Oxygen if present combines with the hot steel to form iron oxides which may remain in and weaken the joint. It could also combine with the carbon in the steel to form carbon monoxide gas. If Gas bubbles are trapped in the steel when it cools will cause cavities. ‘blow holes’
- Nitrogen if absorbed by the weld metal will cause it to become brittle, hard and liable to cracking.

2.2.2 Slag shielded processes:

Metal arc welding started as bare wire welding, the wire being attached to normal power lines. This gave unsatisfactory welds, and subsequently it was discovered that by dipping the wire in lime a more stable arc was obtained. As a result of further developments many forms of slag are now available for coating the wire or for deposition on the joint prior to welding.

2.2.3 Manual Welding Electrodes:

- A) **Rutile electrodes** have coatings containing a high percentage of titania, and are general purpose electrodes which are easily controlled and give a good weld finish with sound properties.
- B) **Basic or low hydrogen electrodes**, the coating of which has a high lime content, are manufactured with the moisture content of the coating reduced to a minimum to ensure low hydrogen properties. The mechanical properties of weld metal deposited with this type of electrode are superior to those of other types, and used in the higher tensile strength steels.

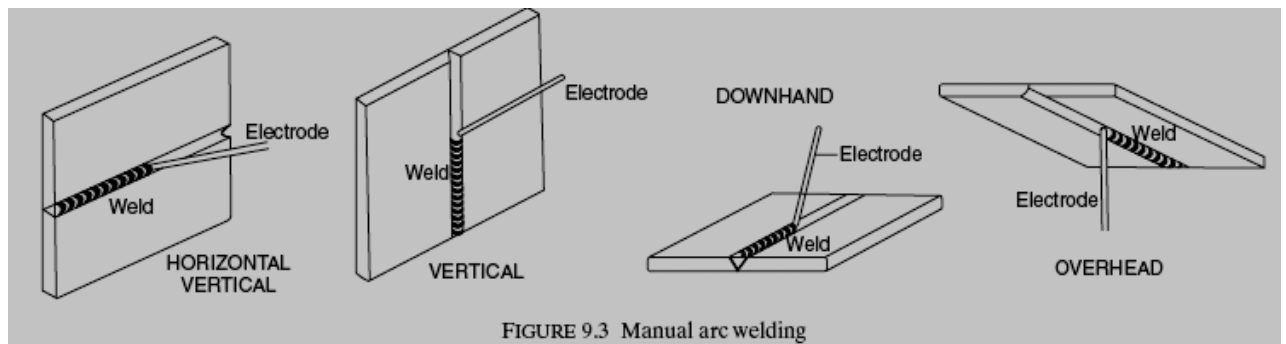


## 2.3 Welding positions

**Down hand** welding is easier to carry out and the various parts are placed in the most convenient position when fabricating. For instance, the bottom of a ship will probably be welded in the upside down position, the section then being turned over for removal to the berth for assembly.

**Vertical welding** may be performed either upwards or downwards. Upwards welding is most common; as the weld metal is deposited it is used as a step on which to continue the deposit.

**Overhead welding** is a difficult operation to perform. Lightly coated rods, correct current control and a short arc are essential for a satisfactory weld.



### 2.3.1 Types of joint design:

**Butt weld:** Plates are 'veed off' to start. The angle between the plates is about 60 degrees. The plates are so spaced to maintain a small gap at the bottom of the 'V'. A series of welding runs is made on the Veed side. When the gap is completely filled in a final back run is made on the opposite side of the joint. Thick plates can be double veed.

**Fillet welds:** They are used for 'T' and lapped joints. The leg length is governed by the abutting part of the joint. Throat thickness is 70% of leg length. Fillet welds can be continuous or intermittent.

**Full penetration fillet welds:** are used when special strength is required at 'T' joints. Here the vertical leg of the joint is veed. This helps the weld metal penetrate right through.

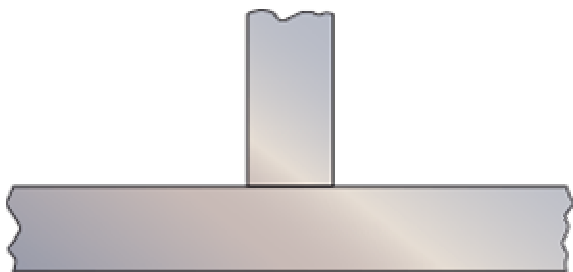
**Double continuous fillet welds:** are used for oil and watertight joints.

**Intermittent fillets:** are used for non watertight joints.

**Tack welds:** are used to hold parts temporarily in place.



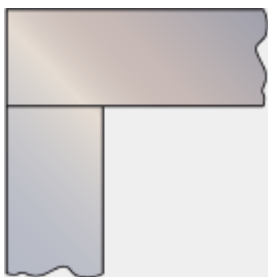
## JOINTS



**T-joint**



**In-line or butt joint**



**Corner joint**



**Lap joint**

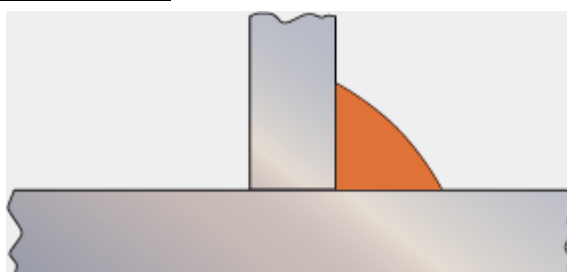


**Edge joint**

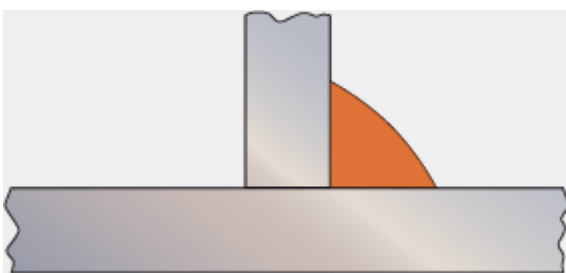
## WELD TYPES



**Butt weld**



**Fillet weld**



**T-joint fillet weld**

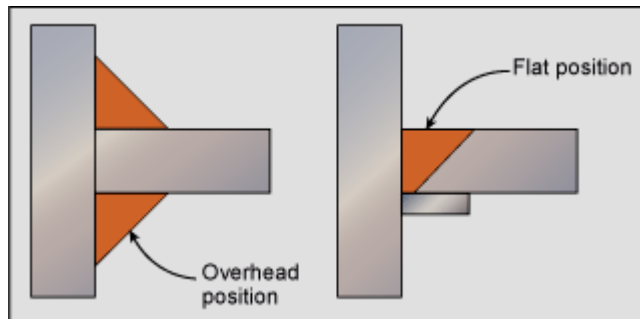


**Corner joint fillet weld**

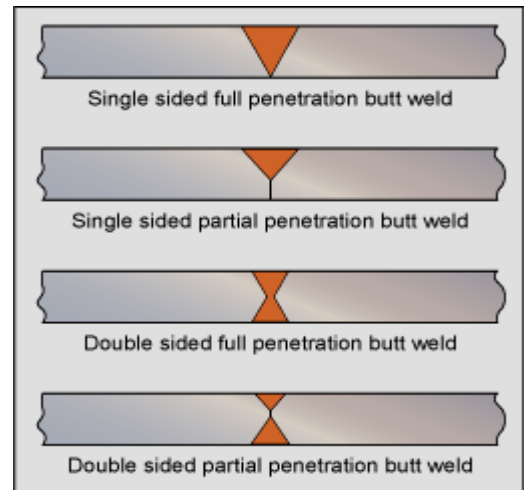


**Lap joint fillet weld**

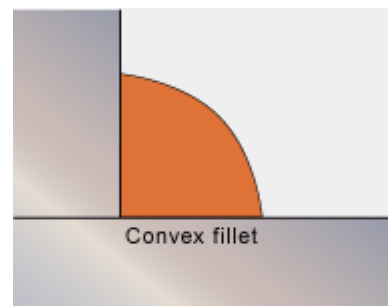
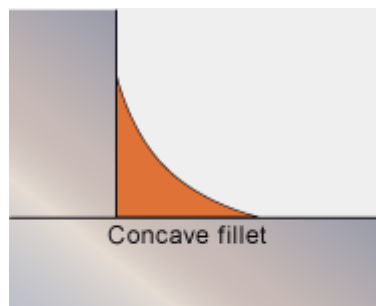
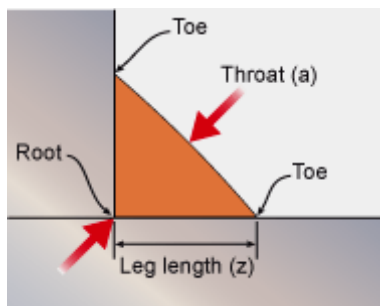




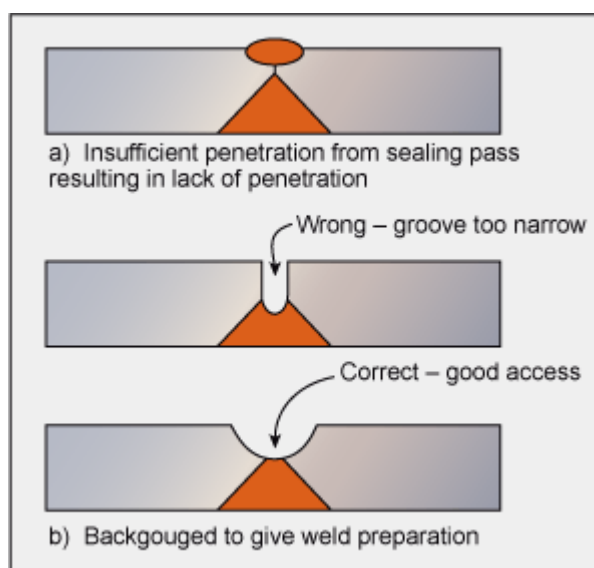
Flat position T-butt weld vs overhead fillet weld



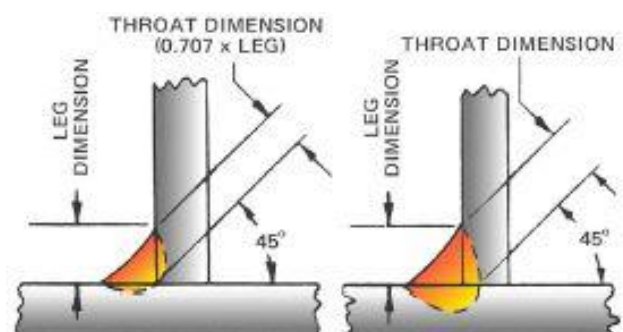
Full and partial penetration welds



Terms used to describe features of a fillet weld



Back gouging to achieve full penetration



Comparison of Manual Arc and Submerged Arc welding Fillet Welds





### 2.3.2 Welding preparation:

- Surfaces to be clean
- Prepare the work properly
- Parts must fit properly, (if they don't butt joints could be made to reduce gaps, T joints may have a liner fitted etc.)
- The order of welding must be planned

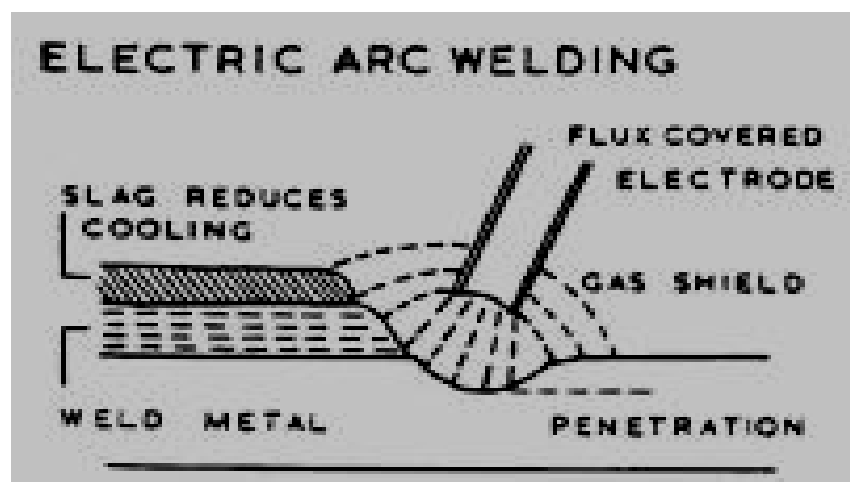
### 2.3.3 The Welding Process:

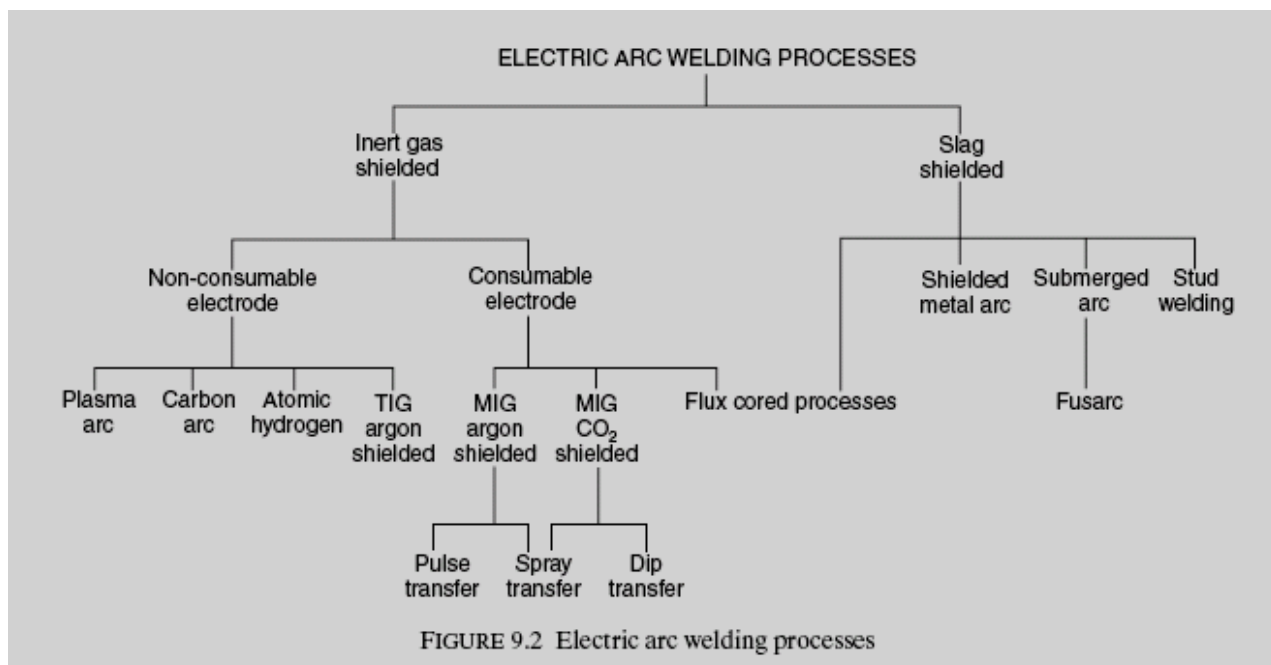
To ensure sufficient deposit of weld metal, more than one welding pass may be required. This is called multi-pass welding. A back run is normally required to complete a weld. Back runs are made on the reverse side of the joint. To do a back run, the joint must be cleaned out. Cleaning out is described as the process of removing the slag.

## **2.4 Types of Welding**

### 2.4.1 Electric Arc Welding

An electric arc is formed when an electric current passes between two electrodes separated by a short distance from each other. In electric arc welding one electrode is the welding rod while the other is the metal (plate etc.) to be welded. The electrode and plate are connected to the supply, an arc is started by momentarily touching the electrode on to the plate and then withdrawing it about 3 to 6 mm from the plate. A spark forms across the gap; the air surrounding the spark becomes ionized and current flows across the gap. The temperature created is approximately 4000°C, the current flow between 20 to 600 amperes depending on the thickness, type of metal being welded and voltage, AC or DC.



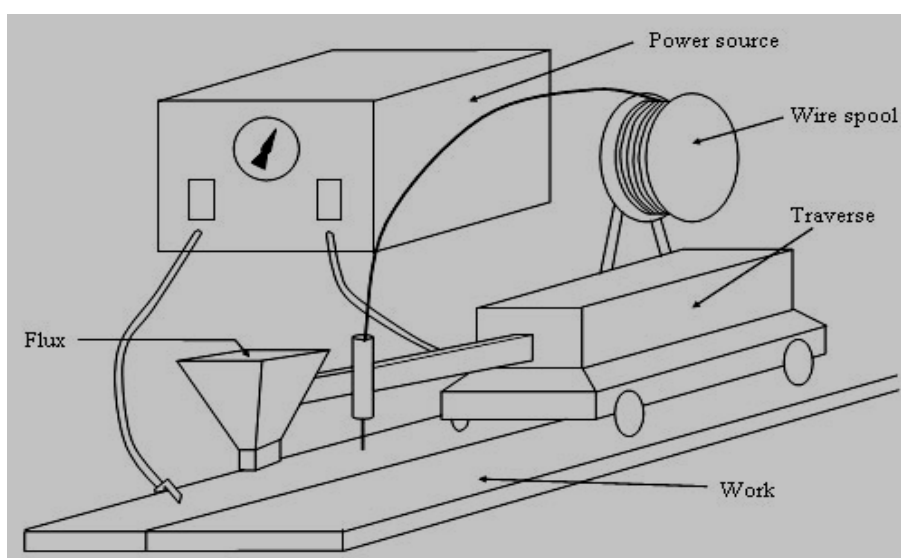


#### 2.4.2 Automatic electric arc welding

The range of manual, semi-automatic, and automatic electric arc welding processes which might be employed in shipbuilding are:

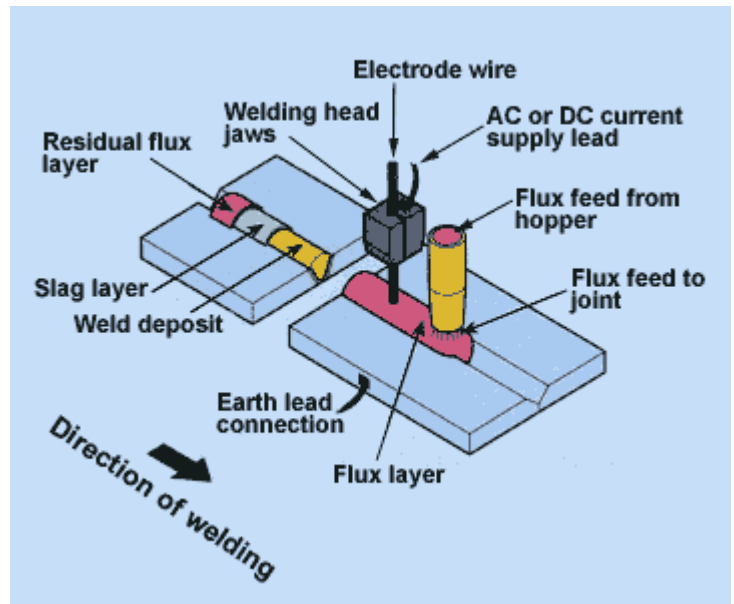
The automatic welding machine travels along metals joint at a fixed speed. Normally this is used for down hand welding of flat panels of mild steel plating. Flux coated or inert gas shielded electrode fed to the joint. The flux covered wire is fed continuously to give the correct arc length and deposition of weld metal. Flux covering of the continuous wire is retained by means of auxiliary wire spirals. The process could tolerate reasonably dirty plates and was a convenient process for welding outdoors at the berth where climatic conditions are not always ideal.

Additional shielding could be supplied in the form of carbon dioxide (Fusarc/CO<sub>2</sub> process) which, together with the flux covering of the wire, allowed higher welding currents to be used with higher welding speeds.



### 2.4.3 Submerged Arc Welding (SAW):

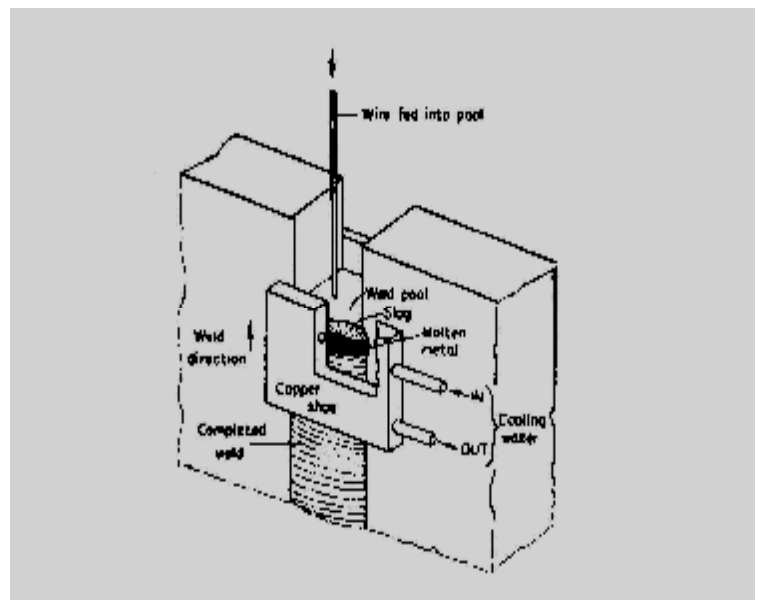
SAW involves formation of an arc between a continuously-fed bare wire electrode and the work piece. The process uses a flux to generate protective gases and slag, and to add alloying elements to the weld pool. A shielding gas is not required. Prior to welding, a thin layer of flux powder is placed on the work piece surface. The arc moves along the joint line and as it does so, excess flux is recycled via a hopper. Remaining fused slag layers can be easily removed after welding. As the arc is completely covered by the flux layer, heat loss is extremely low. This produces a thermal efficiency as high as 60% (compared with 25% for manual metal arc). There is no visible arc light, welding is spatter-free and there is no need for fume extraction.



### 2.4.4 Electro slag welding

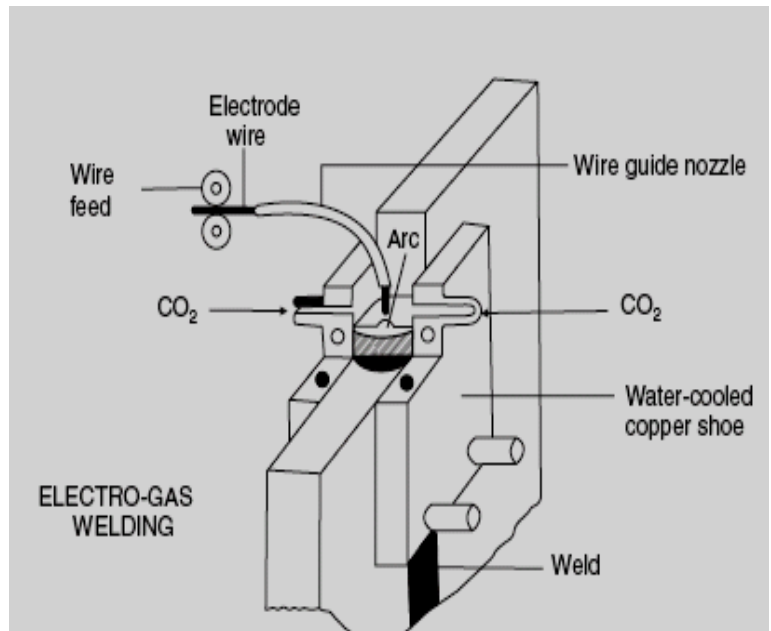
Electro slag welding is a very efficient, single pass process carried out in the vertical or near vertical position and used for joining steel plates/sections in thicknesses of 25mm and above. Unlike other high current fusion processes, electro slag welding is not an **arc** process. Heat required for melting both the welding wire and the plate edges is generated through a molten slag's resistance to the passage of an electric current.

To start the weld an arc is struck, but welding is achieved by resistance path heating through the flux, the initial arcing having been discouraged once welding is started. The current passes into the weld pool through the wire, and the copper water-cooled shoes retain the molten pool of weld metal. These may be mechanized so that they move up the plate as the weld is completed, flux being fed into the weld manually by the operator.



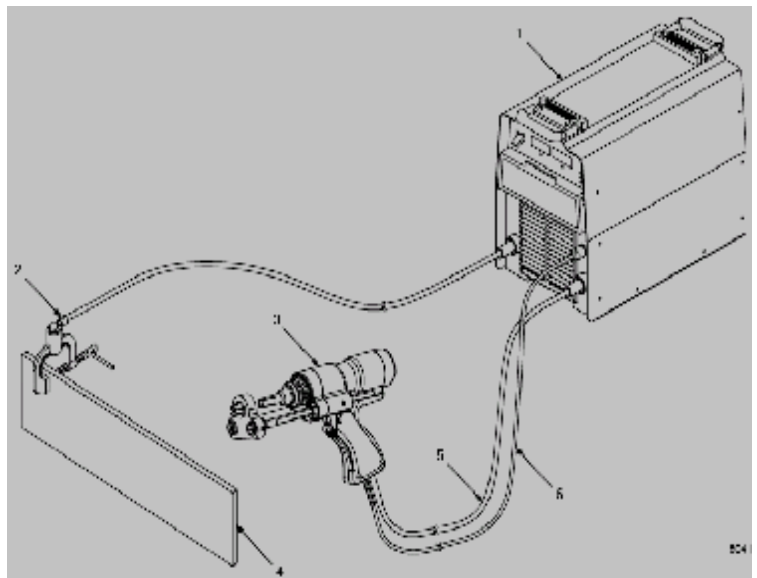
#### 2.4.5 Electro-Gas Welding:

Electro gas welding is a development of electro slag welding and resembles it in terms of its design and use. Instead of slag, the electrode is melted by an arc which burns in a shielding gas, in the same way as in MIG/MAG welding. This method is used for plate thicknesses of 12-100 mm and weaving is used for the thicker materials. The joint is usually a simple I-joint with a gap. V-joints are also used. When welding vertical joints - on large tanks, for example - large cost savings can be made compared with manual MIG/MAG welding.

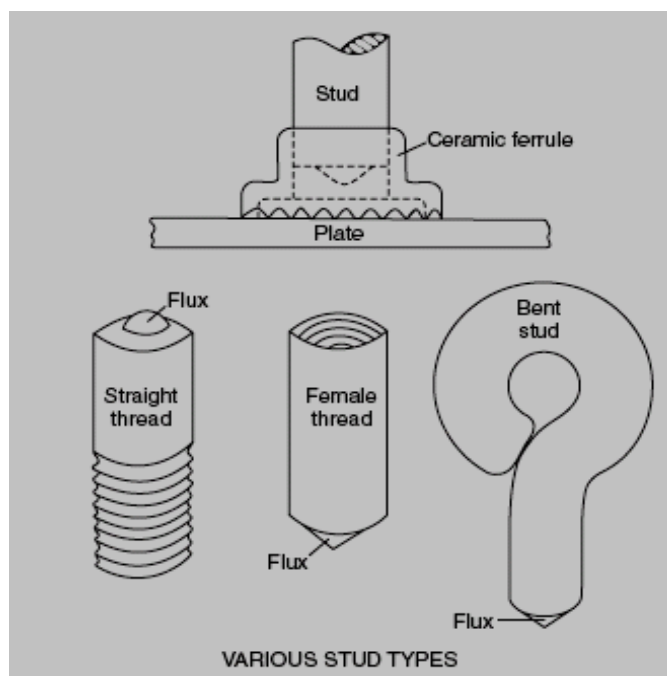
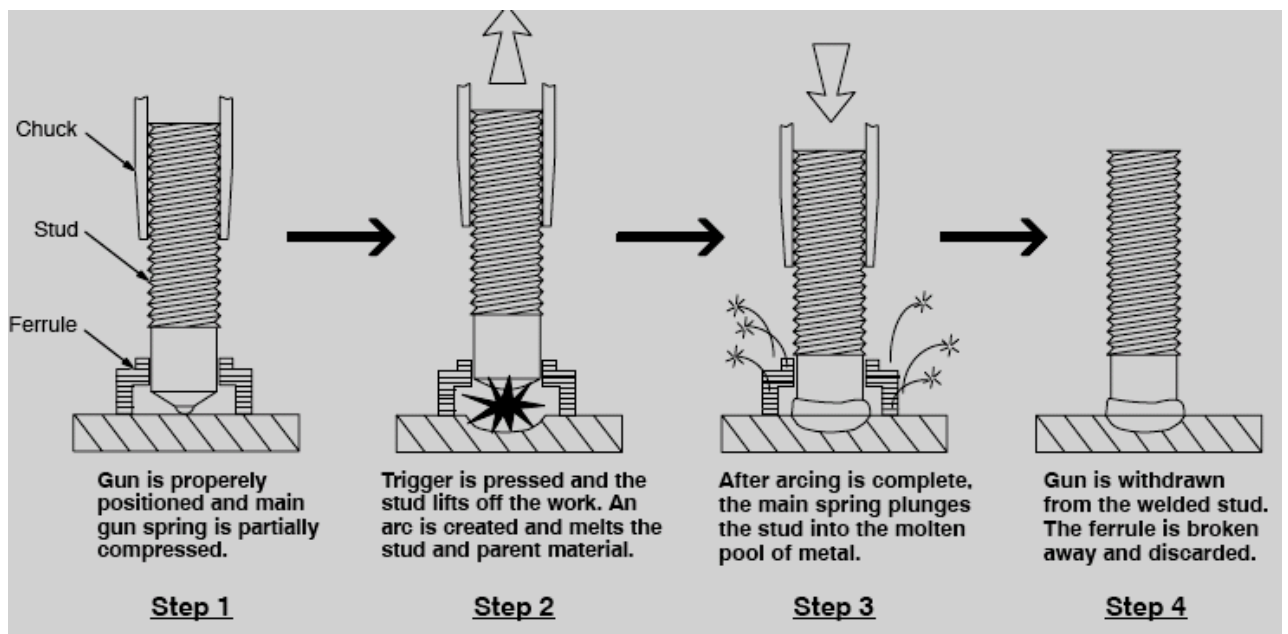


#### 2.4.6 Stud Welding:

Arc stud welding (SW) is a welding process in which a metal fastener (weld stud) is joined to a work piece. This process is generally referred to as stud welding. The metal fastener is joined under pressure once sufficiently heated with an electric arc. The fastener or weld stud is positioned for welding through the use of a stud gun. When the operator activates the stud gun trigger, the fastener (electrode) is welded to the work piece without the use of filler metal. The welding duration of SW is typically one second or less. One end of a SW fastener is prepared for welding. A ceramic ferrule surrounding the weld end of the fastener provides partial shielding of the weld. The ferrule also dams the molten metal to form a fillet type weld. Shielding gases or flux may or may not be used to protect the weld.



