The MSA tankscope is sensitive to tilt, so it is important to keep the instrument in a normal, upright position during operations or there may be a significant error in instrument readings.

### *24.2.2 Guidelines for use*

1. Attach the sampling line to the inlet and the aspirator bulb to the outlet of the instrument. Check the air-tight integrity of the system by pinching a bight on the sampling line and squeezing the aspirator bulb. The bulb should not expand as long as the sampling line is pinched. If the bulb expands, re-check connections and non-return valves on the aspirator bulb.

2. Place the instrument in fresh air.

3. Turn the selector switch to 'Check'.

4. Switch 'On' the unit by lifting the switch on the top left hand corner of the instrument.

5. Flush fresh air through the tankscope by squeezing the rubber aspirator bulb and allowing it to expand completely. 8 to 10 squeezes are sufficient to flush the chamber. If the sampling line is used, two additional squeezes will be required for every 3 metres of line.

6. Adjust the meter pointer to the 'Check' position marked on the dial, using the 'Voltage Adjustment' knob.

7. Turn the selector switch to 'Gas'.

8. Adjust the meter pointer to 'Zero'.

9. Place the end of the sampling line where the sample is to be taken. Aspirate the sample through the instrument. The aspirator should be operated (squeezed) until the meter pointer comes to rest on the scale. With 2 metres of sampling line and probe, the meter pointer should rise on the scale within fifteen squeezes – otherwise the sample point may be considered gas free.

10. Stop aspirating and note the final reading. The reading should be taken with zero flow through the instrument and with the gas at normal atmospheric pressure. Small deviations from the normal atmospheric pressure in the instrument produce significant differences in the indicated gas concentration. If a space under elevated or reduced pressure is sampled, it is important to detach the sampling line from the MSA tankscope when aspiration is stopped; this allows the instrument to attain atmospheric pressure before the reading is noted.

11. After each reading flush the sampling line and instrument with fresh air.
12. Recheck 'Volts' and 'Zero' controls at frequent intervals (steps 5, 6 and 7).
13. Protect the instrument from weather as much as possible and avoid exposure to very wet conditions.

### *24.2.3 Trouble-shooting*

1. *If the meter pointer goes below the scale when the selector switch is turned to 'Gas' and cannot be adjusted to 'Zero' with the zero adjustment control:*

- The batteries may require replacement.
- The thermal conductivity filament (detector filament – white housing) may be defective and requires replacement.

2. *If the tankscope is sluggish and requires more than the specified number of aspirations for maximum deflection of the meter pointer:*

- The flashback arrestors may be clogged.
- There may be an obstruction in the aspirator coupling's flow orifice.
- The cotton filters may be choked.
- There may be a leak in the flow system.

If service other than that outlined is necessary, send the instrument ashore for repair and maintenance.

## 24.3 Thick Film Technology Gas Analysis

The reaction of a combustible gas with oxygen on a catalyst is used to give an extremely sensitive measurement of the concentration of that gas. Thick Film technology is used in combustion gas analysis applications to allow users to enhance combustion efficiency, saving fuel and reducing emissions (Refer Figure 24.5). This technique relies on the combustion of carbon monoxide and oxygen over a catalytic surface.

A four quadrant track is precision-printed onto a substrate using platinum ink. Each quadrant forms one leg of a Wheatstone bridge circuit (Refer Figure 24.6).

A layer of protective glaze, having a consistent thickness, is printed over the complete circuit and the catalyst which also has a consistent thickness, across two of the quadrants.

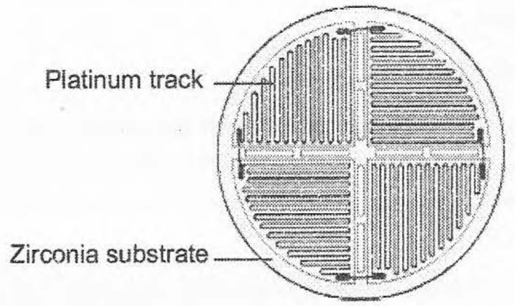



**Figure 24.5 – The Thick Film**

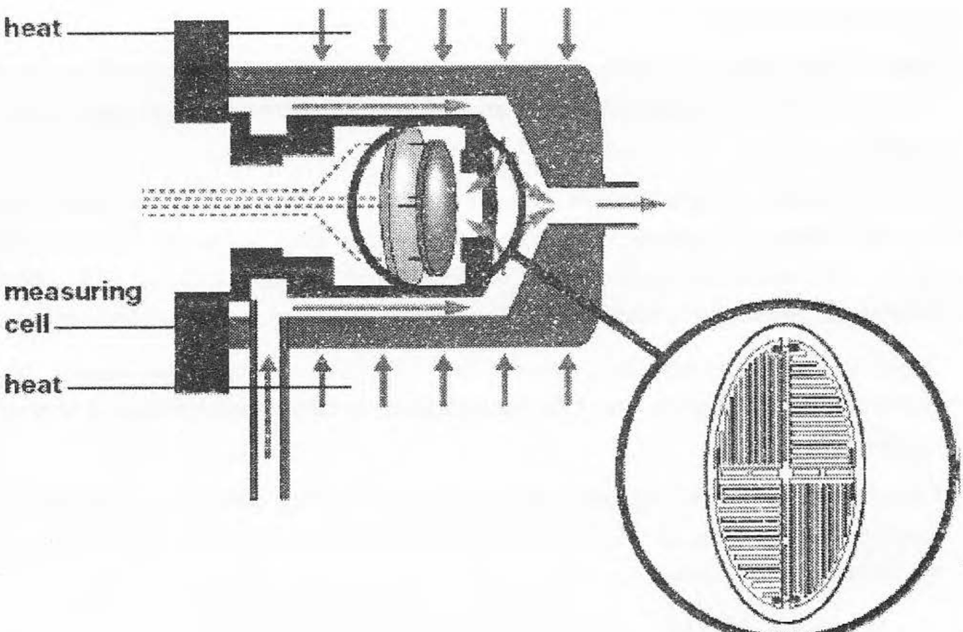



**Figure 24.6 – The Sensor**

The disk is mounted in a measuring cell and heated to 300°C at which stage the gas sample enters. Any carbon monoxide in the sample will burn on the catalytic surfaces, causing a heating effect. This alters the current in the circuit to produce an output that is proportional to the carbon monoxide concentration in the sample.

## 24.4 Carbon Dioxide Analysis

### *24.4.1 Influence of Carbon Dioxide*

Most fruits continue to live after picking, and breathe even when carried under chilled conditions. In breathing they absorb oxygen and release carbon dioxide into the storage space. The $CO_2$ content must be controlled by ventilating the space with outside air for the following reasons:

i) $CO_2$ content in excess of 5% with its associated reduction in oxygen content is dangerous to human life, and levels must be kept below this in case the space has to be entered;

ii) Some port authorities require the $CO_2$ content to be below 0.5% before men are allowed to work in the space;

iii) Many fruits, particularly apples, suffer from "suffocation" and develop internal browning of the flesh if they are kept for long in an environment where the $CO_2$ content is in excess of 2%;

iv) Some fruits, for example bananas, give off ethylene and this ethylene can initiate ripening of other bananas. Vigorous ventilation is desirable to keep down ethylene concentration levels. As there is no ready method of determining ethylene content, $CO_2$ content is determined and kept to a fraction of 1% and ethylene present is thus proportional;

v) Some shippers of citrus fruit request low $CO_2$ contents again to control ethylene concentration levels rather than $CO_2$ concentration, as they consider this may improve the quality of the fruit.

$CO_2$ production is most vigorous on completion of loading warm fruit, and decreases as temperatures are reduced. The $CO_2$ contents should be measured daily after loading until the level has settled down.

### *24.4.2 Monitoring of $CO_2$*

Portable instruments for measuring $CO_2$ are electrical-types (based on measuring changes in thermal conductivity of the gas sample) or chemical-types (based on absorbing the $CO_2$ in a cartridge or solution of caustic soda).

They are used with a short length of rubber sampling tube, which can be lowered down an exhaust ventilator (or coupled to a sampling pipe if one has been built into the cooler room) and a hand aspirator.

As portable instruments, the chemical types are more robust, although the electrical types are often used as permanently installed instruments in the engine room, from which a pipe leads to each cargo space. Permanent installations include a suction pump and manifolds for measuring each space in turn. Whatever instrument is used, it is good practice to carry a gas bottle of known concentration of $CO_2$ for calibration purposes. In the absence of such a bottle a rough check is to breathe into the instrument; a reading of about 5 % should be obtained.

## 24.5 Portable Oxygen Analyser - *Model: Draeger E-11*

The oxygen analyser is used to evaluate the $O_2$ content in the atmosphere. The most important part of the instrument is the sensor, which can be of different types in different makes such as

1. Electrolytic cell (Refer Figures 24.7 and 24.8)
2. Paramagnetic sensor
3. Chemical absorption sensor

### *24.5.1 Operation of the Electrolytic Cell Type*

1. Prior to use, check the battery by changing over the 'Battery Check' switch to 'Battery Check' mode. The meter pointer should lie within the black band marked 'Batt'. It is not necessary to switch the instrument 'On' to check the battery. When it is released, the battery check switch being spring-loaded will return to its normal position.
2. Connect the remote head (sensor) to the instrument via the cable. Switch the instrument 'On' and allow it to stabilise for 10 minutes. At the end of this period, the reading should be 21% $\pm$ 1% oxygen (Provided the head is in open air). If not, it should be set using the panel potentiometer 'Set 21%' to read 21% oxygen in open air.
3. Just above and below the 21% mark there is an upper and lower alarm level. These alarms must be tested by turning the 'Set 21%' potentiometer on the front panel above and below the 21% mark until the respective alarms are activated. The instrument must then be returned to read 21% oxygen in air prior to use.
4. When moving its location, it is recommended that the instrument be kept 'On' owing to the necessary stabilisation time required for the next measurement.
5. Ensure that the alarm switch (on the rear of the instrument casing) is set to 'Operate' when an audible alarm is required, and not to 'Mute'.

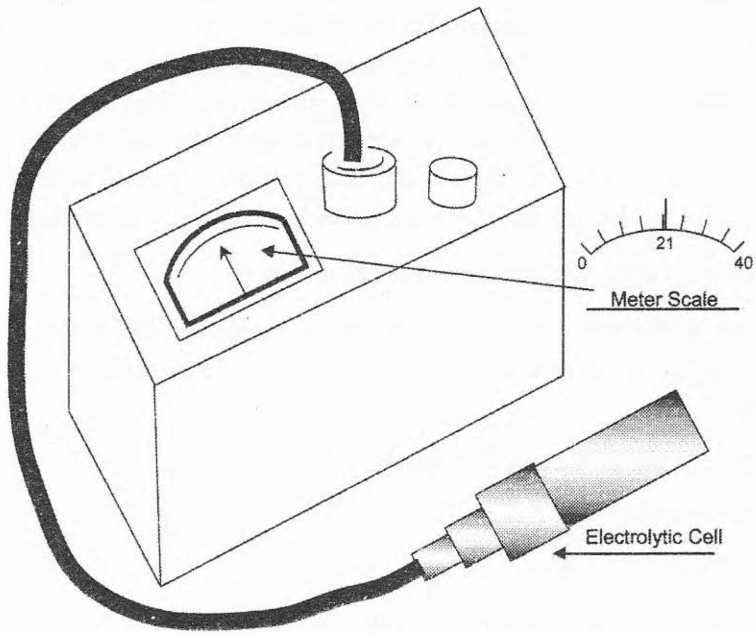



**Figure 24.7 – E-11 Draeger Oxygen Analyser**

### *24.5.2 Technical Specifications of the E-11 Draeger Oxygen Meter*

1. Storage temperature: -3$^0$ to 50$^0$ C.
2. Meter display: 0 to 40 % oxygen.
3. Batteries: 2 x TR 132N Mallory Mercury Cells.
4. Maximum warm-up time: 5 minutes.
5. Accuracy: $\pm$ 5% of the reading.
6. Speed of response: 8 seconds to reach 90% of the reading.
7. Cell life: 130,000% oxygen hours at 20$^0$ C (Guaranteed 6 months of continuous use in 21% oxygen)
8. Remote head: Standard cable length – 10 meters; other lengths are available on demand.
9. Weight: Total weight of sensor and instrument is 2.6 kg.

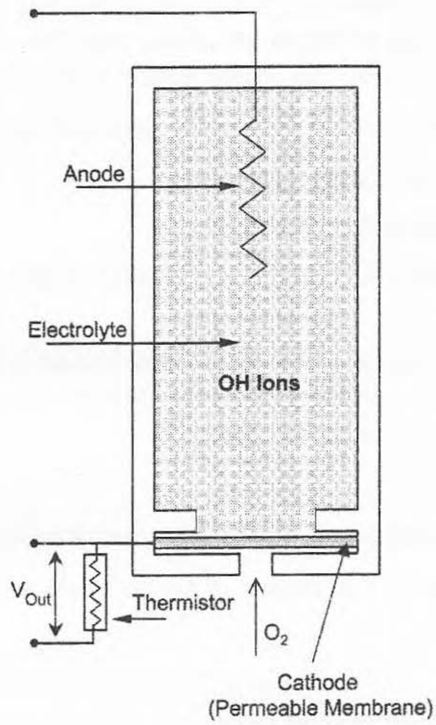



**Figure 24.8 – Draeger Oxygen Analyser E-11 Probe (Electrolytic Cell)**

### *24.5.3 Calibration*

It is important that the $0_2$ meter be calibrated before use. The E-11 is calibrated by using the aspirator attachment to create a flow system for calibration.

1. Open the front panel by removing the four securing screws. Take care not to break the connections to the alarm isolation switch on the rear panel, which should be set to 'Mute'. Locate the 4 potentiometers – 'A', 'B', 'C', 'D'.
2. Connect the sensor to the instrument, connect the aspirator attachment to the remote head, switch 'On' the device and leave it for 20 to 30 minutes.
3. Permit the nitrogen to flow through and leave it for approximately 10 minutes. Using potentiometer 'B' set the instrument to read 0% oxygen.

