NMC 28

NYK Maritime College

NYK SHIPMANAGEMENT

Refrigeration Machinery Training

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Applicable Trainees: Engine Officers

Objectives of the Training

After completion of the training, the trainees should understand the followings:

1) Refrigeration cycle

2) The structure of each component

3) Maintenance works

4) Trouble response

Duration of Training: 2 Days

Course schedule:

	Contents of the course		Contents of the course		
	AM	AM	PM	PM	
1st day	Refrigeration cycle and Refrigerant		Basic knowledge of equipments		
2nd day	Troubleshooting on Simulator		Operation of Reefer container		Examination

Contents and Syllabus

7. Equipments, Materials and Teaching Aids - Refrigeration Simulator, Handout

1. Refrigeration cycle and Refrigerant:

1.1 Refrigeration cycle:

The basic Refrigeration cycle is composed of the following four elements. The cycle also shows the change in the state of refrigerant, while being passed through the cycle.

Compression →	Condensation →	Expansion →	Vaporization
Compressor (Vapor) Press: Low – High	Condenser (Vapor → Liquid)	Expansion Valve (Liquid) Press: High - Low	Evaporator (Liquid →Vapor)

1.1.1 Compression:

The function of a compressor is to raise the pressure of a refrigerant vapor, by compressing the vapor.

With the function of the compressor, a refrigerant carries heat from low temperature region to high temperature region, while circulating in the closed loop of the refrigeration cycle.

When its volume is reduced by compression, the pressure of a gas becomes high and therefore it is possible to condense easily by cooling water or air of room temperature because this temperature is higher than the refrigerator chamber.

1.1.2 Condensation:

The condenser cools the gas discharged from the compressor and turns it into a liquid.

The water-cooling system or air-cooling system is available to cool compressed gas.

The cooled and liquefied refrigerant is stored either in the condenser or the liquid receiver.

1.1.3 Expansion (By Expansion Valve):

Liquefied refrigerant is passed through an expansion valve, where its pressure is reduced to enable optimum evaporation in the evaporator.

The function of the expansion valve is to reduce refrigerant pressure and to control quantity of refrigerant to the evaporator.

1.1.4 Vaporization (By Evaporator):

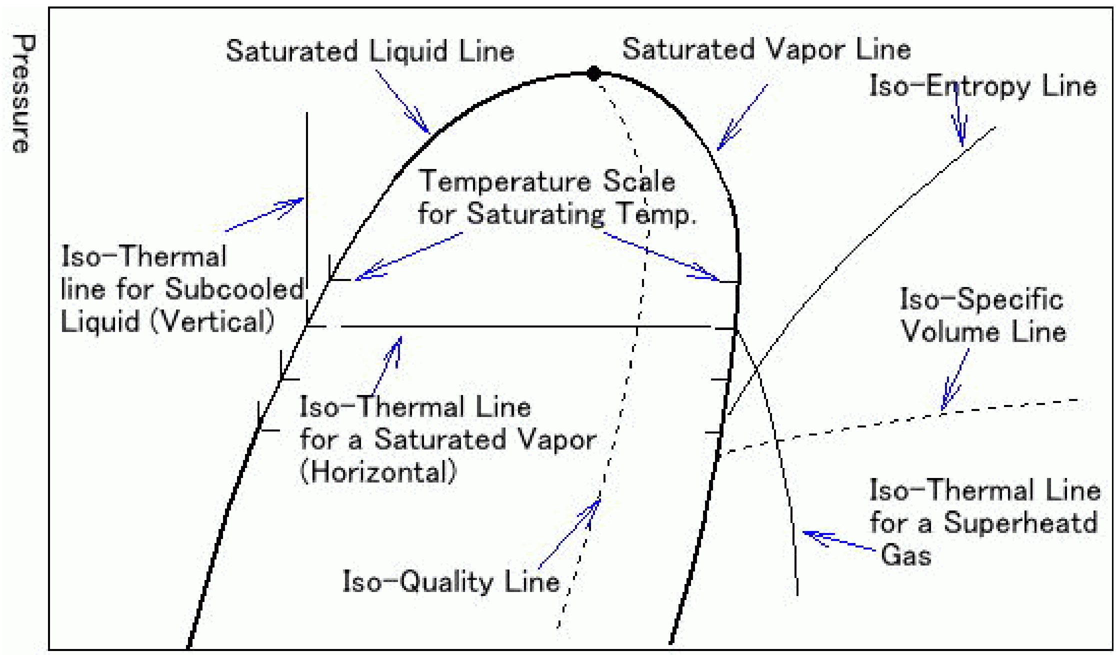
The liquefied refrigerant is evaporated to vapor state in the evaporator.

The low pressure liquefied refrigerant in the evaporator absorbs heat from the surroundings (air being passed through the evaporator) and thus gets evaporated to become dry vapor. Thus, the object of refrigeration is achieved.

1.2 p-h diagram (Mollier Diagram):

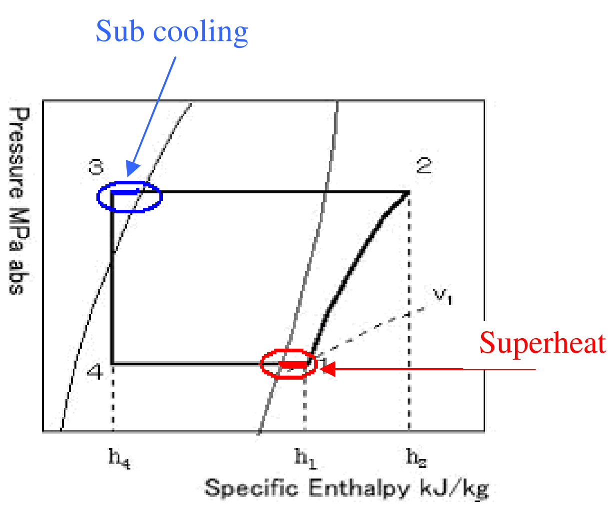
A p-h diagram (pressure - enthalpy) is a graph with a vertical axis of absolute pressure and a horizontal axis of specific enthalpy. It is an important diagram, used frequently for performance calculation of a refrigerating machine.

The figure Fig. 1-1 is a p-h diagram and has lots of thin lines, whose names and natures are important.



[Fig. 1-1 p-h diagram]

The following example is a simplified p-h diagram on which a refrigeration cycle is drawn. (A simple Practical Cycle)



Point 1-2: Compression
Point 2-3: Condensation
Point 3-4: Expansion
Point 4-1: Vaporization

[Fig. 1-2 Simple Practical Cycle]

The refrigerant exists as a mixture of vapor and liquid under the Saturated Liquid line and Saturated Vapor line.
To the left of the Saturated Liquid line the refrigerant exists as a liquid.
To the right of the Saturated Vapor line the refrigerant exists as a superheated vapor.
On the diagram, the refrigeration cycle is represented by the line 1-2-3-4.
1-2 is where the gas is compressed causing a rise in pressure and enthalpy, which equals the energy put into the gas by the compressor, all in the superheat region.
2-3 is where the gas is condensed to a liquid.
3-4 is where the vapor is passed through an expansion valve; the pressure is reduced without any enthalpy change.
4-1 is where the liquid is evaporated completely to a gas and where enthalpy is extracted from surroundings. This is the REFRIGERATION or COOLING effect.

1.3 Simple Practical Cycle:

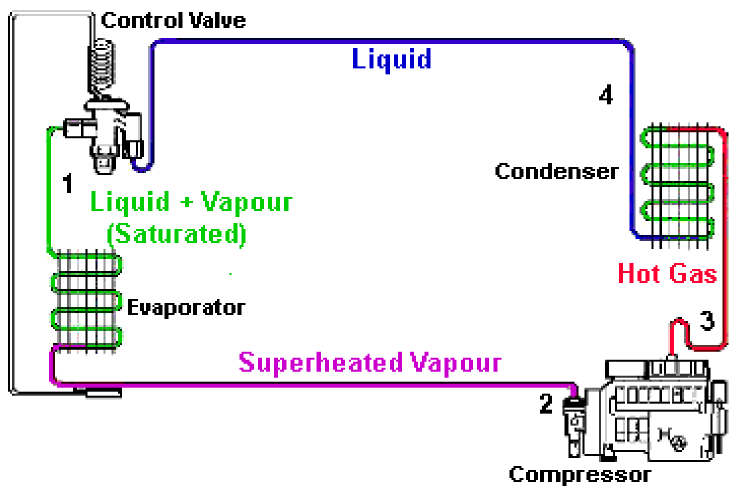
"Sub-cooling" and "Superheat" does not exist in p-h diagram of the basic vapor compression cycle, but the practical refrigeration cycle has them as shown in Figure 1-2.
Superheat and Sub-cooling occupy quite small sections of the p-h diagram, but they are very important for the effective working of the system.

The evaporator should superheat the refrigerant after all the liquid has evaporated. Unless it is complete, some liquid will leave the evaporator, which is basically loss of useful cooling potential.
Moreover, compressor dose not generally appreciate liquid arriving with the vapor. It can damage the compressor parts. So control is provided in such a way so as to ensure that the vapor leaving the evaporator is superheated.
In Fig.1-2 (p-h diagram), the process starts with evaporation of the refrigerant in the evaporator. Point 2 is in the vapor region, to the right of the saturated vapor curve. Compression raises the pressure of the refrigerant, point 2. The vapor is now hot, and is cooled before condensation starts.

Only liquid should flow through the line from the condenser to the expansion valve. If some vapor is present in it, it can cause excessive pressure drop and reduction in performance of the system. The pressure drop should occur in the valve itself. Some degree of sub-cooling is necessary to ensure 100% liquid flow. This sub-cooling can occur in the condenser, and further cooling of the liquid can take place between the condenser and the valve. Point 4 is now in the liquid region, to the right of the saturated liquid curve. The pressure is reduced in an expansion device, and the refrigerant is returned to its original condition 1.
The basic refrigeration system is composed of the compressor, condenser, expansion (control) valve and evaporator.

The expansion (control) valve is a key component. This device regulates the superheat at the outlet of the evaporator. The temperature sensor at the outlet of the evaporator is connected to the valve to provide feedback on the adjustment of the valve. Most valves work automatically by means of a diaphragm and are termed as Thermostatic Valves.

"Components of the Practice Cycle" is shown in Fig.1-3.



[Fig. 1-3 Components of the Practice Cycle]

The refrigeration system is composed of the compressor, condenser, expansion (control) valve and evaporator.