### Stud Welding Sequence



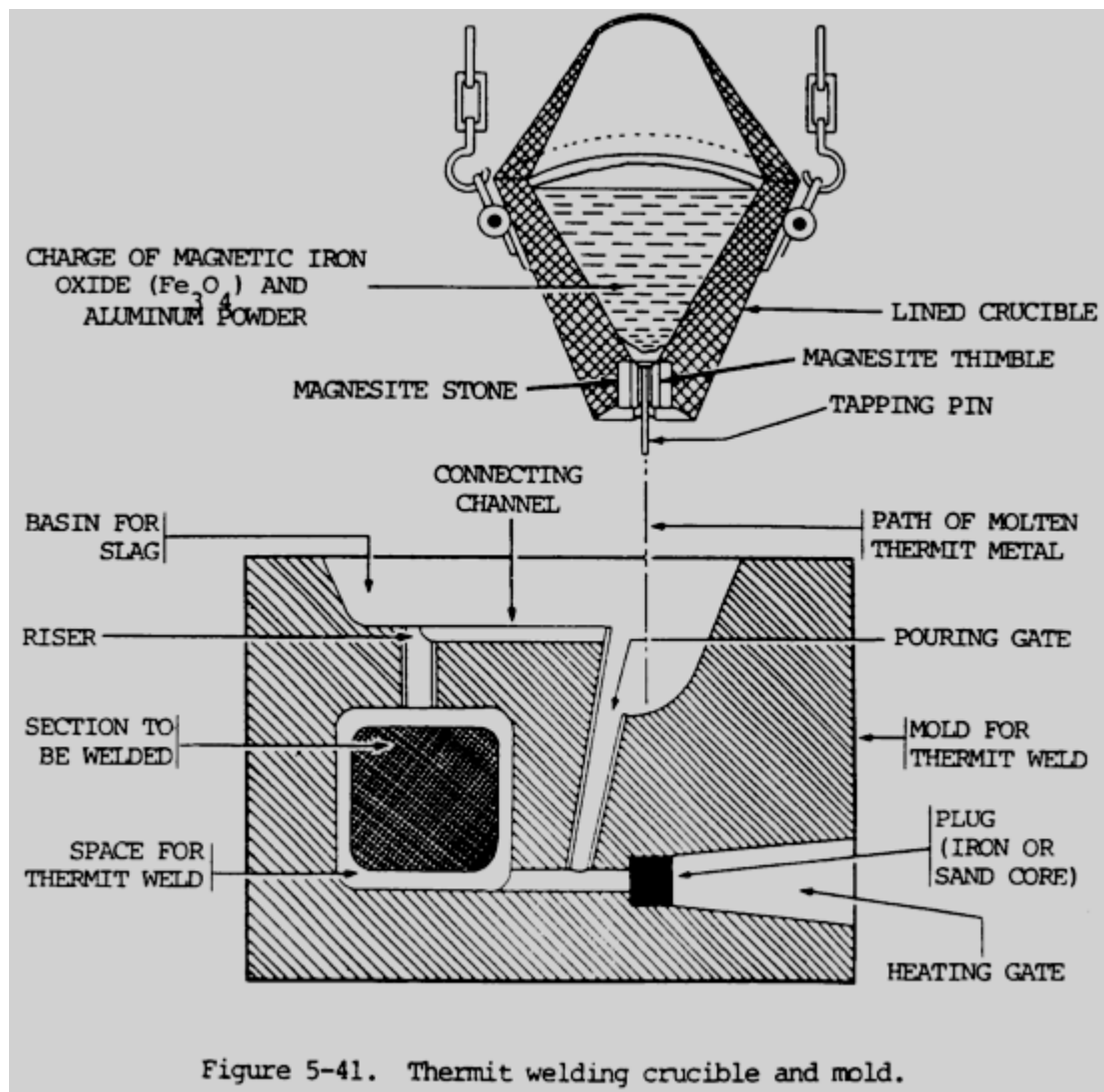
#### 2.4.7 Resistance Welding

In this method the parts to be joined are clamped together and an electric current (AC) is passed through the joint. The resistance to the passage of current across the joint creates heat thus causing the metal to melt with resulting fusion. Spot welding is a similar form of resistance welding.



### 2.4.8 Thermit Welding

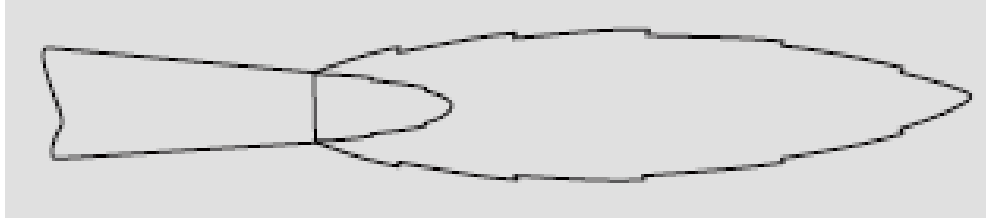
This is a very useful method for welding large steel sections, for example parts of a stern frame. It is basically a fusion process, the required heat being evolved from a mixture of powdered aluminum and iron oxide. The ends of the part to be welded are initially built into a sand or graphite mould, whilst the mixture is poured into a refractory lined crucible. Ignition of this mixture is obtained with the aid of a highly inflammable powder consisting mostly of barium peroxide. During the subsequent reaction within the crucible the oxygen leaves the iron oxide and combines with the aluminum producing aluminum oxide, or slag, and superheated thermit steel. This steel is run into the mould where it preheats and eventually fuses and mixes with the ends of the parts to be joined. On cooling a continuous joint is formed and the mould is removed.





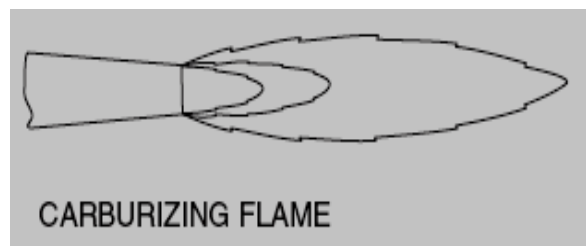
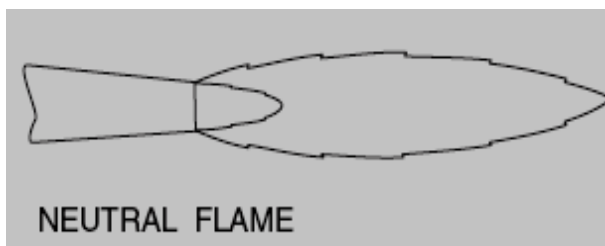
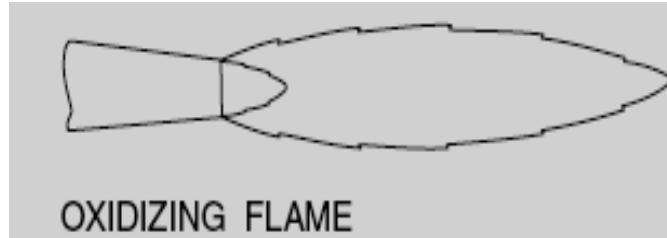
#### 2.4.9 Gas welding:

A gas flame produced by the burning of oxygen and acetylene (average temperature 3000°C) is used in this process. The flame has two distinct regions: Inner cone, oxygen is supplied via the torch and surrounding envelope, oxygen is drawn from the surrounding air.



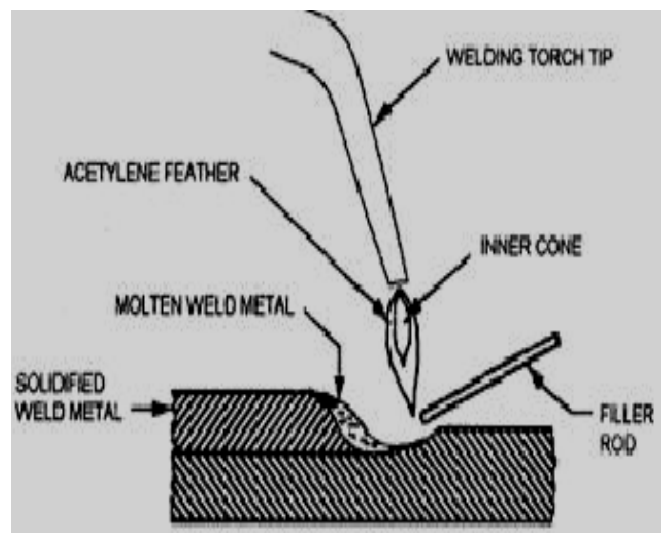
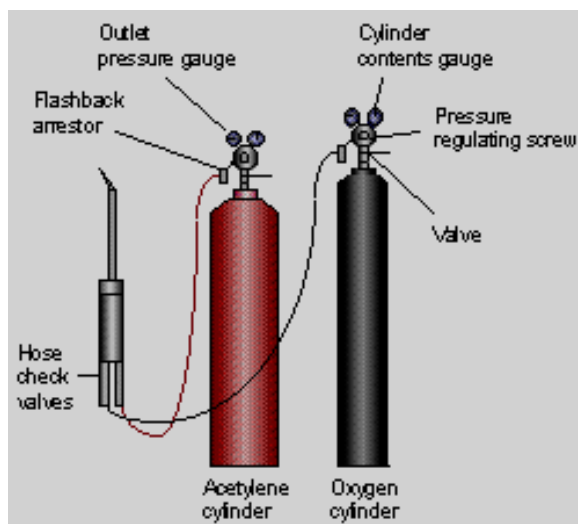
Types of flames:

- n **Oxidizing flame:** supply of oxygen > acetylene by volume. Used for welding materials of high thermal conductivity, e.g. copper, but not steels as the steel may be decarburized and the weld pool depleted of silicon.
- n **Neutral flame:** supply of oxygen = acetylene by volume. Used for welding steels and most other metals.
- n **Carburizing flame:** supply of acetylene > oxygen. the excess acetylene decomposing and producing sub-microscopic particles of carbon & produce metallurgical problems in service.



Each cylinder which is distinctly coloured (red—acetylene, black—oxygen) has a regulator for controlling the working gas pressures. The welding torch consists of a long thick copper nozzle, a gas mixer body, and valves for adjusting the oxygen and acetylene flow rates. Usually a welding rod is used to provide filler metal for the joint, but in some cases the parts to be joined may be fused together without any filler metal.

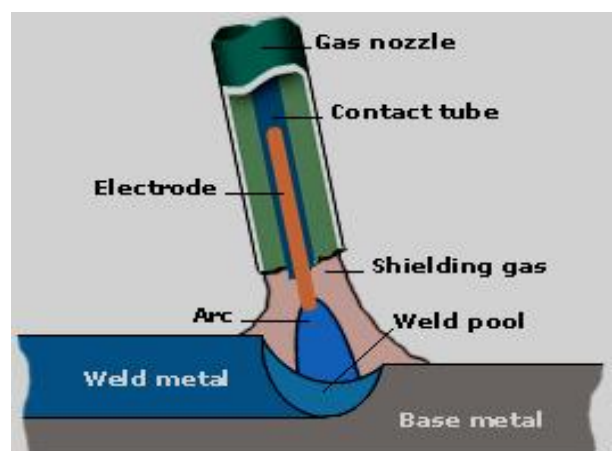
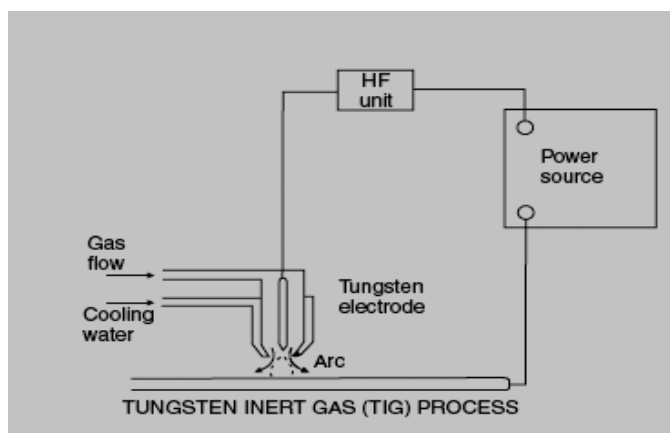




Both oxygen (Black) and acetylene (Red) are supplied in cylinders, the oxygen under pressure and the acetylene dissolved in acetone since it cannot be compressed. A hand held torch is used to direct the flame around the parent metal and filler rods provide the metal for the joint. Gas welding used little, superseded by faster process of electric arc welding. It is used for thinner mild steel plate, thicknesses up to 7 mm. In ship building, fabrication of ventilation and air conditioning trunking, cable trays, and light steel furniture, some plumbing and similar work may also make use of gas welding.

#### 2.4.10 Tungsten Inert Gas (TIG) Welding:

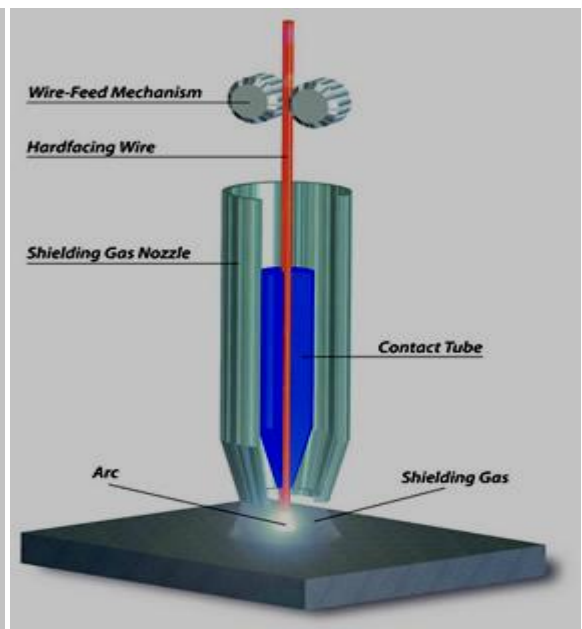
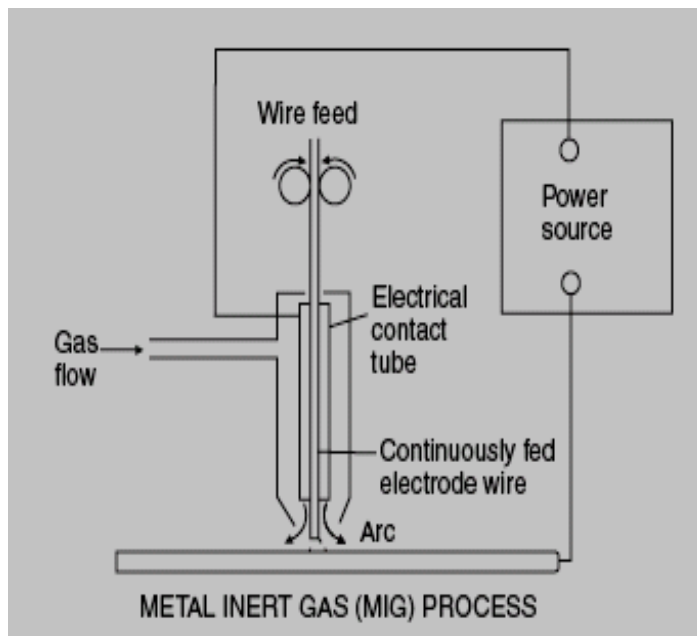
This is used for thin sheets of steel or aluminium less than 6mm. Water cooled non consumable tungsten electrode is used. An inert gas shield is provided to protect the weld metal from the atmosphere, and filler metal may be added to the weld pool as required. (Argon) Ignition of the arc is obtained by means of a high frequency discharge across the gap. This may also be referred to as TAGS welding, i.e. tungsten arc gas-shielded welding.



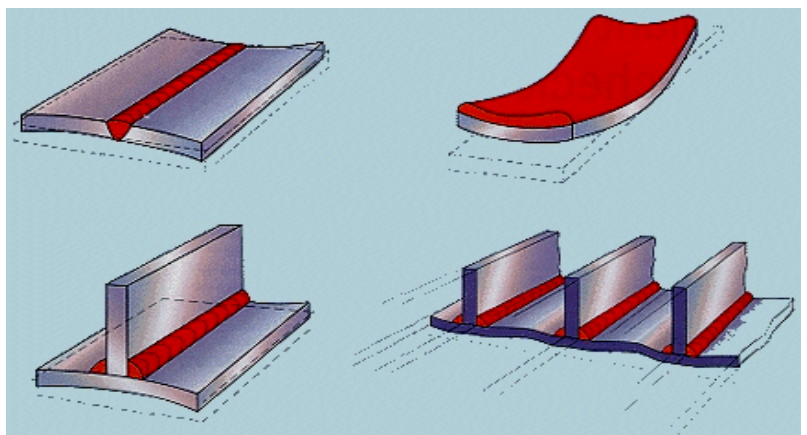


2.4.11 Metal inert gas welding: (MIG):

This is an extension of TIG welding, Used for shipbuilding steel and aluminium. Consumable metal wire electrode used and fed through a holder or torch from feed unit. An inert gas is supplied to the torch to shield the Argon (Al) or CO<sub>2</sub> (Steel). Electric current between plate & torch. Metal Inert gas welding is used for Aluminium superstructures and liquid methane tanks. For lower currents used for thin steel plates.

**2.5 Distortion due to Welding**

Distortion in a weld results from the expansion and contraction of the weld metal and adjacent base metal during the heating and cooling cycle of the welding process. Doing all welding on one side of a part will cause much more distortion than if the welds are alternated from one side to the other. During this heating and cooling cycle, many factors affect shrinkage of the metal and lead to distortion, such as physical and mechanical properties that change as heat is applied. For example, as the temperature of the weld area increases, yield strength, elasticity, and thermal conductivity of the steel plate decrease, while thermal expansion and specific heat increase. These changes, in turn, affect heat flow and uniformity of heat distribution.



### 2.5.1 Types of distortion

Distortion occurs in six main forms:

- Longitudinal shrinkage
- Transverse shrinkage
- Angular distortion
- Bowing and dishing
- Buckling
- Twisting

The principal features of the more common forms of distortion for butt and fillet welds are shown.

### 2.5.2 Shrinkage Control - What You Can Do to Minimize Distortion:

To prevent or minimize weld distortion, methods must be used both in design and during welding to overcome the effects of the heating and cooling cycle. Shrinkage cannot be prevented, but it can be controlled. Several ways can be used to minimize distortion caused by shrinkage:

#### 1- Do not over weld

The more metal placed in a joint, the greater the shrinkage forces. Correctly sizing a weld for the requirements of the joint not only minimizes distortion, but also saves weld metal and time. The amount of weld metal in a fillet weld can be minimized by the use of a flat or slightly convex bead, and in a butt joint by proper edge preparation and fit up. The excess weld metal in a highly convex bead does not increase the allowable strength in code work, but it does increase shrinkage forces.

#### 2- Use intermittent welding

Another way to minimize weld metal is to use intermittent rather than continuous welds where possible. For attaching stiffeners to plate, for example, intermittent welds can reduce the weld metal by as much as 75 percent yet provide the needed strength.

#### 3- Use as few weld passes as possible

Fewer passes with large electrodes, are preferable to a greater number of passes with small electrodes when transverse distortion could be a problem. Shrinkage caused by each pass tends to be cumulative, thereby increasing total shrinkage when many passes are used.

#### 4- Place welds near the neutral axis

Distortion is minimized by providing a smaller leverage for the shrinkage forces to pull



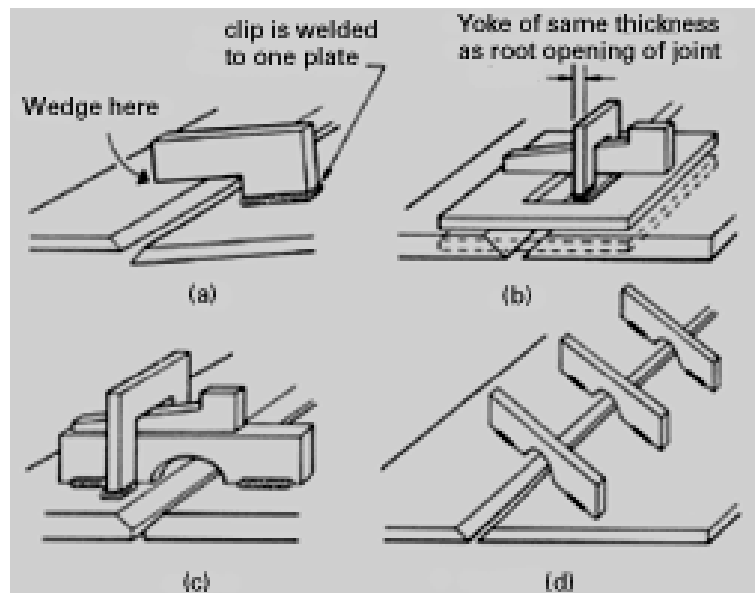
the plates out of alignment. Both design of the weldment and welding sequence can be used effectively to control distortion.

#### 5- Plan the welding sequence

A well-planned welding sequence involves placing weld metal at different points of the assembly so that, as the structure shrinks in one place, it counteracts the shrinkage forces of welds already made. An example of this is welding alternately on both sides of the neutral axis in making a complete joint penetration groove weld in a butt joint.

The "strongback" is another useful technique for distortion control during butt welding of plates, as in Fig. 3-34(a). Clips are welded to the edge of one plate and wedges are driven under the clips to force the edges into alignment and to hold them during welding.

**Fig. 3-34** Various strong back arrangements to control distortion during butt-welding.



#### Review distortion control;

1-use of preferred sequence :e.g the backstop and wandering welding methods. The length of each step in these methods is the amount of weld metal deposited by each electrode. This amount is a variable and depends upon the cross-section of the weld.

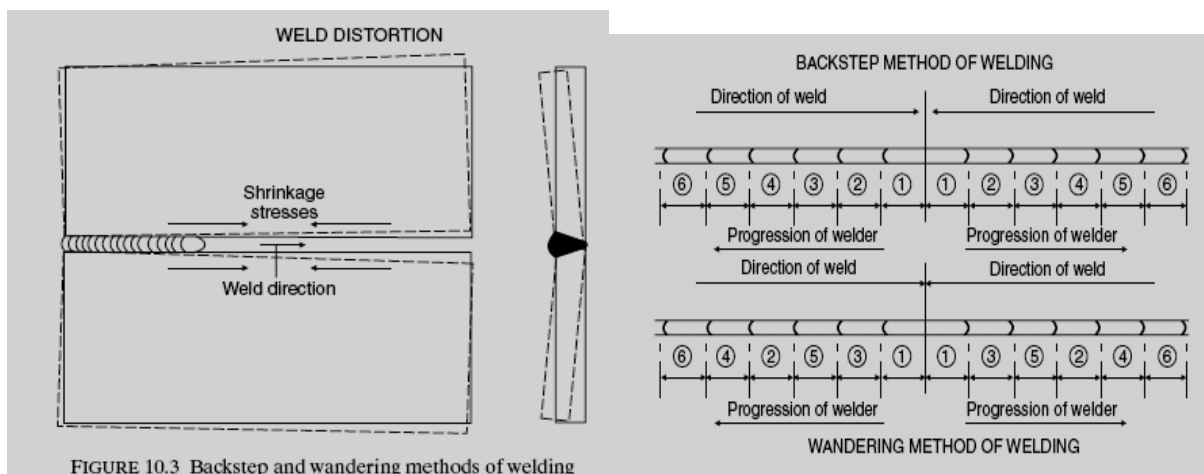
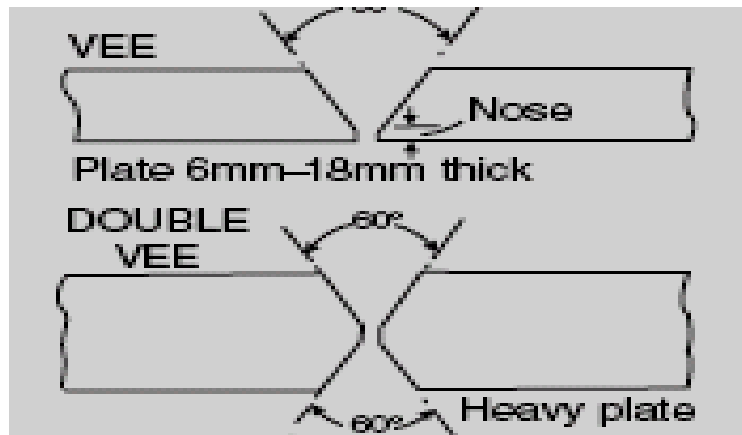


FIGURE 10.3 Backstep and wandering methods of welding



2- Edge preparation: Single V preparation with four runs gives considerable distortion while double V preparation gives only slight shrinkage of the joints.



3-Restraint is a usual method of distortion prevention either by use of tack welding of the work to hold them in place or use of strong backs or clamping arrangement on butt filled welds.

4-preset work so it distorts to its correct shape.

5-Reduce the heat input by reducing the amount of welding e.g employing intermittent scalloping techniques.

6- Avoid excessive reinforcement.

### Summary: A Checklist to Minimize Distortion

In summary, follow the checklist below in order to minimize distortion in the design and fabrication of weldments:

- Do not overweld.
- Control fit up.
- Use intermittent welds where possible and consistent with design requirements.
- Use the smallest leg size permissible when fillet welding.
- For groove welds, use joints that will minimize the volume of weld metal. Consider double-sided joints instead of single-sided joints.
- Weld alternately on either side of the joint when possible with multiple-pass welds.
- Use minimal number of weld passes.
- Use low heat input procedures. This generally means high deposition rates and higher travel speeds.
- Use welding positioners to achieve the maximum amount of flat-position welding.



The flat position permits the use of large-diameter electrodes and high-deposition-rate welding procedures.

- Balance welds about the neutral axis of the member.
- Distribute the welding heat as evenly as possible through a planned welding sequence and weldment positioning.
- Weld toward the unrestrained part of the member.
- Use clamps, fixtures, and strong backs to maintain fit up and alignment.
- Pre-bend the members or preset the joints to let shrinkage pull them back into alignment.
- Sequence subassemblies and final assemblies so that the welds being made continually balance each other around the neutral axis of the section.