4. Place the sensor in a suitable concentration within the range of the instrument and leave it for approximately 1 minute. Fresh air drawn from the atmosphere is ideal and the instrument can be set for 21%. The pointer is set to read 21% using potentiometer 'A'.
5. Repeat steps 3 and 4 and perform any adjustments if necessary.
6. Replace the front panel and secure it.

### *24.5.4 Replacement of the Polarographic Cell*

The polarographic cell will last for a minimum of six months in 21% oxygen at atmospheric pressure.

When the instrument can no longer be adjusted to read 21% oxygen, the cell must be replaced. Replacing the sensor will suffice. As each cell has a slightly different 'oxygen zero', it will be necessary to recalibrate the instrument.

The vessel can either:

- Return the complete instrument to the manufacturer for replacement and calibration.
- Return the sensor only for replacement of the cell if the vessel has adequate calibration facilities.

### *24.5.5 Fault Finding*

1. *Meter pointer deflects over (extreme) positive or negative limits in all ranges of oxygen :*
   - ✓ Ensure that the batteries are firmly held in the pressure contacts; secure loose batteries or replace them.
   - ✓ Check the continuity of the cable and replace it if necessary.
2. *Meter goes to some position and does not respond to oxygen :*
   - ✓ Check the continuity of the cable and replace it if necessary.
3. *Instrument cannot be set to 21% in air:*
   - ✓ Inspect the batteries and replace them if necessary.
   - ✓ Inspect the polarographic cell and replace it if necessary.
4. *Alarm does not sound:*
   - ✓ The alarm mute switch may not be changed over to 'operate'.
   - ✓ Inspect the batteries and replace them if necessary.

### 24.5.6 *Setting the Alarm Level*

1. Using potentiometer 'A' set the pointer to read the required lower alarm level setting of oxygen. Then alter potentiometer 'C' so that the alarm just sounds.
2. Using potentiometer 'A' set the pointer to read the desired upper level alarm setting. Then alter the potentiometer 'D' until the upper level alarm just sounds. Reading of the instrument should then be returned to 21% oxygen in air.

## 24.6 Fixed Oxygen Analyser - *Beckman Oxygen Analyser (Pauling Cell Type)*

### 24.6.1 *Principle of Operation*

The strong magnetic property of oxygen is virtually unique compared to other gases. Its attraction into a magnetic field (paramagnetism) is the basis for high accuracy oxygen analysis, when fast and reliable measurements are needed. On the other hand, Nitrogen is diamagnetic i.e. it is repelled by a magnet. Other paramagnetic gases are NO, and $NO_2$.

### 24.6.2 *Construction*

Two diamagnetic spheres of glass filled with nitrogen are mounted at the ends of a bar to form a dumb-bell. This dumb-bell is suspended horizontally from a quartz fibre. It operates in a strong non-uniform magnetic field. The spheres are repelled from the strongest part of the field and so rotate, twisting the suspension to its zero position when 100% nitrogen is made to flow across the field. The deflection of the pointer from zero is proportional to the force acting on the two spheres, which in turn is proportional to the oxygen content in the sample. If the $O_2$ content in the field changes, the force acting would change and the dumb-bell will attain a new position proportional to the $O_2$ change. The limitation of this type of instrument is that the deflection with a change in $O_2$ content is not linear and so the calibration of the scale is also non-linear. Hence although zero setting with nitrogen flow and 21% oxygen setting with airflow can be done, the scale cannot be divided into 21 equal divisions.

## 24.7 Beckman Oxygen Analyser *(Munday Cell Type)*

### 24.7.1 *Principle of Operation*

The 'Zero' position of the dumb-bell is sensed by a split photocell. This cell receives light reflected from a mirror, which is fixed on the suspension. The output from the photocell is amplified and fed back to a coil wound on the dumb-bell so that a restoring torque due to feedback current balances the torque due to oxygen in the sample.

The measuring system is thus 'null balanced' and has all the inherent advantages of this type of system. This electro-magnetic feedback also stiffens the suspension damping it heavily (Refer Figures 24.9(a) and 24.9(b)).

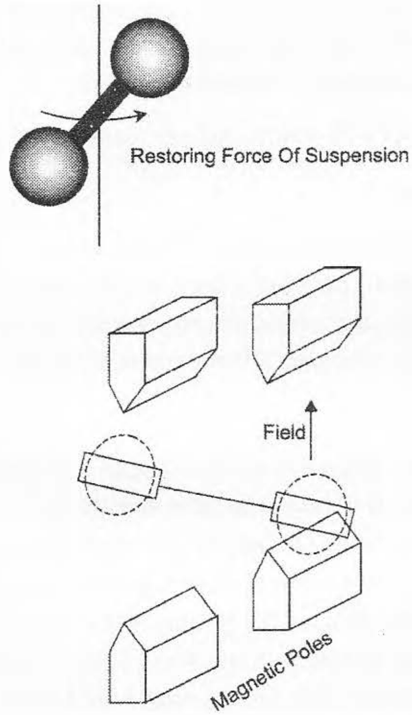



**Figure 24.9(a) – Sensitive Element of the Munday Cell**

Because of a linear relationship between feed-back current and the susceptibility of the sample, a proportional voltage can be developed, and various ranges can be obtained. Linearity of its scale also makes it possible to calibrate the instrument for all ranges by checking it at only two points, i.e., for 'zero' using pure nitrogen and 21% using air and dividing the scale into 21 equal divisions unlike the earlier model.

The instrument continuously monitors the oxygen percentage in the inert gas at a point after the blowers. There are displays in the cargo control room (CCR), engine control room (ECR) and locally at the instrument. An alarm is incorporated to ring when the $O_2$ content goes above 8%. The oxygen content can also be recorded continuously.

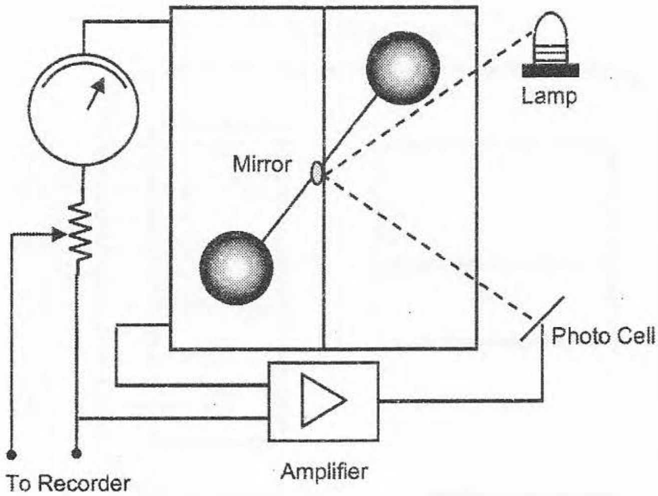



**Figure 24.9(b) – Basic Circuit of the Munday Cell**

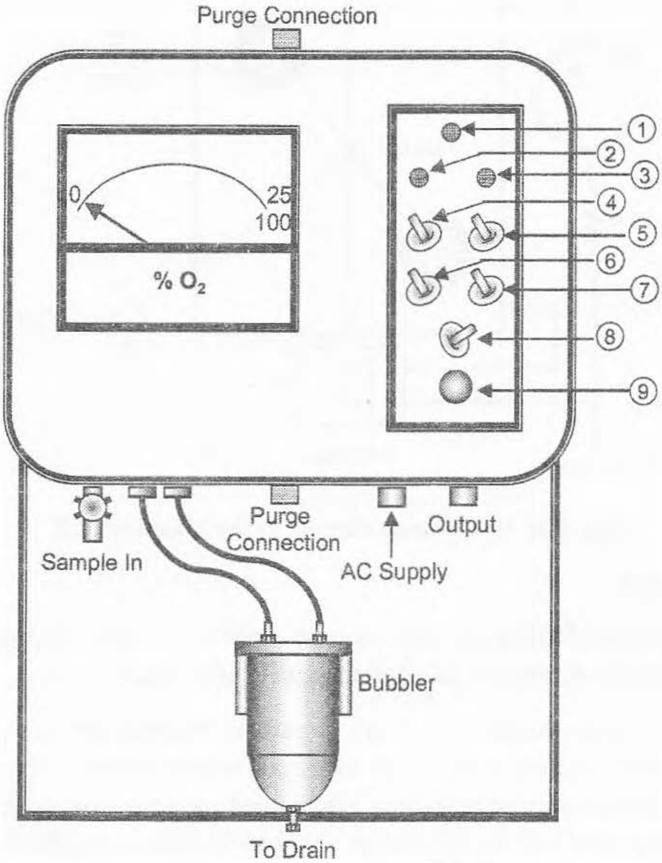
### *24.7.2 Construction*

This differs from the Pauling cell type wherein a platinum ribbon suspension is used and facilitates a considerable increase in physical strength (Refer Figure 24.10).

In addition, an electro-magnetic feedback is used to maintain the dumb-bell at its zero position. In a sample containing oxygen, the dumb-bell tends to deflect. The current required to maintain the dumb-bell at its zero position is measured and shown on the scale. The greater the deflection, the greater will be the current required to restore the dumb-bell to its zero position. Thus, this current represents the magnetic susceptibility of the gas present in the cell and therefore the $O_2$ concentration.

*The advantages of this instrument are:*

- Calibration is simple – nitrogen is used for zero calibration and air for span at 21% oxygen.
- There is virtual independence from variations in the sample gas composition.
- The scale is linear over the complete range (0 – 100 % oxygen), although the meter itself may only be graduated up to 21% or 40% oxygen.
- Response time is fast as there is no heating or cooling of filaments.
- The analyser is not sensitive to tilt.




1 - Set Temperature
2 - Span Adjustment
3 - Zero Adjustment
4 - Lamp On
5 - Feedback On
6 - Power On
7 - Reset
8 - Range (%$O_2$)
9 - Lamp

**Figure 24.10 – An Oxygen Analyser**

#### *24.7.3 Starting Procedure*

- Switch on the supply (the supply is pre-set to 110 or 220V).

*Note: A voltage set higher than this will reduce the life of the lamp.*

- Allow at least 2 hours (or as instructed by the manufacturers) for the analyser to warm up before passing the sample through it. This helps the instrument to attain proper sensitivity and prevents condensation of moisture in the instrument.
- A green indicator lamp glows when the heater is on. The lamp will go off when:
    1. Power supply fails.
    2. Temperature exceeds the cut-off point (around $60^0$ C).
    3. The thermal fuse fails.
- Open the sample flow valve to obtain the normal operation flow rate of 100 cc/min; a total inert gas flow rate between 100 cc/min - 1500 cc/min is acceptable but the instrument should be preferably set at 200 cc/min of which 100 cc passes through the instrument and the excess 100 cc bypasses to the bubbler unit.

#### *24.7.4 Shut-down Procedure*

- Shut off the sample gas supply by closing the gas inlet valve.
- Flush out the sample system with instrument quality dry air for 6 hours or flush with dry nitrogen for 3 hours.
- After flushing for an appropriate time, switch off the main electric supply and allow the analyser to cool.
- Maintain flushing until the analyser has cooled internally to within $2^0$ C of the ambient temperature. This is to avoid condensation of corrosive moisture of the gas trapped in the instrument.

## 24.8 Zirconia Oxygen Analysis

Zirconia is a ceramic that conducts electricity at high temperature by the movement of oxygen ions. This property is used in oxygen measuring cells for applications such as combustion gas analysis or gas purity measurement. This technique gives a robust way of accurately measuring oxygen.

It is used in combustion gas analysis in power stations where aggressive, hot gas mixtures are the norm and other industrial gas applications along with medical and physiological applications where extremely fast response times are paramount.

Some ceramics conduct electricity at high temperature through the movement of charged oxygen ions; zirconia is such a ceramic.

This ability can be used to measure oxygen in a gas mixture especially for direct measurement of hot flue gases; thus the need for sample conditioning equipment in combustion applications is reduced (Refer Figure 24.11).

A zirconia disk is mounted between the gas to be measured and a reference gas (usually air), inside a heater. Electrodes are connected to either side of the disc (Refer Figure 24.12). If there is a difference in oxygen concentration between the two sides of the disk, a voltage is generated and detected by the electrodes.

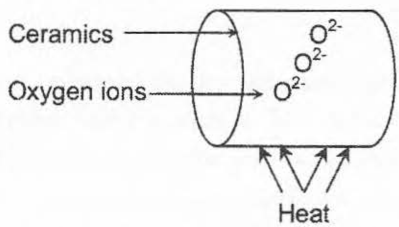



**Figure 24.11 – The Basic Device**

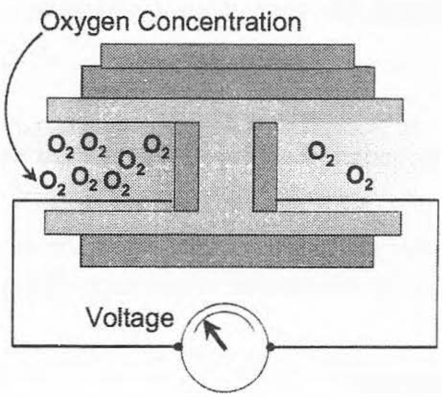



**Figure 24.12 – Construction of the Sensor**

In use, the zirconia disk is mounted on a flexible diaphragm in a rugged body - making it resistant to both thermal and mechanical shock (Refer Figure 24.13).