It is really quite simple in principle. The properties of the Refrigerant or Working Fluid are known to a high level of accuracy and by measuring the pressure and temperature at points 1, 2, 3, 4 the p-h diagram can be established.

1.4 How to draw a refrigeration cycle:

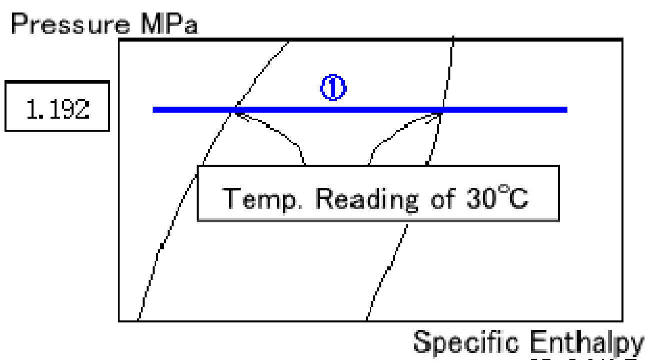
Draw the following refrigeration cycle on a p-h diagram.

Refrigerant	Evaporating Temperature	Condensing Temperature	Temperature before Expansion valve	Suction gas Temperature
R-22	−15℃	30℃	25℃	−10℃

Refrigerant	Evaporating Pressure	Condensing Pressure	Sub-cool	Superheat
R-22	0.296MPa	1.192MPa	5℃	5℃

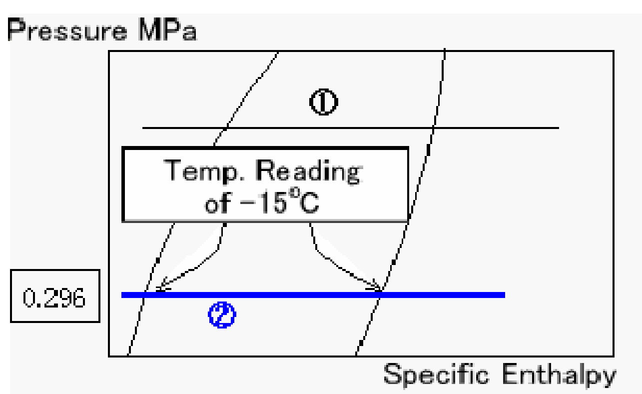
1) Draw a line for the condenser

Draw a horizontal line (1) crossing both the saturated vapor line and saturated liquid line at 30℃. The length of the line is adjusted later. Shorter the line is, easier to adjust.
A horizontal line passing through a condensing pressure of 1.192 MPa for 30 ℃ is same as the above line.



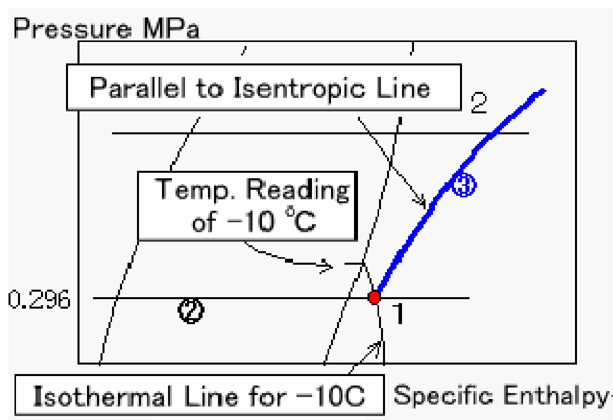
2) Draw a line for the evaporator

Draw a horizontal line (2) crossing both the saturated vapor line and saturated liquid line at -15℃. The length of this line is also adjusted later.
A horizontal line passing through a condensing pressure of 0.296 MPa for -15 ℃ is same as the above line.



3) Draw a line for the compressor:

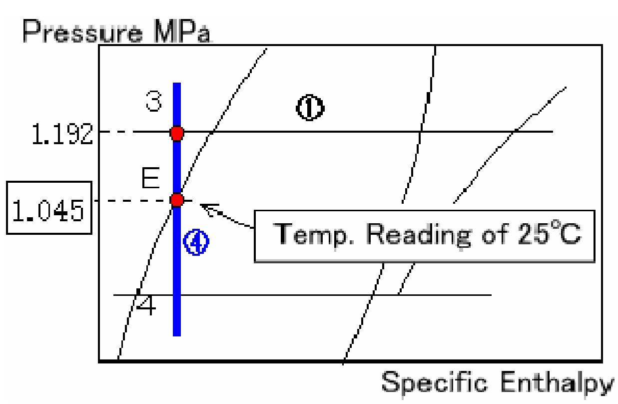
An intersection point (Point 1) of the line for an evaporator (2) and an isothermal line for -10℃ shows the position of a state of suction gas to the compressor. Draw a curve (3) from Point 1 parallel to an isentropic line. An isentropic line is a curve.



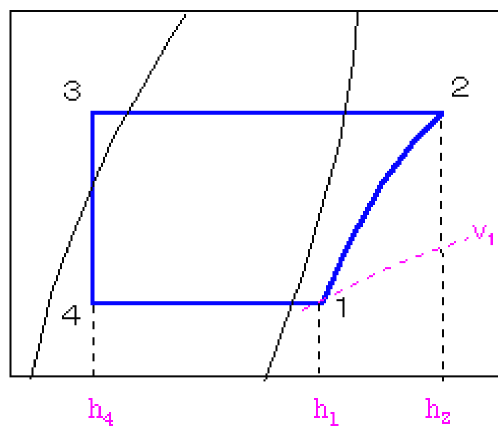
4) Draw a line for the expansion valve:

Since the refrigerant is a sub-cooled liquid of 25℃, draw a vertical line (4) that passes through a saturated liquid line for 25℃ (Point E). An intersection point (Point 3) between the line (4) and the line (1) shows a position of state of refrigerant before the expansion valve.

Point E obtained from saturation pressure of 1.045 MPa for 25℃ is the same.



5) Complete the figure:
Refrigeration cycle can be drawn on a p-h diagram as stated above.
Since it is difficult to understand, the following graph is made clear by erasing extra lines outside of Point 1 to 4. Various values can be read from the diagram
.



(1) Specific volume [V1] : 0.08 m3/kg
(2) Specific enthalpy [h1] : 403 kJ/kg
[h2] : 438 kJ/kg
[h3, h4] : 230 kJ/kg
(3) Cooling Effect [h1- h4] : 404 – 230 = 174 kJ/kg
(Refrigeration Effect: RE)
(4) Work Input [h2 – h1]: 438 – 403 = 35 kJ/kg
(5) Coefficient of Performance [Refrigeration effect / Work Input]
: 174/35 = 4.97

1.5 Refrigerant:

A refrigerant circulates through a refrigerating system while repeating four states.
A refrigerant is the working fluid in the refrigeration system and present either in gas or liquid state at various stages.
A refrigerant works as a medium to move heat from one place (being cooled) to another place (where this heat is supplied to another medium), while circulating in closed loop of the refrigeration cycle.
An ideal refrigerant should:
・be non-toxic.

- be non-flammable
- have a low boiling point, boil or evaporate easily.
- condense easily.
- not mix with oil since compressor parts are lubricated.
- have a high latent heat capacity to transport energy around the refrigeration system.
- operate at moderate pressures to reduce compressor work and leakage.
- be relatively cheap to produce and store.

Most modern refrigerants, except ammonia, incorporate chlorine, fluorine and carbon and are called fluorocarbons.
R11 is a single Chlorofluorocarbon (CFC) compound. It has high chlorine content.
CFC's are ozone depleting.
R22 is a single Hydro chlorofluorocarbon (HCFC) compound. It has a low chlorine content and low ozone depleting potential.
Older refrigeration systems use either R12 for refrigeration or R22 for air conditioning.
Ammonia is used in large ice making plant.
Modern refrigerants (HFCs) are mixtures and are used to reduce harmful ozone depleting properties of some older refrigerants.

The tables below give properties of common refrigerants.

Refrigerant Properties:

Refrigerant	Formula	Boiling Temp. (℃)	Condensing Pressure (bar) at 30℃ condensing Temp.	ODP	GWP	Properties
R12	C CL2 F2	-30.0	6.4	1.0	3.2	Little odor, colorless as gas or liquid, non flammable, non corrosive of ordinary metals, stable
R22	CHCL F2	-40.8	10.8	0.05	0.4	Little odor, colorless as gas or liquid, non toxic, non irritating, non flammable, non corrosive, stable
Ammonia R717	NH3	-33.0	10.5	0	0	Penetrating odor, soluble in water. Harmless in concentration up to 1/30, Non flammable, explosive. Very efficient refrigerant. Attacks copper.

ODP: Ozone Depletion Potential: is the relative amount of degradation it can cause to the ozone layer

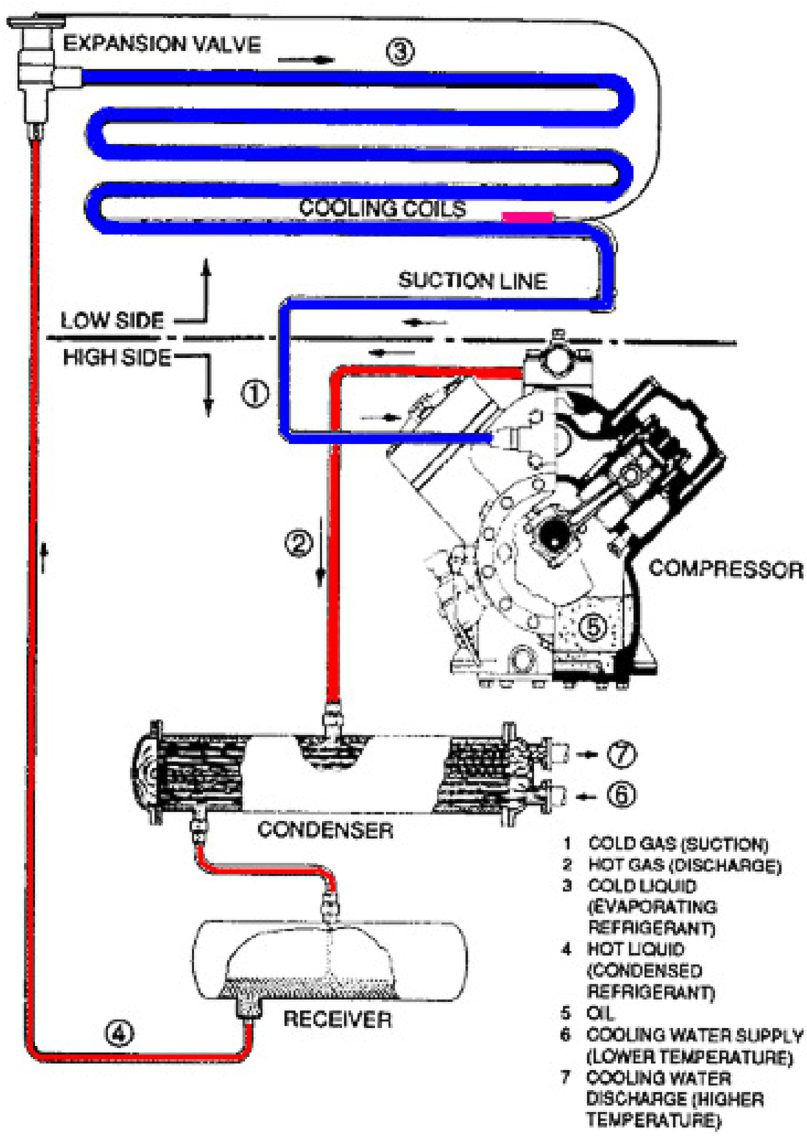
GWP: Global Warming Potential: is a measure of how much a given mass of a gas contributes to global warming. GWP is a relative scale which compares the greenhouse gas to Carbon Dioxide where GWP by definition is 1.