### 2.5.3 Corrective action for distortion:

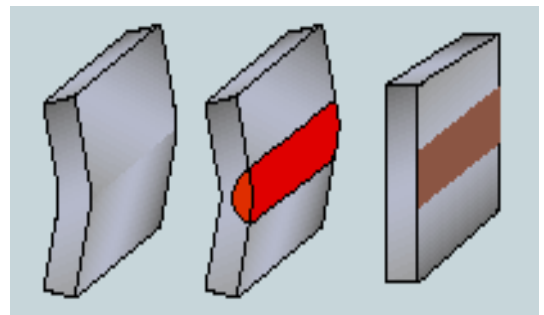
#### Mechanical techniques:

The principal mechanical techniques are hammering and pressing. Hammering may cause surface damage and work hardening.

In cases of bowing or angular distortion, the complete component can often be straightened on a press without the disadvantages of hammering. Packing pieces are inserted between the component and the platens of the press. It is important to impose sufficient deformation to give over-correction so that the normal elastic spring-back will allow the component to assume its correct shape.

#### Thermal techniques:

The basic principle behind thermal techniques is to create sufficiently high local stresses so that, on cooling, the component is pulled back into shape. This is achieved by locally heating the material to a temperature where plastic deformation will occur as the hot, low yield strength material tries to expand against the surrounding cold, higher yield strength metal. On cooling to room temperature the heated area will attempt to shrink to a smaller size than before heating. The stresses generated thereby will pull the component into the required shape. (See Fig. 2)



Best practice for distortion correction by thermal heating:

The following should be adopted when using thermal techniques to remove distortion:

- use spot heating to remove buckling in thin sheet structures
- other than in spot heating of thin panels, use a wedge-shaped heating technique
- use line heating to correct angular distortion in plate
- restrict the area of heating to avoid over-shrinking the component
- limit the temperature to 60° to 650°C (dull red heat) in steels to prevent metallurgical damage
- in wedge heating, heat from the base to the apex of the wedge, penetrate evenly through the plate thickness and maintain an even temperature

## 2.6 Weld faults

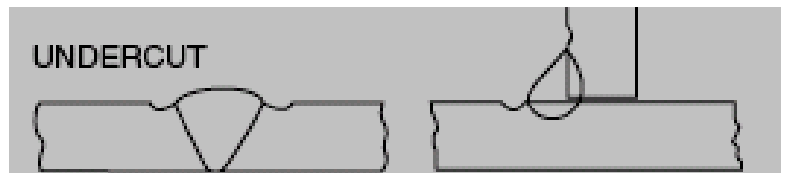
Caused by

- Bad design
- Incorrect welding procedure
- Use of wrong materials
- Poor workmanship

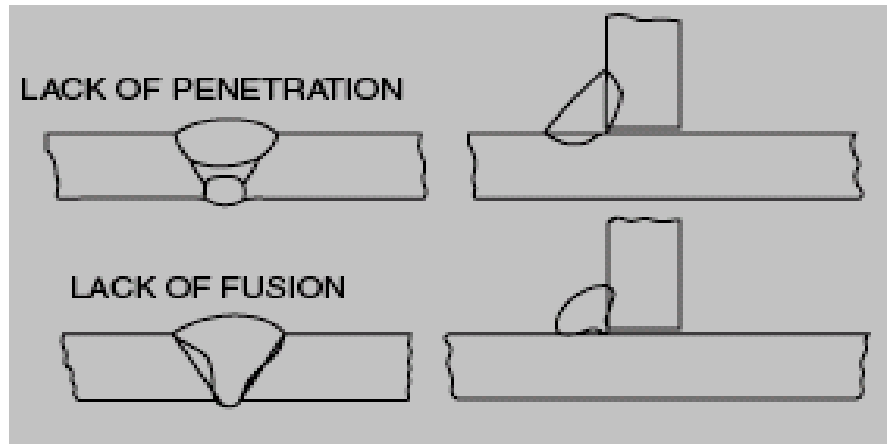
Common faults

- Lack of fusion
- No inter run penetration
- Lack of reinforcement
- No root penetration
- Slag inclusion
- Porosity
- Overlap
- undercut

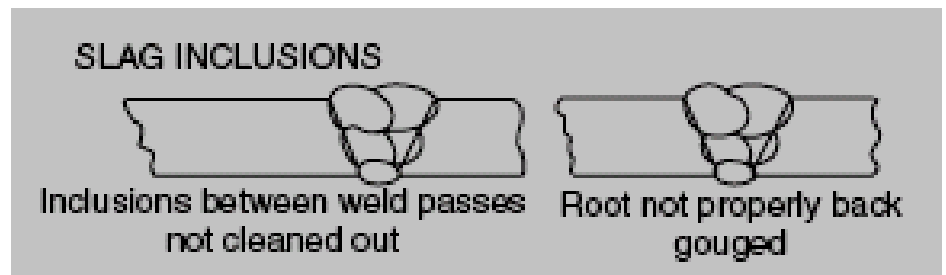
**1-Undercut:** when a groove is burned in a plate close to the weld, it weakens the plate.



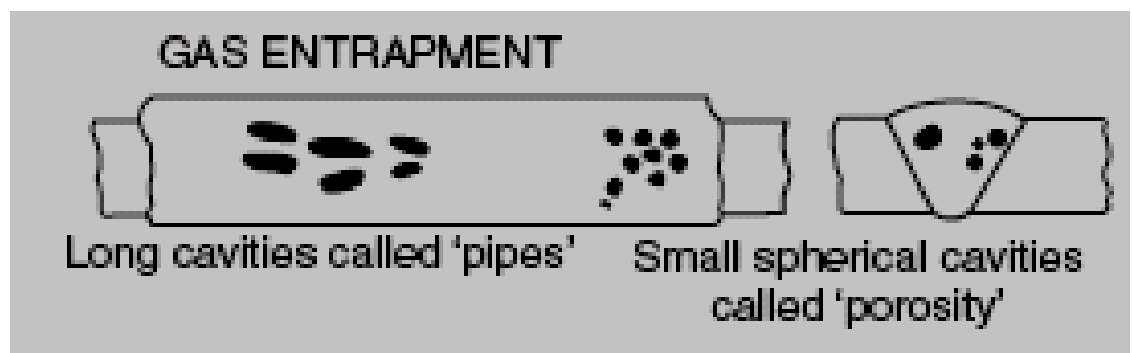
**2-Poor penetration:** if the weld metal does not fill the joint properly, a gap is left between runs. It may appear as **lack of fusion** when the heat does not melt plate or previous runs sufficiently.



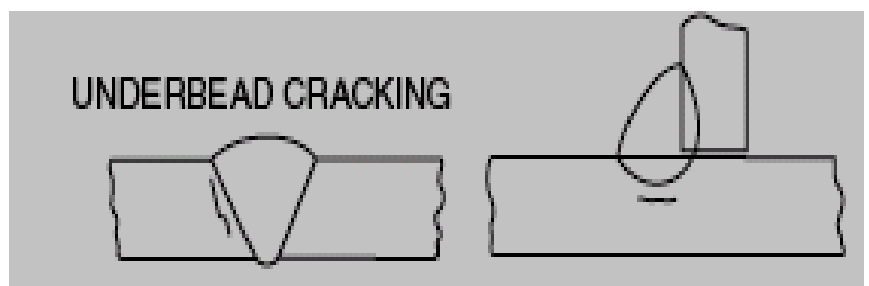
**3-Slag inclusion:** if the slag is not completely cleaned and left between runs.

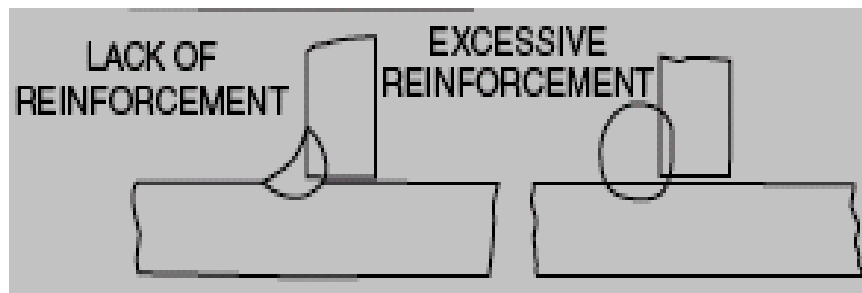
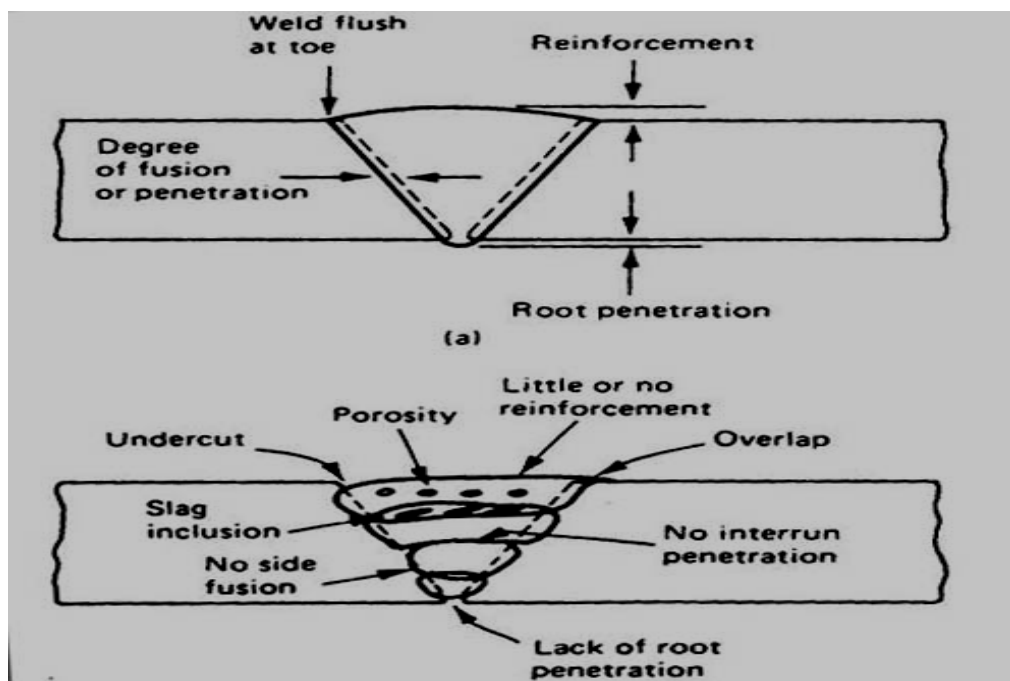
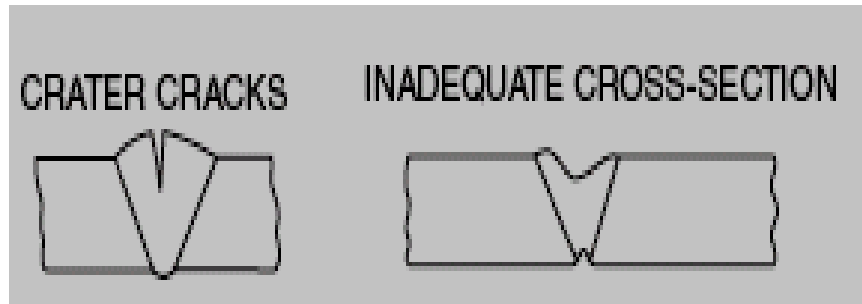


**4-Blow holes:** rounded holes formed by gas trapped in the weld metal as it cools. **Pipes** are elongated holes due to same cause.



**5-Underbed cracking:**



**6-Lack of reinforcement:****7-Cracks****2.7 Testing welds**

The weld testing carried out in shipbuilding is done visually by trained inspectors. Spot checks at convenient intervals are made on the more important welds in merchant ship construction, generally using radiographic equipment. Welding materials are subjected to comprehensive tests before they are approved by Lloyd's Register or the other classification societies for use in ship work. Operatives are required to undergo periodical welder approval tests to ascertain their standard of workmanship.





### 2.7.1 Non-destructive Testing:

NDT (nondestructive testing), is a family of specialized technical inspection methods which provide information about the condition of materials and components without destroying them. NDT examines actual production pieces and reveals the presence of flaws which can be evaluated against accept/reject criteria. There are several established NDT methods currently in industrial use; they may be summarized as follows: Visual examination -Dye penetrant - Magnetic particle – Radiographic and Ultrasonic.

#### 2.7.1.1 Visual examination

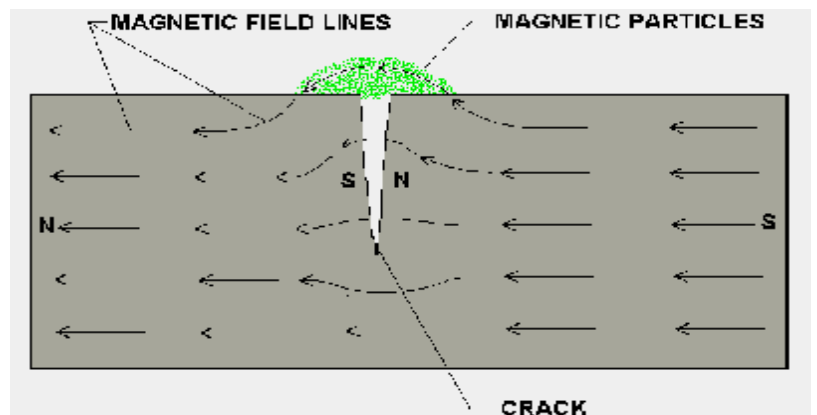
This is the most basic and common inspection method. Tools include fiberscope, bore scopes, magnifying glasses and mirrors can be used. Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines. Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.

#### 2.7.1.2 Dye Penetrant

A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects. The excess liquid is removed from the surface of the part. A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen. Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

#### 2.7.1.3 Magnetic Particle Testing (MT)

MT usually requires electrical equipment to generate magnetic fields. Only metals which can be magnetized are tested by MT. The flaws do not have to be open to the surface but must be close to it. MT works best for flaws which are elongated rather than round. An internal magnetic field is generated in the tested specimen. In locations where flaws (non-magnetic voids) exist, some of the field will leak off the specimen and bridge the voids through the air. Magnetic (iron) particles, dusted over the magnetized area, are attracted by the leakage or



external fields. Their buildups form a flaw indication.

#### 2.7.1.4 Radiographic Testing (RT)

The safety hazard inherent in RT dictates a special installation. Material density and its thickness set the limits of usefulness. Internal, non-linear flaws are RT's forte; its two dimensional views sometimes its drawback. RT uses penetrating radiation and works on the principle that denser or thicker materials will absorb more of it. The specimen is placed between a source of radiation and a sheet of radiographic film. A flaw present anywhere within the specimen will absorb less radiation than the specimen itself. The flaw's presence and location will be indicated on the film by an area of higher or darker exposure.

The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.

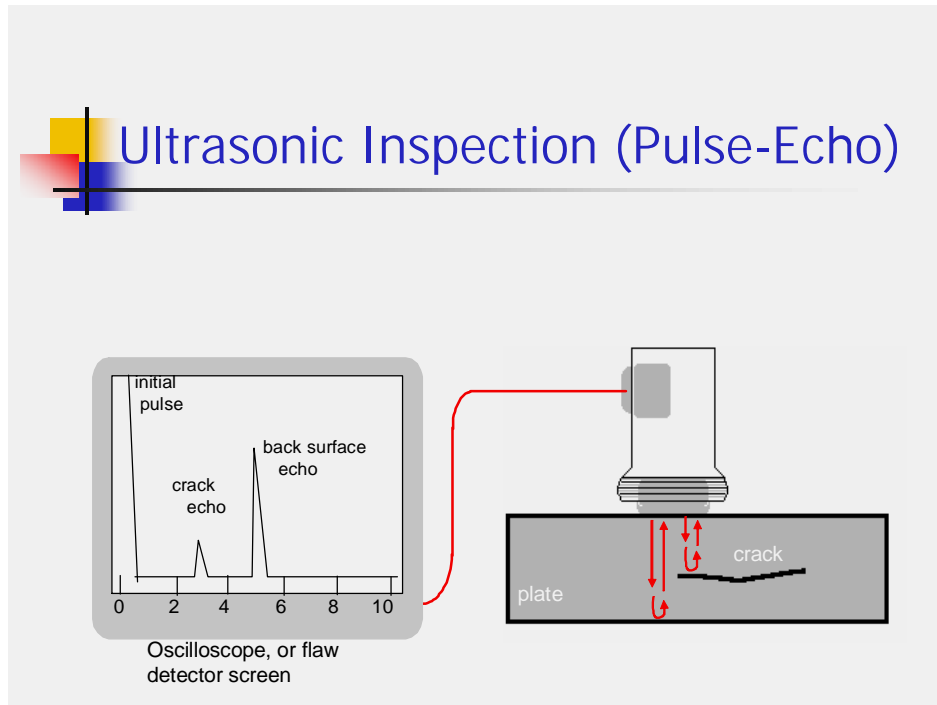
The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

#### 2.7.1.5 Ultrasonic Testing (UT)

UT uses complex electronic equipment. Any material which transmits mechanical vibrations can be tested. UT detects both linear and non-linear flaws and permits three dimensional interpretations. Evaluation is often difficult. The UT instrument converts electrical pulses into mechanical vibrations or pulses. These pulses travel across the tested specimen and reflect from flaws because of their different acoustic nature. The returning reflected pulses are re-converted to electric energy and displayed as signals on a cathode ray tube (CRT). The position and size of these signals correspond to the position and size of the flaws.

(High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws. Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.)





### 2.7.2 Destructive test

Classification societies specify a number of destructive tests which are intended to be used for initial electrode and weld material approval. These tests are carried out to ascertain whether the electrode or wire-flux combination submitted is suitable for shipbuilding purposes in the category specified by the manufacturer. For destructive tests the weld materials or joints are tested until failure occurs, to determine their maximum strength. These are tensile test, bent test and impact test.

## 2.8 Edge preparations

Gas cutting; use an oxy acetylene or oxy propane flame – area to be cut is preheated – Oxygen then blown into the area – iron oxidised – molten metal and oxide removed by Kinetic energy of O<sub>2</sub> stream.

Plasma arc cutting; uses a tungsten electrode with an electric circuit gap from the metal to be cut. The electric arc is completed by a stream of ionised gas – gas ionised by a subsidiary electric discharge.

Water jetting; prevents heat distortion in thinner plates – uses fine high pressure (2000 to 4000 bars) jet of water with abrasive.

Laser cutting; Profile cutting and planning at high speeds can be obtained with a concentrated laser beam and the introduction to shipbuilding of this technique has been evaluated, in particular for a robot cutting head.

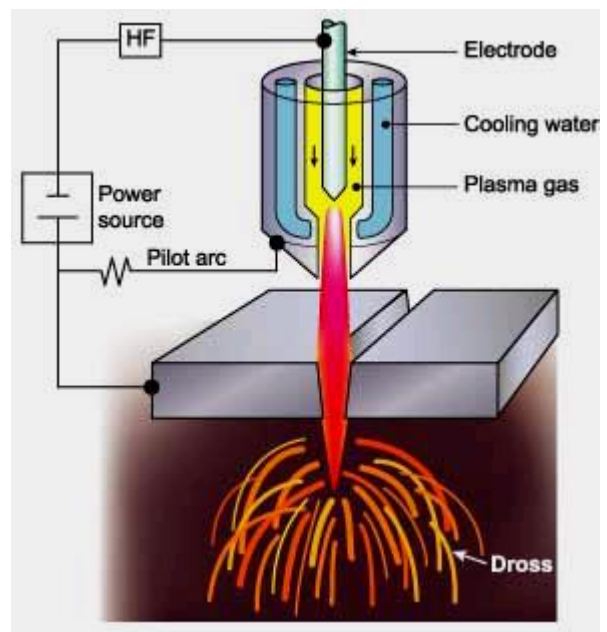


### 2.8.1 Gas cutting:

A process whereby the chemical reaction of a pure oxygen stream with steel at elevated temperature produces local separation along the line of advancement. A small area must first be heated to the temperature of self sustained ignition (less than iron melting point). Concentrated stream of high purity oxygen is directed on the same spot rapidly changing the metal into its oxides which melt and are removed by the force of the impinging stream along with any present molten metal drops.

### 2.8.2 Plasma Arc cutting

Plasma Arc Cutting (PAC) provides a stream of very hot plasma (mass of ionized gas) at 28000° C produced by a constricted arc between an electrode and the work piece. The molten metal is removed by a continuous jet of high speed auxiliary gas provided by the Cutting-torch. It uses a tungsten electrode with an electric circuit gap from the metal to be cut. Current Cutting-torch equipment uses compressed air. In the past other gases were used, both inert and active (nitrogen, argon-hydrogen, oxygen etc.). By this process it is possible to cut at high speed any material conducting electricity.



### 2.8.3 Water jetting

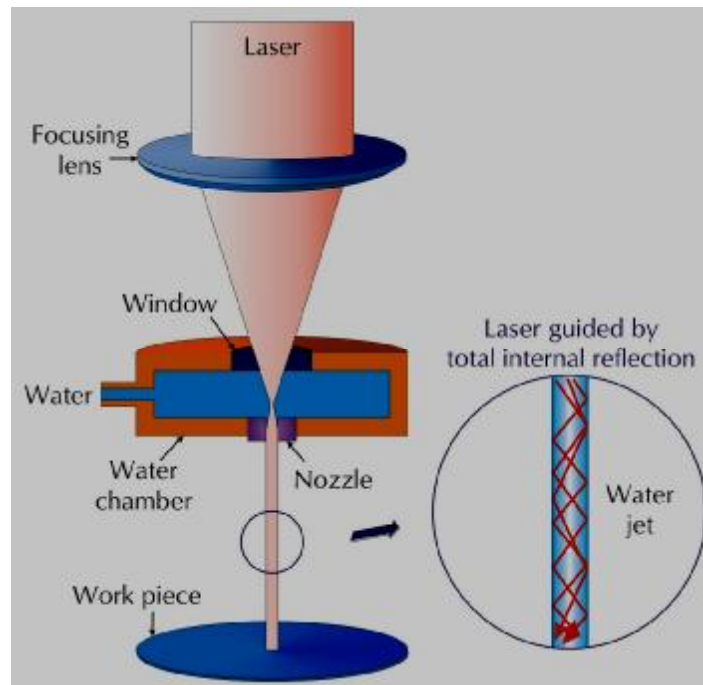
This cutting process may be used where thermal cutting is not possible and mechanical cutting requires extensive and expensive subsequent working. The cutting tool employed in this process is a concentrated water jet, with or without abrasive, which is released from a nozzle at 2½ times the speed of sound and at a pressure level of several thousand bar.

### 2.8.4 Laser Cutting

In a laser beam the light is of one wavelength, travels in the same direction. Such a beam can be focused to give high energy densities. For welding and cutting the beam is generated in a CO<sub>2</sub> laser. This consists of a tube filled with a mixture of CO<sub>2</sub>, nitrogen, and helium which is caused to fluoresce by a high-voltage discharge. The tube emits infra-red radiation with a



wavelength of about  $1.6\ \mu\text{m}$  and is capable of delivering outputs up to 20 kW.



## **Sample questions on welding**

Q-1 what are the advantages of welding?

Q-2 A- Describe with the aid of sketch the T.I.G.

B- Describe gas welding technique, state the different types of flame with their function.

Q-3 Explain different methods carried out to prevent distortion by welding on steel plate.

Q-4 A- What is the distortion due to weld?

B- How it can be avoided. C- What is the corrective action?

Q-5 Write short notes on each type of tests carried out on welded joints.

Q-6 Explain the following processes:

- i) Electro slag welding.
- ii) Electro gas welding
- iii) Gas cutting.

Q-7 Explain the difference between destructive & nondestructive test of welding.

Discuss in details, with the aid of a suitable sketch, a method of welding large castings such as stern frames.

Q-8 A- State different methods of non-destructive welding test carried out in ship's building, to assess effectiveness and safety of construction.

B- Which type of test is useful for locating fine cracks? Ultrasonic test

C- What are the initial main intentions of classification societies to ascertain effectiveness of weld tests in ship building?



## CHAPTER-3 BULKHEADS

### 3.1 Definitions

Aft Peak Bulkhead, is a term applied to the first main transverse watertight bulkhead forward of the stern. The aft peak tank is the compartment in the narrow part of the stern aft of this last watertight bulkhead.

Bulkhead Deck; is the uppermost continuous deck to which transverse watertight bulkheads and shell are carried.

Bulkhead Structure; is the transverse or longitudinal bulkhead plating with stiffeners and girders.

Cargo Hold Bulkhead; is a boundary bulkhead separating cargo holds.

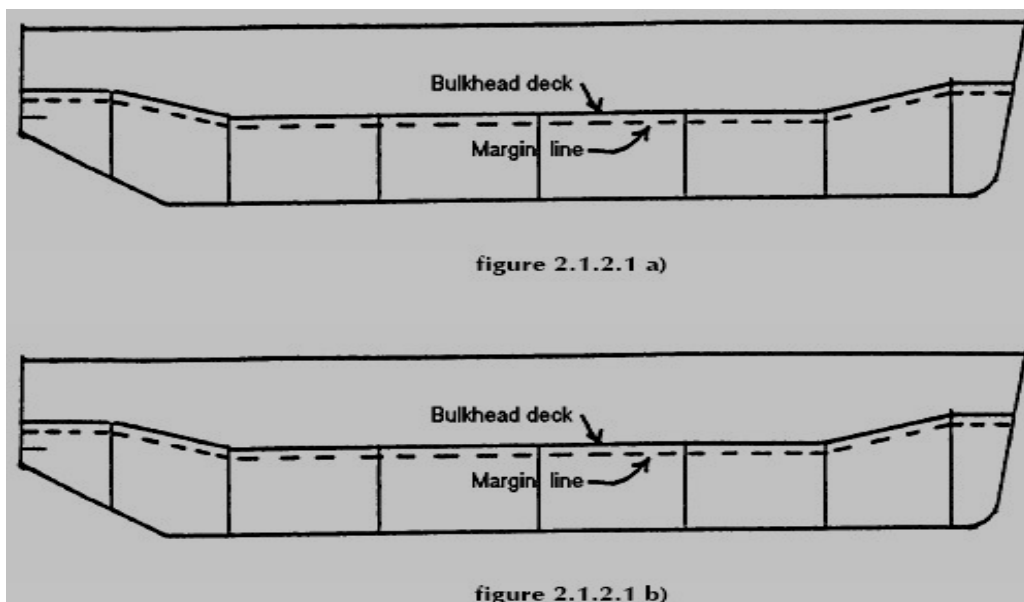
Collision Bulkhead; is the foremost main transverse watertight bulkhead.

Tank Bulkhead; is a boundary bulkhead in a tank for liquid cargo, ballast or bunkers.

Wash Bulkhead; is a perforated or partial bulkhead in a tank.

Watertight Bulkhead; is a collective term for transverse bulkheads required for subdivision of the hull into watertight compartments.

Margin line; is an imaginary line drawn parallel to and at least 76mm below the upper surface of the bulkhead deck at side a ship is deemed to remain afloat after flooding if calculations show that the margin line is not submerged used for passenger ship subdivision criteria.



### **3.2 Watertight, Non-Watertight and oil tight Bulkheads**

The vertical partitions that divide the hull into separate compartments are called bulkheads. Some are watertight. These water-tight bulkheads are so arranged that in case of accident at sea, water would be confined to one compartment only. The collision bulkhead in the front end is constructed to withstand heavy strain and shock in case the bow is staved in.

Those bulkheads which are of greatest importance are the main transverse and longitudinal bulkheads dividing the ship into a number of compartments. There are others, which are of little structural importance, but they act as screens further dividing compartments into small units of accommodation and stores.

The three basic types of bulkheads found on most ships, are watertight, non-watertight and oil tight or tank bulkheads. The main transverse watertight bulkheads divide the ship into a number of watertight compartments and their number is dictated by classification society regulations. Oil tight bulkheads form boundaries of tanks used for the carriage of liquid cargoes or fuels. Non-watertight bulkheads are any other bulkheads such as engine casing, accommodation partitions or stores compartments.