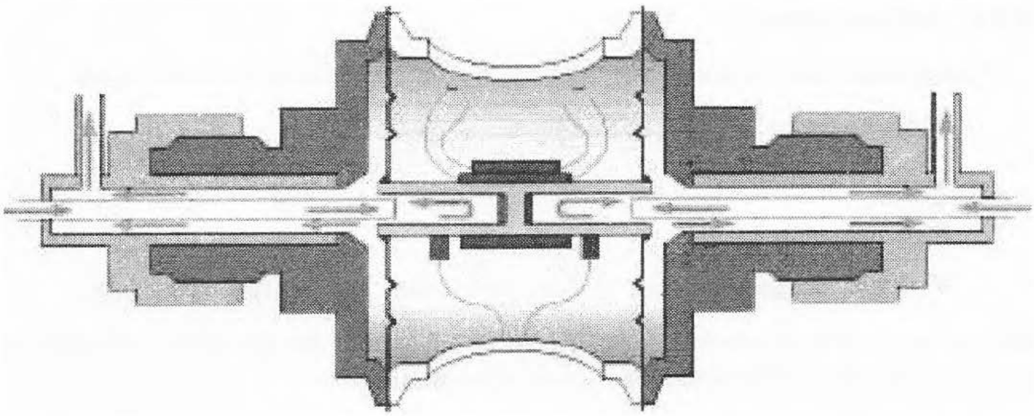


**Figure 24.13 – The Device in use**

## 24.9 Things to Remember

### *24.9.1 Presence of Gas*

There may be flammable gas in the tank; it may be at any opening to the tank -

- After loading or discharging volatile petroleum
- After loading non-volatile petroleum into a tank which is not gas-free

### *24.9.2 Pressure*

- Vapour in tanks may be under pressure

### *24.9.3 In Spaces Declared Gas-Free, Further Gas may be Released…*

- After loose scale or sludge is disturbed
- After a heating coil is opened up
- When a pipeline or valve is opened up
- When a cargo pump or valve is opened up
- When a cargo vent line is opened up

### 24.9.4 In Other Spaces...

Flammable gas may be in any space into which volatile petroleum may leak such as -

- Pump rooms
- Cofferdams
- Ballast tanks
- Empty compartments next to tanks used to carry low flash point petroleum

***Note:*** *A space declared gas-free is free of gas at the time of the test. The space may not remain gas-free. Remember that further gas may be released.*

The absence of flammable mixtures does not necessarily mean the space is gas-free and safe.

***Remember:*** *toxic gases are not necessarily flammable.*

Before you open a tank, any pressure must be released. This has to be done very carefully under controlled conditions.

Openings must be re-closed as soon as possible. A space may be certified gas-free and be:

- ✓ Safe for men and cold work (includes jobs which can cause sparks or enough heat to ignite any nearby vapour e.g., hammering).
- ✓ Safe for hot work (work that is so hot that it can actually cause dirty parts of a tank to give off vapour e.g. welding. This vapour can of course be ignited by the work).

## 24.10 Relevant Rules

### 24.10.1 Relevant SOLAS Regulations

Chapter II – 2 – Part B – Prevention of Fire and Explosion – Regulation 4 – Probability of Ignition and Chapter VI – Part A – General Provisions – Regulation 3 – Oxygen Analysis and Gas Detection Equipment.

### 24.10.2 Summary of Regulations

1) Tankers shall be equipped with at least one portable instrument (and means for its calibration) for measuring flammable vapour concentrations, together with a sufficient set of spares. Suitable means shall be provided for the calibration of such instruments.

2) Suitable portable instruments for measuring oxygen and flammable vapour concentrations shall be provided in double hull spaces and double bottom spaces.

3) Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces shall be fitted with permanent gas sampling lines that are electrically conductive and unrestrictive.

4) When transporting a bulk cargo which is liable to emit a toxic or flammable gas, or cause oxygen depletion in the cargo space, an appropriate instrument for measuring the concentration of gas or oxygen in the air shall be provided together with detailed instructions for its use.

## *Find the Answers*

1. The Combustible Gas Indicator or Explosimeter displays its result as a percentage of __________.
2. The MSA 40 is a dual range CGI, with two scales that read _________ and _________.
3. While using a CGI, it must be remembered that if the sampling line is more than ___ feet.
4. While using a CGI, it must be remembered that ____ additional squeezes will be required for every ten feet of line.
5. A tankscope measures the _____ gas content in a sample of atmosphere.
6. Why is gas-detection equipment required onboard?
7. What is an explosimeter?
8. Give a detailed explanation of the calibration procedure for a CGI of the MSA 40 type.
9. Draw and explain the Munday Cell Oxygen Analyser
10. Draw and explain the Pauling Cell Oxygen Analyser
11. The Tankscope is an important device. Explain this with relevant diagrams.
12. With the help of a diagram explain the Combustible Gas Indicator.
13. With suitable sketches, explain gas analysis using thick-film technology.
14. What is the influence of carbon dioxide on perishable cargo?
15. How is carbon dioxide analysis done?

16. Draw and explain the portable oxygen analyser.
17. Briefly explain the operation of a fixed oxygen analyser.
18. With suitable sketches, explain the role of ceramics in oxygen analysis.
19. What is the correct method of testing the gas detection equipment normally used on board tankers?
20. Entering a hazardous space is dangerous; what must be remembered before entering such spaces?

# Chapter 25
# Miscellaneous Systems

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

- ★ Explain the theory supporting cathodic protection
- ★ Understand the method of monitoring water purity
- ★ State the operating principles of galley and laundry equipment and water-tight doors
- ★ Explain the basic principles of monitoring and control of air-conditioning systems
- ★ Comply with relevant regulations governing some miscellaneous equipment

## 25.1 Introduction

The list of miscellaneous marine systems is exhaustive and volumes could be written on the innovative means of making an engineer's life easier on board a ship today. For example, although refrigeration and air-conditioning is a subject by itself, it has been briefly covered in this chapter in order to provide a pen-picture of the few electrical components found there-in. The others briefly covered are cathodic protection, water purity monitoring, water-tight doors, galley and laundry equipment.

## 25.2 Cathodic Protection

### *25.2.1 The Electrochemical Theory of Corrosion*

The presence of a solution which can conduct an electric current, an electrolyte, is one of the first requirements for corrosion. An electrolytic solution is any liquid that contains ions. Remember that ions are electrically charged atoms in a given solution and that even pure water contains both positively and negatively charged ions in equilibrium. Because of this, solutions of salts, acids and alkalis are all good electrolytes. In addition to an electrolyte, two electrodes - an anode and a cathode - are required for corrosion to be initiated.

The electrodes may consist of two different types of metals or they may be *different areas on the same piece of metal*. In either case, for corrosion to occur, there must be a difference in electrical potential between the two electrodes or areas so that electricity will flow between them. In addition to the portion of the electrical circuit made up of electrolyte, the circuit must be completed by a conductive path between the two electrodes.

If they are on the same piece of metal there is an inherent circuit. If they are separate pieces of metal they must be connected in some manner.

What takes place at the anode in a corrosion cell when corrosion occurs?

Positively charged atoms of metal detach themselves from the surface and enter into solution as ions, while the corresponding negative charges, in the form of electrons, are left behind in the metal (oxidation) (Refer Figure 25.1)

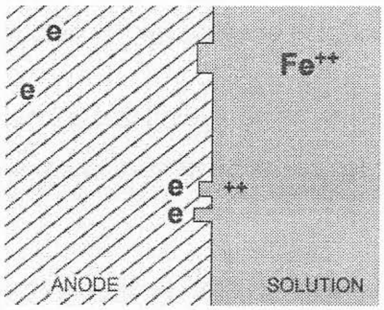



**Figure 25.1 – Detachment of Positive Charges**

The detached positive ions bear one or more positive charges. In the corrosion of iron, each atom releases two electrons and becomes an iron ion carrying two positive charges. The released electrons travel through the metal to the cathode area.

What takes place at the cathode?

The electrons reaching the surface of the cathode by passing through the metal circuit meet and neutralize some positively charged hydrogen ions which were present in the electrolyte. In losing their electric charge by gaining electrons the hydrogen ions become neutral atoms (reduction). They then combine to form hydrogen gas.

The conversion of hydrogen ions to hydrogen atoms and then to hydrogen gas results in a decrease in hydrogen ions in the electrolyte (Refer Figure 25.2). This increases the alkalinity of the electrolyte in the area of the cathode.

The ionic and cationic reactions discussed so far can be written as follows:

$$\text{Anodic Reaction - } Fe^{\circ} \rightarrow Fe^{++} + 2e$$

$$\text{Cathodic Reaction - } 2e + 2H^{+} \rightarrow 2H^{\circ} \rightarrow 1H_2$$

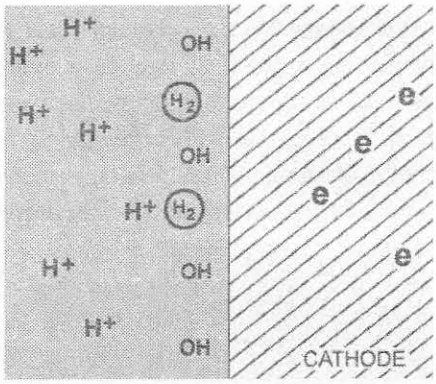



**Figure 25.2 – Conversion of Hydrogen Ions to Hydrogen Atoms**

The general electrochemical theory of corrosion states that corrosion proceeds by an anodic or oxidation reaction and a cathodic or reduction reaction. For a metal M, the reactions involving corrosion in an acid medium are given as:

$$\text{Anodic Reaction } M \longrightarrow M^{+} + e^{-} \qquad (1)$$

$$\text{Cathodic Reaction } 2H^{+} + 2e^{-} \longrightarrow H_2 \qquad (2)$$

From these reactions it becomes clear that metal dissolution involves oxidation of metal into metal ions with a simultaneous release of electrons. Electrons will flow from the anodic area through the hull to the cathodic area. By hydrolysis negatively charged hydroxyl ions will form. At the anode electron depletion leads to positively charged Fe (iron) ions. Hydroxyl ions migrate through the water to the anode, here combining with the iron ions to form $Fe(OH)_2$ which combines with dissolved oxygen to form $Fe(OH)_3$ or rust. In this way the anodic area will corrode. To prevent this it would be necessary to make the entire hull cathodic. Therefore, forcing electrons onto the metal will stop its corrosion. This technique is called "Cathodic Protection".

It is easy to see that several environmental factors can be varied to affect the corrosion rate. If for instance the hydrogen ion concentration is increased (pH reduced) the rate of corrosion is likely to increase since there are more hydrogen ions to receive electrons at the cathode. Conversely if the solution is made more alkaline (by reducing the H ion concentration - pH increased) corrosion can be reduced. Further by reducing the concentration of dissolved material in the electrolyte the conductivity of the electrolyte is reduced and the resistance is increased. An increase in resistance impedes the flow of current and the corrosion rate of an immersed material can be reduced.

It is important to note that anodes and cathodes can occur randomly on a piece of metal. This can be illustrated by placing a piece of steel in a hydrochloric acid solution. Upon immersion of the piece of steel in the acid solution, the vigorous formation of numerous hydrogen bubbles is observed. Hydrogen is evolved seemingly from the entire surface without the indication of either cathodic or anodic areas. This is, in fact, the case since the anodes and cathodes shift from time to time during corrosion under these conditions (Refer Figure 25.3).

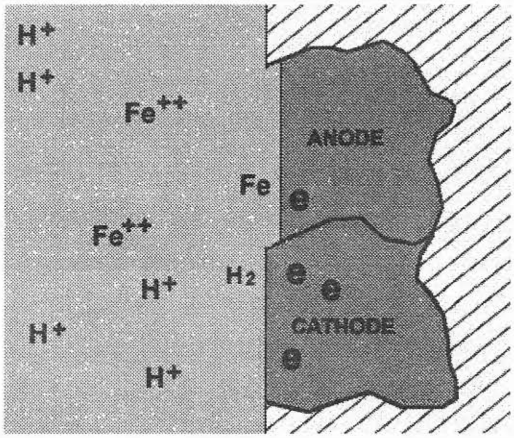



**Figure 25.3 – Anode and Cathode Occurrence on the Same Piece of Metal**

The development of an anode on a metal surface may result from a variety of microscopic surface conditions including local impurities in the metal, surface imperfection, orientation of grains in the metal, localized stresses and variations in environment.

The outer surface of a ship's hull is subjected to electro-chemical attack by corrosive currents that flow between areas of the hull, which are at slightly different electric potentials. Dissimilar metals, variations in structural and chemical uniformity in hull plates and welding, differences in paint thickness and quality, water temperature, salinity and aeration combine to cause areas of the hull to become either anodes (positive) or cathodes (negative).

The value of protection current must be critically controlled to just prevent corrosion, as beyond this value the increase in the rate of release of hydroxyl ions will cause sponginess and flaking of the anti-fouling paint.

Reference electrodes can determine the correct value of protection current. These are either made of zinc or silver attached to the hull below the waterline, but insulated from it.

The principle of cathodic protection can be well understood with the help of the E Log I diagram in Figure 25.4.

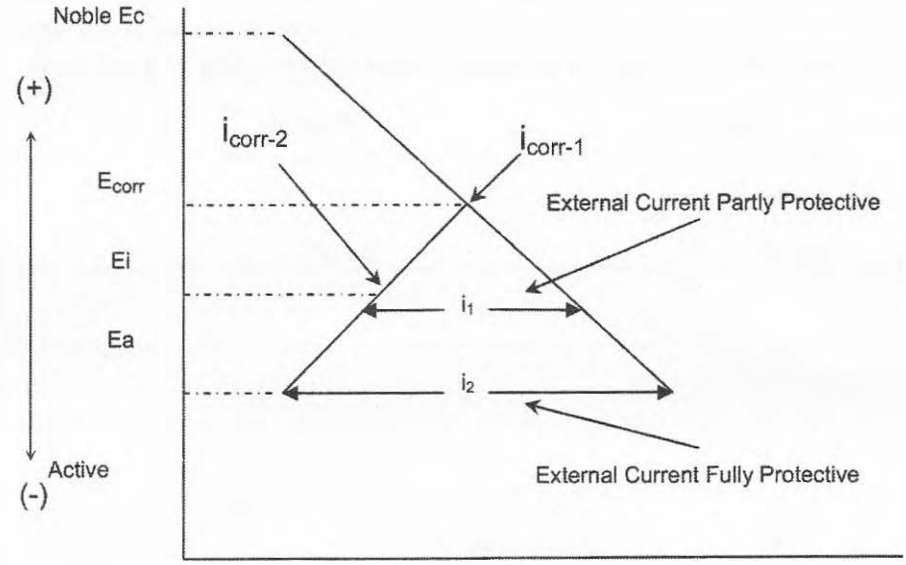



**Figure 25.4 – E Log I Diagram**

Figure 25.4 above illustrates the nature of polarization and the amount of current required when steel is subjected to complete protection by this technique.

Under freely corroding conditions the metal has a potential ($E_{corr}$) and corrodes at a rate equivalent to the corrosion current ($i_{corr-1}$).