Hydro fluorocarbon (HFC) Refrigerants:

Refrigerant	Operating Pressure (bar) at 40℃	Maximum Cycle Efficiency (%)	Properties	Applications
R134a	9.2	83	Non-toxic, No chlorine content, Non ozone depleting, No restrictions on use	Low pressures, high Volume. Centrifugal and high speeds Screw compressors. Used mainly above 250 kW.
R404A	18.0	75		High pressures, low volume suits positive displacement Compressors. Low critical temperature limits the application range. Low efficiency restricts use.
R407C	14.4	80		High pressures, low volume suits positive displacement Compressors. High critical temperature allows wide application range. Used mainly below 250 kW.
R410A	23.0	76		Very high pressures suits positive displacement Compressors. Low critical temperature. Small systems below 20 kW. Used in some split systems.

2. Basic knowledge of equipment:
2.1 Vapor Compression Cycle:

While other cycles such as the absorption are sometimes used for refrigeration systems, almost all marine refrigeration systems operate on the vapor compression cycle. Basically, any cycle consists of a repetitive series of thermodynamic processes.
The operating fluid starts at a particular state or condition, passes through the serious of processes, and returns to the initial condition.
The vapor compression cycle consists of the following processes:
(1) Compression, (2) Condensation, (3) Expansion, (4) Vaporization
The simple vapor compressor cycle is shown in Fig. 2-1.



[Fig. 2-1 Simple Vapor Compressor Cycle]

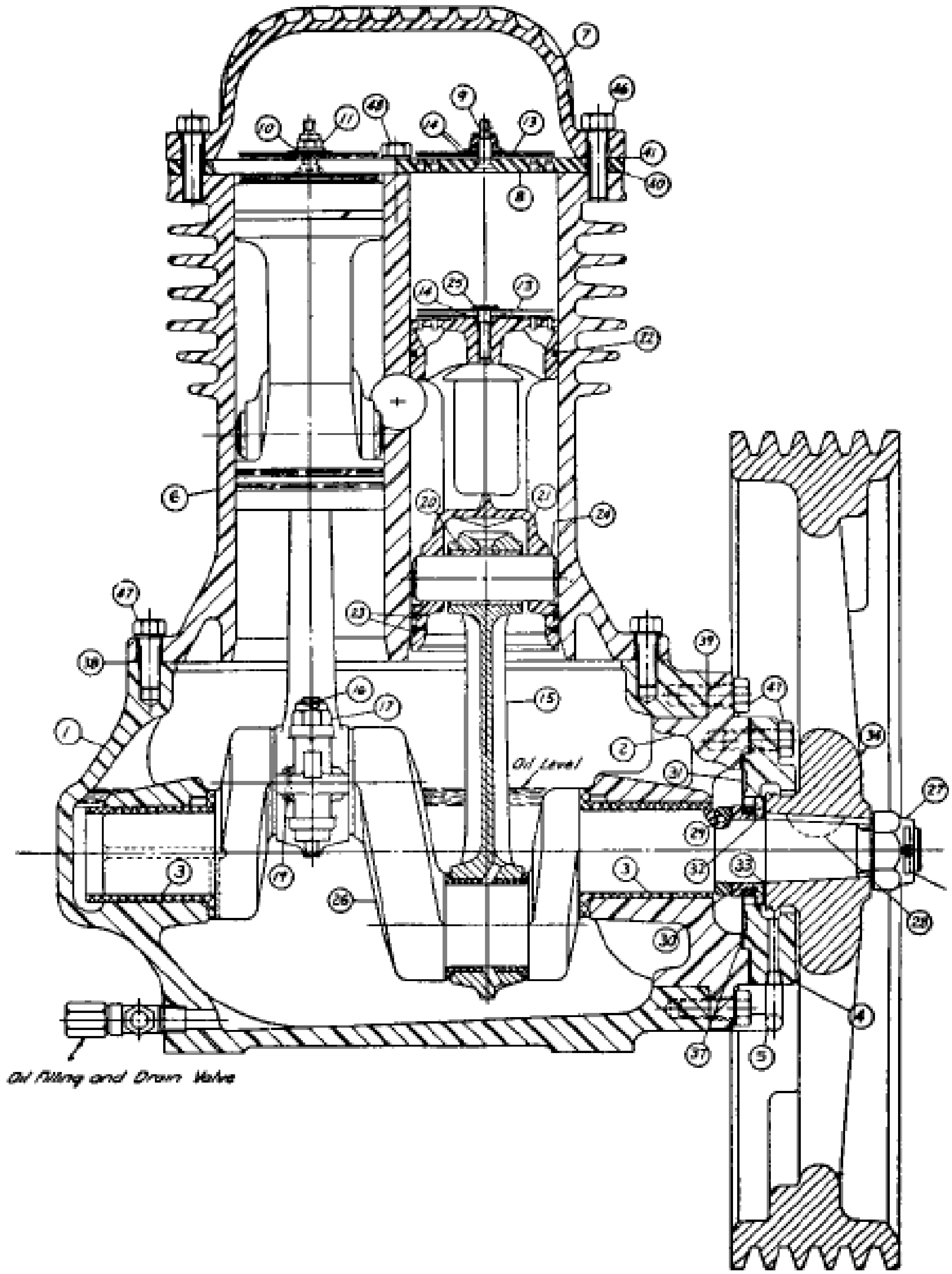
Starting at the e (condenser temperature) and pressure flows from receiver to the expansion valve. The pressure and temperature of this refrigerant is reduced by the expansion so that the evaporator temperature will be below the temperature of the refrigerated space. Some of the liquid refrigerant flashes to vapor due to reduction in pressure.
In the evaporator, the liquid vaporizes at a constant temperature and pressure as heat that catches up through the walls of the cooling coils. The compressor draws the vapor from the evaporator through the suction line.
In the compressor, the refrigerant vapor pressure and temperature are increased and the vapor at high temperature and pressure is discharged into the hot gas line.
This refrigerant vapor then flows to the condenser, where it comes in contact with the relatively cool condenser tubes. The refrigerant vapor gives up heat to the condenser cooling medium, condenses to a liquid, condensate refrigerant from the condenser into the receiver and thus ready to be re-circulated.

2.2 Compressor:

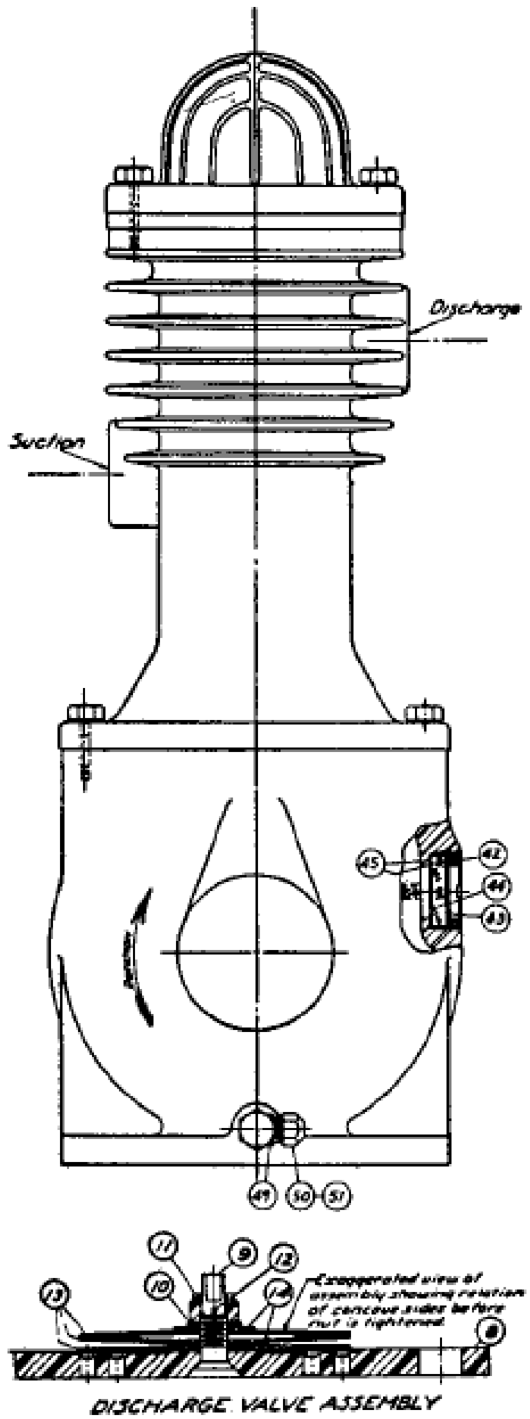
Compressors for refrigerating machines are gas compressors, which inhale the refrigerant gas whose cooling effect has reduced due to its heat absorption at low temperature, compress and discharge it.
The compressors are mainly classified into “Reciprocating Compressor” and “Screw Compressor”.