#### **3.2.1 General Purpose of bulkhead:**

- 1- Subdivision, to divide the ship into a number of compartments.
- 2- Contain flooding in the event of damage.
- 3- Transverse strength member, provide structural strength, some of the bulkhead do not offer any structural strength and act as 'screens' to divide units of accommodation, store
- 4- Protection against racking stresses
- 5- Effective barrier against the spread of fire in holds and E/R.
- 6- Resisting any tendency for transverse deformation of the ship

##### **n Transverse Watertight Bulkheads**

- subdivide a ship against flooding and spread of fire
- Support decks
- Resist racking stresses
- Maintain transverse form
- Number and spacing of WT bulkheads governed by statutory requirements





**n Longitudinal Watertight Bulkheads**

- provide longitudinal strength
- control width of flooding & prevent excessive list
- subdivide liquid cargoes & reduce free surface effect
- prevent spread of fire

**3.2.2 Transverse W/T Bulkheads – Requirements in Cargo Ships**

A collision bulkhead shall be fitted which shall be watertight up to the freeboard deck. This bulkhead shall be located at a distance from the forward perpendicular of not less than 5% of the length of the ship or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than 8% of the length of the ship. Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances stipulated in paragraph above shall be measured from a point either:

- 1-At the mid-length of such extension; or
- 2-At a distance 1.5% of the length of the ship forward of the forward perpendicular; or
- 3-At a distance 3 m forward of the forward perpendicular; whichever gives the smallest measurement. (SOLAS, CH.II-I, Reg-11)

**3.2.3 Position of collision bulkhead:**

Type of bow	Length (m)	Distance of collision bulkhead abaft of FP
Ordinary	$\leq 200$	0.05L ---- 0.08 L
	$>200$	10 m ---- 0.08 L
Bulbous bow	$\leq 200$	0.05 l- f1 ---- 0.08 l- f1
	$>200$	10m- f2 -----0.08 l – f2
f1 = 0.5 b.bow length or 0.015 l (whichever is best)		
f2 = 0.5 b.bow length or 3 m (whichever is best)		

The minimum number of transverse watertight bulkheads which must be fitted are stipulated, a collision bulkhead, an aft peak bulkhead must be fitted and watertight bulkheads must be provided at each end of the machinery space. This implies that for a vessel with machinery amidships the minimum possible number of watertight bulkheads is four. With machinery aft this could be reduced to three, the aft peak bulkhead being at the aft end of the machinery space.



**3.2.4 Additional bulkheads requirement by classification society's rule:**

The number of bulkheads on a ship increase with length. Their numbers are governed by class. These additional bulkheads are spaced at uniform intervals. These intervals could be made greater at the ship owner's request. However for an increase in length of the hold, additional transverse stiffening is required. In certain cases one complete bulkhead could be omitted, with class approval. Adequate structural compensation is a must if this is done.

In container ships bulkheads are spaced to suit the standard lengths of containers carried. Each of the main watertight bulkheads may extend up to the uppermost continuous deck; but in case the freeboard is measured from the second deck they need only to be taken to that deck. The collision bulkhead extends to the uppermost continuous deck and the aft peak bulkhead may terminate at the first deck above the load waterline provided that it is made watertight to the stern, or to a watertight transom floor.

In case of bulk carriers further consideration may come into the spacing of watertight bulkheads where a ship owner desires to obtain a reduced freeboard. It is possible to obtain a reduced freeboard under the Merchant Shipping (Loadline) Rules 1968 if it is possible to flood one or more compartments without loss of the vessel.

**3.2.5 Transverse W/T Bulkheads – Requirements in Passenger Ships**

These are governed strictly by statutory regulations for subdivision, floodability and damage stability with minimum 3 (for ships with machinery aft) or minimum 4 (for ships with machinery amidships), including:

A Collision Bulkhead watertight to the bulkhead deck, spaced not less than 5% and not more than  $3\text{m} + 5\%$  of ships length from FP – allowance made in case of extensions like bulbous bow forward of FP.

An Aft Peak Bulkhead watertight to the bulkhead deck but may be stopped below bulkhead deck if subdivision safety is not compromised

A Bulkhead shall be fitted at each end of the machinery space watertight up to the bulkhead deck. Stern tube to be enclosed in a W/T compartment. Stern gland to be situated in a W/T shaft tunnel, or space separate from the stern tube compartment, of specifically calculated size.



### 3.3 Construction of watertight bulkheads

Each watertight subdivision bulkhead, whether transverse or longitudinal, shall be constructed in such a manner that it shall be capable of supporting, with a proper margin of resistance, the pressure due to the maximum head of water which it might have to sustain in the event of damage to the ship but at least the pressure due to a head of water up to the margin line. The construction of these bulkheads shall be to the satisfaction of the Administration. (SOLAS, CH.II-I, Reg-14)

#### 3.3.1 Plane or flat watertight bulkhead

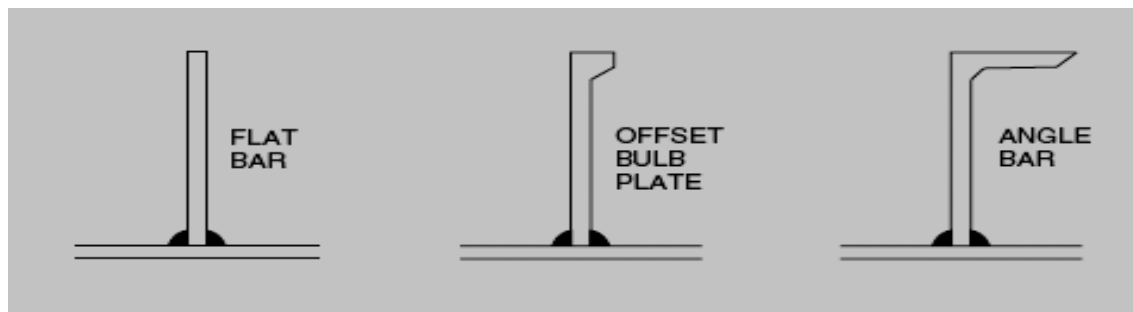
##### 3.3.1.1 Plating

Watertight bulkheads because of their large area are formed of several strakes of plating. They are welded to the shell, deck and tank top. The plating strakes are normally horizontal and the stiffening is vertical. It has always been the practice to use horizontal strakes of plating since the plate thickness increases with depth below the top of the bulkhead. The reason for this is that the plate thickness is directly related to the pressure exerted by the head of water when a compartment on one side of the bulkhead is flooded. Apart from the depth the plate thickness is also influenced by the supporting stiffener spacing.

The collision bulkhead must have plating some 12% thicker than other watertight bulkheads. Also, plating in the aft peak bulkhead around the stern tube must be doubled or increased in thickness to reduce vibration.

##### 3.3.1.2 Stiffeners:

Vertical stiffeners are fitted to the transverse watertight bulkheads of a ship; these are usually in the form of welded inverted ordinary angle bars, or offset bulb plates, the size of the stiffener being dependent on the unsupported length, stiffener spacing, and rigidity of the end connections. The ends of stiffeners may be welded directly to the inner bottom or deck, or they may be attached by angle lugs or by brackets. Stiffeners could also be supported by horizontal stringers (normally found on tank boundaries), this permits reduction in stiffener spacing.



They are made heavier in the way of deck girders and are attached by deep flanged bracket. They are spaced 750mm apart except collision/deep tank bulkhead that are spaced 600mm apart.

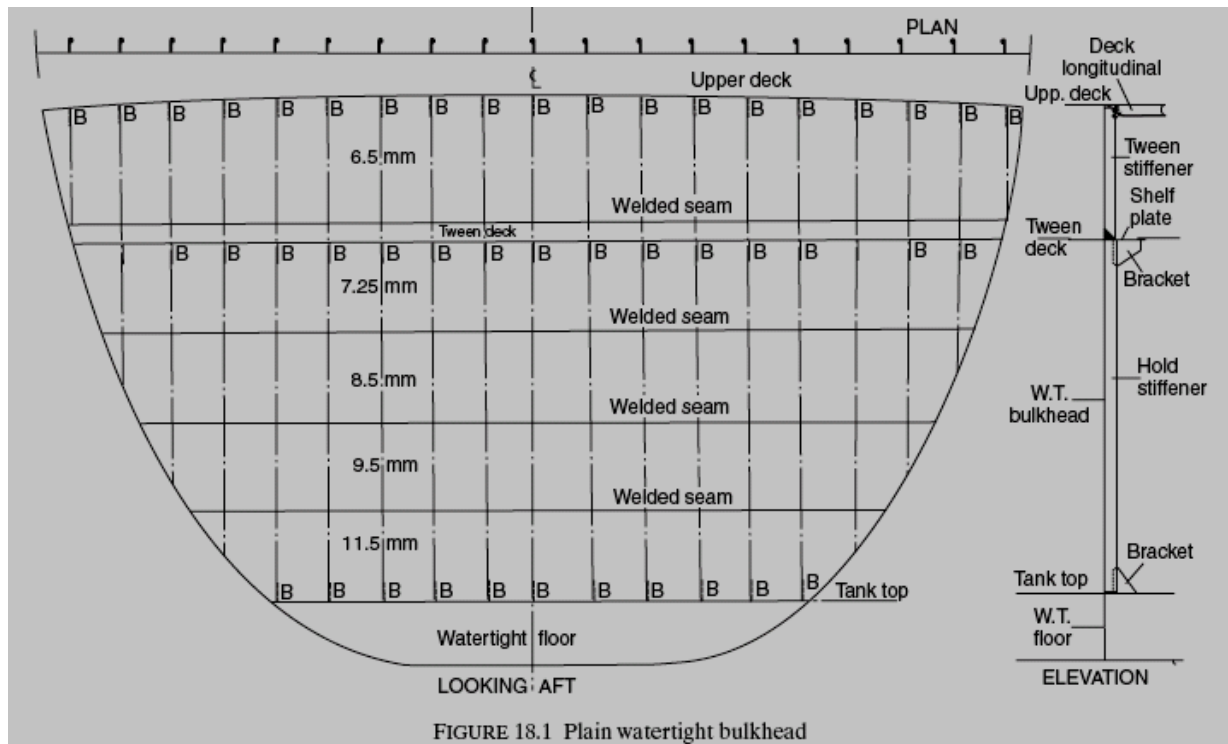


FIGURE 18.1 Plain watertight bulkhead

At the line of the tween decks a 'shelf plate' is fitted to the bulkhead and when erected the tween decks land on this plate which extends 300 to 400 mm from the bulkhead. The deck is lap welded to the shelf plate with an overlap of about 25 mm. In the case of a corrugated bulkhead it becomes necessary to fit filling pieces between the troughs in way of the shelf plate.

### 3.3.2 Corrugated / swedged watertight bulkhead

Corrugated / Swedged bulkheads are now frequently found in tankers, general cargo ships, ore carriers etc. They are usually trapezoidal in shape and though easy to prefabricate they require heavy presses to give the required shape. They afford a considerable reduction in welding, less welding results in reduced buckling, and are less susceptible to corrosion (more efficient tank cleaning). Superstructure bulkheads are occasionally swedged, the spacing of swedged being 610mm or less. They produce strong structure with reduction in weight. The troughs are vertical on transverse bulkheads but on longitudinal bulkheads they must be horizontal in order to add to the longitudinal strength of the ship.



The strakes run vertically and the plating must be of uniform thickness and adequate to support greater loads at the bottom of the bulkhead. The boundary connections may be directly welded to shell plating or welding to a flat bar, angle or T-bar. On high bulkheads with vertical corrugations, diaphragm plates are fitted across the troughs. This prevents any collapse of the corrugations.

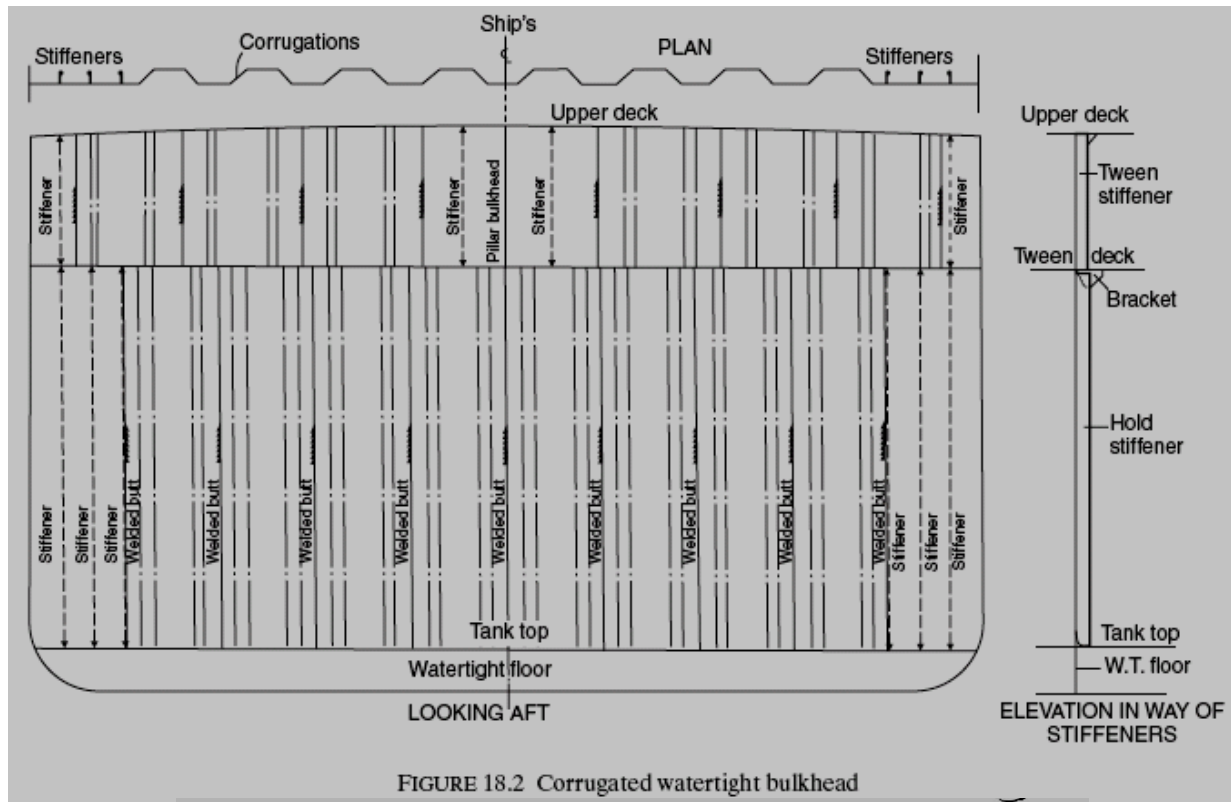
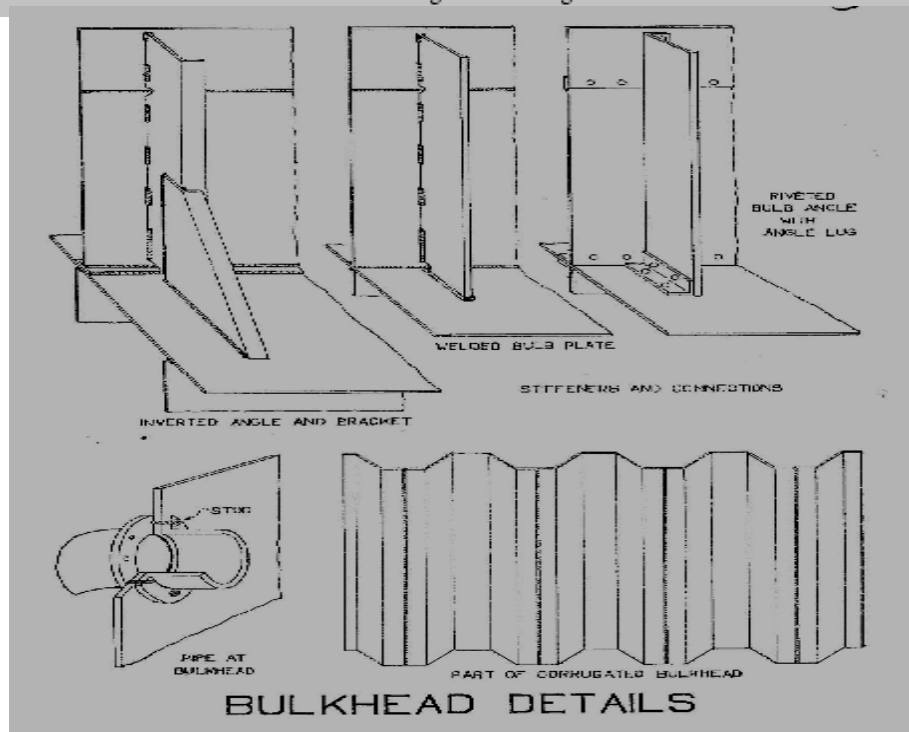
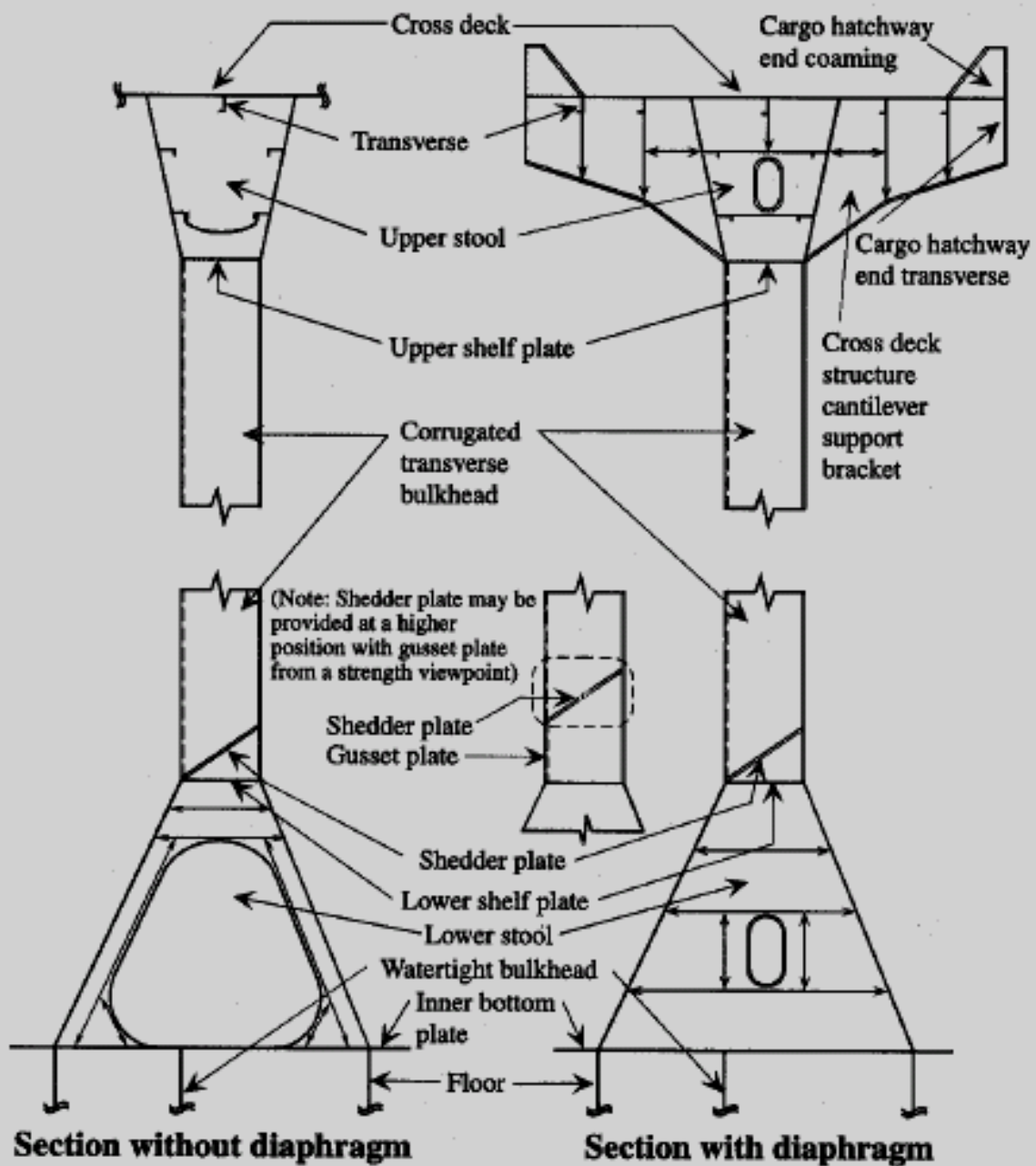
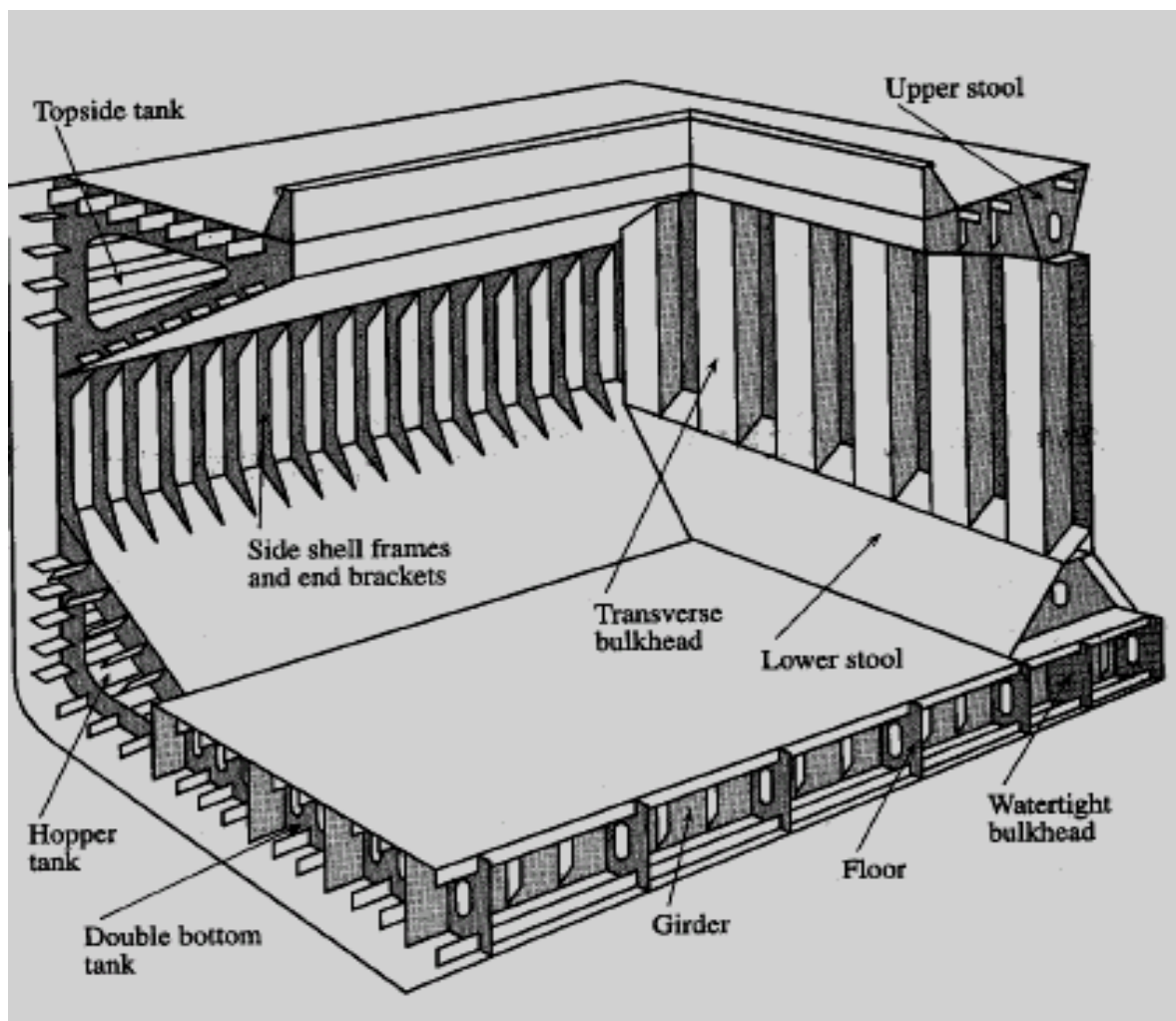
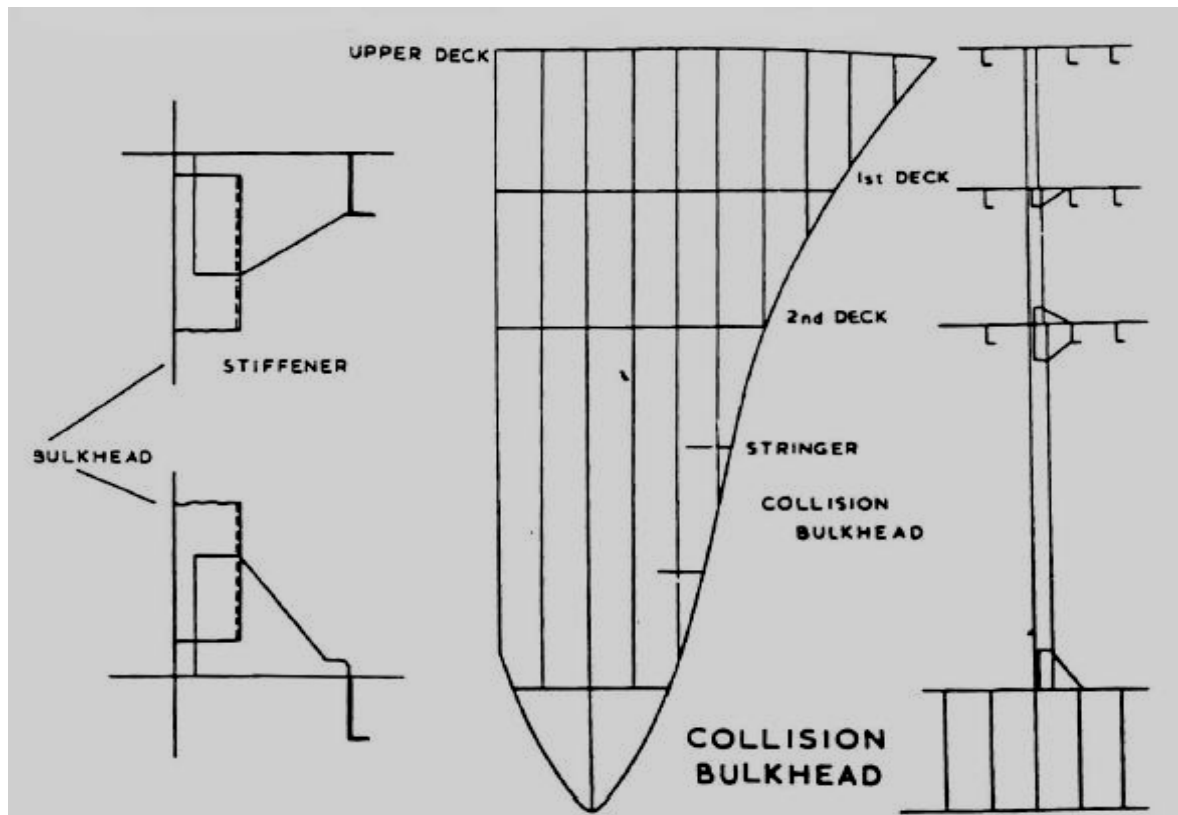


FIGURE 18.2 Corrugated watertight bulkhead





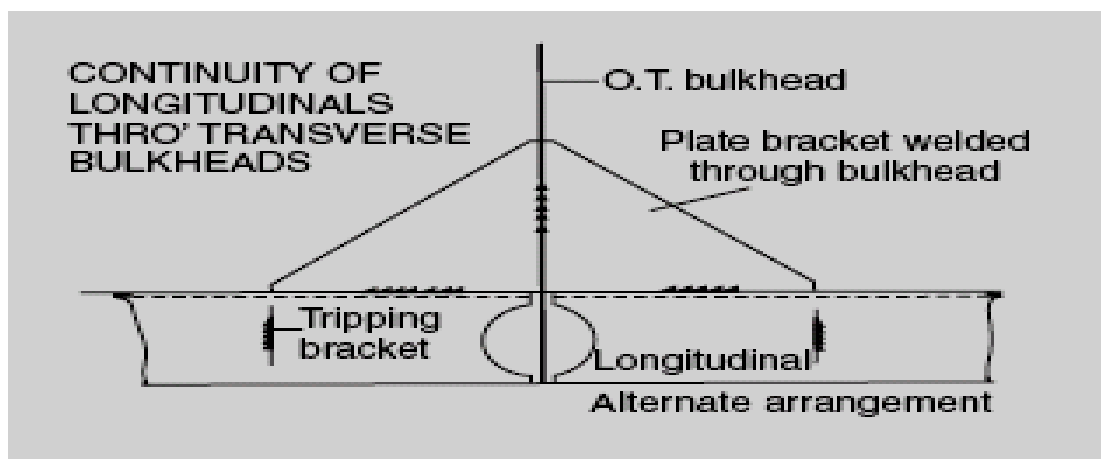




### 3.4 Longitudinal passing through bulkhead

Where frames or beams pass through a watertight deck or bulkhead, such deck or bulkhead shall be made structurally watertight without the use of wood or cement. (SOLAS, CH.II-I, Reg-14)

An important feature of the longitudinal framing is that continuity of strength is maintained, particularly at the bulkheads forming the ends of the tanks. The bottom and deck longitudinal being continuous through the bulkhead where the ship length is excessive (over 190m), unless an alternative arrangement is permitted by the classification society. In this case longitudinal frames and beams may be cut at transverse bulkhead and attached to them by brackets.