If the potential of the metal is reduced from $E_{corr}$ to $E_a$ (equilibrium potential at the anode) by externally applied current $i_2$ then the metal will be protected.

Thus $E_a$ is the required potential at which the structure should be polarized for complete cathodic protection. Any amount of current less than $i_2$ will give partial protection. The voltage measured between the hull and reference electrodes of an unprotected ship is:

a) Zinc – 450 mV negative to hull with seawater as an electrolyte.

b) Silver – 600 mV positive to hull.

When satisfactorily protected, the protection current will make the hull 200 mV more negative, i.e. a zinc reference electrode will register 250 mV negative with respect to the hull and silver 800 mV positive with respect to the hull. The reference electrode voltage may, therefore, be used to monitor the protection, but more importantly, is used as the signal source to automatically control the value of protection current (Refer Figures 25.5 and 25.6).

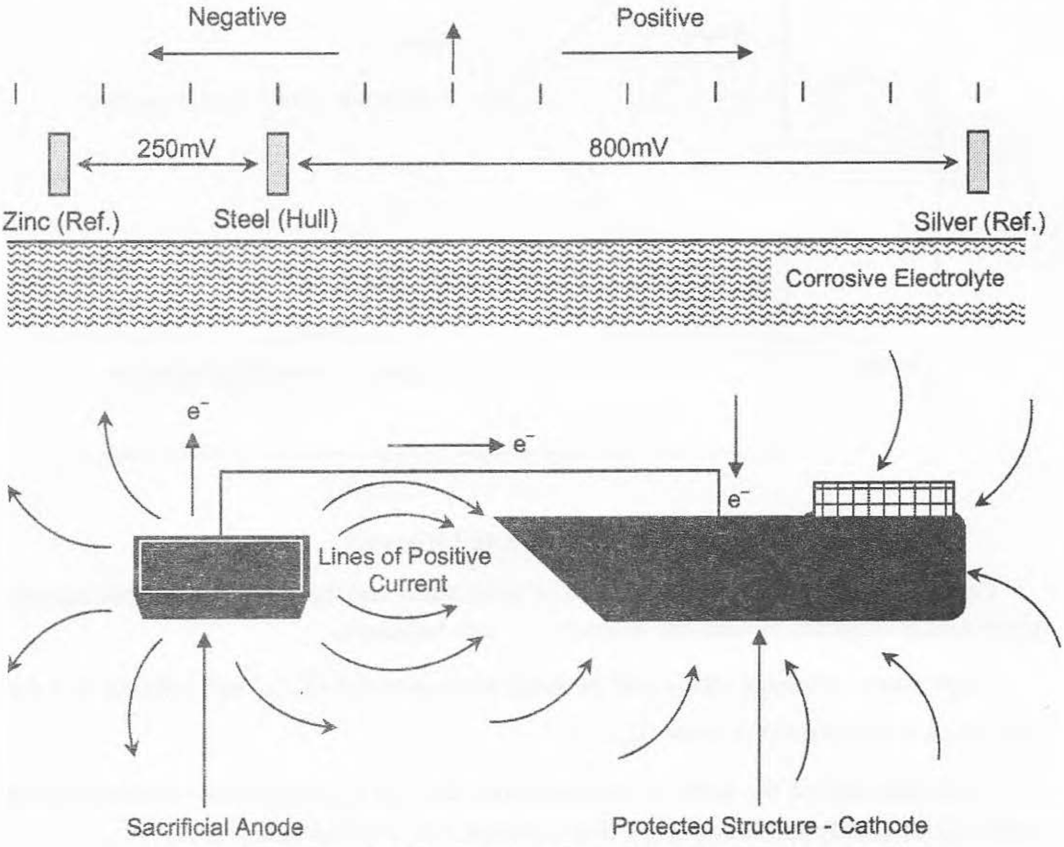



**Figure 25.5 – Sacrificial Anode System**

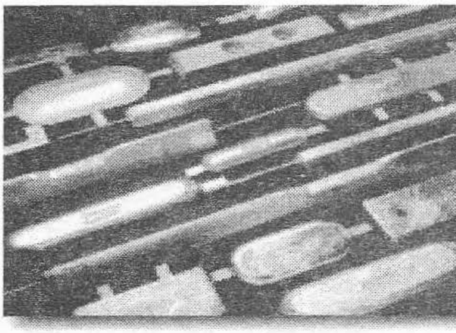


**Figure 25.6 - Sacrificial Anodes**

### *25.2.2 Impressed Current Cathodic Protection*

Cathodic protection systems fitted on ships consist of a number of anodes fitted to the hull at selected places below the waterline, and control equipment, which automatically regulates the anode current to the required value (Refer Figures 25.7 and 25.8). Direct current is supplied to the anodes, from the ship's 440V 60Hz 3-phase distribution system, after transformation and rectification. The amount of current required by the system depends upon the area beneath the waterline, the quality and state of the paintwork, the temperature of the seawater (higher the temperature, greater the electrolysis) and the speed of the vessel. Since the speed of the vessel constantly changes, it is most likely to cause changes in the current demanded too. It has been found to be almost twice as high when the vessel is underway (i.e., in motion) as compared to the period when it is alongside i.e., at rest.

The control equipment comprises reference electrodes, an amplifier assembly and one or more transformer-rectifier units. There are basically 4 modes of operation namely:

1. The Standby Mode - all output currents are zero.
2. The Manual Mode - the output currents are manually adjustable and must be carefully adjusted so as to prevent any permanent damage to the paintwork. As mentioned above, it may be required to double the current when the speed is say between 5 and 10 knots. Further increase in speed generally has little impact on the current demand.
3. The Automatic Mode - the outputs vary to provide a constant electrode potential. This installation is relatively expensive as compared to the manual system but the end results are better. Here, the potential difference between the hull and the reference electrode is constantly monitored and the output current is controlled.

4. The Configuration Mode - the controller set points may be adjusted (say one setting when the speed is zero knots and one when the vessel is underway)

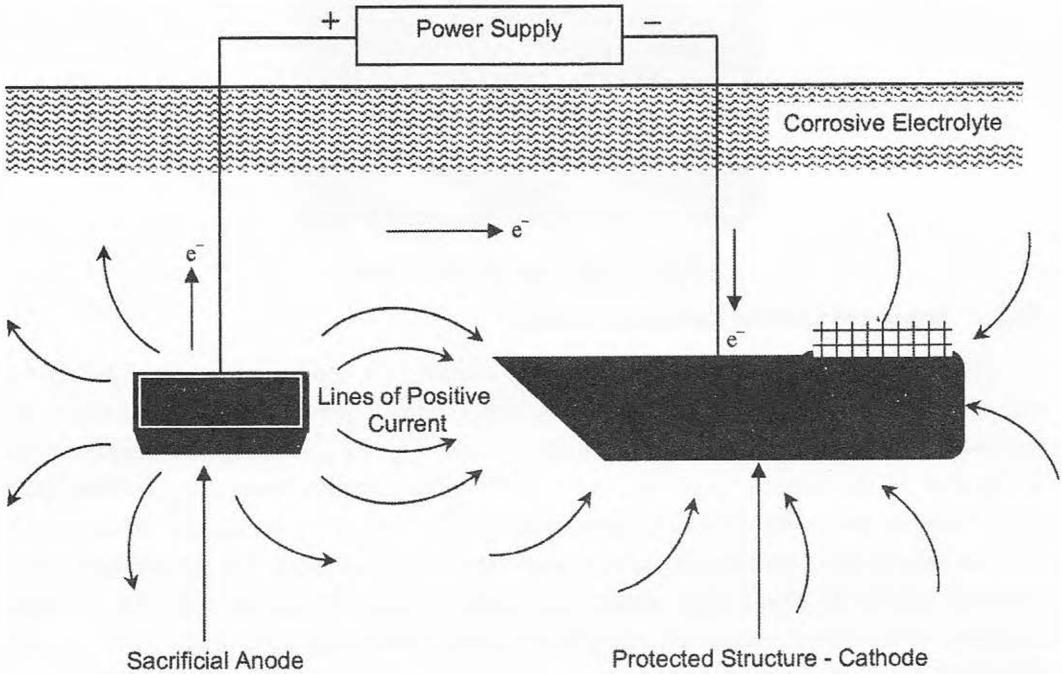



**Figure 25.7 – Impressed Current System**

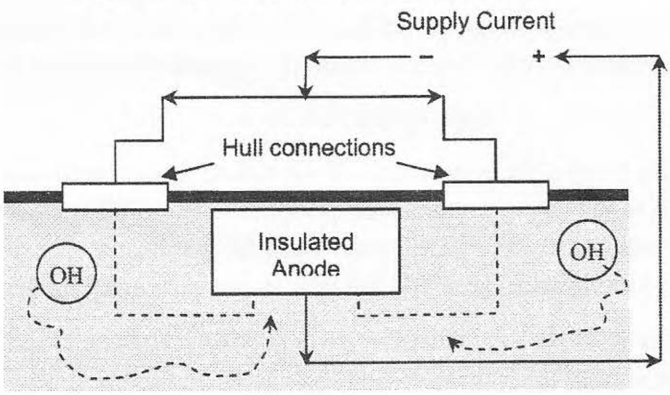



**Figure 25.8 – Impressed Current System Circuit**

Generally there are two subsystems comprising a Forward Controller Power Unit and an Aft Controller Power Unit. One central remote monitoring unit is normally shared between the two units; it is normally located in the engine control room. This unit helps to maintain the daily log of readings and also caters to housing the alarm circuits in case of any abnormalities in the system. Some monitoring facilities in the cathodic protection control cabinet / remote monitoring unit may facilitate the measurements of the following:

- Reference Electrode Voltage (hull potential)
- Amplifier output voltage
- Total anode current
- Individual anode current

Electronic thyristor amplifiers or magnetic amplifiers may control the anode current. The schematic diagrams in Figures 25.9, 25.10, 25.11 and 25.12 are examples of this.

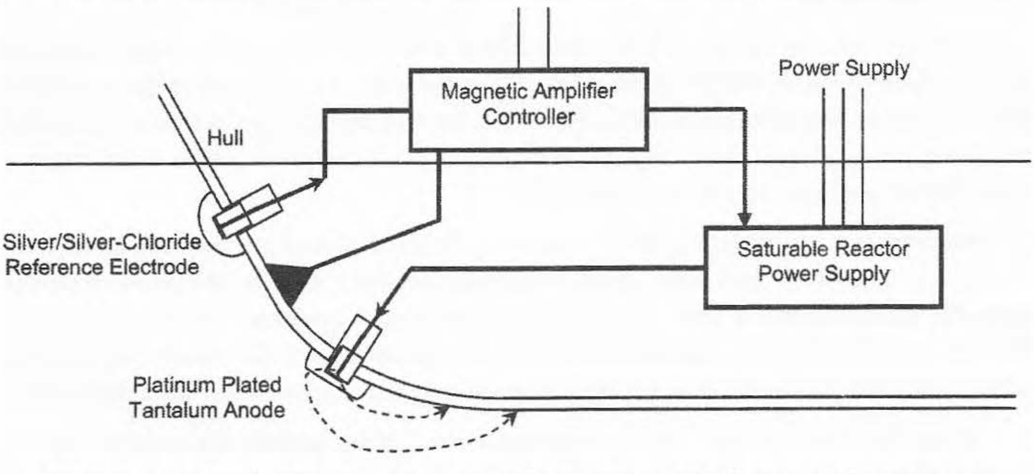



**Figure 25.9 – Layout of a Basic Impressed Current Cathodic Protection System**

The control equipment automatically monitors the magnitude of anode current required. This will vary with the ship's speed, water temperature and salinity, condition of paint work, etc. Typical anode current densities range from $10mA/m^2$ to $40mA/m^2$ for the protection of painted surfaces and 100 to $150mA/m^2$ for bare surfaces. The total controller current for a hull in good condition may be as low as 20A.

Maximum controller outputs in the automatic mode may be up to about 600A at 8V. Manual adjustments are also possible. Cathodic protection does not appear to deter molluscular growth on the ship's hull so a topcoat of anti-foul (poisonous) paint is still necessary.

As seen in Figure 25.8, the anode is insulated from the hull, electrical connection is via cable and ships side gland box. It may be made of lead or Platinised Titanium. With the lead anodes, the hydroxyl ions turn the surface of the lead to a rich brown colour ($PbO_2$).

A d.c. voltage is applied to just overcome the natural galvanic voltage. If the current is allowed to become too great then the increased hydroxyl release causes sponginess and flaking of the paint.

Referring to Figure 25.10, the cathodic system should make the hull 200mV more cathodic i.e. 200mV negatively charged. The system measures this by checking the hull voltage against an insulated reference anode which has a known value of galvanic voltage with the hull material.

Typically this may be Zinc which is normally at a voltage 450mV more negative than the hull, or silver which is 600 mV more positive than the hull. The Cathodic protection system will try to make the potential difference between the hull and the zinc reference anode 250 mV (Zinc anode 250mV more negative than the hull), and the silver anode 600mV (Silver anode 800mV more positive than the hull).

Measurements should be regularly logged, e.g. location, draught, water temperature, etc. Changes in underwater hull area, speed, water temperature / salinity and paint conditions cause the anode current to vary. The hull potential should, however, remain constant in a properly regulated system. Although the reference electrodes and the monitoring facilities give a reasonable day-to-day check they only measure in the vicinity of the fitted electrodes.

When the ship is moored singly or stopped at sea, voltage reading can be taken between portable silver or zinc test electrode and the ship's hull. This portable electrode is lowered 6-8 feet below the water surface, as close as possible to the hull at a specified position around the ship.

Check the manufacturer's instructions regarding the storage and setting up of the portable electrode. Some have to be immersed in a plastic bucket of seawater for about 4 hours before the hull test.

With the cathodic protection system switched on and working normally, the voltage measured between the hull and a silver / silver chloride portable electrode should be 750-850mV using a high-resistance multimeter (e.g. an AVO meter of the analog or digital type), the electrode being positive with respect to the hull. When the ship is dry-docked, ensure that the main anodes and reference electrodes are covered with paper tape to prevent contamination by paint.