1) Reciprocating compressor:
The reciprocating compressor is the most common type found in marine refrigeration systems. It is found in systems rated from less than one to several hundred tons and in high, medium and low temperature applications. It is durable and efficient and can be manufactured economically.
Marine reciprocating compressors are typically of the single-acting enclosed type. In single-acting compressors, vapor compression occurs on only one side of the piston, while in double-acting compressors, vapor compression occurs on both sides of the piston. Enclosed type compressors drive piston by a connecting rod, driven by the crankshaft. The crankshaft is airtight and exposed to the system refrigerant.
Reciprocating compressors can be further classified as open, hermetic, or semi-hermetic.

An open type unit has a separate motor and compressor. A hermetic unit is sealed motor-compressor assembly and is a unit in which the shell of assembles is bolted rather than welded.
Fig. 2-2 and 2-3 show the constructional details of typical compressor.



[Fig. 2-2 Two - cylinder Compressor - 1]



1 Crankcase
2 Bearing head
3 Crankshaft bearing
4 Shaft seal ring cover plate
5 Shaft seal ring cover plate drain pipe
6 Cylinder
7 Top head
8 Discharge valve plate
9 Discharge valve bolt
10 Discharge valve washer
11 3/8" castellated nut (24th'ds)
12 3/32" × 1 cotter pin
13 3 3/4" diaphragm valve
14 Diaphragm valve spacer
15 Connecting rod
16 Connecting rod bolt
17 9/16" castellated nut (18-thread)
18 1/8" × 1 7/8" wire keeper
19 Taper pin #2 × 3/4" long
20 Piston pin bushing
21 Piston
22 4" × 3/16" piston ring, plain
23 4" × 3/16" piston ring, ventilated
24 Piston pin
25 Suction valve screw
26 Crankshaft
27 1 1/4" nut, 12 threads
28 5/16" × 2 1/8" Woodruff key #28
29 1/4" steel ball
30 Shaft seal collar
31 Shaft seal assembly
32 Felt washer
33 Felt washer retainer
34 Flywheel 23" diameter
37 Gasket (shaft seal diaphragm)
38 Gasket (cylinder to crankcase)
39 Gasket (bearing hd. to crankcase)
40 Gasket (discharge valve plate)
41 Gasket (top head)
42 Oil sight nut
43 Oil sight washer
44 Oil sight glass
45 Oil sight gasket
46 Hex head cap screw 9/16" × 2"
47 Hex head cap screw 9/16" × 1 1/2"
48 Hex head cap screw 9/16" × 1"
49 Angle valve, 3/8" mp × 3/8" flare
50 Seal cap 3/8"
51 Flare gasket 3/8"

[Fig. 2-3 Two - cylinder Compressor - 2]

There are a number of methods for controlling the capacity of reciprocating compressors. One method is to vary the speed of the compressor and other most common method of varying the capacity of multi-cylinder compressors is to vary the number of active cylinders by holding the suction valves open.

2) Screw compressor:

Screw compressors comprise of two oppositely rotating and intermeshed rotors, each having a number of lobes and number of flutes respectively, which effect continuously the three strokes i.e. gas suction, compression and delivery strokes.

They rotate at speeds (about 3,000 to 7,000rpm) much higher than those of reciprocating type and rotary piston type compressors and have comparatively high capacities (60 to 1,500kw). The construction and mechanism of the screw compressors are shown in Fig. 2-4 and their characteristic features are as follows:

a) Advantage:

・Small size, light-weight and less space for installation.

・Less vibration, and no provision of rigid foundation is required.

・Step-less control in volume in the range of 100 to 15% can be made and automatic operation is easy.

・Because there are no valves and sliding parts, it is possible to make continuous operation for a long time.

・The number of parts is small and service life is long.

b) Disadvantage:

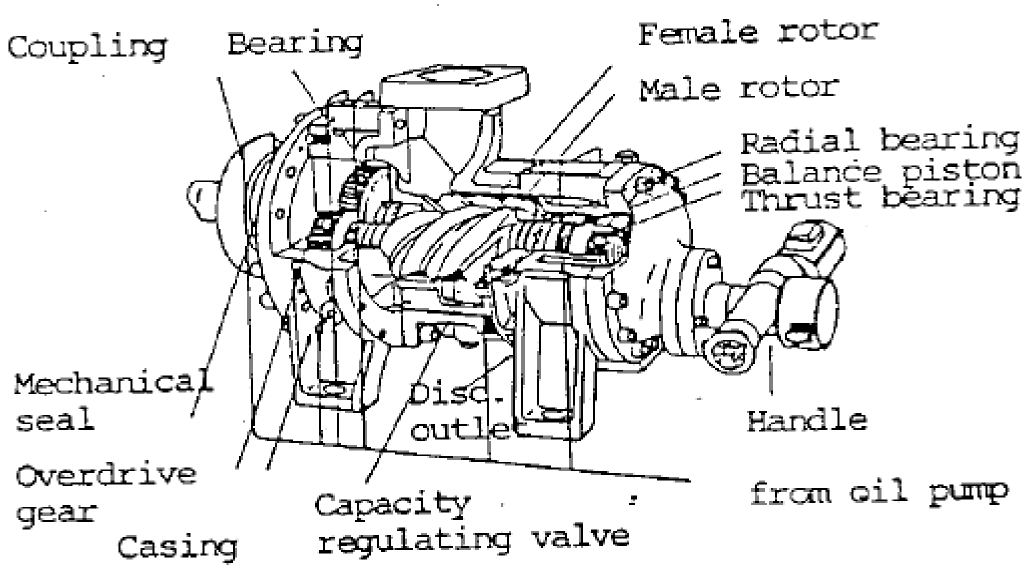
・The dimensions/capacities of oil separator and oil cooler are large.

・Lubricating arrangement requires provision of an independent pump.

・A large power is required.

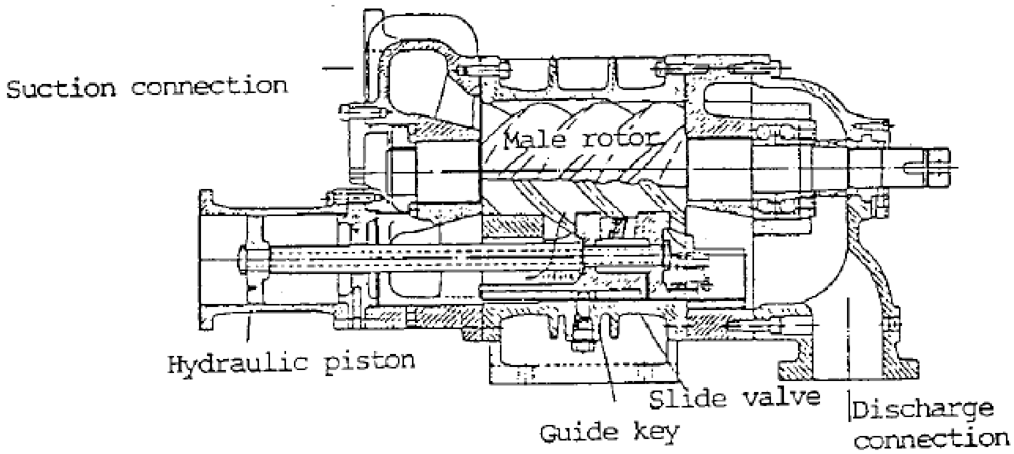
・Noises of high levels are generated when the running speed increases.

Fig. 2- 4 shows the construction of a screw compressor.



[Fig. 2-4 Screw Compressor]

Fig. 2- 5 shows the construction of slide valve.



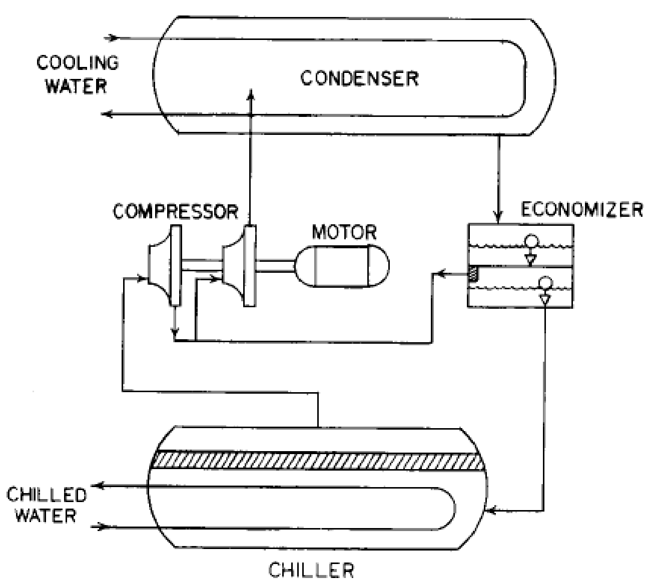
[Fig. 2-5 Construction of slide valve]

The screw compressor is one kind of Rotary compressors and in addition, there is a vane compressor.

3) Centrifugal compressor:

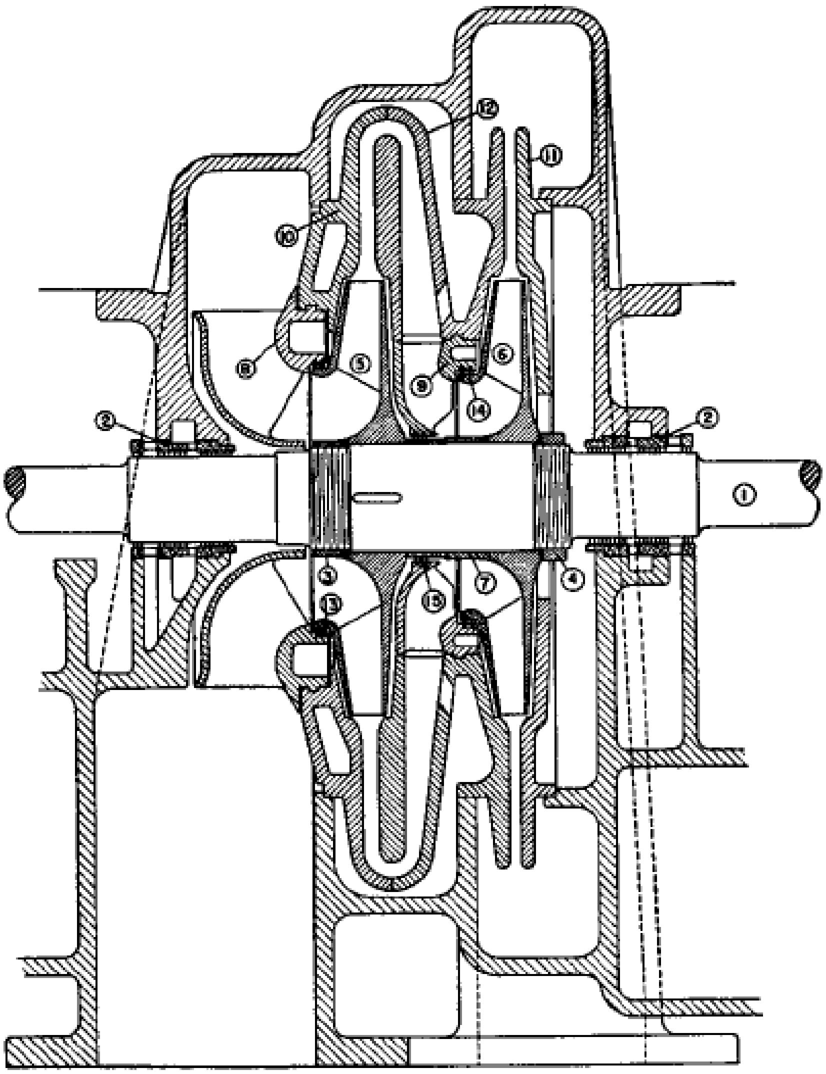
Centrifugal compressors are commonly used on systems 300tons and larger. They are especially suitable for large chilled water air-conditioning systems.