### 3.5 Regulations regarding openings in a watertight bulkhead

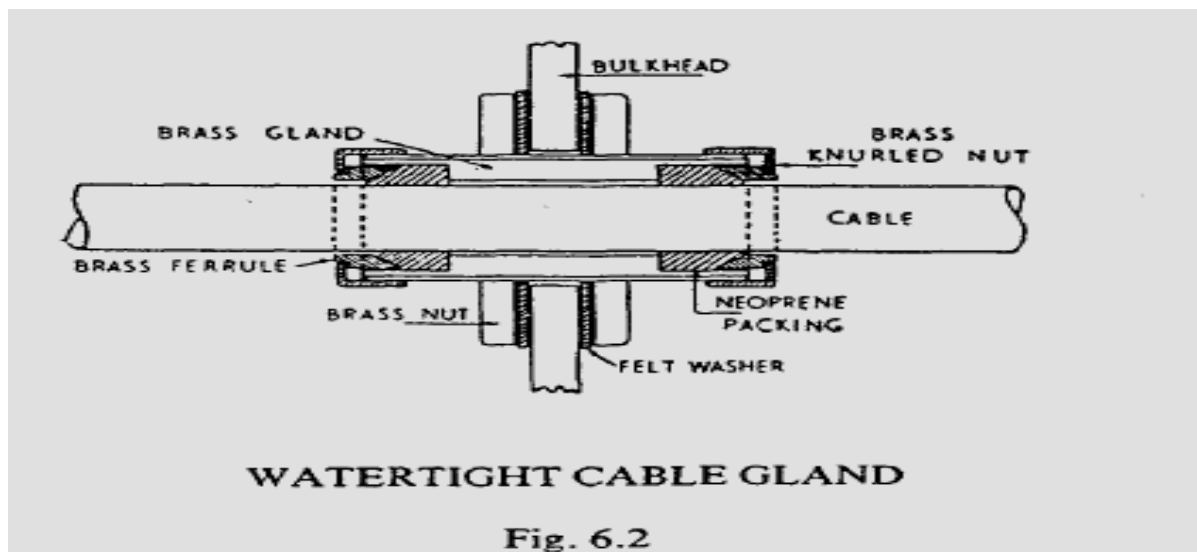
Passage of piping and ventilation trunks on bulkheads must be avoided, however if required, pipes must be flanged, and a WT shutter provided for trunks. Pipes piercing Collision Bulkheads in cargo ships (*below margin line in passenger ships, only one piercing allowed*) are to be fitted with suitable valves operable from above the freeboard deck and with valve chest secured at bulkhead inside the forepeak tank. No manholes, doors etc are allowed in this bulkhead.

Pipes passing through bulkheads are either welded, or fastened to the bulkhead by studs or bolts screwed through tapped holes in the plating. They must not be secured by ordinary bolts passing through clear holes in the plating. Number of openings in W/T subdivisions is to be kept to a minimum.

When pipes or electrical cables pass through a bulkhead the integrity of the bulkhead must be maintained, Fig.6.2 shows a bulkhead fitting in the form of a water tight gland for an electrical cable.

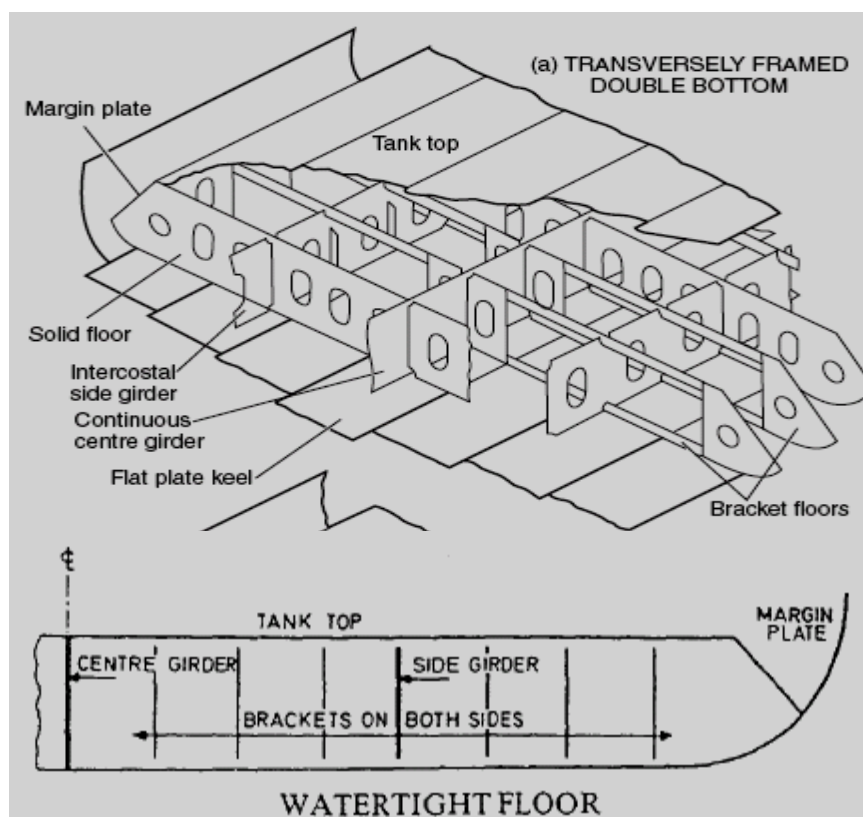






### 3.6 Watertight floors

Cellular double bottom main structure are consist of bracket floors and plate (solid ) floors; the bracket floors middle part of the plate is omitted and replaced by frame bar and reverse bar with the bracket at either end. The plate floors consist of a plate, running transversely from the center girder to the margin plate on each side of the ship. These have lighting holes in them unless they are to be watertight. Watertight plate floors must be fitted under or near bulkheads and if the depth of the center girder exceeds 915mm, they must have vertical stiffeners on them.



### 3.7 Oil tight Bulkheads (Oil tankers construction)

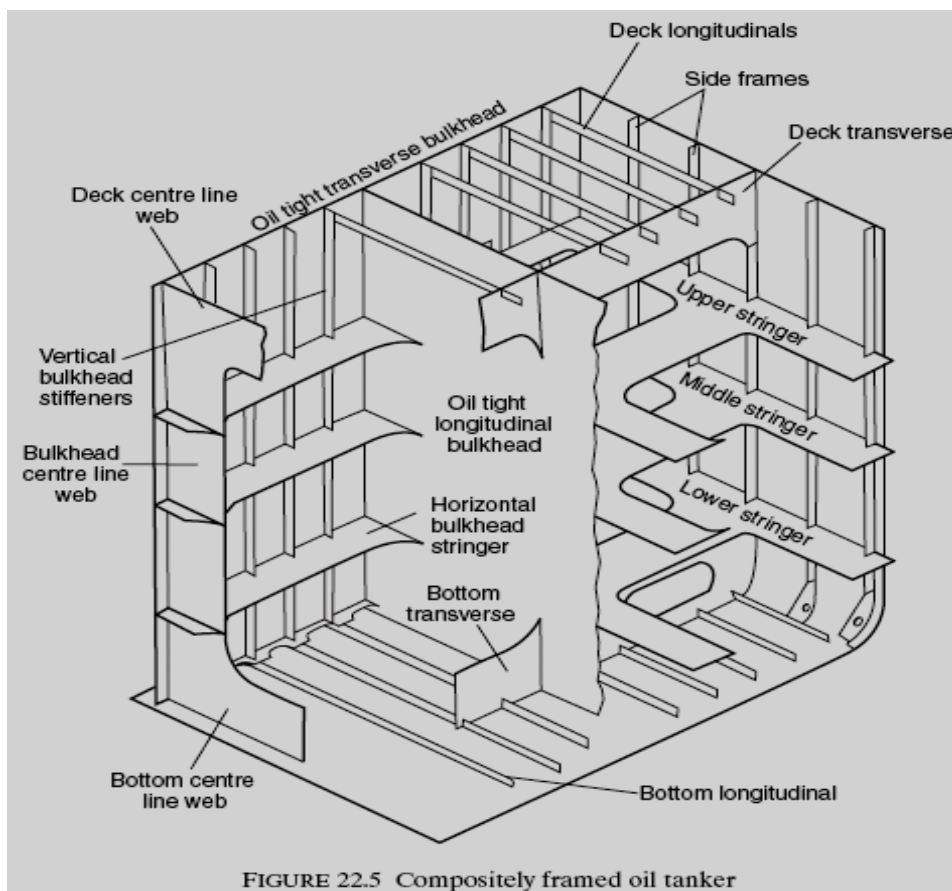
Transverse bulkheads; must not be spaced more than 0.2 of the ship's length apart. If the length of any tank is more than 0.1 of the ship's length, or 15m, a perforated bulkhead must

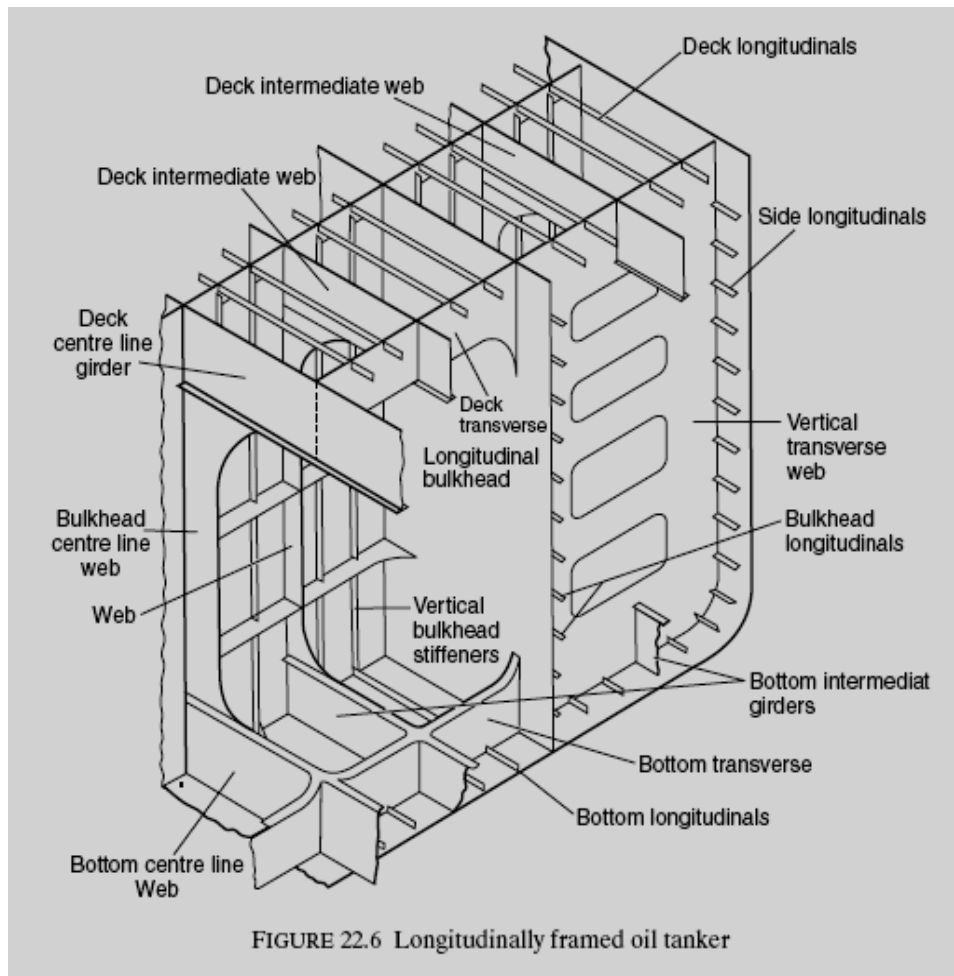


be fitted, about midway between the transverse oil tight bulkheads. The purpose of this wash bulkhead is to give extra transverse strength and to reduce any fore and aft movement of oil in the tank.

The construction of the transverse bulkheads is similar to that of longitudinal bulkheads. If they are corrugated, the corrugation may run either vertically or horizontally and they must have stiffening webs, running at right angles to the corrugations. Vertical webs must be fitted on all transverse bulkheads in the way of the center girder, and similar webs are often fitted at side girders.

Longitudinal bulkheads; may be plane or corrugated. On plane bulkheads the structure is very similar to that on the ship's side. The stiffeners run the same way as the side framing, i.e horizontal stiffeners with longitudinal frames, or vertical stiffeners with transverse frames, and they are attached by brackets at their ends. When side transverses are fitted, there must be vertical webs on the bulkheads. If side stringers are required at the ship's side, horizontal girders are attached to the bulkhead at the same level i.e the structure on the bulkhead is similar to that on the ships side.





### 3.8 Testing of W/T Bulkheads/Tanks

Bulkheads: Hose tested, unless they form boundary of a tank subjected to head of liquid.

Collision Bulkheads and Aft Peak Bulkheads: If not used as tanks, tested by filling with water up to the load waterline or maximum head in case of damage.

If used as tanks, tested by subjecting to water head to which they might be in service (i.e. top of air pipe)

Deep tanks: Tested by subjecting to water head to which they might be in service (ie top of air pipe) - not less than 2.5m above crown of the tank

DB tanks: Tested to max water head in service (top of air pipe), alternatively by air testing.

The forepeak tank: shall be tested to a pressure due to the maximum head of water it might have to sustain in the event of damage to the ship but at least the pressure due to a head of water up to the margin line.



## Sample questions

Q-1 A- Sketch & describe the type, location & construction of collision bulkhead.

B- Sketch the method of fitting the pipe & maintenance of water tightness. Explain testing of collision bulkhead.

Q-2 A- Discuss the function and number of transverse bulkheads in a cargo ship.

B- Draw a transverse watertight bulkhead showing the stiffeners, and in a cross section illustrate the stiffen connection.

Q-3 A- Explain by diagram how longitudinal pass the bulkhead and how the water tightness is maintained.

B- Describe the test required for tightness of water tight door.

Q-4 Define the bulkhead, types, plates' form, number & express the class rules regarding the collision bulkhead.

Q-5 A- Sketch a wash bulkhead and state its application

B- What is water tight floor, its function and its test

C- What is collision bulkhead regulation regarding spacing & testing.

Q-6 Draw the plain view and elevation of watertight bulk-Head and describe the methods of testing them.

Q-7 a-Explain by the diagram how pipes pass the bulkhead & how Water tightness is maintained.

b-Describe the tests required for tightness of watertight doors.

Q-8 a) What are the functions of water tight doors?

b) What are the structural requirements of the water tight doors fitted below water line?

c) What safety features are required for water tight doors fitted below water Line?

d) Why a swinging hinged type water tight door is not allowed below water Line?

Q-9 Draw a neat sketch of an outward side, swinging shell door and briefly explain it?



## CHAPTER-4 WATERTIGHT & WEATHERTIGHT DOORS

Watertight: in relation to a structure in a ship, means capable of preventing the passage of water through the structure in any direction under a head of water up to the margin line of the ship.

Weather tight: in relation to a structure means, capable of preventing the passage of sea water through the structure in ordinary sea conditions.

### 4.1 Watertight/ Weathertight doors Types and function

#### 4.1.1 The functions of Watertight / Weathertight door are:

- 1- To maintain the efficiency of a W/T bulkhead, it is desirable that it remains intact.
- 2- To provide access between compartments on either side of a watertight bulkhead a watertight door is fitted.

Examples: In cargo ship; access from E/R to shaft tunnel. In passenger ship, to allow passengers to pass between one point of the accommodation and other.

#### Watertight doors- general requirements:

The doors are fitted to open the following:

- In bulkheads at end of superstructure.
- In deck house or companion way protecting openings leading into enclosed superstructure or to spaces below the freeboard deck.
- In deck houses on top of deckhouses to protect openings leading to spaces below freeboard deck.

The doors are to be steel permanently fitted & strongly attached, they are to be framed & stiffened so that the whole structure equivalent strength to the bulkhead & watertight closed.

The doors are to be gasketed & secured by the permanently attached clamping devices. The doors should open outwards & be operable from both sides.

In other locations' doors have similar design but are reduced specification may be used i.e. Sliding type doors. Alternatively hard wood doors may be used in other locations not less than 50 mm thick.

Direct access from freeboard deck to the machinery spaces is not permitted on ship types A, B 100, B 60 freeboard. However doors may be fitted to exposed machinery cases on these



ships providing lead to space of equivalent strength, to casing with second weather tight doors.

#### Height of door seals

Door seals in position 1 generally not less than 600mm ,door in position 2 generally not less than 380mm .the internal doors fitted in e/r casing not less than 230mm ,seal height may have to be increased on ship's types a,b 100,b 60 where necessary.

### **4.1.2 Categories of watertight doors**

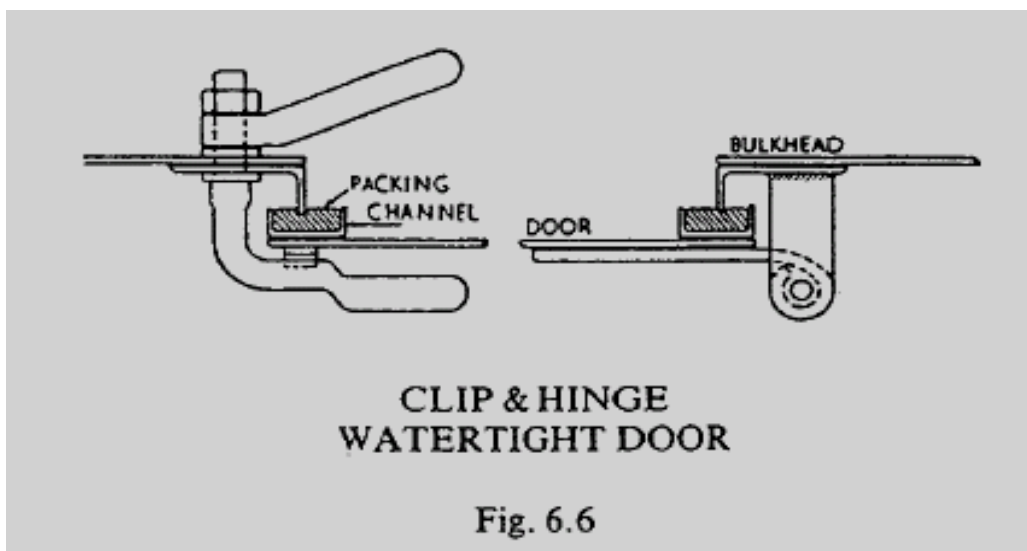
Class-1 Hinged doors

Class-2 Hand operated sliding doors

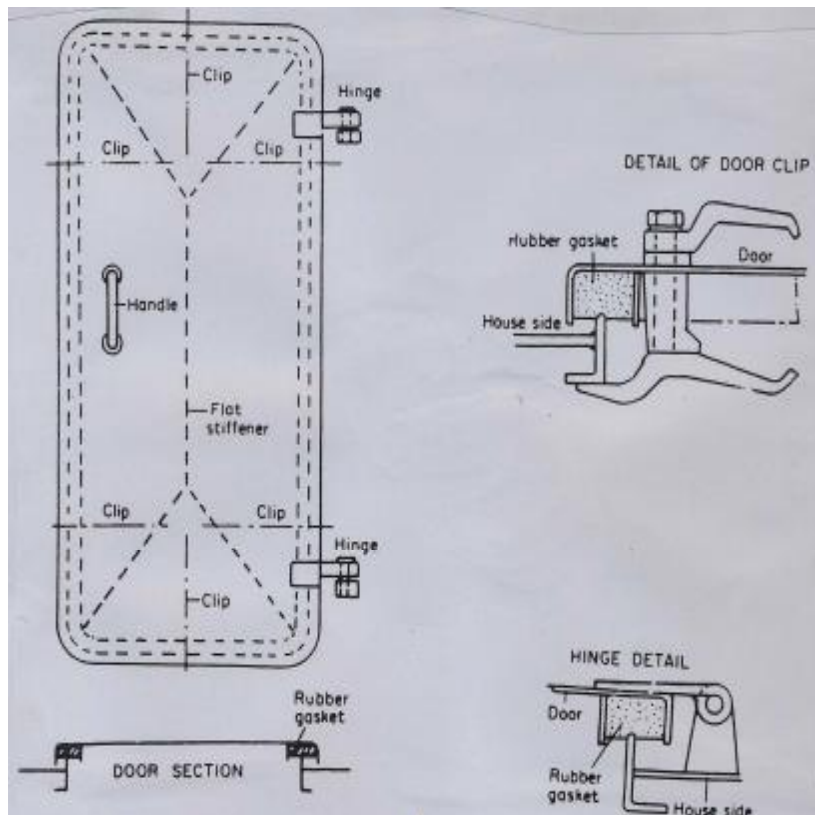
Class-3 Sliding doors, hand / power operated

#### 4.1.2.1 Hinged watertight doors

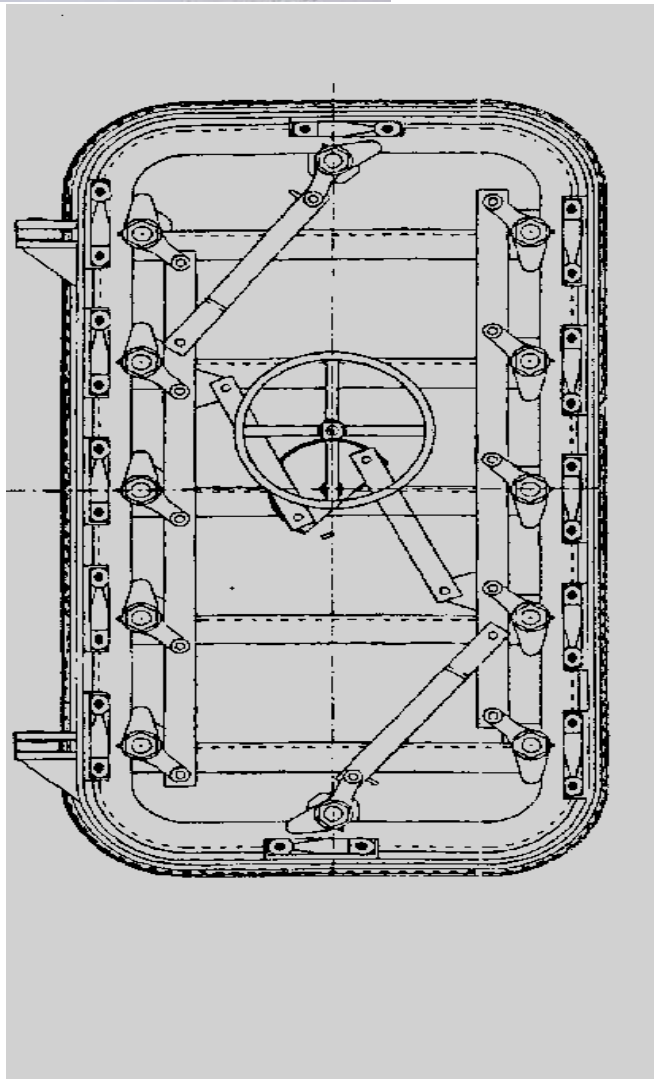
Hinged watertight doors may be fitted to watertight bulkheads in passenger ships, above decks which are 2.2 m or more above the load waterline. Similar doors are fitted in cargo ships to weather deck openings which are required to be watertight. The doors are secured by clips which may be fitted to the door or to the frame. The clips are forced against brass wedges. The hinges must be fitted with gunmetal pins. Some suitable packing is fitted round the door to ensure that it is watertight. Fig. 6.6 shows the hinge and clip for a hinged door, six clips being fitted to the frame.







**High pressure quick acting watertight door.**



#### 4.1.2.2 Hand operated sliding doors

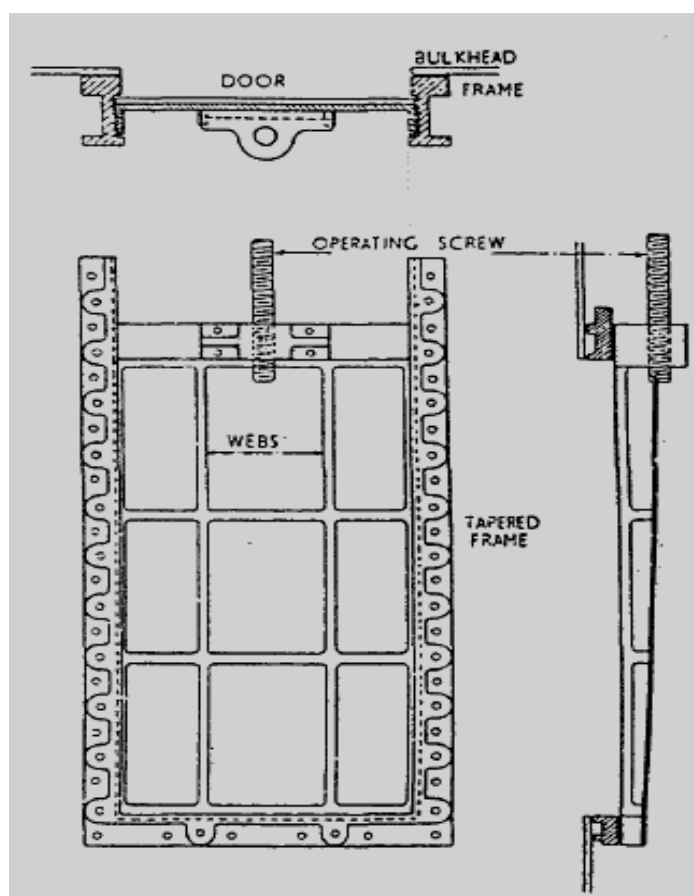
These types of doors have either horizontal or vertical motion. Hand operating mechanism to be above bulkhead deck. The time needed to close the door, when in upright position by hand gear is not to exceed 90 seconds.

#### 4.1.2.3 Sliding doors, hand / power operated:

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control Position showing whether the doors are open or closed and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimizing the effect of control system failure. Each power-operated sliding watertight door shall be provided with an individual hand-operated mechanism. It shall be possible to open and close the door by hand at the door itself from both sides. (SOLAS Ch II-I Reg 25.9)

#### Sliding doors types and features

The doors may be mild steel, cast steel or cast iron, and either vertical or horizontal sliding, the choice being usually related to the position of any fittings on the bulkhead. The means of closing the doors must be positive, *i.e.*, they must not rely on gravity or a dropping weight. Vertical sliding doors are closed by means of a vertical screw thread which turns in a gunmetal nut secured to the door. The screw is turned by a spindle which extends above the *bulkhead* deck, fitted with a crank handle allowing complete circular motion. A similar crank must be fitted at the door. The door



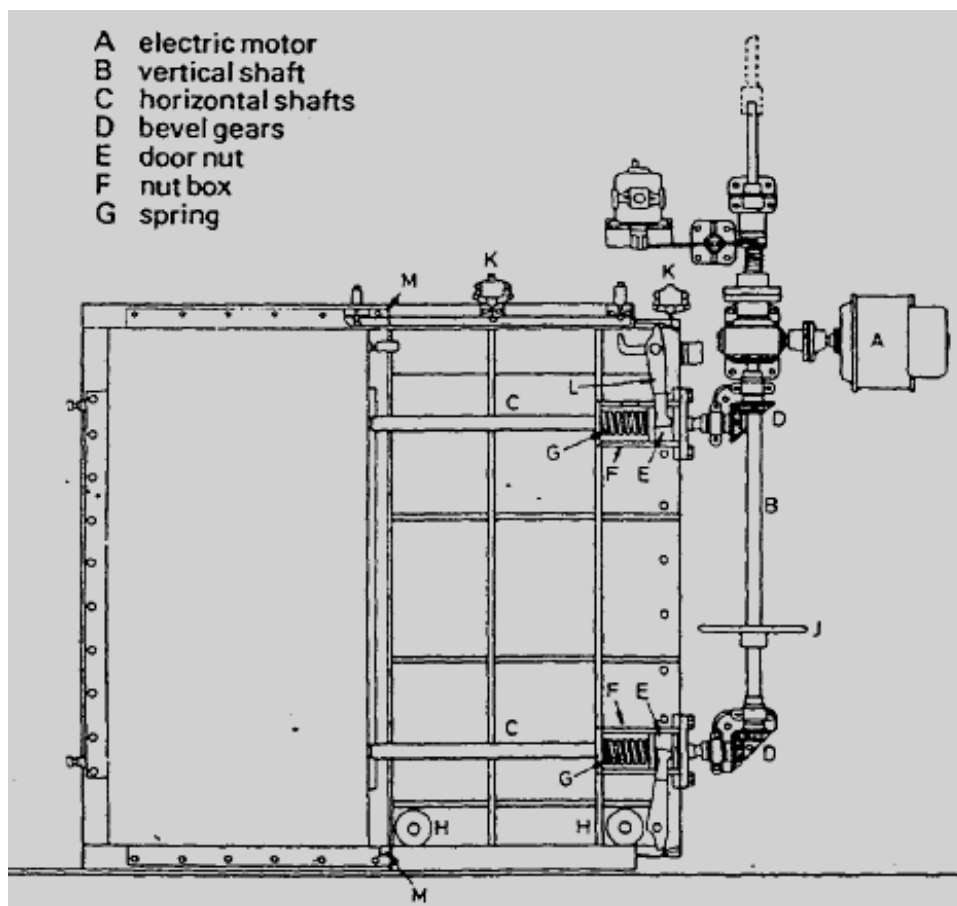
runs in vertical grooves which are tapered towards the bottom, the door having similar taper,





so that a tight bearing fit is obtained when the door is closed. Brass facing strips are fitted to both the door and the frame. There must be no groove at the bottom of the door to collect dirt which would prevent the door fully closing. An indicator must be fitted at the control position above the *bulkhead* deck, showing whether the door is open or closed.