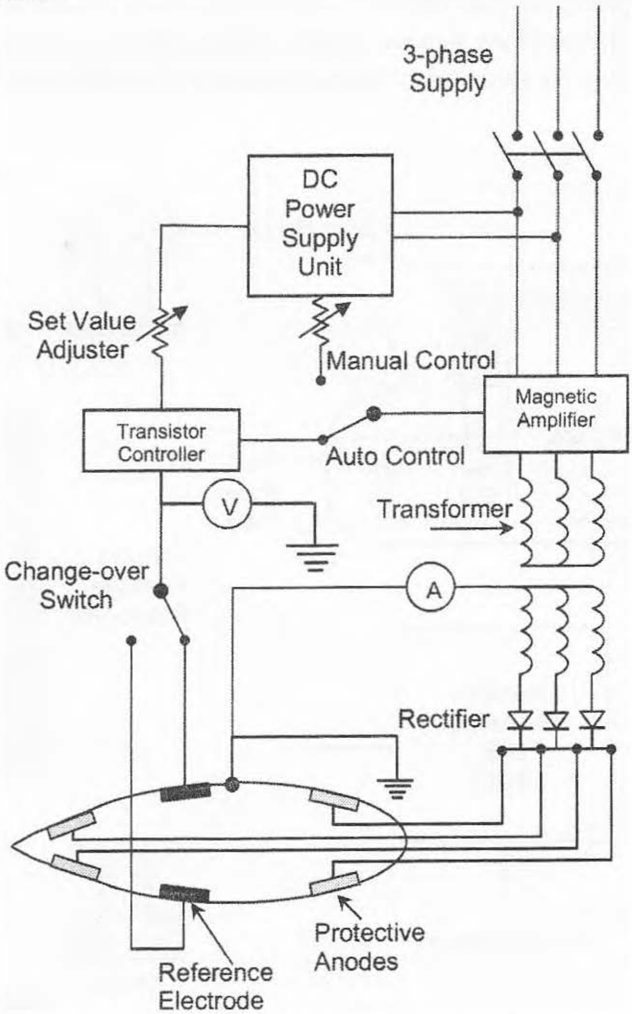



**Figure 25.10 – Schematic Diagram of an Impressed Current Cathodic Protection System**

In order to ensure that the rudder, propeller and stabiliser fins receive the same degree of cathodic protection as the hull, it is necessary to electrically bond these to the hull. The rudderstock may be bonded by a wire braid linking the top of the stock to the deck head directly about it. Carbon brushes in contact with slip rings on the main propulsion shaft effectively bond the shaft to the hull.

A periodic inspection of such earthing is worthwhile as the brushes wear away and may occasionally stick in their brush holders; this also ensures efficient bonding. A second set of brushes, insulated from the earth, can be used to connect a mV meter that monitors the shaft's potential.

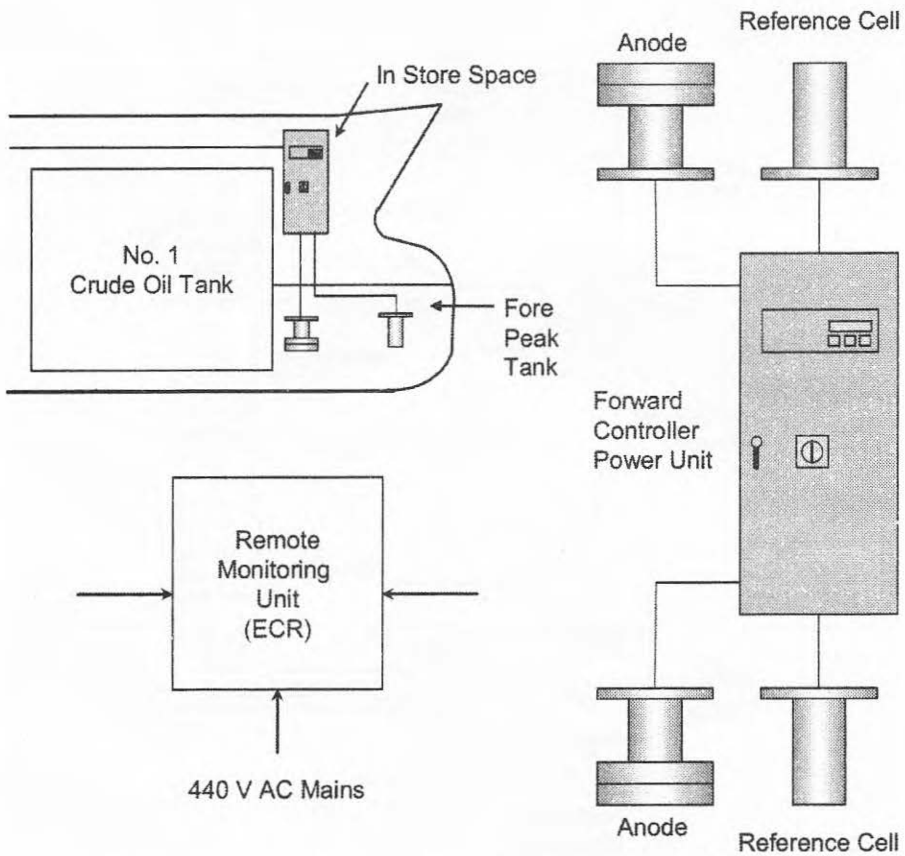



**Figure 25.11 – Example of System Components (Forward) and Remote Monitor**

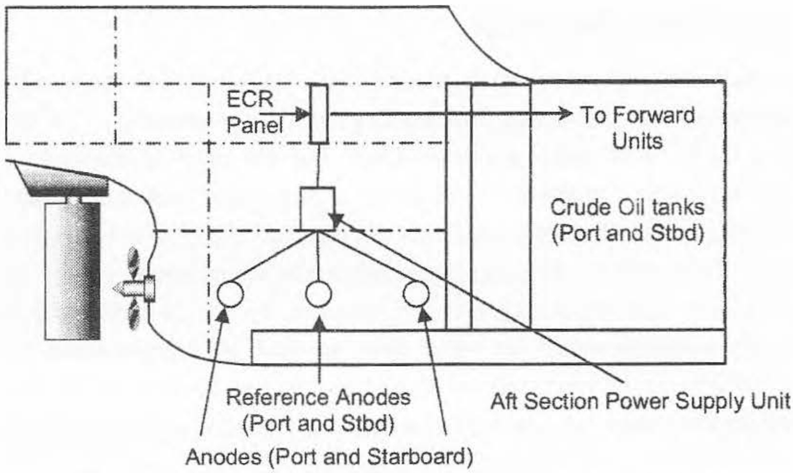



**Figure 25.12 – Example of System Components (Aft)**

### *25.2.3 Routine Checks*

- ✓ Record the output current and all voltages, including the reference electrode voltage, on a daily basis.
- ✓ Check and clean the propeller shaft's slip ring and brushes every week.
- ✓ Inspect the rudder stock earth strap once a month.
- ✓ Carry out other inspections / maintenance as directed in the ship's manuals.

### *25.2.4 Dangers to be avoided*

- Considerations should be given to spark hazards created by introduction of electric currents into structures situated in hazardous atmosphere.
- Any secondary structure residing in the same electrolyte may receive and discharge the cathodic protection dc current by acting as an alternative low resistance path. Corrosion will be accelerated on the secondary structure at any point where current is discharged to the electrolyte. This phenomenon is called as "interaction".
- Interaction is minimized by careful design of the cathodic protection system. Therefore where there are chances of interaction to take place we use SACP systems because they are less prone to interaction.

## 25.3 Monitoring of Water Purity

### *25.3.1 The Dionic Water Purity Meter*

Specific conductivity is measured in mhos / $cm^3$ and is equal to the conductance of a column of mercury - 1 $cm^3$ in volume. This is a large unit and micro mhos / $cm^3$ is used; when corrected up to $20^0C$, it is called a *Dionic Unit*. The electrical conductivity of water is dependent upon dissolved impurities. Conductivity of pure water is about 0.5 and fresh water is about 500 dionic units. The meter measures the conductivity of two columns of water, in parallel between the (positive) platinum rings and (negative) gunmetal collars of the sensor (Refer Figure 25.13). The insulating plunger, operated by the bi-metal strip temperature compensator, automatically varies the water flow, to facilitate compensation equivalent to $20^0C$. Dissolved $CO_2$ can be produced and should be removed by de-gasifiers. It is important that the measuring electrodes are kept very clean and the electrical connections are tight.

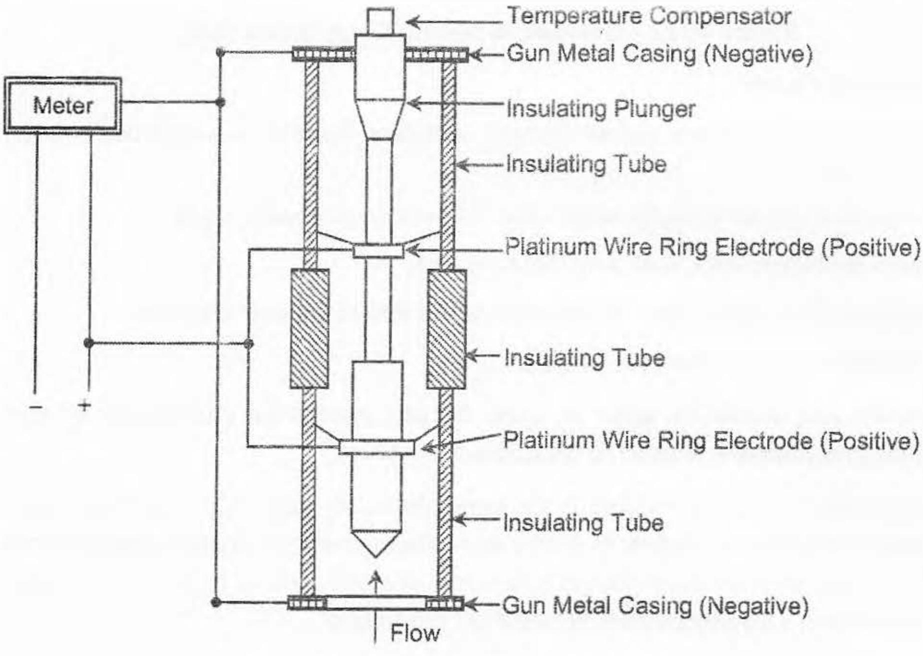



**Figure 25.13 - Dionic Water Purity Meter**

### 25.3.2 The Salinometer

It is a device which measures the impurity of water. The conductivity of the water can be continuously tested by the salinometer. If the device registers an excess of salinity, it can also dump the product using a solenoid valve and simultaneously activate an alarm.

Pure distilled water may be considered a non-conductor of electricity. The addition of impurities such as salt in solution increases the conductivity of water, and this can be measured. Since conductivity of water is, for low concentration, related to impurity content, a conductivity meter can be used to monitor the salinity of water; Figure 25.14 depicts one such circuit, the explanation of which is given in the following paragraphs. The incoming a.c. power supply, through the main switch and fuses, is fed to the transformer. A pilot-lamp on the 24-volt secondary winding indicates that the power supply is available.

A voltage is applied across the electrode cell and the indicator. The indicator shows salinity by measuring the current (in mA) which at a preset value (set with the help of the potentiometer) actuates an alarm circuit that incorporates a warning relay.

The transformer's secondary voltage is applied across a series circuit comprising the bridge rectifier, the current limiting resistor R2 and the electrode cell.

The current from the rectifier branches out into 2 paths, one through the temperature compensator within the probe, via resistor R2 and the other through the alarm relay's potentiometer (Pot.), the indicator (a mA meter) and resistor R3. The two circuits join a common return line to the low potential side of the rectifier.

The indicator is protected from overload by a zener diode and resistor R4 (connected in shunt across the indicator itself) and the potentiometer. When the water temperature is at the lower limit of the compensated range the total resistance of the compensator (a thermistor) is in the circuit.

As the temperature of the water increases the resistance of the compensator drops progressively, the electrical path through the compensator now has a lower resistance than the other branch and hence a large portion of current flows through it.

Conversely due to a fall in temperature the resistance of the compensator rises and a corrected reading is thus obtained over the (compensated) range. The compensator therefore ensures that the circuit is balanced and the total resistance of the two paths correspond to the water's conductivity alone.

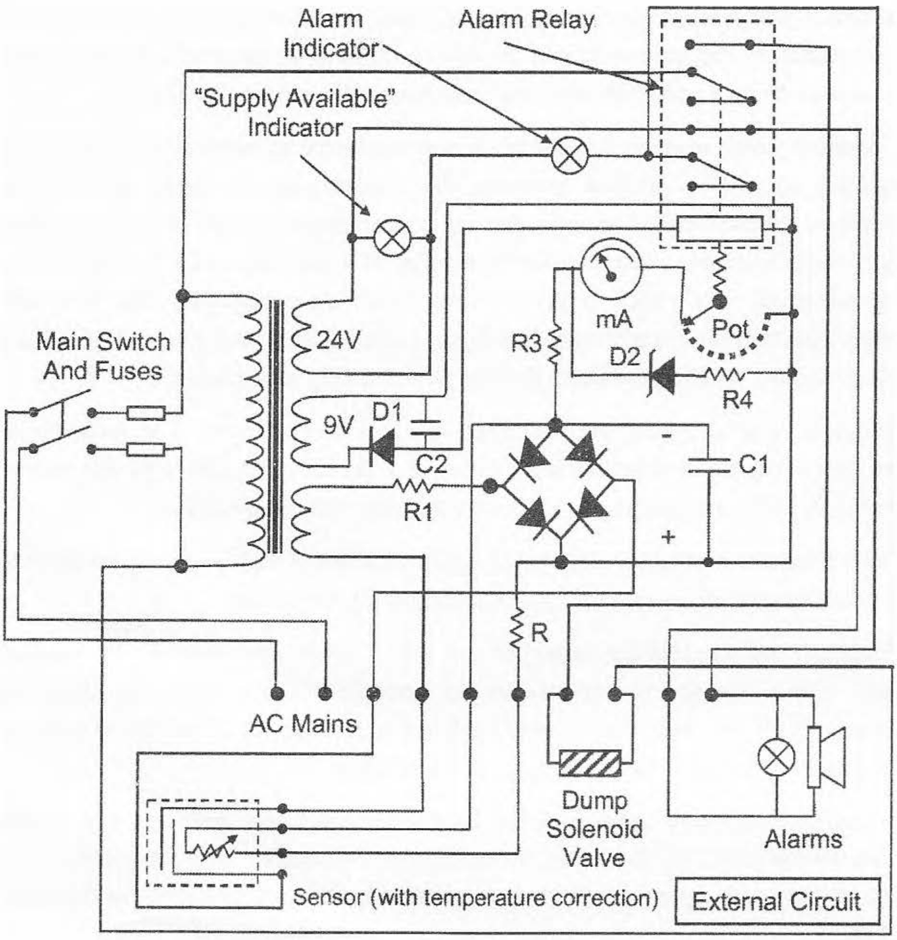



**Figure 25.14 – The Basic Salinometer**

The alarm setting is adjustable (with the help of the potentiometer) and the contacts of the warning relay make so as to complete the electrical circuit for a lamp or to activate an alarm when salinity exceeds the acceptable level. As mentioned earlier, the salinometer can also control a solenoid valve which dumps unacceptable feed water; this is made possible through the contacts of the same relay.