Centrifugal compressors are similar in construction to centrifugal pump and Fig.2-6 shows a centrifugal compressor system.



[Fig. 2-6 Centrifugal compressor system]

Fig.2-7 shows the construction of a typical centrifugal compressor.



1 Shaft
2 Shaft labyrinth, either end
3 Impeller lock nut, suction end
4 Impeller lock nut, discharge end
5 Impeller, first stage
6 Impeller, second stage
7 Impeller spacer
8 Inlet guide vane, first stage
9 Inlet guide vane, second stage
10 Intake wall
11 Discharge wall
12 Diaphragm, first stage
13 Inlet labyrinth, first stage
14 Inlet labyrinth, second stage
15 Spacer labyrinth

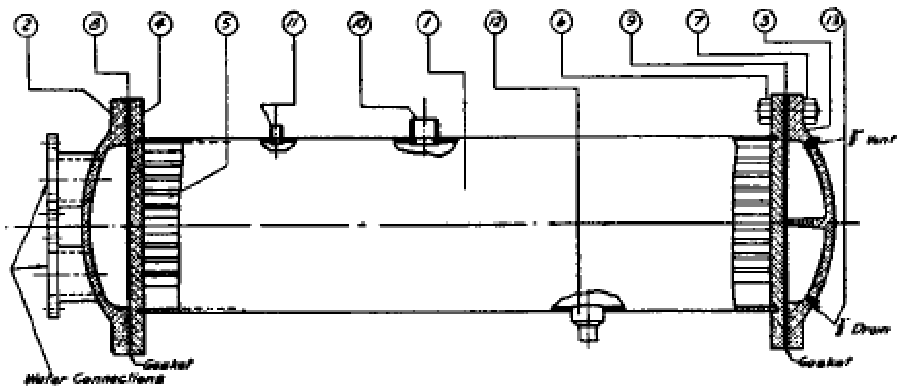
[Fig. 2-7 Centrifugal compressor]

Due to the low density of the typical refrigerant gas, the pressure developed per stage is typically fairly low.

2.3 Condenser:

Condensers are equipments, adapted, to give off or emit the heat generated by the compressor into water or in the air, thereby causing condensation of the refrigerant gas again.

Most marine refrigeration condensers are of water-cooled, multi-pass, shell- and-tube type as shown in Fig. 2-8.



1 Condenser shell
2 Front head
3 Back head
4 Tube head
5 Tubes
6 Bolts
7 Hex nuts
8 Gasket
9 Gasket
10 Coupling, gas inlet
11 Coupling, purge
12 Coupling, liquid outlet
13 ⅜-inch pipe plug

[Fig. 2-8 Condenser]

Seawater or fresh water is circulated through the tubes and hot gas from the compressor discharge is admitted to the shell, where it condenses on the outer surfaces of the tubes. The condenser is typically constructed of a steel shell, copper-nickel tubes and tube sheets, and bronze water-heads.

Gas inlet, liquid outlet, purge and water regulating valve control connections are provided.

Small systems such as found in drinking water coolers are usually air-cooled, with finned tubes and a cooling fan.

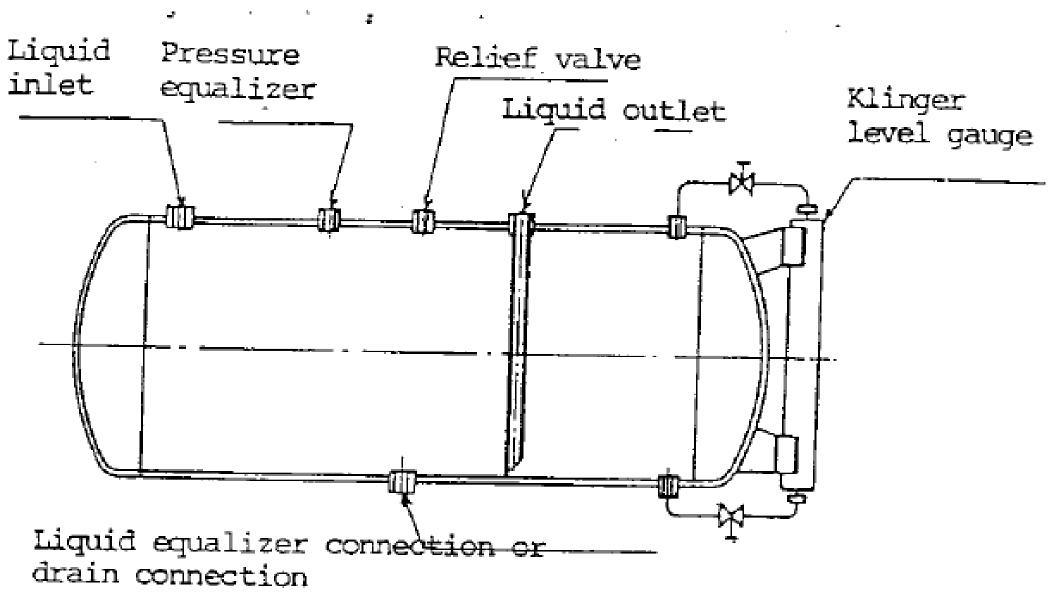
2.4 Receiver:

The receiver collects the liquid refrigerant condensations from the condenser. It consists of a steel shell with steel dished heads, welded on each end. Sight glass or a liquid level indicator is installed to check the amount of liquid refrigerant in the receiver.

The receiver will typically have sufficient capacity to hold the entire system refrigerant charge and will retain a small liquid level during full load operation.

High levels indicate overcharge and low levels indicate undercharge.

Fig. 2-9 shows the construction of a horizontal type liquid receiver.



[Fig. 2-9 Horizontal type liquid receiver]

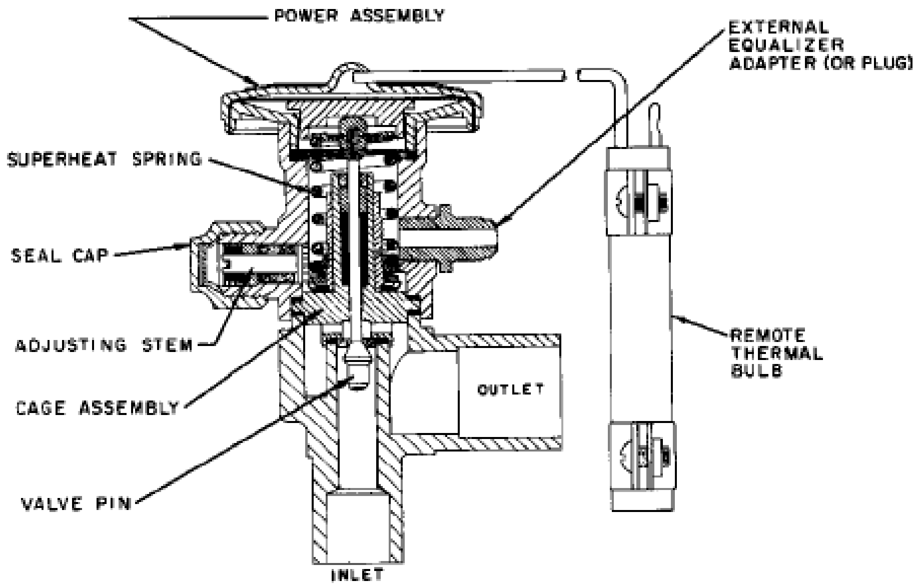
2.5 Expansion valve:

While there are a number of devices available to control the flow of refrigerant to the evaporator, such as the capillary tube, the float valve and the constant-pressure expansion valve, the thermostatic expansion valve is the device most commonly found in the marine refrigeration systems.

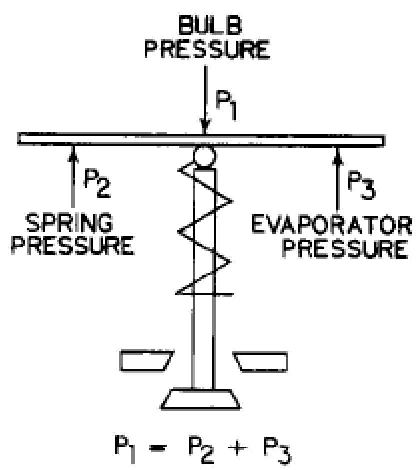
The thermostatic expansion valve responds to the evaporator temperature and the pressure, and thus maintains a constant superheat at the outlet of the evaporator. There are two kinds of thermostatic expansion valve i.e. internally equalized valve and externally equalized valve. As refrigerant is fed to the evaporator, the liquid boils off into a vapor. By the time the refrigerant gas reaches the end of the evaporator, it is superheated. Feeding more refrigerant to the evaporator will lower the superheat temperature, while feeding less refrigerant to the evaporator will raise the superheat temperature.

Fig. 2-10 shows an external thermostatic expansion valve.