A horizontal sliding door is shown in below figure. It is operated by means of an electric motor A which turns a vertical shaft B. Near the top and bottom of the door, horizontal screw shafts C are turned by the vertical shaft through the bevel gears D. The door nut E moves along the screw shaft within the nut box F until any *slack* is taken up or the spring G is fully compressed, after which the door moves along its wedge-shaped guides on rollers H.



Some door systems are hydraulically-operated, having a pumping plant which consists of two units. Each unit is capable of operating all the watertight doors in a passenger ship, the electric motor being connected to an emergency power source. The doors may be closed at the door position or from a control point. If closed from the control point they may be opened from a local position, switches being fitted on both sides of the bulkhead, but close automatically when the switch is released.



**Sliding watertight doors- control requirements;****Mode of Control**

Control system should give efficient operation but reduce risk of injury to personnel to a minimum. Central control to have two positions - 'Local Control' and 'Doors Closed'

'Local Control' for normal use.

'Doors Closed' for emergency or drill use, because of risk of injury. It must be preceded by an adequate warning signal. Door must automatically shut if opened locally, alarm to sound until door has shut.

**Door operation**

Doors to have two sources of power. Hydraulic fluids to be non-freezing. Door control to be operable from both sides of the door and power control within reach of the doorway.

**Speed of operation**

All power operated doors must be capable of being closed from the remote position within one minute. When being closed it must be accompanied by an audible alarm.

Doors must be closed promptly in an emergency to prevent progressive flooding – potentially very hazardous, especially Ro-Ro ships.

Doors should close at a uniform rate in not less than 20 seconds, but not more than 40 seconds when the ship is upright.

**Watertight door general features:**

- Where a doorway is cut in the lower part of a W.T.B care must be taken to maintain the strength of the bulkhead.
- The opening is to be framed and reinforced, if the vertical stiffeners are cut in way of the opening.
- Number of openings are to be kept to a minimum and small, compatible with design and as required for the safe working of the ship.( 1.4m x 0.75m is usual)
- Stiffener scantling to be increased on either side of large opening to get equivalent strength of un-pierced bulkhead.
- Below the water line; W.T.D are Mild steel, cast steel or cast iron, vertical or horizontal sliding type.
- Sliding doors to be closed against an adverse list of 15°.
- Door controls to be kept as close to the bulkhead as practicable and position above the bulkhead deck.
- Power operated doors must have indicators at remote position (bulkhead deck or



Navigation bridge)

- Simultaneous closure from a central console, to be closed in 60s when ship upright. (sliding type)
- Doors that cannot be controlled from a central position must be closed before the voyage commences, log entries to be made.
- Sliding doors shall have both power and manual controls, both from a central control position and on either side of the door.
- Alarms when closed by power remotely (sliding)
- Uniform rate of closure, in upright position between 20 & 40 seconds.
- To be supplied by an emergency source of power.
- Power operated doors can have either a centralised hydraulic system, an independent hydraulic system or an electrical system.
- Single electrical failure should not result in the closed door opening

#### **4.2 Watertight doors door types**

Type A – a door which may be left open.

Type B – a door which should be closed it may remain open only whilst personnel are working in the adjacent compartment

Type C – a door which should be closed. It may be opened for sufficient time to permit through passage.

All doors must be closed in a potentially hazardous situation except for the passage of personnel.

#### **4.3 Watertight door testing**

Initial test, in passenger ships and cargo ships each watertight door shall be tested by water pressure to a head up to the bulkhead deck or freeboard deck respectively. The test shall be made before the ship is put into service, either before or after the door is fitted. (SOLAS Ch II-I, Reg.18) After fitting, Passenger ships tested to a head of pressure to the bulkhead deck, others given a hose test.

#### **4.4 Operations, Inspections & Drills Involving Watertight Doors**

All watertight doors fitted in the main transverse bulkheads, in use at sea, must be operated daily. All watertight doors and their mechanisms, indicators & valves, necessary to make a compartment watertight, must be inspected at sea once a week. Drills for the operating of



watertight doors, side scuttles, valves & closing mechanisms must be held weekly. Written instructions must be available. Records of operations, inspections & drills are to be entered in the deck/Engine log book along with record of any defects found.

#### **4.5 Openings in watertight bulkheads** (Extracted from SOLAS CH-II.I)

##### Regulation 25-9 Openings in watertight bulkheads and internal decks in cargo ships

The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

##### Regulation 25-10 External openings in cargo ships

1. All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.
2. External openings required to be watertight in accordance with paragraph 1 shall be of sufficient strength and, except for cargo hatch covers, shall be fitted with indicators on the bridge.
3. Openings in the shell plating below the deck limiting the vertical extent of damage shall be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, they shall be fitted with a device which prevents unauthorized opening.
4. Notwithstanding the requirements of paragraph 3, the Administration may authorize that particular doors may be opened at the discretion of the master, if necessary for the operation of the ship and provided that the safety of the ship is not impaired.
5. Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings shall be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

##### Regulation 15 Openings in watertight bulkheads in passenger ships

1. The number of openings in watertight bulkheads shall be reduced to the minimum compatible with the design and proper working of the ship; satisfactory means shall be provided for closing these openings.

3.1 No doors, manholes, or access openings are permitted:



3.1.1 In the collision bulkhead below the margin line;

3.1.2 In watertight transverse bulkheads dividing a cargo space from an adjoining cargo space or from a permanent or reserve bunker, except as provided in paragraph 10.1 and in regulation 16.

10.1 If the Administration is satisfied that such doors are essential, watertight doors of satisfactory construction may be fitted in watertight bulkheads dividing cargo between deck spaces. Such doors may be hinged, rolling or sliding doors but shall not be remotely controlled. They shall be fitted at the highest level and as far from the shell plating as practicable, but in no case shall the outboard vertical edges be situated at a distance from the shell plating which is less than one fifth of the breadth of the ship, as defined in regulation 2, such distance being measured at right angles to the centerline at the level of the deepest subdivision load line.

Regulation 16 (Passenger ships carrying goods vehicles and accompanying personnel)

3.2 The collision bulkhead may be pierced below the margin line by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a screw down valve capable of being operated from above the bulkhead deck, the valve chest being secured inside the forepeak to the collision bulkhead. The Administration may, however, authorize the fitting of this valve on the after side of the collision bulkhead provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space.

## **4.6 Openings in the shell plating**

1. The number of openings in the shell plating shall be reduced to the minimum compatible with the design and proper working of the ship.

2. The arrangement and efficiency of the means for closing any opening in the shell plating shall be consistent with its intended purpose and the position in which it is fitted and generally to the satisfaction of the Administration.

3.1 Subject to the requirements of the International Convention on Load Lines in force, no side scuttle shall be fitted in such a position that its sill is below a line drawn parallel to the bulkhead deck at side and having its lowest point 2.5% of the breadth of the ship above the deepest subdivision load line, or 500 mm, whichever is the greater.

3.2 All side scuttles the sills of which are below the margin line, as permitted by paragraph



3.1 shall be of such construction as will effectively prevent any person opening them without the consent of the master of the ship. (SOLAS Ch II-I, Reg.17)

#### 4.7 Cargo Doors (side doors)

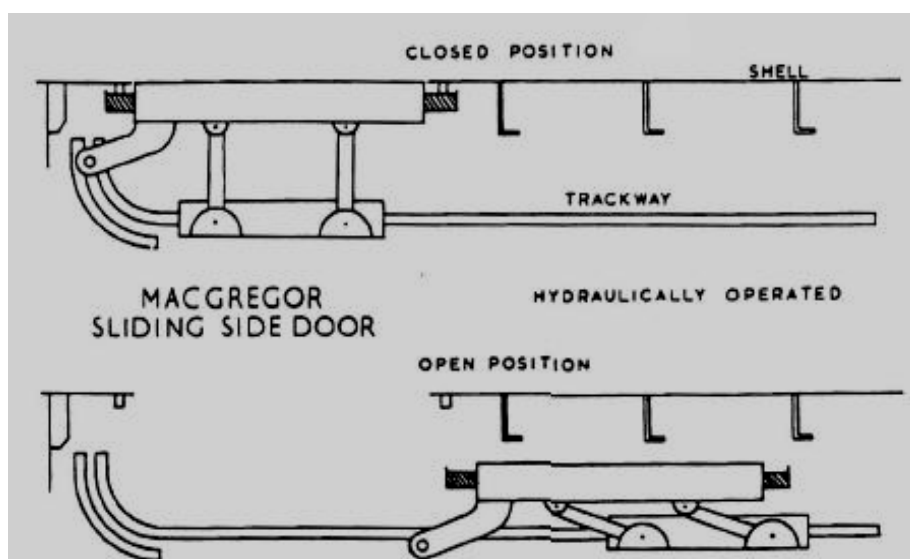
Cargo doors are fitted in certain trades to provide access to between deck spaces, i.e. direct loading by fork lift truck from the quay into the tween deck. Openings are cut into the shell plating and arrangements must be made to maintain the strength, particularly in a longitudinal direction. The corners of all openings should be well rounded to avoid stress concentrations.

(1) A cargo port, manually operated, secured by closely spaced dogs or bolts. This arrangement is typical of the type fitted to facilitate the loading of stores, etc.

(2) A hydraulically operated sliding door shown in the open and closed positions. This type is simple and fast to operate and is self closing since the door is forced against the perimeter of the opening due to the eccentric path of its guide rollers.

(3) A swing door.

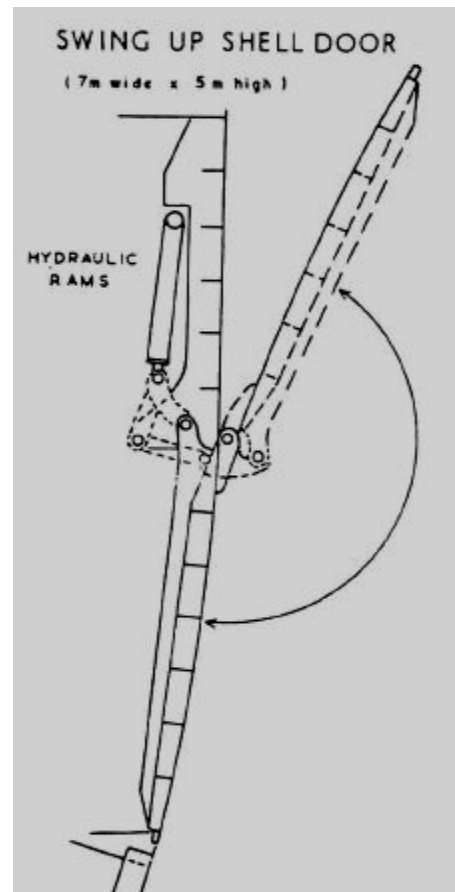
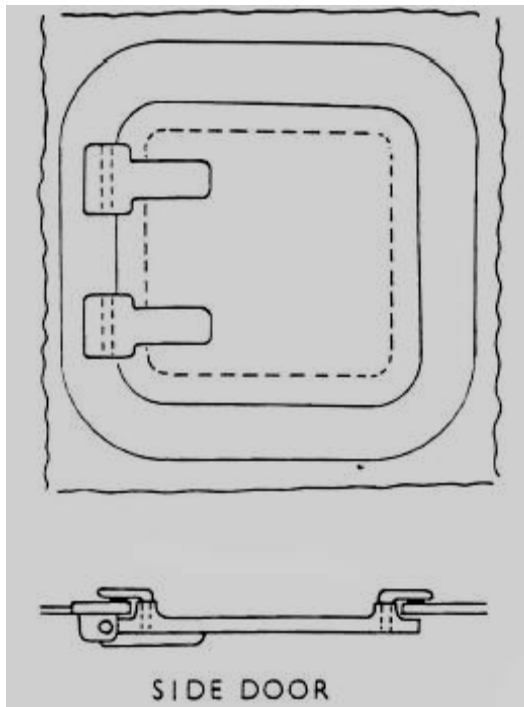
This type of door may be fitted at the sides of the vessel to give access to tween deck or at the stern to give access for vehicles i.e. Ro Ro Vessels. In the latter case the ramps will be a separate piece of equipment.



Side doors may be found in both general cargo and RO-RO ships, they are generally additional to the main cargo access. The design depends on type of cargo, the method of handling and distance between quay and ship.

Openings must have well rounded corners with heavy inserted plates in addition. Served frames land on a carling which carries their loads to deep transverse frames. The doors must be adequately stiffened itself and have the watertight integrity of the surrounding structure. The lower edges must be 50mm above the highest load line.





#### Inboard opening doors

This slides longitudinally to lie along the ship side inside space. It may be driven by an electric motor connected to a rack pinion and itself closing by means of guide forcing the door against a frame. It may then be cleated manually. These are small and used as store door etc, they may always be opened and closed in port.

#### The outboard swinging side door

The door is hydraulically operated by means of a piston attached by a flexible linkage to the deep plate hinge. It stows alongside the hull and requires only the length of the hinged for space in which to swing. A rod attached to one edge of the door at the top keeps it parallel. The door may be cleated hydraulically by means of dogs fitted on the inside of the door and driven by an actuator. Larger opening can be secured by this type and even larger access can be achieved by fitting in pairs.





## CHAPTER-5 CORROSION AND ITS PREVENTION

### 5.1 Definitions

5.1.1 Corrosion; is the chemical or electrochemical reaction between a material, usually a metal and its environment that produces a deterioration of material and its properties, usually an oxide is formed.

5.1.2 Rust; is a visible corrosion product consisting of hydrated oxides of iron and is formed on steel surfaces exposed to moist atmospheric conditions.

5.1.3 Scale; is surface oxidation, consisting of partially adherent layers of corrosion products, left on metals by heating or casting in air or in other oxidizing atmospheres and is the product of the corrosion process of steel with a porous surface layer or flakes, in volume greater than the metal from which it was formed.

5.1.4 Abrasion; is the removal of material by mechanical, i.e. rubbing or frictional, means.

5.1.5 Extensive Corrosion; is an extent of corrosion consisting of hard and/or loose scale, including pitting, over 70% or more of the area under consideration, accompanied by evidence of thickness diminution.

5.1.6 Excessive Corrosion; is an extent of corrosion that exceeds the Allowable Corrosion.

5.1.7 Substantial Corrosion; is an extent of corrosion such that assessment of corrosion pattern indicates wastage in excess of 75% of allowable corrosion, but within allowable corrosion limits.

5.1.8 Allowable Corrosion; or Wastage Limit is the acceptable thickness diminution of structural elements.

5.1.9 Erosion; is the physical removal of material from a surface by mechanical means such as e.g. flowing liquid and it may be accelerated by corrosion

### 5.2 Types of corrosion

Corrosion is the wasting away of a material due to its tendency to return to its natural state, which, in the case of a metal, is in the form of an oxide. If a metal or alloy is left exposed to a damp atmosphere, an oxide will form on the surface. If this layer is insoluble, it forms a protective layer which prevents any further corrosion. Copper and aluminum are two such metals. If, on the other hand, the layer is soluble, as in the case of iron, the oxidation continues, together with the erosion of the material.



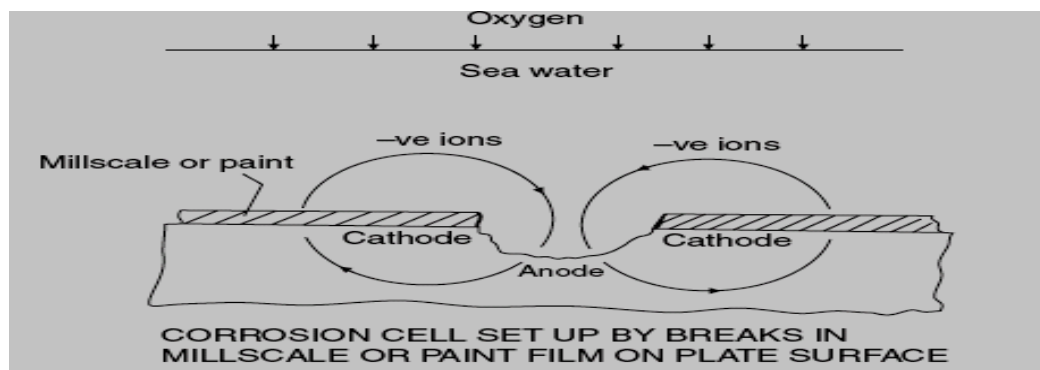
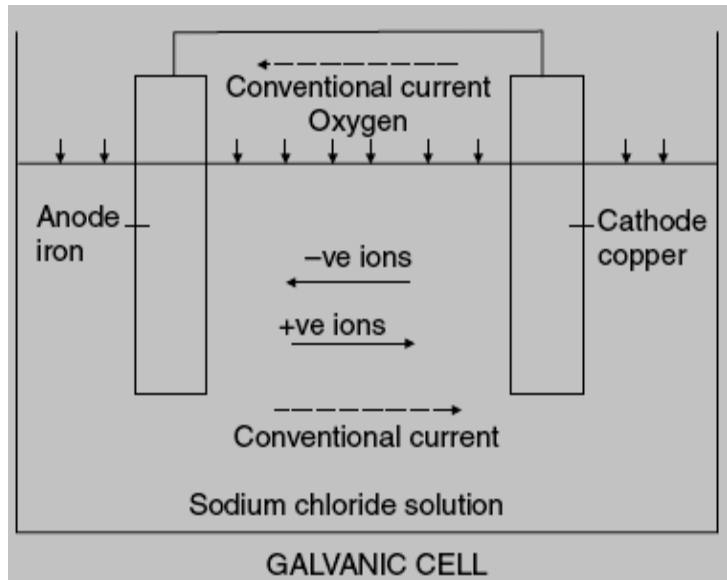


### 5.2.1 Electro-Chemical Corrosion

This is the oxidising (or rusting) of unprotected iron/steel by electro-chemical reaction when submerged in sea-water. Primarily a Corrosion Cell is formed between two metal surfaces (not necessarily different metals) in a solution of salt water (the 'electrolyte'), when connected externally. A current will flow from one metal (the 'anode') to the other (the 'cathode') as a result of a potential difference between them. This current flow results in metal being removed from the 'anode', whilst the 'cathode' is protected.

**Anode** is the positively charged metal surface and the corroding part of an electrochemical corrosion cell at which the oxidation or loss of electrons occurs. (Sacrificial anode or impressed current anode)

**Cathode** is the negatively charged metal surface and the non-corroding or protected part of an electrochemical corrosion cell.



Definition by class: Electrochemical Corrosion is corrosion associated with the passage of an electric current. If the current is produced by the system itself it is called Galvanic Corrosion and if it results from an impressed current it is called Electrolytic Corrosion.

#### Corrosion between two areas of same metal

Steel plate, is not perfectly homogeneous and will therefore have anodic and cathodic areas. Corrosion may therefore occur when such a plate is immersed in an electrolyte such as sea water or even exposed to air and moisture. The majority of the corrosion of ships is due to this electrolytic process.



**Galvanic series:** Common shipbuilding metals may be arranged to show, relatively, which one would become an anode (or cathode) when placed in sea-water

**Noble (cathodic or protected) end**

Platinum, gold

Silver

Titanium

Stainless steels, passive

Nickel, passive

High duty bronzes

Copper

Nickel, active

Millscale

Naval brass

Lead, tin

Stainless steels, active

Iron, steel, cast iron

Aluminium alloys

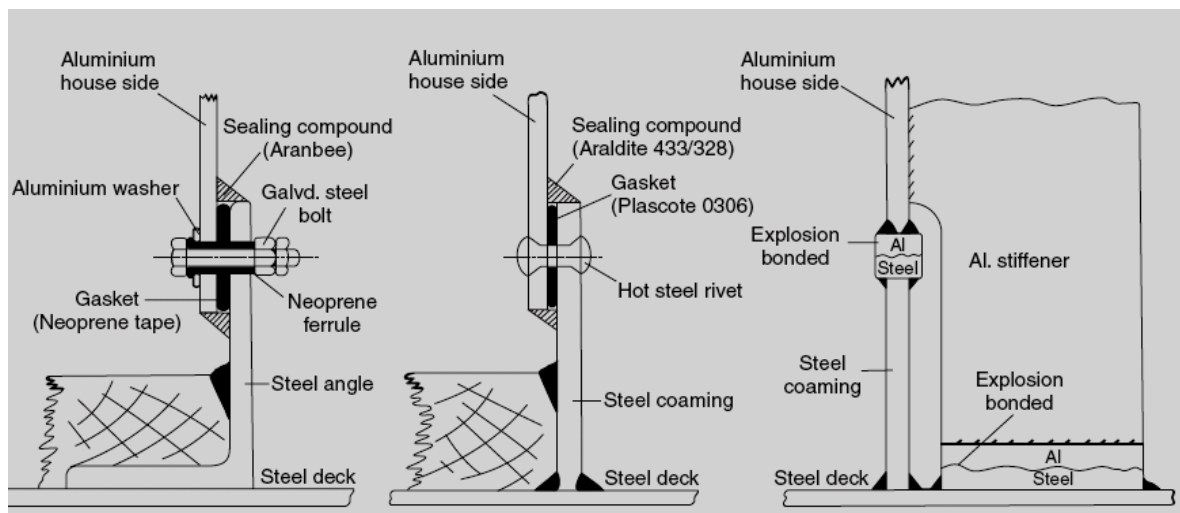
Aluminium

Zinc

Magnesium

**Ignoble (anodic or corroding) end**

Metals of the world are arranged in series, those on top are considered cathodic (noble) those at the bottom are anodic (ignoble). If any two metals are connected externally in an electrolyte – the metal at the lower end of the series will waste. To protect steel using the sacrificial anode system – metals that are anodic to steel are welded to the steel hull so that these waste – e.g. Mg and Zn



### 5.2.2 Bi-Metallic (Galvanic) Corrosion

This is a name given to corrosion occurring when two different metals form part of a corrosion cell i.e galvanic corrosion, the metal which is relatively 'lower' (or less 'noble') in the galvanic series will form the anode tend to corrode, whilst the one which is relatively



‘higher’ (or more ‘noble’) will form the cathode and be protected. There are many possibilities of such ‘cells’ forming on board eg. Aluminum & steel in close proximity in the presence of sea water.

Definition by class: Galvanic Corrosion is electrochemical accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte.

Where aluminum superstructures are introduced, the attachment to the steel hull and the fitting of steel equipment to the superstructure require special attention. This latter problem is overcome by insulating the two metals and preventing the ingress of water as illustrated in above Figure. A further development is the use of explosion bonded aluminum/steel transition joints also illustrated. These joints are free of any crevices, the exposed aluminum to steel interface being readily protected by paint.

### **5.2.3 Stress Corrosion**

Accelerated corrosion may occur in locations where the metal is ‘stressed’ (either inherent or due to ‘working’ in the seaway) leading to fatigue and minute cracks – with corrosion cells forming at these cracks. The combined action of stress and the consequent corrosion may have a considerable effect on the metal. Places liable to such localized corrosion are:

Cold flanged brackets, Welded joints, -Aluminum/magnesium alloy rivets

Definition by class: Stress Corrosion is the preferential attack of areas under tensile stress in a corrosive environment, where such an environment alone would not have caused corrosion. Tensile stresses may be residual stresses from welding or cold working or applied working stresses.

**5.2.4 Pitting corrosion:** corrosion at one spot so localized that eat away the spot and finally perforate the metal.

Definition by class: Pitting Corrosion is local, random scattered corrosion mainly on horizontal surfaces and at structural details where water is trapped, particularly at bottom of tanks. For coated areas the attack produces deep and small diameter pits which may lead to perforation. Pitting of uncoated areas in tanks, as it progresses, forms shallow but very wide scabby patches (e.g. 300 mm in diameter) and the appearance resembles condition of general corrosion.



**5.2.5 Microbiological corrosion:** deterioration of material caused directly or indirectly by bacteria, algae, moulds, fungi single or in combination.

Definition by class: Bacterial Corrosion or Microbially Influenced Corrosion (MIC) is corrosion which is induced or accelerated by the presence of micro organisms.

**5.2.6 Crevice corrosion:** is a localized form of corrosive attack. It occurs at narrow openings or spaces between two metal surfaces or between metal and non-metal surface. A concentration cell forms with the crevice being depleted of oxygen. This differential aeration between the crevice and external surface gives the crevice an anodic character. e.g. flanges, washer, threaded joints, gaskets, O-rings.

How to reduce it:

- 1- Eliminate the crevice from the design.
- 2- Select materials more resistant to crevice corrosion.
- 3- Reduce the aggressiveness of the environment.

Definition by class: Crevice Corrosion is localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity between the metal and surface of another material. It is usually associated with small volumes of stagnant water; within lapped joints, under heads of fastenings, under gaskets and packing, under marine organisms and porous deposits.

### **5.2.7 Deposit corrosion:**

This is a corrosion occurring under or around a discontinuous deposit on a metallic surface. It is due to attack as result of an oxygen concentration cell set up under deposits of organic matter. It is also called poultice corrosion.

### **5.2.8 Erosion**

Essentially it is the loss of metal due to mechanical action; however, it may become associated with electro-chemical corrosion under certain circumstances, namely:

5.2.8.1- Impingement Attack: Air bubbles entrained in flow of water strike metal surface on the hull and 'erode' any protective film, eroded surface becomes anode to the surrounding surface and corrosion occurs. (*corrosion cell*) This effect is greater if the water is warm, Eg. Locations in way of ship's seawater discharges.

5.2.8.2- Cavitations: At certain regions in the flow the local pressures drop below that of the absolute vapour pressure. Vapour cavities, that is areas of partial vacuum, are formed locally,



but when the pressure increases clear of this region the vapour cavities collapse or ‘implode’. This collapse occurs with the release of considerable energy, and if it occurs adjacent to a metal surface damage results. The damage shows itself as pitting which is thought to be predominantly due to the effects of the mechanical damage.

Definition by class: Erosion Corrosion is a combined action involving corrosion and erosion in the presence of a moving corrosive fluid, leading to the accelerated loss of material. Erosion corrosion is characterized by grooves, gullies, waves, valleys etc., usually with directional pattern and with bright surfaces free from corrosion products.

### **5.3 Treatment of Steel**

#### **Mill scale;**

Is a ‘resistant’ iron oxide ( $\text{FeO}$ ) scale formed on steel during hot working processes in air e.g. during hot rolling, heat treatment, hot fabrication etc. May appear like a shiny bluish film on new steel can be removed by weathering, use of mild acids, sand blasting etc. The most effective method of removing mill scale is shot blasting. This system removes 95% to 100% of mill scale, surface rust, dirt etc. and result rough surface for adequate adhesion of the paint.

This scale is insoluble and, if maintained over the whole surface, would reduce corrosion. It is, however, very brittle and does not expand either mechanically or thermally at the same rate as the steel plate. Unless this mill scale is removed before painting, the painted scale will drop off in service, leaving bare steel plate which will corrode rapidly. Not only does the non-uniform mill scale set up corrosion cells, but it may also come away from the surface removing any paint film applied over it.

Definition by class: Mill Scale is thick oxide film formed on wrought-metal products which have been hot-rolled or forged and allowed to cool in air, the term is principally applied to steel on which the oxide is essentially magnetic black oxide.