The salinometer's alarm circuit and solenoid valve reset automatically when the salinity drops to the desired value - based on the setting at the potentiometer due to the changing over of the relay's contacts.

The alternative to the circuit in Figure 25.14 is to have a digital meter. This is made possible by a comparator circuit where-in a reference signal serves to act as a base. The algebraic output of the comparator can be amplified, converted and fed adequately to the remote digital readout.

| Mg / litre | Ohmic value at $20^0$ C |
|---|---|
| 0.5 | 20632.0 |
| 1.0 | 10319.0 |
| 2.0 | 5162.0 |
| 3.0 | 3443.0 |
| 4.0 | 2583.0 |
| 5.0 | 2068.0 |
| 6.0 | 1724.0 |
| 7.0 | 1478.0 |
| 8.0 | 1294.2 |
| 10.0 | 1036.2 |

**Table 25.1 - Salinity to Ohmic Value**

## 25.4 Galley Equipment

*Extract from SOLAS Consolidated Edition 2004*

*Chapter II-2 - Construction – fire protection, detection, extinction*

*Regulation 10*

*Suppression of fire*

*Quote*

6.4 *Deep-fat cooking equipment*

Deep-fat cooking equipment shall be fitted with the following:

.1 an automatic or manual fire-extinguishing system tested to an international standard acceptable to the Organisation;

.2 a primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat;

.3 arrangements for automatically shutting off the electrical power upon activation of the fire-extinguishing system;

.4 an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

.5 controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

*Unquote*

The electrical power in a galley is largely utilised to produce heat. Ovens, deep frying pans, water boilers and the hotplates on the galley range employ resistive heating elements, which are usually controlled by bi-metallic thermostatic switches.

Other miscellaneous electric galley equipment may include oven air-circulating and range-exhaust fans, meat slicers, food mixers and grinders, dishwashers, potato peelers and garbage disposal units. Most of this equipment will utilise small electric motors together with their necessary control switches, safety interlocks and indicator lamps.

Due to the large power requirement for food preparation and cooking, the major galley items are supplied from the 3-phase 440V system. Smaller galleys may be supplied from the low-voltage 220V system.

The electrical equipment has to work safely in the usual galley atmosphere of high humidity and high temperature. The galley's electrical equipment thus operates in such an area where it must be prepared for faults caused by the environmental hazards of grease, grime, dust and dampness. Heating elements are usually formed from Nichrome wire insulated with magnesium oxide (MgO) powder within an Inconel tube, which forms the outer sheath. Power ratings vary from1kW to about 4kW and some elements are connected so as to give varying levels of heat.

The simplest arrangement is obtained using a 3-heat-level, 4-position switch to control 2 elements within a single hot plate. The switch settings give one a choice of *Off* (disconnected), *Low* (both in series), *Medium* (one element) and *High* (both in parallel). In order to obtain the same, the two resistance elements are generally interconnected as shown in Figure 25.15. Better control of heating elements is obtained by using 'simmerstat' switches and electronic switching. The simmerstat switch-type houses a bi-metallic switch that 'cycles' the heating element on and off at a rate pre-determined by the switch setting.

Average hot-plate temperature is fixed by the ratio of time that the element is switched on, to the time it is switched off. Circuit current heats the bi-metallic thermostat, which operates a switch for the same. Oven simmerstat controls have a similar switching action but a temperature sensing capillary tube, located in the oven, deflects a diaphragm or bellows that activates the switch.

Electronic switching devices such as transistors, thyristors and triacs may also be used for temperature control of ovens and hot plates. One must be careful not to megger test low-voltage electronic components during maintenance and faultfinding. Check the manufacturer's instructions and drawing before locating faults in a control circuit.

The most likely fault in a heating element is a simple open-circuit. Earth faults within the element or in the cables supplying it are also probable. Loose wire-connections can cause localised over-heating, with the wire burning away to leave on open-circuit, but the possibility of short-circuits or earth fault conditions also arise. Connecting wires close to heating elements should be covered with a high-temperature silicone or fibreglass sleeving or with ceramic beads.

When measured cold, the resistance value may be slightly lower than the calculated value. High power ovens and hot-plate ranges are often supplied from the 3-phase, 440V supply. Thermostats control the on-off heating cycle.

Microwave ovens provide rapid defrosting and cooking of foods. The microwaves are produced by a *magnetron* operating at around 4000V with a frequency of approximately 2450MHz. Specialised knowledge is required for the repair of this type of oven and internal faultfinding is not recommended without the manufacturer's guidance.

Inspection and maintenance of galley equipment is most important. The main objective is to keep the electrical parts dry and free of oil, dust and grease.

Pay particular attention to all connection points in high-current heating circuits where loose connections cause overheating and further problems. For operator safety, all related metalwork must be earthed and regular checks of earthing straps must be given priority.

Insulation tests on heating elements, when they are cold, may reveal surprisingly low values (10-100kΩ) even with new elements. This is because the element insulation (magnesium oxide powder) is somewhat hygroscopic (absorbs moisture).

The insulation resistance of a healthy heating element should rise rapidly after being operated for a few minutes. Obviously, if the insulation resistance of an element remains low when hot, it is defective and must be replaced.

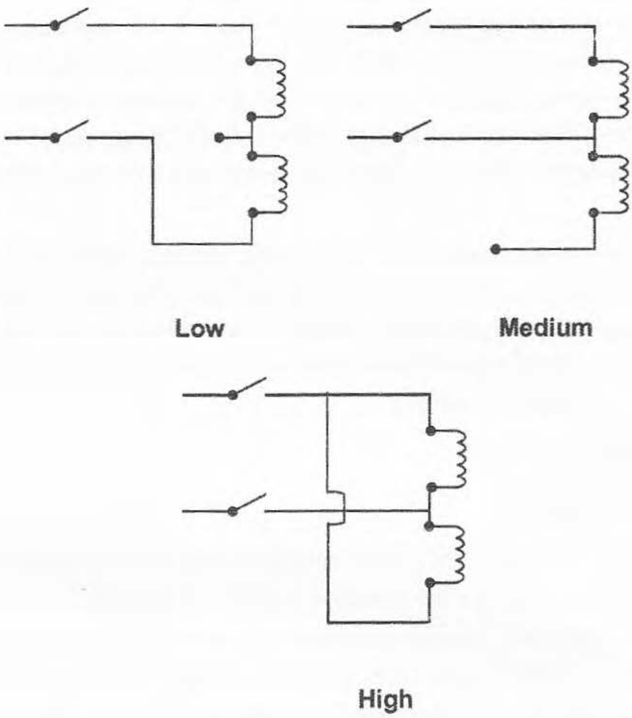



**Figure 25.15 - Heater Connections for Galley Plates**

## 25.5 Laundry Equipment

Washing machines' spin driers and tumble dryers utilise heat and mechanical rotation during their laundry processes.

The sequence of events is controlled by timers which are often simple electric timer motors driving cam-operated switches. Alternatively, electronic timers with relay-switching or solid-state switching using thyristors or triacs may be employed.

Small washing machines operating on a single-phase supply have motors, which are usually the split-phase type of the capacitor-start, capacitor-run variety.

Larger washing machines operate with 3-phase supply (i.e., with a 3-phase induction motor drive). When using such machines, care should be taken to ensure that the right voltage and frequency is available; failure to do so will result in over-heating and consequent damage (Refer Articles 4.3.1 and 4.3.2 for further information).

Control items in washing machines include water level switches, temperature switches (bi-metallic) and solenoid valves in the inlet and outlet water lines. Lid and door switches interrupt the main power supply if operated after the washing sequences have begun. Spin-dryers have a safety-door interlock that prevents it from being opened while the drum is still revolving. Tumble dryers often only have one motor with a double-ended shaft for drum and blower fan drives.

Lint and fluff collects on the motor and wiring, which causes no trouble while it remains dry and in small quantities. Periodic removal of the fluff will help prevent faults arising where dampness may combine with the fluff to cause conductive tracking between live conductors and also to the earth. Small single-phase motors are sometimes protected by a thermal cut-out connected to the stator-end windings.

## 25.6 Water-tight Doors

### *25.6.1 Control of Doors*

Where doors are designed for power operation, they will be capable of being remotely closed from the bridge and are also locally controlled from each side of the bulkhead. Each power-operated sliding door will be provided with an individual hand-operated mechanism (Refer Figure 25.16). Where designed for power operation, a single failure in the electric or hydraulic power-operated system excluding the hydraulic actuator will not prevent the manual operation of any door. Where necessary for power operation of the door, means to start the hydraulic unit, or equivalent arrangement, will be provided at the navigation bridge, and at each remote control position, if provided, and also the local control position.

### *25.6.2 Monitoring of Doors*

Displays provided at the control position indicate whether the doors are open or closed. Display and alarm systems are generally self-monitoring such that any failure in the system (e.g. power failure, sensor failure, etc.) will be detected and displayed at the navigation bridge control panel.

### *25.6.3 Alarm while Closing Power-operated Doors*

Every power-operated sliding door is provided with an audible alarm which will be activated whenever the door is closed remotely; it will be active for at least five to ten seconds before the door begins to move and will continue until the door is completely closed.

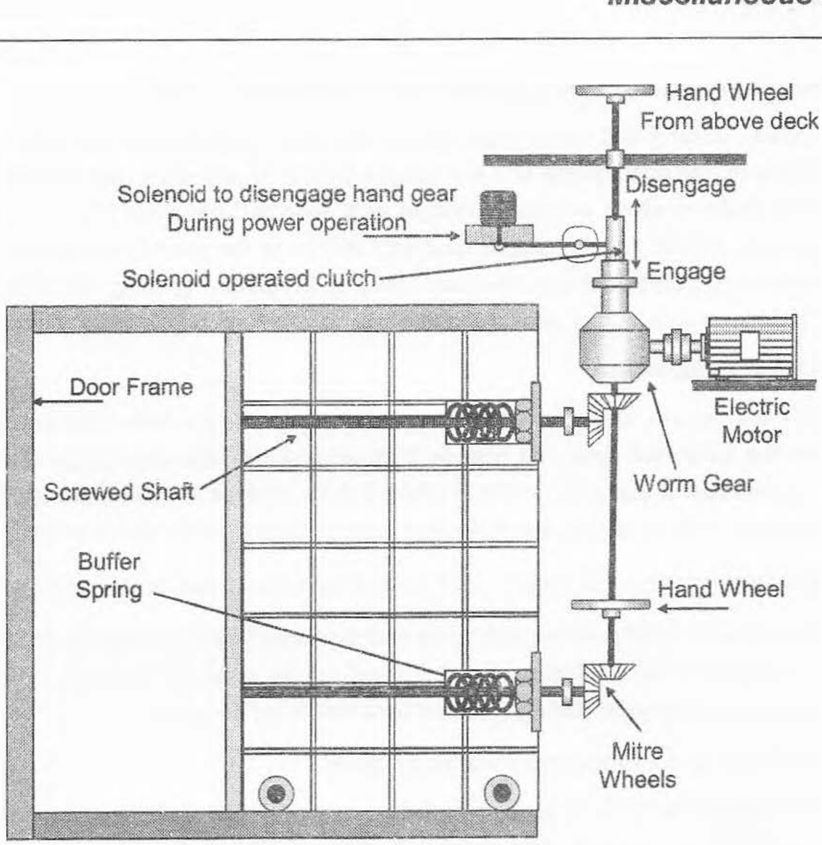



**Figure 25.16 – A Watertight Door**

### *25.6.4 Electrical Power Supply*

The electrical power required for power-operated doors is generally supplied from the emergency switchboard either directly or through a distribution board situated above the bulkhead deck. The associated control and monitoring circuits are supplied from the emergency switchboard also, either directly or through a distribution board situated above the bulkhead deck.

The power circuits for power-operated doors are segregated from the power supply to any other systems. The availability of the power supply is continuously monitored on the load side of the feeder's protective device and the loss of any such power supply activates an audible and visual alarm at the navigation bridge control panel.

### 25.6.5 *Protection of Electric Power, Control and Monitoring Circuits*

Electric power, control and monitoring circuits are also protected against faults in such a way that a failure in one door circuit will not cause a failure in any other door circuits. Short-circuits or other faults in alarm or display circuits of a door will generally not result in a loss of power operation of that door. A single electrical failure in the power-operating or control system of a power-operated door also does not result in accidental opening of a closed door. This feature is important in areas below the waterline.

### 25.6.6 *Electrical Equipment*

As far as is practicable, electrical equipment and components for watertight doors will be situated above the freeboard deck and outside hazardous areas. The enclosures of electrical components necessarily situated below the freeboard deck provide suitable protection against the ingress of water. In this context, the following degrees of protection are to be maintained:

※ IPX7 standard for electrical motors, their associated circuits and control components;.

※ IPX8 standard for door position indicators and associated circuit components; the water pressure testing of the enclosure is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.

※ IPX6 standard for door movement warning signals.

Doors and hatches fitted with gaskets and dogs are provided with means of indicating locally and on the bridge, whether they are open or secured closed. For this purpose all dogs are generally monitored individually. When all dogs are linked to a single acting mechanism, then only the monitoring of a single dog is required.