A feeler bulbs partially filled with a volatile liquid, typically the system refrigerant, is clamped to the outlet of the evaporator so that the bulb and the power fluid inside closely assume the evaporator outlet gas temperature. The pressure of power fluid is applied to the top of the valve diaphragm and the evaporator pressure acts on the bottom. A spring applies a force and balances the valve assembly as shown in Fig. 2-11. For the valve to open and feed refrigerant to the evaporator, the bulb pressure must be higher than the evaporator pressure. Since, the bulb pressure responds to the evaporator outlet temperature, this can only occur when the evaporator outlet gas is superheated. The spring is normally adjusted to about 5℃ of superheat in service.



[Fig. 2-10 External thermostatic expansion valve]



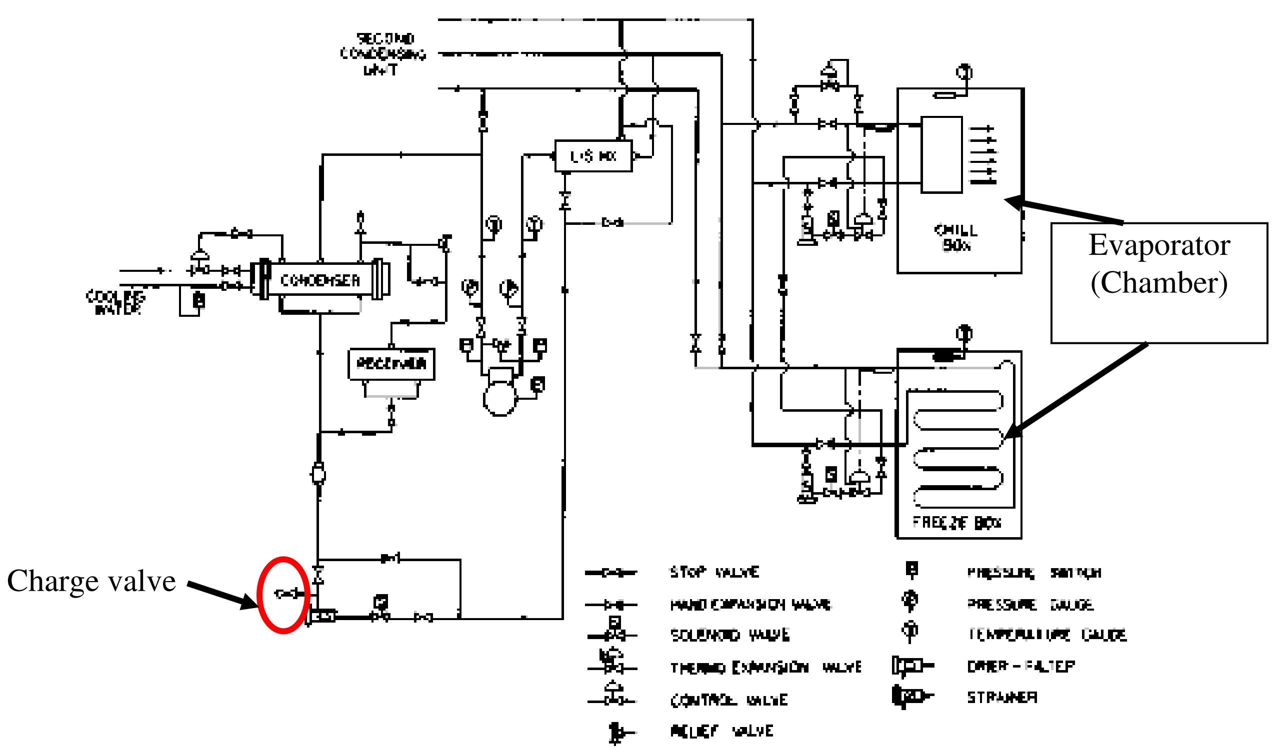
[Fig. 2-11 Thermostatic expansion valve equilibrium]

Valves, set for less than this, will not operate properly and may flood back liquid refrigerant to the compressor.
An internally equalized valve has a small port, which admits the valve outlet pressure (i.e. the evaporator inlet pressure) to the bottom of the valve diaphragm. Some refrigeration systems have an appreciable pressure drop in the evaporator. Use of an internally

equalized valve in such applications will result in unacceptably high superheat at the evaporator outlet. The solution is to use an externally equalized valve, which has a fitting for connecting the evaporator outlet pressure rather than the inlet pressure to the bottom of the valve diaphragm. In general, an externally equalized valve should be used when the evaporator pressure drop is sufficient to change the saturation temperature 1.5℃ in air conditioning systems and 1℃ in refrigeration systems.
The superheat setting of most thermostatic expansion valves is adjustable. Remove the seal cap on the valve and turn the adjusting stem with a screwdriver. Turning the stem to the right increases the spring pressure, reducing refrigerant flow and thus increasing superheat. Turning the stem to the left decreases the spring pressure, increasing refrigerant flow and thus reducing superheat. Two turns of the stem will typically change the superheat about 0.5℃.

2.6 Evaporator:

The evaporator refrigerates through the evaporation of liquid refrigerant at low temperature. The evaporators have a multiple construction and are designed such that the heat from the external space can be transferred well to the liquid refrigerant contained inside the evaporator and thus, the objects of refrigeration can be cooled effectively.
The tube coil type is generally used in marine refrigeration systems. There are two types, one for Ship's provision stores refrigeration equipment and other for Air-conditioning equipment. In addition, there is a refrigerated container system.
Fig. 2-12 shows Ship's stores refrigeration system diagram.



[Fig. 2-12 Ship's stores refrigeration system diagram]

Fig. 2-13 shows Refrigerated container unit.

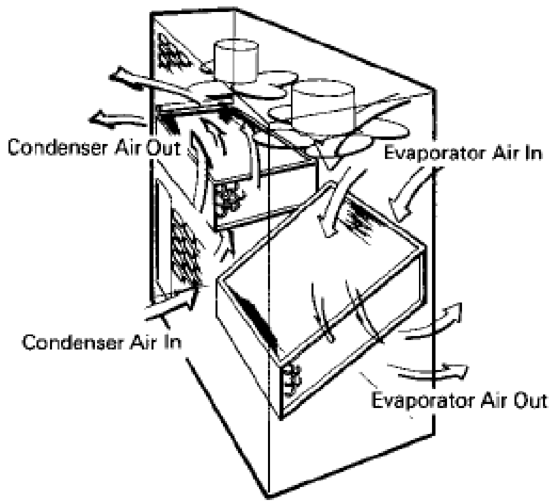
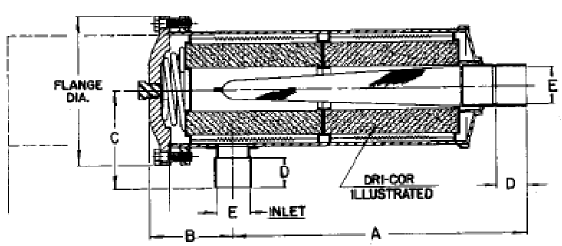
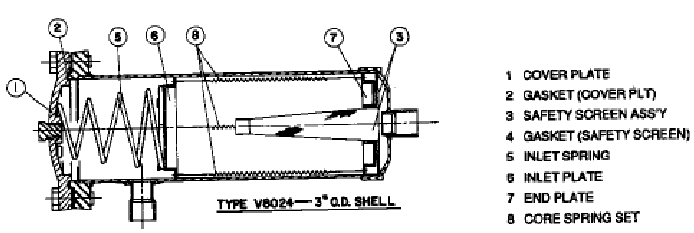


Fig. 2-13 Refrigerated container unit

2.7 Accessories and other components:

1) Dehydrator (Dryer):





[Fig. 2-14 Dehydrator]

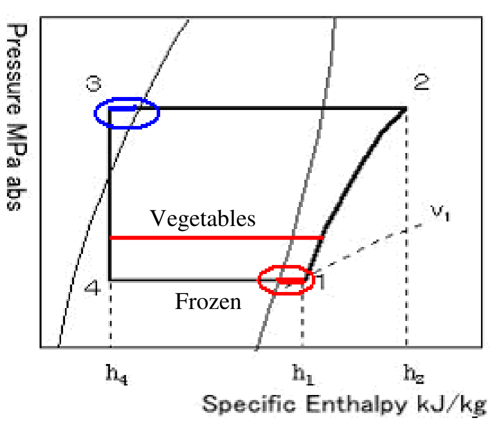
2) Defrosting:

When the evaporator cools down to a certain temperature, the moisture in the air condenses on it and therefore forms a coating of frost around the tube. Because frost does not transfer heat exchange well, the situation resembles that if the evaporator were clad with something and thus results in poor heat exchange. Therefore, it becomes necessary to carry out defrosting from time to time.
There are two kinds of defrosting methods, one with hot gas and other by electric heater.

a) Hot gas defrosting:
Hot gas defrosting is performed by pumping hot discharging gas from the compressor directly into the cooling coil circuit to be defrosted. The hot gas is cooled and condensed and the frost melts off the coils. The resulting liquid refrigerant is expanded and evaporated in a second coil through a hand expansion valve.

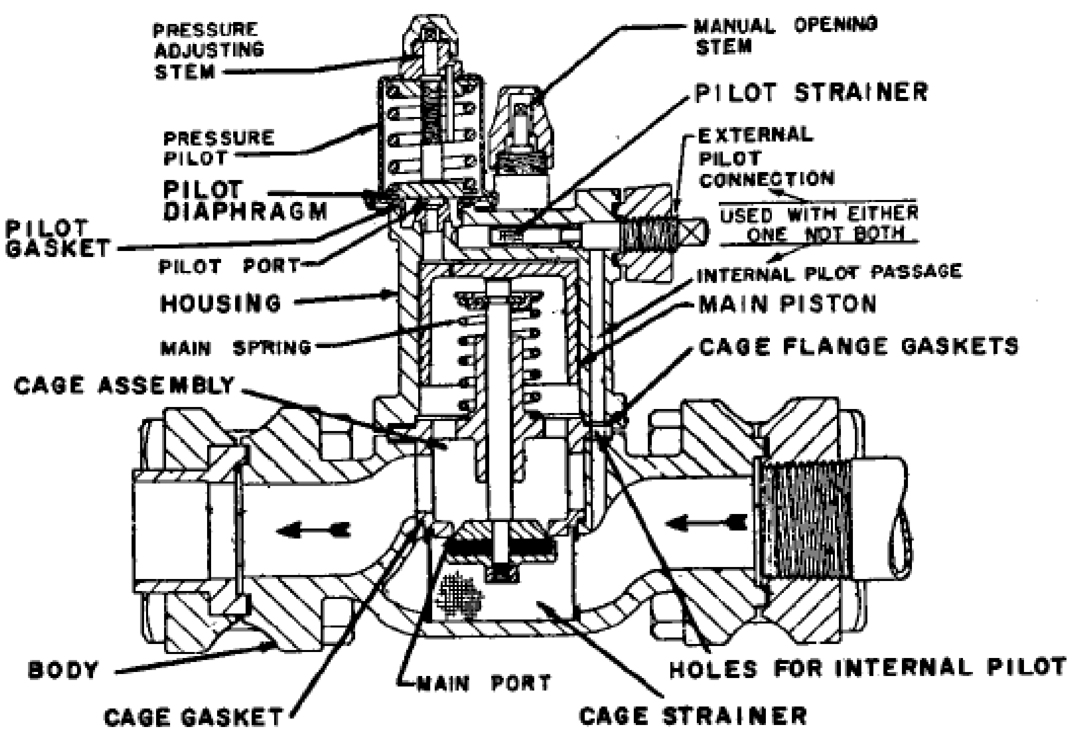
b) Electric heater:
This defrosting is mostly used in Ship's provision stores refrigeration system. The electric heater is installed into each evaporator fan unit and is controlled by electric timer. When the electric timer is ON, supply of the refrigerant to evaporator is stopped by a liquid refrigerant solenoid valve and the evaporator fan is stopped and then electric heater switch is on. After the timer is over and the defrosting operation is stopped, the evaporator fan and refrigerant liquid solenoid valve are switched ON automatically.