#### **Treatment of steel in a shipyard (surface preparation / holding primer)**

- 1- Removal of mill scale from new plates (set up corrosion cell and cause paint film to be removed)
- 2- Removal of rust and damaged paint from existing plates
- 3- Ensuring surfaces are clean, free of grease/oils and dry
- 4- Modern paints, such as epoxy & polyurethane require a very clean shot-blasted surface in shipyards steel is given temporary protection during ship building, by use of a ‘holding or shop



primer' (usually low zinc based). It has the following properties:

Non-toxic & dries rapidly, does not give fumes during welding/cutting, Is compatible with other paints.

The most common methods employed to prepare steel surfaces for painting are:

- Blast cleaning; is the most efficient method for preparing the surface.
- Pickling; immersion of the metal in an acid solution, usually hydrochloric or sulphuric acid in order to remove the mill scale and rust from the surface.
- Flame cleaning; useful for cleaning plates under inclement weather conditions, the flame drying out the plate.
- Preparation by hand; by various forms of wire brush is often not very satisfactory, and would only be used where the mill scale has been loosened by weathering, i.e. exposure to atmosphere over a long period.

## **5.4 Methods of Corrosion Control**

**5.4.1 Barrier Protection;** Provided by a protective coating that acts as a barrier between corrosive elements and the metal substrate. The application of barrier or protective coating to isolate the steel (or other metal) from the air or from the seawater electrolyte e.g. Painting or galvanizing.

### 5.4.1.1 Painting

Work done in efficient surface preparation is wasted unless backed up by suitable paint correctly applied. The priming coat is perhaps the most important. This coat must adhere to the plate and, if applied before construction, must be capable of withstanding the wear and tear of everyday working. The subsequent coats must form a hard wearing, watertight cover. The coats of paint must be applied on clean, dry surfaces to be completely effective.

Paints are a mixture of 3 elements, namely:

- The pigment (provides colour & covering capacity, includes any special additives)
- The vehicle or binder (decides consistency, adhesion, ease of application and film quality)
- The solvent or thinner (added to dissolve the vehicle making the paint flow easily & control drying time)



**Paint drying process:**

- 1- When the vehicle consists of solid resinous material dissolved in a volatile solvent, the latter evaporates after application of the paint, leaving a dry film.
- 2- A liquid like linseed oil as a constituent of the vehicle may produce a dry paint film by reacting chemically with the surrounding air.
- 3- A chemical reaction may occur between the constituents of the vehicle after application, to produce a dry paint film. The reactive ingredients may be separated in two containers ('two-pack paints') and mixed before application.

**How paint protect the metal?**

- Prevent attack on the metal covered simply by excluding the corrosive agency.
- The paint is richly pigmented with a metal anodic to the basis metal like zinc dust as sacrificial anode with respect to the steel.
- Protect by certain pigments (red lead, zinc chromate) anodic or cathodic inhibitor.
- Protection against marine vegetables / animal to grow on under water area by Anti Fouling Paint.

**A typical ship painting scheme;**

The painting of the external ship structure is divided into three regions

- below the waterline
- the waterline or boot topping region where immersion is intermittent
- the topsides and superstructure

Below the waterline: Priming coats of corrosion-inhibiting paints, these paints must resist alkaline conditions, suitable paints include, pitch or bitumen types, chlorinated rubber, coal tar/epoxy resin or vinyl resin paints. An antifouling paint applied on top of the corrosion inhibiting paint.

Waterline or boot topping region: Complete paint system of the hull, consisting of a corrosion inhibiting paint and a finishing gloss coat that is resistant to abrasion.

Superstructures: Red-lead or zinc chromate based primers, and a top coat of a white finishing paint (normally). Lead based paints not allowed on aluminium superstructures.



Cargo and ballast tanks; Epoxy resin, vinyl resins or zinc rich coatings are used. High performance two pack coal tar/epoxy, two pack epoxy oxide primer and two pack epoxy high build coating mostly recommended.

Severe corrosion may occur in a ship's cargo tanks as the combined result of carrying liquid cargoes and sea water ballast, with warm or cold sea water cleaning between voyages. This is particularly true of oil tankers. Tankers carrying 'white oil' cargoes suffer more general corrosion than those carrying crude oils which deposit a film on the tank surface providing some protection against corrosion. The latter type may however experience severe local pitting corrosion due to the no uniformity of the deposited film and subsequent corrosion of any bare plate when sea water ballast is carried. Epoxy resin paints are used extensively within these tanks, and vinyl resins and zinc rich coatings may also be used.

**Common 'vehicles' used in corrosion inhibiting paints include:**

- 1-Bituminous or Pitch (bitumen/pitch dissolved in a white spirit solvent)
- 2-Oil based (vegetable drying oils like linseed oil, dehydrated castor oil, not suitable for underwater area.
- 3-Oleo-resinous (natural or artificial resins mixed into drying oils)
- 4-Alkyd-resin (a special oleo-resin - not suitable underwater)
- 5-Chemical resistant, extremely good resistance to sever condition of exposure. (epoxy resins, coal tar /epoxy resin, chlorinated rubber, polyurethane resins, vinyl resins – polyurethane not suitable underwater)

Epoxy resins; produce from petroleum, natural gas- very good adhesion and excellent chemical resistance- good flexibility and toughness- two packs and expensive.

Coal tar /epoxy resin; similar to above but a grade of coal tar pitch is blended with the resin. A formulation of this type combines to some extent the chemical resistance of the epoxy resin with the impermeability of coal tar.

Chlorinated rubber; consists of a solution of plasticized chlorinated rubber, or isomerizes rubber. Isomerizes rubber is produced chemically from natural rubber, and it has the same chemical composition but a different molecular structure. Thick film and are resistance to attack from acid and alkalis.

Polyurethane resins; One /two pack paint is available- properties are: toughness, hardness, gloss, abrasion resistance, as well as chemical and weather resistance. It is not used in under water area, only used on supper structure.

Vinyl resins; obtained by the polymerization of organic compounds containing the vinyl group.





Solid content is low thus dry film is thin and require more coats. Poor adhesion to bare steel so generally applied over pretreatment primer. It is effective for U.W protection of steel.

**Anti-fouling Paints:**

Fouling is the covering up of ship's bottom by green slime, weeds and barnacles. The fouling increases when ship is at rest for long periods or has a slow speed. Anti fouling paints consists of a vehicle with pigments which give body and colour, together with materials toxic to marine vegetable and animal growth. Copper is the toxin normally used in anti-fouling paints. This type of paints works by slowly releasing (or leaching) poison into the sea layers, destroying the fouling causing organisms.

To prolong the useful life of the paint the toxic compounds must dissolve slowly in sea water. Once the release rate falls below a level necessary to prevent settlement of marine organisms the anti-fouling composition is no longer effective. The effective period for traditional compositions was about 12 months. To reduce very high docking costs an A.F.P developed with an effective life up to 24 months in the early 1970s.

Self-polishing A.F.P with longer effective life (5 years) and smooth surface which reduces friction and fuel consumption was developed.

Tributyltin (TBT) based anti-fouling paint, most common in the past, have been banned for use since 1 Jan 2003 as they use to damage to the shell fish & marine environment. IMO deadline was Sep 2008. Currently TBT-free anti-fouling paints may be of two types:

- Biocidal (where a chemical or 'biocide', usually copper oxide, is 'leached' into the seawater layer at a controlled rate to inhibit the growth of fouling organisms for periods ranging from 24 months for self-polishing paints using rosin-based 'binders' to 60 months for self-polishing paints using acrylic polymer-based 'binders')
- Foul Release, where a silicone-based 'non-stick' surface does not allow fouling organisms to adhere to it. To be effective ship is required to have speeds greater than 30kts in coastal waters & over 15kts deep sea. Coating is easily damaged by abrasion and needs regular cleaning.

The International Convention on the Control of Harmful Anti-fouling Systems on Ships, which was adopted on 5 October 2001, will prohibit the use of harmful organotins in anti-fouling paints used on ships and will establish a mechanism to prevent the potential future



use of other harmful substances in anti-fouling systems. Under the terms of the convention, by 1 January 2008 (effective date), ships either:

Shall not bear such compounds on their hulls or external parts or surfaces; or

Shall bear a coating that forms a barrier to such compounds leaching from the underlying non-compliant anti-fouling systems.

**The safety precautions to be taken when using paints:**

- 1- Paints may contain toxic or irritant substances and a paint for which no manufacturer's information is available should not be used.
- 2- Some paints dry by evaporation of the paint's solvent and the process may cause flammable or toxic vapours. All interior and enclosed spaces should be well ventilated while painting is in progress and until the paint has dried.
- 3- Smoking should not be permitted during painting. Naked lights, such as matches, should not be used in spaces until paint has fully dried.
- 4- Great care should be taken when mixing two-pack (two components) paint as a chemical reaction takes place during the mixing which might create heat and fumes.
- 5- Chemical rust removers are corrosive and precautions should be taken to protect eyes and skin.
- 6- Spaces where paint and painting equipment are stored should be well ventilated.

5.4.1.2 Galvanizing

Galvanizing is the process of coating iron or steel with a thin zinc layer, by passing the steel through a molten bath of zinc at a temperature of around 460 °C. When exposed to the atmosphere, pure zinc reacts with oxygen to form zinc oxide, which further reacts with carbon dioxide to form zinc carbonate, a dull grey, fairly strong material that stops further corrosion in many circumstances, protecting the steel below from the elements.

**5.4.2 Cathodic Protection;** Employs protecting one metal by connecting it to another metal that is more anodic, according to the galvanic series. Using 'cathodic protection' to prevent the steel from forming the anode of a corrosion cell eg. Sacrificial zinc anodes.

OR

Impressed current systems (this can be used only in submerged areas, like the ships underwater hull or in ballast tanks). Note: it may be quite common on modern ships to find both the control methods being used to compliment each other.



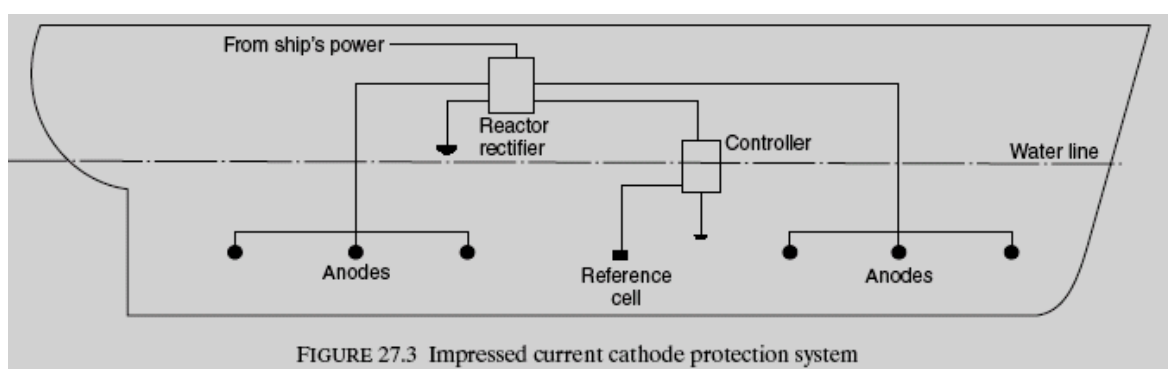
Corrosion can be prevented by this method when metals are immersed in an electrolyte. Small corrosion cells are set up when a metal is immersed in sea water. This is because of a difference in potential between different parts of the metal. This results in current flowing from the high to the low potential points. The metal gets corroded at the low potential point. Cathodic protection operates by providing a reverse current flow to that of the corrosive system. There are two methods of cathodic protection, the sacrificial anode system and the impressed current system.

#### 5.4.2.1 The Sacrificial anode system;

These are metals or alloys that are less noble than the ships steel. They are normally made of Aluminium or zinc, usually alloyed. They are welded to the ships hull by their steel core to give a good electrical connection. These anodes supply the cathodic protection current and are consumed in doing so. They normally have a lifespan of between 3 and 4 years and are replaced in dry dock. Sacrificial anodes are also fitted in ballast tanks. Anodes of magnesium are not allowed on cargo/ballast tanks of tankers as they have a 'spark' hazard. Aluminium alloy anodes are normally fitted on tankers.

#### 5.4.2.2 The impressed current system;

A number of zinc reference anodes are fitted to the hull but insulated from it. It is found that the potential difference between the anode and a fully protected steel hull is about 250 mV. If the measured difference at the electrode exceeds this value, an electric current is passed through a number of long lead-silver alloy anodes attached to, but insulated from, the hull. The protection afforded is more positive than with sacrificial anodes and it is found that the lead-silver anodes do not erode. A current of 7 to 350 mA/m<sup>2</sup> is required depending upon the surface protection and the degree to which the protection has broken down.



This is applicable to the protection of the immersed external hull only. The system comprises of several anodes, reference electrodes and a controller power unit. A reference anode detects the potential difference between it and the ships hull. This is fed to an amplifier controller unit



which amplifies this difference and then compares it with the pre-set potential value. Any change that may be required in the pre-set potential value is then adjusted and the amount of current is fed to the anodes through the reactor rectifier unit. This unit is connected to the ships electrical system. This method ensures that the current that is fed to the anodes is optimum and not too much. When the underwater paintwork deteriorates, higher currents are required for protection. Too high a current can damage the paintwork. A protective shield of epoxy resin is applied for about 1 metre around the anodes to withstand alkaline conditions.

Care is required in their use in port alongside ships or other unprotected steel structures. This system is also used to protect the rudder and propeller from corrosion. The propeller and shafting are electrically grounded to the hull structure with a shaft slip spring. A flexible cable is used to ground the rudder. When electrical continuity is established between these components and the hull, the impressed current system will protect them all.

Typical feature of impressed current system:

- Longer intervals between dry dockings reducing operating costs
- Minimum time and cost for maintenance
- Fully automatic operating giving optimum hull protection
- Better long-term hull protection than sacrificial anode system
- Minimum frictional resistance on the hull
- Constant hull potential monitoring for continuous protection
- Smaller and lighter than any other anode

## **5.5 Enhanced structural protection**

This is a painting system suggested for use in Tankers and Bulk carriers to prolong their life at sea. The painting system is so developed such that key areas (vessels decks, cargo tanks, water ballast tanks, under water hull and topsides) of a vessel can survive uninterrupted service periods without the paint coats being damaged for periods of up to 20 years. Requirements before paint application are :

- 1- Good pre-treatment standards
- 2- Controlled conditions while painting
- 3- Advanced technology
- 4- Experienced supervisors



**5.6 Corrosion & its prevention by good design**

1. Discharges or scuppers must be designed not result dripping water.
2. Proper ventilation should be arranged for underside of enclosed structure to avoid condensation of moisture.
3. Steel decks which covered by wood, can be corroded unless it is suitably protected and the wood is scaled by bitumen coating.
4. All joints must be sealed by suitable filler and any bolt through the woods should have proper washers under nut.
5. Surface of metals to be covered by adequate thickness of paint.
6. Welding can be used to fill small cracks.
7. Welded surface to be suitably prepared for painting.
8. Proper paint to be applied in places where the machinery sets must be fitted.
9. Where the aluminum superstructure is in contact with steel deck transition plate shall be used.
10. Two different metals in contact in the presence of an electrolyte can result corrosion cell. Proper insulation must be made.
11. The atmosphere of E/R is in contact with the heat, moisture, vibration which can result corrosion. The surfaces should be kept water free by good drainage design, insulation of steam pipes and proper ventilation to avoid condensation.
12. Sharp bend to be avoided in piping system. (to avoid erosion)

**5.7 Related Regulations / Convention on Paint**

5.7.1 IMO “Control of Harmful Anti-fouling Systems for Ships.” The convention has been developed to immediately ban the use of Tributyltin (TBT) globally in anti-fouling paints to “protect the marine environment”.

5.7.2 White Lead (Painting) Convention, 1921 is an International Labour Organization Convention. It was established in 1921: Having decided upon the adoption of certain proposals with regard to the prohibition of the use of white lead in painting.

5.7.3 International Ship Recycling Convention, Issues being considered for regulation include controlling the amounts of hazardous materials, including toxic paints used in ship construction and requiring old ships to be broken down in specific ship yards that meet environmental standards.



## **Sample question on corrosion**

Q-1 Explain how the corrosion can be prevented by good design.

Q-2 Explain following types of corrosions:

A) Pitting. B) Crevice corrosion., C) Deposition corrosion , D) Microbiological corrosion.

Q-3 Regarding the marine paint as corrosion preventing measure;

- i) Describe the component of marine paint., Describe 5 types of vehicles.
- ii) Imo new regulation regarding anti-fouling.
- iii) What type of paint is used for under water?

Q-4 Define the corrosion control system used on board Ships and explain one of those methods.

Q-5 Explain:

- i) electro-chemical corrosion (sketch)
- ii) Erosion :
- iii) Crevice corrosion (sketch).
- iv) Deposit corrosion.

Q-6 a) What are the main components of paint?

b) How does the drying process occurs?

c) Explain briefly:

- i) Epoxy resin:
  - ii) Coal tar epoxy resin:
  - iii) Chlorinated rubber:
  - iv) Polyurethane resin:
  - v) zinc-rich paint:
- d) Briefly explain the new IMO regulation regarding application of anti-fouling.

Q-7 a- how corrosion occur in water ballast tank & how it Can be prevented.

b-what are the methods of surface preparation for Painting.



Q-8 A) Discuss how aluminum alloys are utilized in present day ship construction?

B) Show with the aid of sketch how the problem of corrosion is contained when aluminum is attached to steel?

Q-9 i) Explain electro-chemical nature of corrosion.

ii) Explain impress-current system.

Q-10 Show with the aid of sketches that how the bimetallic corrosion occurs.

Q-11 Describe the causes of corrosion in a ship's structure and the methods used to reduce wastage. What parts of the ship are most liable to attack?

Q-12 Give a reason for corrosion in each of the following instances:

(i) Connection between aluminum superstructure and steel deck.

(ii) In crude oil cargo tanks.

(iii) Explain how in each case corrosion can be inhibited.



## CHAPTER-6 CLASSIFICATION, SURVEY & DRY DOCKING

### 6.1 Classification society

A classification society is an organization whose function is to ensure that a ship is soundly constructed and that the standard of construction is maintained. The ship is classified according to the standard of construction and equipment. The cost of insurance of both ship and cargo depends to a great extent upon this classification and it is therefore to the advantage of the ship owner to have a high class ship. It should be noted, however, that the classification societies are independent of the insurance companies.

Some of the major organizations are as follows:

Lloyd's Register of Shipping

American Bureau of Shipping

Bureau Veritas

Det Norske Veritas

Registro Italiano

Teikoku Kaiji Kyokai

Germanischer Lloyds

Classification societies, with their rules and regulations relating to classification, provide a set of standards for sound merchant ship construction which have developed over many years. These rules are based on experience, practical knowledge and considerable research and investigation. The classification societies operate by publishing rules and regulations relating to the structural efficiency and the reliability of propelling machinery and equipment. These rules are a result of years of experience, research and investigation into ship design and construction. They are in fact a set of standards. To be classed e.g. with Lloyd's, approval is necessary for the constructional plans, the materials used and the constructional methods and standards, as observed by the surveyor.

#### 6.1.1 Functions of all classification societies:

- 1- To ensure that the ship maintains her strength and seaworthiness throughout her life.
- 2- Check that the vessel complies with international codes and conventions.
- 3- Publishes a register book, collection of data on behaviour of ship structures.





4- Damage surveys, of the various machinery on board ships, inspection of land based engineering projects.

5-Research of ship problems, technical investigations of problems in service, risk and reliability analysis and quality assurance inspections.

## **6.2 Ships Classification**

Standards set for the classification of ships (by classification societies) are based on experience, research, technical knowledge and information gained by regular communication with its customers. The society has the responsibility of ensuring that these standards are met during the design and construction of the vessel and are maintained during the working life of the vessel. To ensure that the vessel maintains the standards that are set as per class rules she will have to undergo surveys and these will provide for:-

- structural strength of all material parts of the hull and where necessary watertight integrity
- safety and reliability of steering and propulsion systems
- effectiveness of other features and auxiliary systems built into ships, in order to safely carry appropriate cargoes and personnel when at sea, moored or at anchor.

Compliance with the Rules & Regulations (standards), of a particular Classification Society, ensures assignment & maintenance of the 'ship's class'. In general, classification Rules & Regulations DO NOT cover ship's floatational stability, LSA, pollution prevention arrangements, FFA/fire detection arrangements under SOLAS, nor do they protect personnel on board from dangers connected with their own actions or movements on board. These are normally dealt with by flag state authorities, however, some flags delegate such responsibilities to Class who then act on their behalf as per agreed procedures.

Classification is NOT a Statutory requirement. It is a commercial facility mainly required by hull & machinery insurers, P&I clubs, ship financiers & cargo insurers. Classification is useful & considered when selling or purchasing ships. It gets indirectly linked with statutory certification (SAFCON), for example if a ship has her Class suspended normally the flag administration will also withdraw her statutory certificates.

### 6.2.1 Class notations

A ship's class is denoted by hull & machinery 'class notations'. Classification societies may use different systems of notation. For Lloyd's Register of Shipping (LR) a hull notation may consist of the followings:



**+ 100 A 1 Double Hull Oil Tanker, ESP, \*IWS, LI**

(Actually a Maltese cross) = Hull constructed under LR special survey

**100** = suitable for sea-going service

**A** = accepted into LR class & maintained in good/efficient condition

**1** = has good/efficient anchoring & mooring equipment

**Double Hull Oil Tanker** = structure designed/constructed in accordance with LR rules for double hull oil tankers – ‘*a ship type & cargo notation*’

**ESP** = she is subject to an *Enhanced Survey Programme*

**\* IWS** = applicable LR requirements for in-water survey are complied with

**LI** = approved loading instrument installed as a LR requirement

**6.2.2 Conditions for Classification of a ship**

Under IACS requirements, for a ship to remain in class the Owner must ensure that the following ‘Conditions for Classification’ are met:

1-Ship maintained to standard meeting rule requirements when examined at periodical surveys. Periodical Surveys include: annual surveys, intermediate surveys, docking surveys and special surveys

2- All damages, defects, breakdowns and groundings are reported.

3- Ship has on board following valid statutory convention certificates: (Load Line, Safety Construction, Safety Equipment, Safety Radio, IOPP, certificate of Fitness for Carriage of Dangerous Chemicals in Bulk, certificate of Fitness for Carriage of Liquefied Gases in Bulk and Safety Management certificate).

4-Ship is properly loaded and operated at all times.

5-Ship has on-board loading guidance in form of a loading manual & loading instrument as required by class rules.

6-Ship is operated in environmental conditions she is designed for (unless prior agreement from class) voyages are to or between service areas as per class notation, where applicable (unless prior agreement obtained from class)

**6.2.3 Ships Classification certificates**

**Certificate of Class:** is awarded to new or existing vessels, on completion of special survey and reports to this effect have been submitted by Surveyors. When these reports have been approved by the Committee a certificate of first entry of classification is issued.



Certificate of class maintenance; this can be issued in respect of completed periodical surveys of hull and machinery on application.

Provisional or Interim certificates; this can be issued to a classed vessel by the societies surveyors to enable her to proceed on her voyage, provided in their opinion it is fit and in efficient condition. Such certificates will embody the surveyor's recommendations for continuance of class, but they are in all cases subject to confirmation by the committee.

### **6.3 Classification Surveys**

Typical 'Periodical' Hull Classification Surveys are named as:

6.3.1-Initial Survey: carried out during construction of new ship. (Special survey) Include design, materials, quality/workmanship & arrangements for issue of Certificate of Class.

3.3.2-Annual Survey: carried out within 3 months, before or after, of each anniversary date of the ship's commissioning or last Special Survey (6 month window with range dates). It Confirms that general condition of the hull, openings, free board marks, steering gear, watertight doors, Gangways, anchors/mooring, loading instrument, equipment, related piping and timber deck cargo fittings etc is being maintained at satisfactory level. Annual Load line inspection items also covered. (No extension of range dates is allowed)

6.3.3-Intermediate Survey: carried out instead of the 2nd or 3rd annual Survey, it includes internal examination of sea water ballast tanks as follows:

- Representative tanks for vessels over 5 years
- All tanks for vessels over 10 years
- In dry cargo ships over 15 years to examine a forward & after cargo hold.
- For ESP ships (tankers, dry bulk carriers) there are enhanced intermediate survey requirements. For ESP ships over 15 years an intermediate survey is as stringent as the previous special survey.

6.3.4-Bottom/Docking Survey: Two 'Docking Surveys' are required to be completed within any 5 year survey cycle. Max period between two successive dockings not to exceed 30 months and one must coincide with Special Survey. The 'Intermediate Docking Survey' may be replaced with an 'in-water survey', if the ship meets the in-water survey and has IWS notation. (IWS not permitted for Enhanced Survey Programmed ships over 15 years).



Items to be examined during dry-docking are; the shell plating, cathodic protection systems, stern frame and rudder, propeller, anchor and chain cable, external and through hull fittings, and all parts of the hull particularly liable to corrosion and chafing, and any unfairness of bottom.

6.3.5-Special survey: carried out at 5 years interval to renew class certificate (may be referred to as 'renewal survey'). First Special Survey is completed within 5 years from date of the Initial Survey & thereafter every 5 years from the date of the previous Special Survey. Scope of this survey includes all Annual Survey hull & equipment items (more stringent to verify if can last another 5 years) and in addition thickness measurements of plating, internal examination of holds /tanks cofferdams/bilges etc., examination of engine structure, examination of underwater parts with ranging of anchors/cables & examination of sea chests (hence coincide with one Docking Survey).

6.3.6-Continuous hull survey: Allowed (at owners request) in lieu of Special Surveys for ships other than oil/chemical tankers, bulk carriers and combination carriers. Complete survey of items required under Special Survey is carried out, including opening up of hull compartments, and must be completed within the 5-year class survey cycle period. During each survey in the cycle all items are surveyed/tested in regular rotation with uniform 20% annual share within the 5-year period.

6.3.7-In-Water Survey (IWS): A bottom survey permitted to be carried out by qualified divers and equipment under supervision of a Surveyor, in-lieu of an Intermediate Docking Survey. Ship must meet certain IWS requirements & have \*IWS notation. The survey is carried out with ship at light draft in sheltered clear waters. If any damage/deterioration is detected, a Docking Survey for more detailed examination may become liable. Items to be examined during IWS are those for dry-docking but generally consideration is only for suitable high resistance paint.

#### 6.3.7.1 Requirements for a Ship to Obtain In-Water Inspection Notation

- A) To have arrangements for obtaining stern bush and rudder pintles & rudder bush clearances can be ascertained afloat .
- B) Arrangement to verify security of rudder pintles when afloat.
- C) High-resistance paint has been applied to the underwater portion of the hull as per manufacturer's requirements (coating condition confirmed at each dry-docking).



D) Plans with all above details have been submitted and approved by Class, and copies placed on the ship.

6.3.8-Damage Survey: A survey requested as a result of hull damage or other defects to items covered under class. In order that the ship maintains its class, approval of the repairs undertaken must be obtained from the surveyors either at the time of the repair or at the earliest opportunity. Master/Owner is obligated to advise the Society when such damages, defects occur. If possible, Surveyor may defer permanent repairs (with temporary repairs) until next periodical /planned Survey, giving a 'Condition of Class'

## **6.4 Survey Items**

### **6.4.1 Items Inspected during load line survey:**

- A visual examination of the load line certificate and all other certificates to ensure that they are valid and all endorsements are carried out.
- A general inspection to ensure that no unauthorized modifications are carried out which affect the condition of assignment of load lines for the vessel.
- An inspection of the strength in general will be carried out. One or two holds may be internally inspected to gauge the strength of the transverse girder, framing, knees, etc. This is so that the vessel will be able to withstand flooding of the compartment, the strength of superstructure bulkheads and machinery casing walls will be checked.
- The Master must be provided with loading and ballasting information to be capable of carrying out such operations without causing excessive stresses. Stability information has also to be provided to enable him calculate the stability of the ship.
- The position and marking of the load lines on the P and S side of the ship will be confirmed to be as per the load line certificate.
- Hatch covers are to be weather tight. Tests will be carried out on one or more hatch covers as the surveyor decides. All fittings of the hatch cover such as rubber packing and closing appliances are to be in good condition.
- Ventilators are to be capable of being closed weather tight. If the covers are permanent, packing should be in good condition. Ventilator flaps are to be operative and marked 'open' and 'shut'.
- Watertight door packing is to be in good condition and the position of dog bolts is to



be marked 'open' and 'shut'.