### 25.6.7 *Displays and Alarms*

The alarm system is designed on the fail-safe principle. The display and alarm system will be of the self-monitoring type and incorporate the following:

- ✓ Separate indicator lights are provided on the navigation bridge and on each operating panel to indicate when the doors are closed and that their locking devices are properly positioned.
- ✓ The display panel on the navigation bridge is equipped with a mode selection function ''harbor/sea voyage'', arranged so that an audio-visual alarm is activated if whilst it is in the "sea voyage" mode, the doors are not closed, or any of the securing devices are not in the correct position.

- ✓ Display of the open/closed position of every door and every securing and locking device is available at the operating panels.

### *25.6.8 Indicator Lights*

Indicator lights are designed so that they cannot be manually turned off. The display panel also incorporates a lamp-test function.

### *25.6.9 Power Supply*

The power supply for the display system is independent of the power supply for operating and closing the doors.

### *25.6.10 Protection of Sensors*

Sensors are protected from water, ice formation and mechanical damage.

### *25.6.11 Leakage Monitoring*

#### *25.6.11.1 Bow Doors and Inner Doors*

For vessels fitted with bow and inner doors, a water leakage detection system with an audible alarm and sometimes television surveillance, provide an indication to the navigation bridge and to the engine control room, of leakage through the inner door.

#### *25.6.11.2 Side Shell Doors and Stern Doors*

In the case of passenger vessels fitted with side shell or stern doors, a water leakage detection system with an audible alarm and television surveillance provides an indication to the navigation bridge and to the engine control room of leakage through any of the doors.

For cargo vessels fitted with side shell or stern doors, a water leakage detection system with an audible alarm provides an indication to the navigation bridge of any leakage through the doors.

### *25.6.12 Drainage*

A drainage system is arranged in the area between the bow door and ramp and in the area between the ramp and inner door, where fitted. The system is generally equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding half a metre above the car deck level.

### *25.6.13 Door Surveillance*

Between the bow door and the inner door a television surveillance system is fitted with a monitor on the navigation bridge and in the engine control room. The system monitors the position of doors and a sufficient number of their securing devices.

### *25.6.14 Features of an Electrical System as Installed Onboard*

★ The local indication system consists of an indication panel and magnetic sensors

★ Magnetic sensors indicate when the equipment (e.g. a door) is closed and all the cleatings are locked.

★ The indication panel is located close to the manoeuvring stand from where the operator also has a good view of the cargo access equipment being controlled.

★ The bridge indication system comprises a remote indication panel and one control unit

★ The bridge indication panel shows the closed and *cleated* status of all the ship's watertight items with a green and red light-emitting diode (LED) for each (the green diode indicates that the door, etc, is closed and all cleatings are locked, while the red diode indicates improper securing).

★ An audible alarm (a buzzer) is activated when any of the watertight doors, etc are open causing the indications to change from green to red thus immediately drawing attention to this change. This alarm can be reset by operation of an "*alarm accept*" button. In order to assist night vision on the bridge, all green diodes can be dimmed; for safety reasons this cannot be done to the red ones. All LEDs can be tested by an indication check push button.

★ The signals indicating closed and cleated status of watertight items are also continuously transmitted to the ship's Voyage Data Recorder (VDR), to be used in subsequent investigations in case of an incident.

★ The control unit is normally located below the bridge indication panel inside the bridge console. This unit controls the bridge indication panel described above.

In addition to its use with watertight items, the indication system can be employed with weather-tight equipment such as bow and stern doors on Ro-Ro vessels, and side shell doors on other ships.

*Extract from SOLAS Consolidated Edition 2004*

*Chapter II-1*

*Construction – Structure, Subdivision and Stability, Machinery and Electrical Installations*

*Part B – Subdivision and stability*

*Regulation 15 - Openings in watertight bulkheads in passenger ships*

*Quote*

8.1 The central operating console at the navigating bridge shall have a "master mode" switch with two modes of control: a "local control" mode which shall allow any door to be locally opened and locally closed after use without automatic closure, and a "doors closed" mode which shall automatically close any door that is open. The "doors closed" mode shall permit doors to be opened locally and shall automatically recluse the doors upon release of the local control mechanism. The "master mode" switch shall normally be used in an emergency or for testing purposes. Special consideration shall be given to the reliability of the "master mode" switch.

8.2 The central operating console at the navigation bridge shall be provided with a diagram showing the location of each door, with visual indicators to show whether each door is opened or closed. A red light shall indicate a door is fully open and a green light shall indicate a door is fully closed. When the door is closed remotely, the red light shall indicate the intermediate position by flashing. The indicating circuit shall be independent of the control circuit for each door.

8.3 It shall not be possible to remotely open any door from the central operating console.

*Unquote*

## 25.7 Refrigerating Machinery

### *25.7.1 The Vapour Compression Refrigeration Cycle*

Most marine refrigeration plants make use of the vapour compression refrigeration cycle. As refrigerants are too expensive, it should be ensured that after the refrigerant has done its cooling job, the gas is collected and re-liquefied. This is accomplished by using a compressor to suck gas from the evaporator at low pressure and to deliver it as hot compressed gas to a condenser.

The compressor raises the gas temperature above that of the atmosphere (or seawater) so that either air or water at normal atmosphere temperature can be used as the cooling medium in the condenser (Refer Figure 25.17).

In order to complete the circuit, the liquid from the condenser passes through a regulator, or expansion valve, which controls the flow of liquid to the evaporator. The part of the circuit downstream from the expansion valve to the suction valve of the compressor is called the low-pressure side of the system, and that from the compressor delivery valve to the upstream side of the expansion valve is the high-pressure side. The correct functioning of the expansion valve is of paramount importance.

Compressors are usually of the continuous running, fixed-speed-type; the correct functioning of the expansion valve is necessary in order to maintain the appropriate amounts of refrigerant in the high and low pressure sides.

In order to obtain high efficiency, the amounts of refrigerant must be correct so that there is enough refrigerant in the condenser for the liquid refrigerant to be sub-cooled and only enough refrigerant in the evaporator to ensure that there is some superheating of the gas.

This correct working of the cycle is obtained when the total charge of refrigerant in the system is correct, and the expansion valve is correctly maintaining its distribution between the low and high-pressure sides.

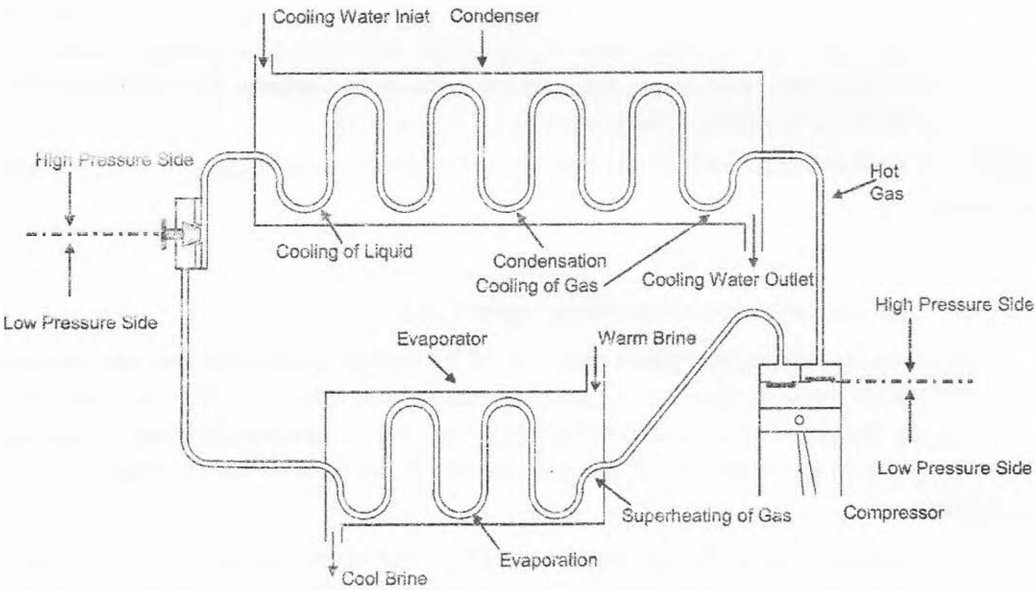



**Figure 25.17 – The Refrigeration Cycle (with a Water-Cooled Condenser)**

### 25.7.2 Refrigerants

Refrigerants play a vital role in most cooling systems. Amongst refrigerants, R-12 (Dichlorodifluoromethane) with a boiling point of -30$^0$C, R-22 (Monochlorodifluoromethane) with a boiling point of -41$^0$C and R-502 (48.8% R-22 and 51.2% R115) are used.

The first two are popular because of the following characteristics:

- ✓ Non-explosive
- ✓ Non-combustible
- ✓ Non-toxic (however at high temperatures they can decompose causing toxic phosgene gas to be evolved and vapours may turn explosive, so they should not be taken for granted)
- ✓ Non-irritant
- ✓ Odourless, liquid and oil miscible.
- ✓ Available worldwide

### 25.7.3 Compressor Safety Devices

The compressor is protected by three safety switches;

#### 25.7.3.1 HP or High Pressure Switch

This is fitted to the outlet of the compressor before the isolating valve. On over-pressurisation, dependent on the refrigerant, up to about 24 bars for R22, the switch will trip the compressor and a manual reset is required before restart.

#### 25.7.3.2 LP or Low Pressure Switch

When activated (at about 1 bar for R22), it will trip the compressor and require a manual reset before the compressor can be restarted

#### 25.7.3.3 OP switch or Oil Differential Pressure Switch

This compares the measured lubricating oil pressure with the suction (crankcase) pressure. Should the differential pressure fall below a pre-set minimum value, (about 1.2 bars) then the compressor will trip and requires a manual reset to restart. A time delay is built into the circuit to allow sufficient time for the lubricating oil pressure to build-up when starting before preparing the circuit to be capable of tripping in case of a drop in lubricating oil pressure below the nominal value.

### *25.7.4 Compressor Control Devices*

This normally takes the form of a Low Pressure cut-out pressure-switch with an automatic reset when the pressure rises. The cut-out set point is just above the LP trip point say at about 1.4 bars. An adjustable differential is set to about 1.4 bars to provide a cut-in pressure of around 2.8 bars. The electrical circuit is so arranged that even when the switch has reset, if no rooms' solenoid-valves are open the compressor will not start. This is to prevent the compressor cycling due to a leaky solenoid valve. In addition to this, extra LP switches may be fitted which operate between the extremes of the LP cut in and cut out to operate compressor unloaders. Some modern systems contain a rotary vane compressor with variable speed control (with the help of frequency variation).

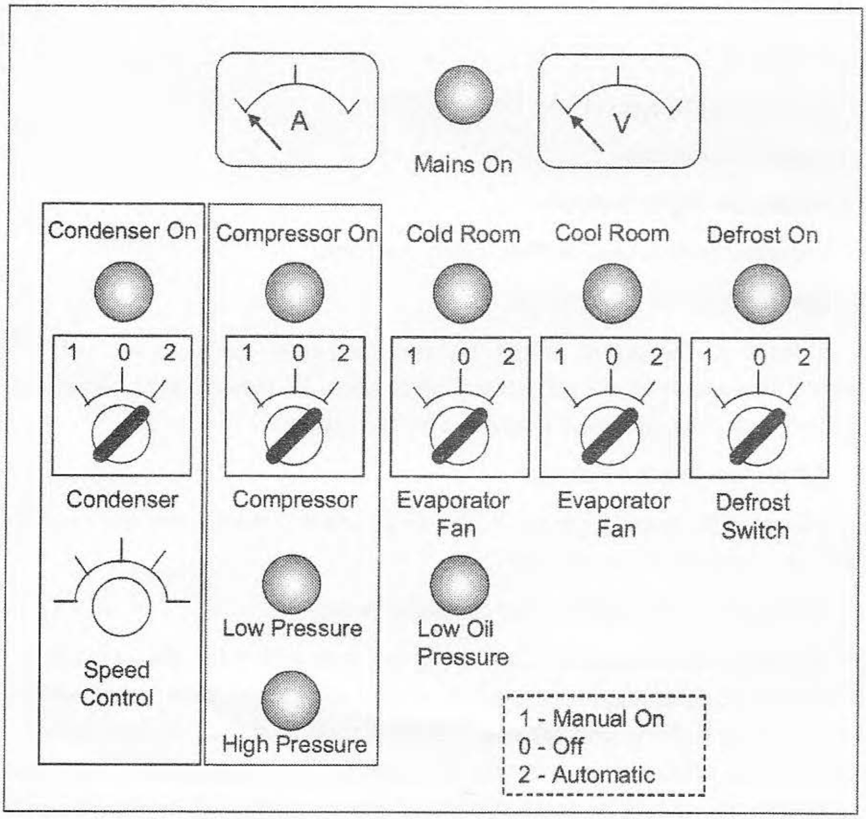
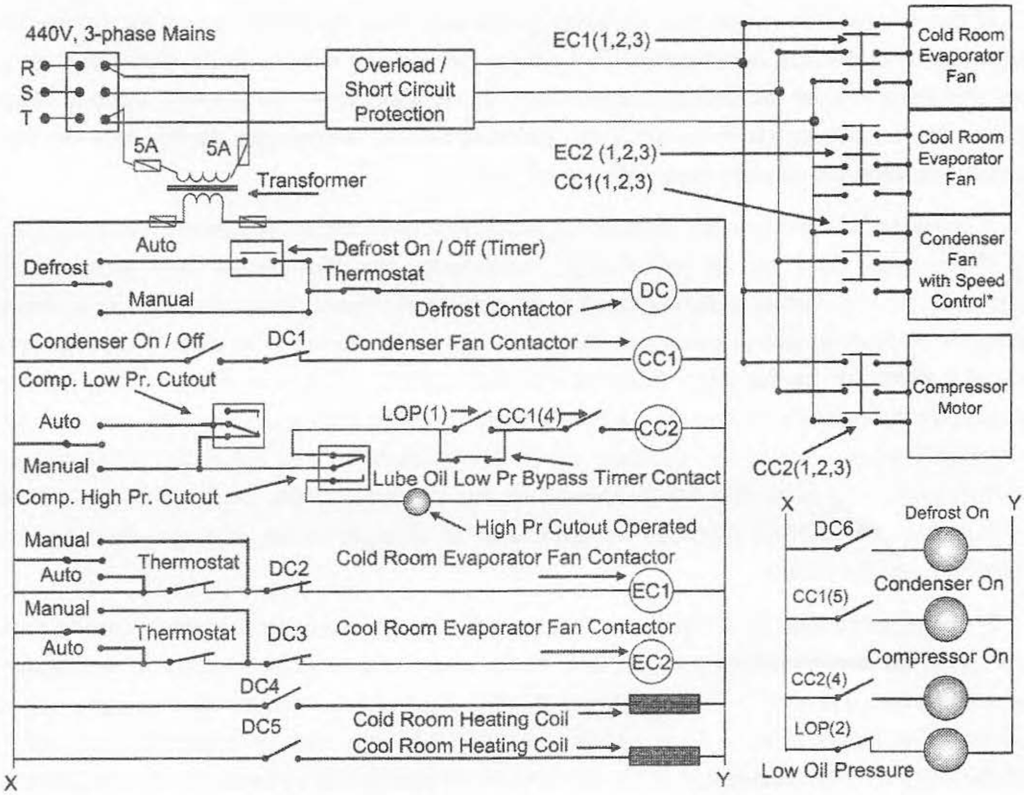



**Figure 25.18 - A Refrigeration System's Control Panel (with an Air-Cooled Condenser)**




***Note:*** *Each motor in the circuit will have dedicated overload and short circuit protection*

**Figure 25.19 - A Refrigeration System's Basic Circuit (with an Air-Cooled Condenser)**

## 25.8 Air-conditioning Systems

### *25.8.1 What Air-conditioning Means...*

Air-conditioning means to *modify the temperature and humidity of a room in order to achieve a more comfortable living condition.* An air-conditioning system has the capacity to take the air of a room, treat and deliver it back in a cool and dehumidified state. An air-conditioner also normally has the capacity to heat the room when it is equipped with either the reverse cycle system or with an electrical heater. An air-conditioner is also supplied with a room temperature controller (thermostat), an on/off switch and a fan-speed controller with multiple speeds.