3) Evaporation pressure regulating valve:
Evaporation pressure regulating valves are commonly installed at the outlet of the higher temperature evaporators in a multi-box system. Actually this valve is installed at the outlet of the evaporator for vegetable chamber in Ship's provision stores refrigeration system to prevent vegetables from being spoiled by freezing and from losing weight in case of their refrigeration.



The evaporation temperature of vegetable is higher than the frozen items, therefore saturation pressure is also higher. If the pressure is same, it is a risk that the outlet temperature evaporator of vegetable cooling fan is near the frozen temperature. It makes damage to vegetable.

Fig. 2-15 shows a typical regulating valve. Its function is to prevent the evaporator pressure and therefore its temperature from falling below a predetermined minimum value, regardless of compressor suction pressure.



[Fig. 2-15 Evaporation pressure regulating valve]

4) Water-regulating valves:

Most marine refrigeration systems use seawater-cooled condensers.

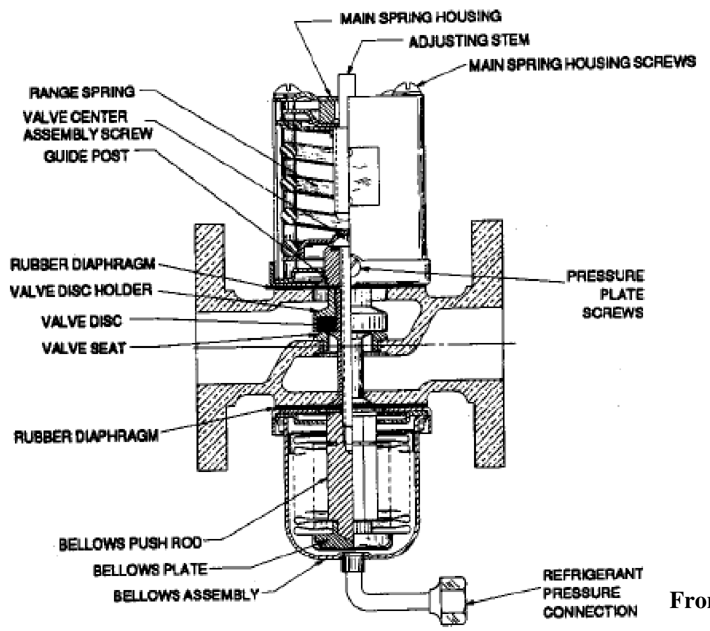
Water-regulating valves are commonly installed to control the quantity of cooling water circulating through the condenser.

The valve is actuated by the refrigerant pressure in the condenser. If the condenser pressure should increase, the valve will open, admitting more cooling water and returning the pressure back to the set point. A decrease in condenser pressure will cause the valve to close and reduce the water flow.

When cooling water temperature goes down, condenser pressure will go down too, depending on the saturate temperature and pressure. The expansion valve has the flow capacity as an orifice. When seawater temperature goes down and refrigeration chamber surrounding temperature is high, the differential pressure between expansion valve inlet

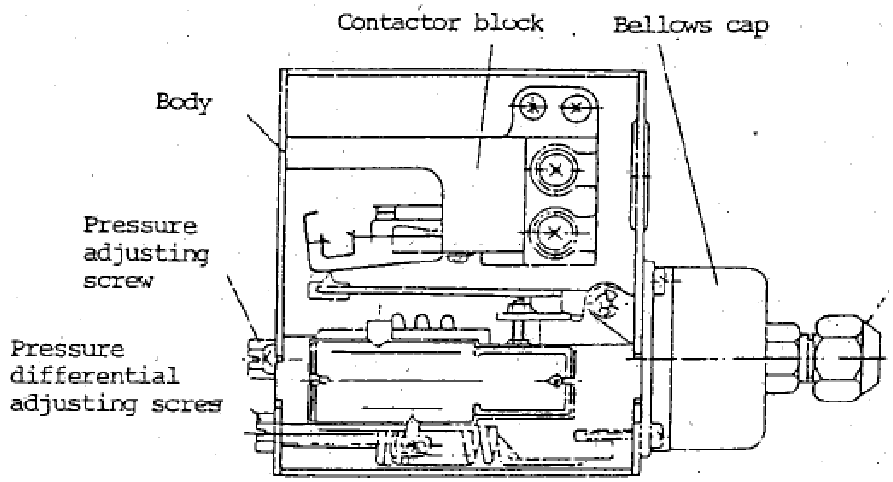
and outlet becomes small due to decrease in the cooling water temperature. It means that refrigerant flow will be small and thus short. Finally the temperature of refrigeration chamber goes up. Therefore, it's necessary to maintain the differential pressure by controlling the cooling water flow.
Moreover, when the compressor stops, the condenser pressure gradually decreases to the saturated vapor pressure corresponding to the ambient temperature. This decrease in pressure is sufficient to close the regulating valve and stop the flow of cooling water.

Fig. 2-16 is a typical water-regulating valve.



[Fig. 2-16 Water-regulating valve]

5) Pressure switches:
Pressure switches are designed to make and break an electric circuit in response to changes in the pressure. They include high pressure switches, low pressure switches and high and low (dual) pressure switches.
a) High pressure switches (HPS):
High pressure switches serve to break the electric circuit to stop the compressor when the delivery pressure exceeds a predetermined pressure because of overcharging of the refrigerant, shortage of the amount of cooling water or mixing of non-condensing gas, etc. This pressure switch is a safety device for compressor.
Fig. 2-17 shows a high pressure switch.



[Fig. 2-17 High pressure switch]

b) Low pressure switches (LPS):

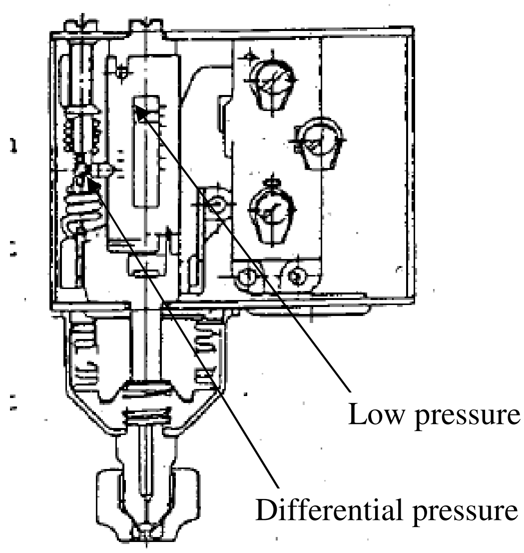
Low pressure switches serve to break the electric circuit to stop the compressor when the suction pressure becomes lower than a predetermined pressure or to excite above to start the compressor when it becomes higher than the setting pressure.

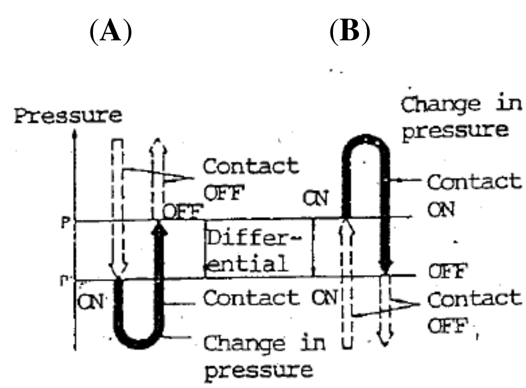
These switches may be combined with a solenoid valve to control the capacity delivered by a multi-cylinder compressor.

Fig. 2-18 shows a low pressure switch.

Fig. 2-19 shows the explanatory view of operation of a high and low pressure switch.

(A) indicates for opening HP circuit and (B) indicates for opening LP circuit.





[Fig. 2-18 Low pressure switch]   [Fig. 2-19 Explanatory view of operation]

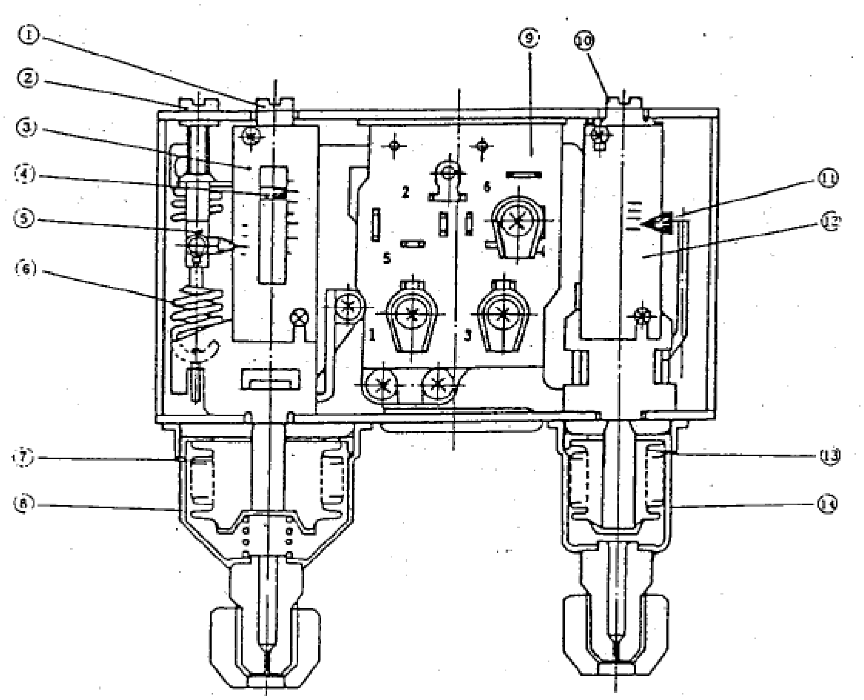
c) Dual pressure switches (DPS):

The dual pressure switch is composed of a high pressure switch and a low pressure switch and is designed to stop the compressor, when the delivery pressure becomes higher than a predetermined pressure or when the suction pressure becomes lower than the setting pressure.