- Air pipe flaps are to be capable of being shut, packing in good condition and valves operative.
- Machinery spaces openings to be capable of being tightly shut.
- Portholes are to be weather tight with those below the main deck being fitted with deadlights and capable of being closed watertight.
- All inlet and outlet valves are to be checked that they are watertight. The forepeak tank screw down valve is to be capable of being closed watertight.
- A life line is to be provided on deck for use in rough weather. Guard rails and bulwarks are to be fitted .Catwalks are to be provided on tankers.
- Freeing ports provided on the bulwarks should not be blocked or obstructed.
- The spurling pipe opening must be capable of being closed. The educator system for the chain locker and forepeak stores must be working.

Conditions under which an International Load line certificate may be cancelled:

- 1) The ship does not comply with the conditions of assignment.
- 2) The structural strength of the vessel is reduced such that it is unsafe.
- 3) The information on the basis of which the freeboard were assigned are incorrect
- 4) The certificate is not endorsed in accordance with the requirement relating to periodical inspections
- 5) A new certificate is issued with respect to the ship
- 6) Change of registry to another country

Circumstances that an extension may be granted to an International Load line Certificate:

- 1) Owner request for Extension of the Certificate before the current certificate expires. The ship will then be surveyed to check that the vessel complies with the relevant requirements of the Load line Convention.
- 2) The assigning authority may when satisfied with the surveyors report and after notifying the Director of Marine that the vessel complies with the requirements relating to stability, and if it considers it not practicable to issue the new certificate before the expiry of the present one, extend the period of validity of the present one to a period not exceeding 5 months.



**6.4.2 Items Inspected during an Annual Hull classification Survey**

These include items required for Annual Inspections under Load Line 1966, and cover general condition of:

- Hull and its closing appliances (Hatches, ventilators, side scuttles, overboard discharges chutes etc)
- Watertight doors and W/T bulkhead penetrations
- Water clearing arrangements, freeing-ports, scuppers etc.
- Gangways/walkways, lifelines, guardrails
- Access to crew quarters & working areas
- Freeboard / load line marks, anchoring / mooring equipment, salt water tanks, pipelines
- Container securing arrangements (if any)
- Permanent fittings for Timber Deck cargoes (if any)

**6.4.3 Items Inspected During Dry-Docking Survey**

- Shell plating (including bottom & bow plating) checked for excessive corrosion, deterioration, unfairness or buckling. Special attention to bilge strakes & bilge keels sea-chests & gratings, sea connections & overboard discharge valves/cocks and fastenings.
- Visible parts of rudder, rudder pintles, rudder shafts/couplings and stern frame. Rudder bearing clearance to be obtained. Pressure test of rudder may be required.
- Visible parts of propeller & stern bush. Stern bush clearance & efficiency of stern gland to be determined. CPP fastenings & tightness of hub if fitted.
- Visible parts of side thrusters if fitted.
- Cathodic protection systems.
- Anchors & chain cable ranged.
- Hull Painting ; Underwater hull cleaned of all fouling barnacles, weeds etc, De-scaling and application of primers, application of anti-fouling paint (precautions with echo-sounder apertures, probes, tank-plugs), Wetted surface area of underwater hull obtained by formula: wetted area (sq.m) =  $2.58 \times \sqrt{L.D}$  (tonnes) x ship length (m).



**6.4.5 Items to be inspected prior to renewing a SAFCON Certificate:**

Structural Strength, Watertight doors, bilge pumping and drainage arrangements, electrical equipment and installation, emergency sources of electrical power, electric and electro-hydraulic steering gear, precaution against shock, fire and other hazards of electrical origin, fire protection, boilers and machinery, means of going astern, shafts, boiler feed systems, steam pipe systems, air pressure systems, cooling water systems, fuel, lubricating and other oil systems, communications, steering gear, anchor chain and cables, means of escape, means of stopping machinery, shutting of fuel suction pipes and closing openings.

Withdrawal/suspension of class conditions include:

- owners request
- regulations as regards surveys on hull equipment or machinery have not been complied with
- when defects to hull/machinery have not been rectified as per the societies regulations
- when the vessel proceeds to sea with less freeboard than approved by the committee or the freeboard marks are placed higher on the sides than approved by the committee
- when a specialised ship is being operated in a manner contrary to that agreed at the time of classification





## **CHAPTER -7 SOLAS REQUIREMENTS**

### **7.1 Structural, mechanical and electrical requirements for ships**

SOLAS CHAPTER II.I, Part A-1,

#### **Regulation 3-1 (Structural, mechanical and electrical requirements for ships)**

"In addition to the requirements contained elsewhere in the present regulations, ships shall be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognized by the Administration in accordance with the provisions of regulation XI/1, or with applicable national standards of the Administration which provide an equivalent level of safety."

SOLAS regulation II-1/3-1 requires that ships "shall be ... maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognized by the Administration".

### **7.2 Electrical installations (SOLAS CHAPTER II.I, Part D)**

#### **Regulation 40 General**

1. Electrical installations shall be such that:

1.1 All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;

1.2 Electrical services essential for safety will be ensured under various emergency conditions; and

1.3 The safety of passengers, crew and ship from electrical hazards will be ensured.

#### **Regulation 41 (passenger and cargo ships)**

##### **Main source of electrical power and lighting systems**

1.1 A main source of electrical power of sufficient capacity to supply all those services mentioned in regulation 40.1.1 shall be provided. This main source of electrical power shall consist of at least two generating sets.

1.2 The capacity of these generating sets shall be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal



operational conditions of propulsion and safety. Minimum comfortable conditions of habitability shall also be ensured which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.

1.3 The arrangements of the ship's main source of electrical power shall be such that the services referred to in regulation 40.1.1 can be maintained regardless of the speed and direction of rotation of the propulsion machinery or shafting.

1.4 In addition, the generating sets shall be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a dead ship condition. The emergency source of electrical power may be used for the purpose of starting from a dead ship condition if its capability either alone or combined with that of any other source of electrical power is sufficient to provide at the same time those services required to be supplied by regulations 42.2.1 to 42.2.3 or 43.2.1 to 43.2.4.

2.1 A main electric lighting system which shall provide illumination throughout those parts of the ship normally accessible to and used by passengers or crew shall be supplied from the main source of electrical power.

2.2 The arrangement of the main electric lighting system shall be such that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, the main switchboard and the main lighting switchboard, will not render the emergency electric lighting system required by regulations 42.2.1 and 42.2.2 or 43.2.1, 43.2.2 and 43.2.3 inoperative.

2.3 The arrangement of the emergency electric lighting system shall be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated transforming equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render the main electric lighting system required by this regulation inoperative.

3. The main switchboard shall be so placed relative to one main generating station that, as far as is practicable, the integrity of the normal electrical supply may be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating the switchboards from the generators.



### 7.3 Subdivision and stability ((SOLAS CHAPTER II.I, Part B)

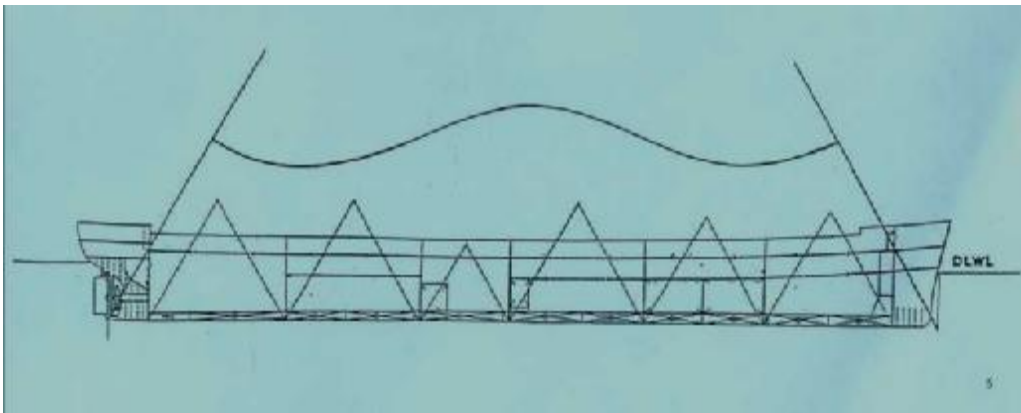
Floodable length; is the maximum allowable length of a compartment that can be flooded without submerging the line, the ship is to maintain upright with no heel.

Margin line; means a line drawn at least 76 mm below the upper surface of the bulkhead deck at side of the ship and assumed for the purpose of determining the floodable length of the ship. Margin line is a line drawn.

Subdivision Load-line; is the water-line drawn parallel to the keel, used in determining the subdivision of the ship.

Deepest subdivision load line; is the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable.

In order to determine the subdivision of a ship it will be necessary to develop flooding curves which will indicate the floodable length at any point in the length of the ship.



#### Regulation- 4 Floodable length in passenger ships:

1. The floodable length at any point of the length of a ship shall be determined by a method of calculation which takes into consideration the form, draught and other characteristics of the ship in question.
2. In a ship with a continuous bulkhead deck, the floodable length at a given point is the maximum portion of the length of the ship, having its centre at the point in question, which can be flooded under the definite assumptions set forth in regulation 5 (Permeability) without the ship being submerged beyond the margin line.
- 3.1. In the case of a ship not having a continuous bulkhead deck, the floodable length at any point may be determined to an assumed continuous margin line which at no point is less than 76 mm below the top of the deck (at side) to which the bulkheads concerned and the shell are carried watertight.



3.2. Where a portion of an assumed margin line is appreciably below the deck to which bulkheads are carried, the Administration may permit a limited relaxation in the watertightness of those portions of the bulkheads which are above the margin line and immediately under the higher deck.

Permeability; of a space in a ship is the percentage of that space which can be occupied by water; this factor affects the damaged stability of the ship when watertight integrity of its hull is breached. The volume of a space which extends above the margin line shall be measured only to the height of that line.

### **Regulation 5 Permeability in passenger ships**

1.1 The definite assumptions referred to in regulation 4 relate to the permeability of the spaces below the margin line.

1.2 In determining the floodable length, a uniform average permeability shall be used throughout the whole length of each of the following portions of the ship below the margin line:

1.2.1 The machinery space as defined in regulation 2;

1.2.2 The portion forward of the machinery space; and

1.2.3 The portion abaft the machinery space.

5. In the case of unusual arrangements the Administration may allow, or require, a detailed calculation of average permeability for the portions forward of or abaft the machinery space. For the purpose of such calculation, the permeability of passenger spaces as defined in regulation 2 shall be taken as 95, that of spaces containing machinery as 85, that of all cargo, coal and store spaces as 60, and that of double bottom, oil fuel and other tanks at such value as may be approved in each case.

6. Where a between-deck compartment between two watertight transverse bulkheads contains any passenger or crew space, the whole of that compartment, less any space completely enclosed within permanent steel bulkheads and appropriated to other purposes, shall be regarded as passenger space. Where, however, the passenger or crew space in question is completely enclosed within permanent steel bulkheads, only the space so enclosed need be considered as passenger space.



Regulation 25-7 (cargo ships)

**Permeability:**

For the purpose of the subdivision and damage stability calculations of the regulations, the permeability of each space or part of a space shall be as follows:

Spaces	Permeability
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Void spaces	0.95
Dry cargo spaces	0.70
Intended for liquid	0 or 0.95

**Regulation 25-8 Stability information**

1. The master of the ship shall be supplied with such reliable information as is necessary to enable him by rapid and simple means to obtain accurate guidance as to the stability of the ship under varying conditions of service. The information shall include:

I) A curve of minimum operational metacentric height (GM) versus draught which assures compliance with the relevant intact stability requirements and the requirements of regulations 25-1 to 25-6, alternatively a corresponding curve of the maximum allowable vertical centre of gravity (KG) versus draught, or with the equivalents of either of these curves;

II) Instructions concerning the operation of cross-flooding arrangements; and

III) All other data and aids which might be necessary to maintain stability after damage.

2. There shall be permanently exhibited, or readily available on the navigation bridge, for the guidance of the officer in charge of the ship, plans showing clearly for each deck and hold the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding. In addition, booklets containing the aforementioned information shall be made available to the officers of the ship.

**7.4 Definitions**

Machinery space; is to be taken as extending from the moulded base line to the margin line and between the extreme main transverse watertight bulkheads, bounding the spaces containing the main and auxiliary propulsion machinery, boilers serving the needs of propulsion, and all permanent coal bunkers. In the case of unusual arrangements, the Administration may define the limits of the machinery spaces.



Passenger: is every person other than:

- (i) The master and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship; and
- (ii) A child under one year of age.

Passenger ship: is a ship which carries more than twelve passengers.

Cargo ship: is any ship which is not a passenger ship.

Passenger spaces: are those spaces which are provided for the accommodation and use of passengers, excluding baggage, store, provision and mail rooms. For the purposes of regulations 5 and 6, spaces provided below the margin line for the accommodation and use of the crew shall be regarded as passenger spaces.

Control stations: are those spaces in which the ship's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized.

Main vertical zone: in relation to a ship, means one of the main vertical zones into which the hull, superstructure and deck-houses of the ship are divided in accordance with regulations.

Machinery spaces: are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

Machinery spaces of category A: are those spaces and trunks to such spaces which contain:

1. Internal combustion machinery used for main propulsion; or
2. Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
3. Any oil-fired boiler or oil fuel unit.

Accommodation space: includes:

- (a) Passenger space;
- (b) Crew space;
- (c) Office space;
- (d) Pantry space other than main pantry space; and
- (e) Other similar space other than service space or open space on deck.

Public space: includes a hall, a dining room, a bar room, a smoke room, a lounge room, a recreation room, a children's nursery and a library.

Service space: includes galleys, main pantries, laundries, store rooms, paint rooms, baggage rooms, mail rooms, bullion rooms, carpenters' workshops, plumbers' workshops and any



trunk way leading to such a space.

Watertight; in relation to a structure in a ship, means capable of preventing the passage of water through the structure in any direction under a head of water up to the margin line of the ship.

Weather tight; in relation to a structure, means capable of preventing the passage of sea water through the structure in ordinary sea conditions.

## **7.5 Suppression of fire (SOLAS CH: II.2, Part C)**

### **Regulation 7**

#### **Detection and alarm**

##### **1. Purpose**

The purpose of this regulation is to detect a fire in the space of origin and to provide for alarm for safe escape and fire-fighting activity. For this purpose, the following functional requirements shall be met:

1.1 fixed fire detection and fire alarm system installations shall be suitable for the nature of the space, fire growth potential and potential generation of smoke and gases;

1.2 manually operated call points shall be placed effectively to ensure a readily accessible means of notification; and

1.3 fire patrols shall provide an effective means of detecting and locating fires and alerting the navigation bridge and fire teams.

##### **2. General requirements**

2.1 A fixed fire detection and fire alarm system shall be provided in accordance with the provisions of this regulation.

2.2 A fixed fire detection and fire alarm system and a sample extraction smoke detection system required in this regulation and other regulations in this part shall be of an approved type and comply with the Fire Safety Systems Code.

2.3 Where a fixed fire detection and fire alarm system is required for the protection of spaces other than those specified in paragraph 5.1, at least one detector complying with the Fire Safety Systems Code shall be installed in each such space.

##### **3. Initial and periodical tests**

3.1 The function of fixed fire detection and fire alarm systems required by the relevant



regulations of this chapter shall be tested under varying conditions of ventilation after installation.

3.2 The function of fixed fire detection and fire alarm systems shall be periodically tested to the satisfaction of the Administration by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond.

#### **4. Protection of machinery spaces**

##### **4.1 Installation**

A fixed fire detection and fire alarm system shall be installed in:

4.1.1 Periodically unattended machinery spaces; and

4.1.2 Machinery spaces where:

4.1.2.1 The installation of automatic and remote control systems and equipment has been approved in lieu of continuous manning of the space; and

4.1.2.2 The main propulsion and associated machinery, including the main sources of electrical power, are provided with various degrees of automatic or remote control and are under continuous manned supervision from a control room.

#### **5. Protection of accommodation and service spaces and control stations**

5.1 Smoke detectors in accommodation spaces Smoke detectors shall be installed in all stairways, corridors and escape routes within accommodation spaces as provided in paragraphs 5.2, 5.3 and 5.4. Consideration shall be given to the installation of special purpose smoke detectors within ventilation ducting.

##### **5.2 Requirements for passenger ships carrying more than 36 passengers**

A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors, stairways and escape routes within accommodation spaces. Smoke detectors need not be fitted in private bathrooms and galleys. Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with a fixed fire detection and alarm system.

5.3 Requirements for passenger ships carrying not more than 36 passengers There shall be installed throughout each separate zone, whether vertical or horizontal, in all accommodation and service spaces and, where it is considered necessary by the Administration, in control





stations, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc., either:

5.3.1 a fixed fire detection and fire alarm system so installed and arranged as to detect the presence of fire in such spaces and providing smoke detection in corridors, stairways and escape routes within accommodation spaces; or

5.3.2 an automatic sprinkler, fire detection and fire alarm system of an approved type complying with the relevant requirements of the Fire Safety Systems Code and so installed and arranged as to protect such spaces and, in addition, a fixed fire detection and fire alarm system and so installed and arranged as to provide smoke detection in corridors, stairways and escape routes within accommodation spaces.

## **5.5 Cargo ships**

Accommodation and service spaces and control stations of cargo ships shall be protected by fixed fire detection and fire alarm system and/or an automatic sprinkler, fire detection and fire alarm system as follows, depending on a protection method adopted in accordance with regulation 9.2.3.1.

5.5.1 Method IC – A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

5.5.2 Method IIC – An automatic sprinkler, fire detection and fire alarm system of an approved type complying with the relevant requirements of the Fire Safety Systems Code shall be so installed and arranged as to protect accommodation spaces, galleys and other service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc.

In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

5.5.3 Method IIIC – A fixed fire detection and fire alarm system shall be so installed and arranged as to detect the presence of fire in all accommodation spaces and service spaces, providing smoke detection in corridors, stairways and escape routes within accommodation spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.



**9. Fire alarm signaling systems in passenger ships\***

9.1 Passenger ships shall at all times when at sea, or in port (except when out of service), be so manned or equipped as to ensure that any initial fire alarm is immediately received by a responsible member of the crew.

9.2 The control panel of fixed fire detection and fire alarm systems shall be designed on the fail-safe principle (e.g., an open detector circuit shall cause an alarm condition).

9.3 Passenger ships carrying more than 36 passengers shall have the fire detection alarms for the systems required by paragraph 5.2 centralized in a continuously manned central control station.

In addition, controls for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location. The ventilation fans shall be capable of reactivation by the crew at the continuously manned control station. The control panels in the central control station shall be capable of indicating open or closed positions of fire doors and closed or off status of the detectors, alarms and fans. The control panel shall be continuously powered and shall have an automatic change-over to standby power supply in case of loss of normal power supply. The control panel shall be powered from the main source of electrical power and the emergency source of electrical power defined by regulation II-1/42 unless other arrangements are permitted by the regulations, as applicable.

9.4 A special alarm, operated from the Navigation Bridge or fire control station, shall be fitted to summon the crew. This alarm may be part of the ship's general alarm system and shall be capable of being sounded independently of the alarm to the passenger spaces.

**7.6 Structural Fire Protection****Regulation 9: Containment of fire**

Of the requirements of the International Conventions for the Safety of Life at Sea those having a particular influence on ship construction are the requirements relating to structural fire protection. Varying requirements for vessels engaged in international voyages are given for passenger ships carrying more than thirty-six passengers, passenger ships carrying not more than thirty-six passengers, cargo ships and tankers.

**Requirements:**

Ships carrying more than thirty-six passengers are required to have accommodation spaces and main divisional bulkheads and decks which are generally of incombustible material in association with either automatic fire detection and alarm system or an automatic sprinkler



and alarm system.

The hull, superstructure, and deckhouses are subdivided by 'A' class divisions into main vertical zones the length of which on any one deck should not exceed 40m. Main horizontal zones of 'A' class divisions are fitted to provide a barrier between sprinklered and non-sprinklered zones of the ship.

Bulkheads within the main vertical zones are required to be 'A', 'B' or 'C' class divisions depending on the fire risk of the adjoining spaces and whether adjoining spaces are within sprinkler or non-sprinkler zones.

Passenger vessels carrying not more than thirty-six passengers are required to have the hull, superstructure and deckhouses subdivided into main vertical zones by 'A' class divisions. The accommodation and service spaces are to be protected either by all enclosure bulkheads within the space being of at least 'B' class divisions or only the corridor bulkheads being of at least 'B' class divisions where an approved automatic fire detection and alarm system is installed.

Cargo ships exceeding 500 gross tonnages are generally to be constructed of steel or equivalent material and to be fitted with one of the following methods of fire protection in accommodation and service spaces.

'Method Ic' All internal divisional bulkheads constructed of noncombustible 'B' or 'C' class divisions and no installation of an automatic sprinkler, fire detection and alarm system in the accommodation and service spaces, except smoke detection and manually operated alarm points which are to be installed in all corridors, stairways and escape routes.

'Method IIc' An approved automatic sprinkler, fire detection and fire alarm system is installed in all spaces in which a fire might be expected to originate, and in general there is no restriction on the type of divisions used for internal bulkheads.

'Method IIIc' A fixed fire detection and fire alarm system is installed in all spaces in which a fire might be expected to originate, and in general there is no restriction on the type of divisions used for internal bulkheads except that in no case must the area of any accommodation space bounded by an 'A' or 'B' class division exceed 50 square metres.

Crowns of casings of main machinery spaces are to be of steel construction and insulated. Bulkheads and decks separating adjacent spaces are required to have appropriate A, B or C ratings depending on the fire risk of adjoining spaces. Cargo spaces of ships 2000 gross tonnage or more are to be protected by a fixed gas fire-extinguishing system or its equivalent



unless they carry bulk or other cargoes considered by the authorities to be a low fire risk. Cargo ships carrying dangerous goods are subject to special fire protection precautions.

In the construction of tankers, particular attention is paid to the exterior boundaries of superstructures and deckhouses which face the cargo oil tanks. Accommodation boundaries facing the cargo area are insulated to A60 standard, no doors are allowed in such boundaries giving access to the accommodation and any windows are to be of non-opening type and fitted with steel covers if in the first tier on the main deck. Bulkheads and decks separating adjacent spaces of varying fire risk are required to have appropriate A, B, and C ratings within the accommodation space. For new tankers of 20 000 tons deadweight and upwards the cargo tanks deck area and cargo tanks are protected by a fixed deck foam system and a fixed inert gas system (*see* Chapter 26). Tankers of less than 2000 tons deadweight are provided with a fixed deck foam system in way of the cargo tanks.

### ‘A’, ‘B’ and ‘C’ Class Divisions

‘A’ class divisions are constructed of steel or equivalent material and are to be capable of preventing the passage of smoke and flame to the end of a one-hour standard fire test. A plain stiffened steel bulkhead or deck has what is known as an A–O rating. By adding insulation in the form of approved incombustible materials to the steel an increased time is taken for the average temperature of the unexposed side to rise to 139 °C above the original temperature or not more than 180 °C at any one point above the original temperature during the standard fire test. The ‘A’ class division rating is related to this time as follows.

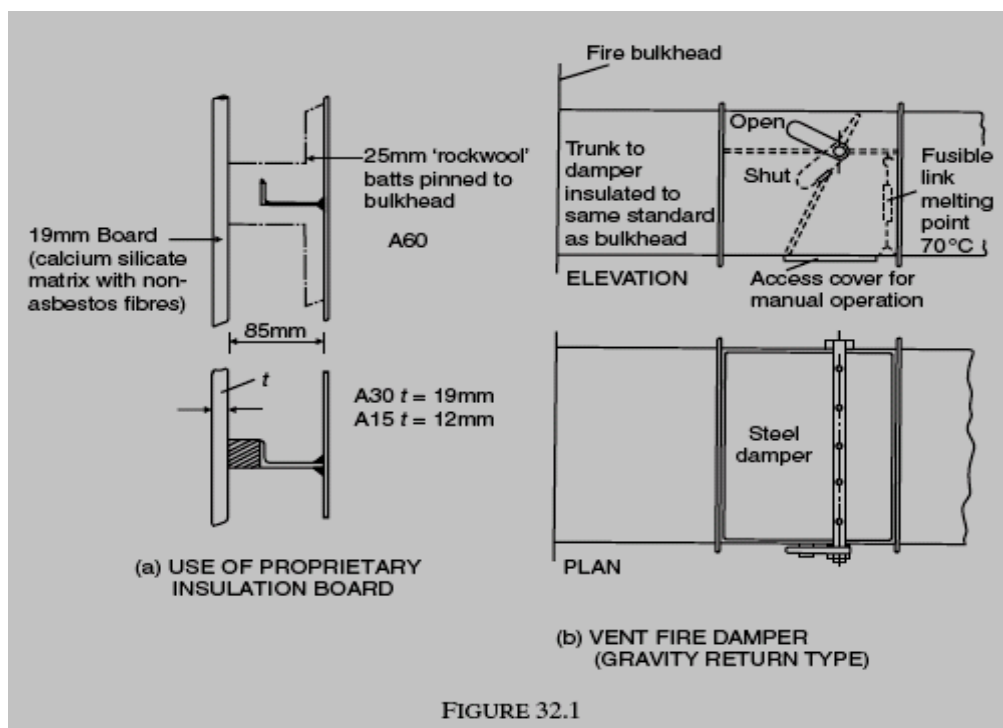


Figure 32.1 shows typical steel divisions with typical proprietary non-asbestos fiber reinforced silicate board insulation. 'B' class divisions are those which are constructed as to be capable of preventing the passage of flame to the end of half an hour of the standard fire test. Various patent board materials are commonly used where 'B' class divisions are required and there are two ratings B-0 and B-15. These relate to the insulation value such that the average temperature of the unexposed side does not rise more than 139 °C above the original temperature and at any one point more than 225 °C above the original temperature when the material is subjected to the standard fire test within the following times.

Class	Time(min)
B-15	15
B-0	0

'C' class divisions are constructed of approved incombustible materials but do not need to meet with any specified requirements relative to passage of smoke and flame nor temperature rise.

The standard fire test referred to is a test in which a specimen of the division with a surface area of not less than 4.65sq.m and height or length of 2.44 m is exposed in a test furnace to a series of time-temperature relationships, defined by a smooth curve drawn through the following points.

At end of first 5 minutes 538 °C

At end of first 10 minutes 704 °C

At end of first 30 minutes 843 °C

At end of first 60 minutes 927 °C

Some typical examples of fire divisions are given below for a passenger ship carrying more than thirty-six passengers.

Bulkhead	Adjacent compartments	Class
Main fire zone	Galley/passageway	A-60
Main fire zone	Wheelhouse/passageway	A-30
Within fire zone	Fan room/stairway	A-15
Within fire zone	Cabin/passageway (non-sprinklered zone)	B-15
Within fire zone	Cabin/passageway (sprinklered zone)	B-0



**Openings in Fire Protection Divisions**

Generally openings in fire divisions are to be fitted with permanently attached means of closing which have the same fire resisting rating as the division. Suitable arrangements are made to ensure that the fire resistance of a division is not impaired where it is pierced for the passage of pipes, vent trunks, electrical cables, etc.

Greatest care is necessary in the case of openings in the main fire zone divisions. Door openings in the main fire zone bulkheads and stairway enclosures are fitted with fire doors of equivalent fire integrity and are self-closing against an inclination of  $3\frac{1}{2}^\circ$  opposing closure. Such doors are capable of closure from a control station either simultaneously or in groups and also individually from a position adjacent to the door. Vent trunking runs are ideally contained within one fire zone but where they must pass through a main fire zone bulkhead or deck a fail safe automatic-closing fire damper is fitted within the trunk adjacent to the bulkhead or deck. This usually takes the form of a steel flap in the trunk which is held open by a weighted hinge secured by an external fusible link. The flap must also be capable of being released manually and there is some form of indication as to whether the flap is open or closed (*see* Figure 32.1).

**Protection of Special Category Spaces**

A special category space is an enclosed space above or below the bulkhead deck used for the carriage of motor vehicles with fuel for their own propulsion in their own tanks and to which passengers have access. Obvious examples are the garage spaces in Ro-Ro passenger ferries and vehicle decks in RO-RO cargo ships. Such spaces cannot have the normal main vertical fire zoning without interfering with the working of the ship. Equivalent protection is provided in such spaces by ensuring that the horizontal and vertical boundaries of the space are treated as main fire zone divisions and an efficient fixed fire-extinguishing system is fitted within the space. This takes the form of a fixed pressure water spraying system generally in association with an automatic fire detection system. Special scupper arrangements are provided to clear the deck of the water deposited by the system in the event of a fire to avoid a drastic reduction in stability.