If the air-conditioner also has the heating function, then the control panel also gives the choice between cooling and heating. This choice can also be automatically made, in such a way that once you set the desired temperature, the air-conditioner control will automatically choose the functioning mode to reach and maintain the set temperature. In this case the air-conditioner becomes an environmental control system.

All types of thermostats are found in air conditioning systems - pneumatic and electrical. By themselves, they are all satisfactory instruments, but the results they achieve are dependent on the correct installation of their sensing elements. Even the site for a direct acting thermostat to control one single-berth cabin must be chosen with care. If it is masked behind curtains, or too far away from the air inlet, control will be too sluggish. The correct location for a thermostat to control a block of cabins is more difficult to find. One can pick on a "typical" cabin - but if the occupant opens his porthole he can upset the whole block. Another possibility is to site the thermostat in the alleyway of the block of cabins. This position may be affected more by an open door or draught in the alleyway than by the temperature of the cabins.

Yet another possibility is to site the thermostat in the re-circulation air trunk, carrying air back from the accommodation to the unit. If the re-circulation grille is close to an outside door, this position too can be affected by outside air temperature when the door is open, rather than by cabin temperature. A large public room, say a lounge, may be impossible to control satisfactorily by one thermostat. If one thermostat is positioned awkwardly, it may sense a temperature higher than the average in the room and cause air to be delivered, which will be too cold for the comfort of those sitting around the edge of the room.

Similarly, a thermostat sited at the edge of the room may leave too high a temperature in the central area. The only satisfactory arrangement for such rooms is to have different controls for different parts of the room. Accurate temperature records for cargo spaces are essential to guide the operating engineer and also as evidence that correct temperatures were maintained in the event of any cargo arriving in less than a perfect condition.

Remote reading thermometers are usually platinum resistance thermometers, with a resistance of about $100\Omega$ at $0^0C$ (known as the PT-100 type), whose bulbs are rubber-covered and vulcanised to the cable to ensure complete water-tightness. The calibration of this type of thermometer can also be checked in melting ice.

The earliest installations of this type were connected via a selector switch in the engine room, to an indicator in which manual adjustment of a Wheatstone bridge circuit was made to ensure zero deflection on a sensitive galvanometer. Great care was taken to prevent accidental circuit resistance, all terminal boxes had joints screwed and soldered and the overall accuracy was $\pm 0.1^0$F. This manual balancing has now been replaced in modern installations with self-balancing electronic indicators, strip chart recorders, or data loggers.

The recorders and data loggers used, have sometimes been general-purpose instruments and not engineered with the accuracy required for refrigerated cargo in mind. Tolerances have increased to $\pm$ 0.1$^0$C and even $\pm$ 0.2$^0$C. Yearly checks on thermometers in melting ice are advisable, and if the thermometer bulb or probe is not fully watertight, a rubber or plastic covering before testing should protect it. The refrigerated cargoes that demand the most precise control of temperature are those carried at about 0$^0$C, and great precision is required to be sure that the cargo is not accidentally frozen. Accordingly, testing thermometers in melting ice check the calibration at the point (in the range) where accuracy is most required. Thermistors in place of resistance thermometers are gaining acceptance as reliable thermometers. The sensor has a resistance of thousands of ohms and stray circuit resistances become relatively less important since they are swamped out.

### *25.8.2 Types of Air-conditioners*

There are three types of air-conditioners:

***a) Independent direct expansion units as self-contained or two-part units which are used to air-condition one or two rooms close to one another***

The air-conditioner treats the room air and delivers it back directly to the room, through air ducting with sizes from 75 to 175 mm which avoids making complicated and long distribution systems. An interesting version of the independent unit is the split model which is built in two parts: a compressor assembly and a separate evaporator/fan assembly which can be installed several metres apart from the compressor, saving cabin space and permitting the air-conditioning installation in boats where there is no space for both components in one piece. The temperature control is made by stopping and running the compressor and also by controlling the fan speed.

***b) Central units with direct expansion circuit to several evaporators (fan coils)***

These are very common units used in land installations where they can be called 'multi-split'. In marine applications there are some installations made with this configuration where one (large) compressor supplies several evaporators.

Unfortunately this simplified configuration makes the system rigid and it tends to become unbalanced, particularly when the thermal load is reduced at night and with the large compressor balanced for the high load of the day, it becomes far in excess of the reduced night load.

This situation can cause an increase in the fan coil noise into the cabins. In addition to this, the piping for the refrigerant connection to each fan coil could become a weak point if it is not correctly designed and installed, as any leak will stop the entire system and the repair could be a real hassle.

With this type of system it is not possible to connect several compressors in parallel on the same circuit; each compressor must have its independent circuit connected to its evaporators. The temperature of each room is controlled by stopping the fan of that room or by stopping the refrigerant flow to that fan coil. In either case again the system becomes unbalanced if not properly designed as the compressor capacity is still the same while the fan coil load is reduced.

*c)* ***Central systems with chilled (or heated) water distribution to several fan coils each installed in the room to be air-conditioned.***

In this case the central system, which can be made with one or more compressors, cools (or heats) the water of a closed water circuit which is pumped to each fan coil. This type of unit has several advantages:

The distribution system of the chilled (or heated) water has the same characteristics as a heating circuit but instead of a boiler there is one or more chiller compressors and at the place of the radiator in each room, there are the fan coils. Each fan coil is completely independent of the central unit, which is set to keep the fresh water circuit temperature at a preset value (normally $+12^0$C in summer mode and $+40^0$C in winter mode); all the fan coils are connected in parallel to the fresh water circuit and the room temperature.

### 25.8.3 Cooling Mode

The air-conditioner, when used in the cool mode (summer use), is a refrigerating unit which extracts the heat from the room air (directly in the direct expansion systems, and indirectly with an intermediate fluid in case of 'chiller' systems. The heat removed together with the heat generated by the compressor working, must be then dissipated outside the air-conditioned space. The marine air-conditioner uses a special marine heat exchanger to dissipate the heat to the sea water, which is circulated by a pump.

### 25.8.4 Heating Mode

The same air-conditioner which produces cool air in summer can produce heat in winter. In order to produce hot air, the air-conditioner must be equipped either by a 'reverse cycle valve' or by an electric resistor. The reverse valve is a special 4-way valve which can "reverse" the refrigerating circuit so that the evaporator becomes a condenser and the condenser becomes an evaporator. In this way the heat is taken from the sea water (which is consequently cooled) and given to the room air which is heated.

The heat is sufficient for Mediterranean climate, with mild winter temperature and, more important, sea water temperature above 0°C. The sea water temperature must be carefully considered as the air-conditioner's efficiency drops dramatically if the sea water temperature drops below 10°C. If this happens, the air-conditioner loses efficiency and it can no longer be used. For cold seas it is advisable to install a system equipped with electrical heating, which does not lose its efficiency in cold waters. In the market air-conditioners equipped with electrical heating are also available.

### 25.8.5 Sea Water Cooling of the Air-conditioner

As the heat is rejected overboard by an air-conditioner when cooling, and the consequent problems in a typical marine installation, all marine air-conditioners are water-cooled, in other words the air-conditioner dissipates the heat into the sea water, using a special marine heat exchanger in which the sea water is circulated by means of a pump. The pump used to circulate the sea water should be rated for continuous duty and built to marine specifications. It normally uses a marine centrifugal pump which is installed below the water line as the standard centrifugal pump is not self-priming.

### 25.8.6 Safety

The marine air-conditioning system has two aspects which must be well considered for safety reasons:

a) The system is connected to the mains supply and it is essential that the connections follow the safety rules.

b) The air-conditioner unit (or its fan coils) must recirculate the cabin air and possibly a small percentage of external air. The air intake should never come from a contaminated compartment or even worse, from the engine or generator room. In case of a problem in the exhaust system of the engine or generator, the exhaust gas is toxic and if the air-conditioner takes and delivers these gasses, it will be extremely dangerous or even lethal to the people on board.

### 25.8.7 Automatic Temperature Controllers

The automatic control of space temperature in general becomes easier as the space becomes larger. This is because the thermal capacity of the contents provides a "flywheel" effect to overcome temperature variations caused by the functioning of the controllers.

It is sometimes difficult to decide whether the best place for a controller's sensing element is in the space to be controlled or in the air delivery stream of the air cooler.

For cargo spaces, which may be used for fruit carriage, the air delivery temperature is the correct temperature to control in order to be sure that temperatures never fall low enough to injure fruit. In systems with reversible fans, the sensing element is placed in a by-pass duct (between delivery and suction ducts) so that air delivery temperature is detected whichever way the fan is running.

An electric solenoid valve located before the expansion valve in the liquid line and incorporating a simple on/off thermostat usually controls a direct-expansion cooler. Alternatively, for small installations with only one cooler served by one compressor, the on/off thermostat may control stopping and starting of the compressor.

Small installations, for example, integral refrigeration units on containers, can suffer from "short cycling", i.e. too frequent stopping and starting of the compressor, if the control is a simple on/off type and no other controls are fitted.

This occurs under light-load conditions, i.e. high container temperature and low ambient conditions and there is little the operator can do to alleviate it, except for possibly restricting the condenser cooling to give the compressor more work to do.

The simplest controller used in brine (or chilled water) systems is the direct-acting type, where the temperature-sensing phial is liquid-filled and connected by capillary tubing to the head of a diaphragm valve in the brine delivery pipe. These controllers are found in air conditioning installations, but not used for cargo storage, as the alteration from one set-point to another cannot be carried out quickly and accurately. A more sophisticated controller is the all-pneumatic controller with a compressed air operated valve in the brine pipe. The controller is mounted outside the battery room and receives a signal from a mercury-filled bulb in the air delivery stream, via a capillary tube and bellows.

The controller produces an output signal at varying pressures to maintain the brine valve in a "floating" or modulating, partially-open position. Slight adjustments to the set-point may be required to maintain the same air delivery temperature under ambient conditions as the capillary is affected by ambient temperature.

In order to overcome the limitations of capillary length, pneumatic controllers are available where the temperature-sensing bulb is mounted in the air stream, and integral with it is the pneumatic controller whose output is used to control the brine valve.

The pneumatic controller has its set-point adjusted by a pressure signal, which is supplied by a signal line from a central control station in the engine room. This system also provides modulating control.

Combined electronic-pneumatic systems are also used; here the sensing element is a resistance thermometer, and the primary controller is a Wheatstone bridge network arranged so that the output signal operates a solenoid valve (on/off) in a compressed air line. This compressed air line then controls a pneumatically-operated brine valve - but the mode of action is on/off and not modulating.

It is essential that all the electric components of this system are completely watertight, as they are liable to soaking by condensation. Whatever type of controller is used, it is important that the brine valves are correctly set, and the spring tension is adjusted to facilitate fully-closed and fully-opened positions at the designed air pressures. If this is not so, there is a possibility of valves passing on brine when they are nominally closed. Brine valves are normally mounted within cooler rooms, where they are not subject to undue condensation.

However, if they are mounted outside cooler rooms, ice formation on the stems can be troublesome; the valve stem should be coated with low temperature grease.

Engineers onboard the ship may be faced with a dilemma when the air delivery temperature as recorded on the recorder or data logger differs from that set on the controller. On such occasions it is not clear as to which is the true temperature.

It is recommended that recorders and data loggers should be calibrated regularly and they should be relied upon for accuracy. Where scale adjustment is provided on controllers, this should be used to calibrate the scale against the recorder or data logger.

### *Find the Answers*

1) What do you understand about the electrochemical theory of corrosion?
2) With simple sketches explain the Impressed Current Cathodic Protection System
3) What is the role of a magnetic amplifier in a cathodic protection system? Explain its basic operating principle.
4) What are the various protections / components in a basic Refrigeration system? Explain.
5) Briefly explain the operation of a Dionic Water Purity Meter.
6) With the help of a diagram explain the working principle of a Salinometer.
7) With the help of diagrams explain the working principle of a galley range
8) What are the main features of an electrical system for the operation of water-tight doors? Briefly explain the control system too.
9) Briefly explain the role of an air-conditioning system's temperature controllers.
10) What is the significance of pressure switches in a refrigeration plant?
11) How is the temperature of a cold room maintained?
12) What is a self-monitoring alarm circuit?