The high pressure switch is designed fundamentally to make the electric circuit to start the compressor, when the pressure on the high pressure side drops again, however, some of them required to be reset manually for starting the compressor.

The low pressure switch is adopted to make the electric circuit in response to an increase in the pressure on the low pressure side, thereby starting the compressor.

Fig. 2-20 shows a dual pressure switch.

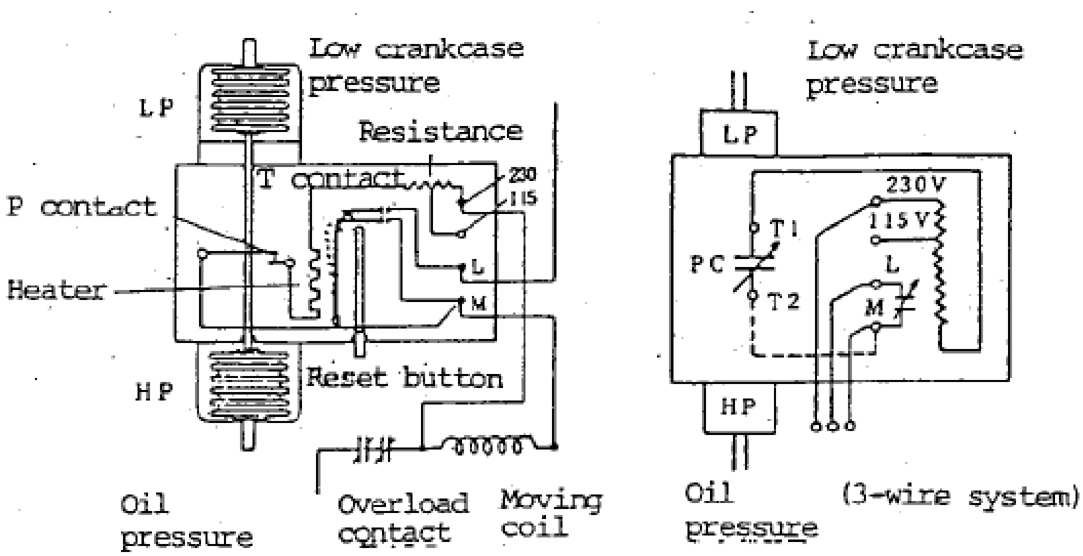


1) Pressure adjusting screw
2) Pressure differential adjusting screw
3) Low pressure graduated plate
4) Pressure indicator
5) Differential pressure indicator
6) Differential pressure adjusting screw
7) Low pressure bellows
8) Low pressure bellows cover
9) Microswitch
10) High pressure adjusting screw
11) High pressure indicator
12) High pressure graduated plate
13) High pressure bellows
14) High presure bellows cover

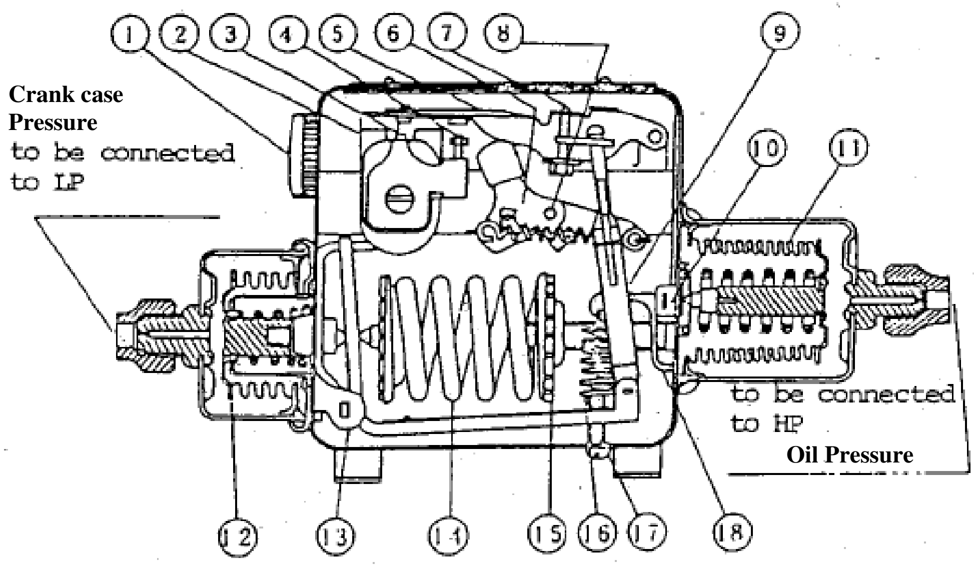
[Fig. 2-20 Dual pressure switch]

d) Oil pressure protection switches (OPS):

These switches are used to stop the compressor to protect it, when the oil pressure becomes lower than the setting pressure, in case of forced lubrication type compressors.
When the difference between the oil pressure and the suction pressure becomes lower than a predetermined value, these switches are activated after a lapse of predetermined time. Unless the switch is reset manually, it is impossible to return the electric circuit to its operating condition.
Fig. 2-21 is a explanatory view of operation of oil pressure protection switch and
Fig. 2-22 shows an oil pressure protection switch.



[Fig. 2-21 Explanatory view of operation of oil pressure protection switch]



1. Water-proof inlet for lead wire
2. Permanent magnet
3. Auxiliary contact
4. Main contact
5. Switch arm
6. Safety breaker
7. Adjusting screw
8. Fulcrum
9. Adjusting arm
10. Fulcrum
11. High pressure bellows
12. Low pressure bellows
13. Fulcrum
14. Spring
15. Adjusting nut
16. Spring
17. Adjusting screw
18. L-shaped arm

[Fig. 2-22 Oil pressure protection switch]

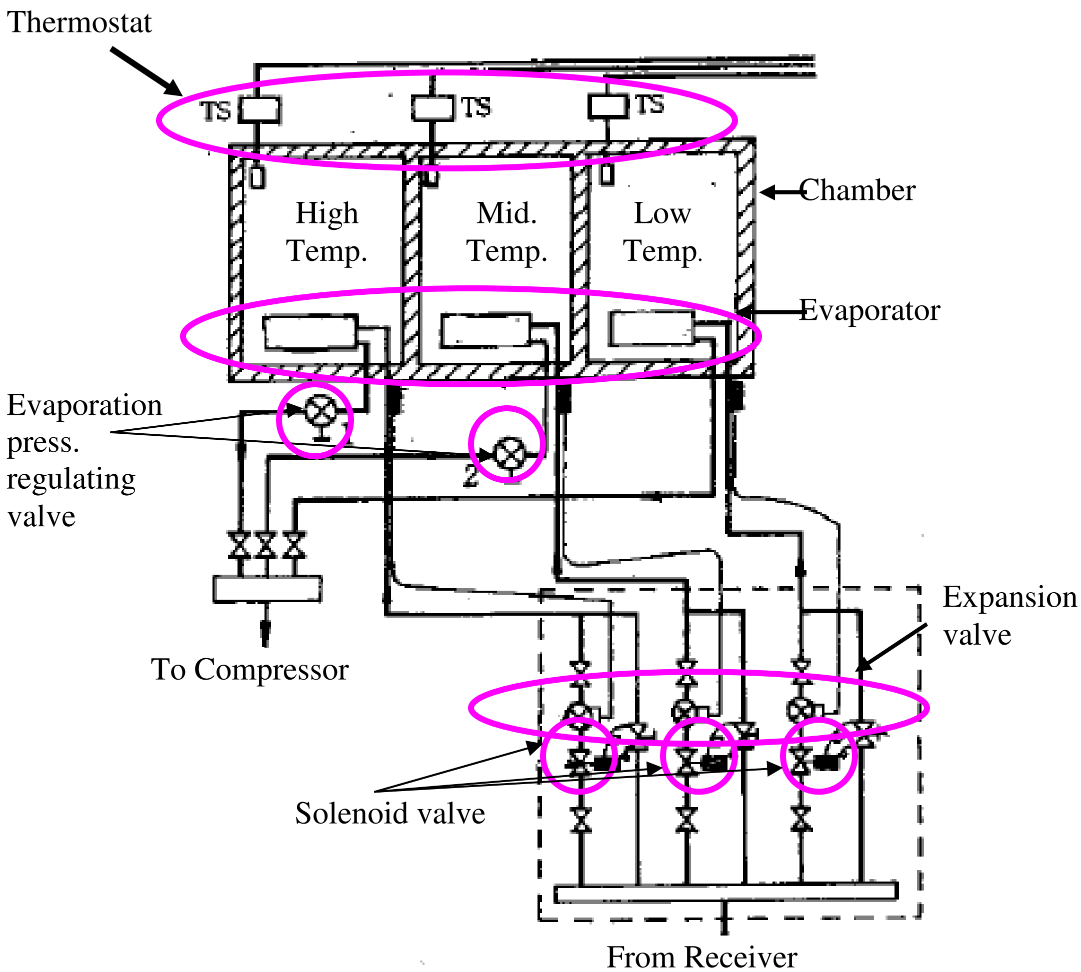
6) Thermostatic switch:

A thermostatic switch (or thermostat) is a temperature control switch, used to open or close an electric contact after sensing the temperature. The remote sensing bulb of the thermostat is filled with a volatile liquid charge.

Changes in the sensed temperature cause changes in the pressure exerted by the remote bulb on a bellows, which then operates the switch. On temperature rise, the pressure increases and the bellows close the switch contact to complete to the electric circuit. The circuit is interrupted on reduction in temperature. A permanent magnet is typically part of the mechanism to impart a snap action to the switch and prevent excessive arcing at the contacts.

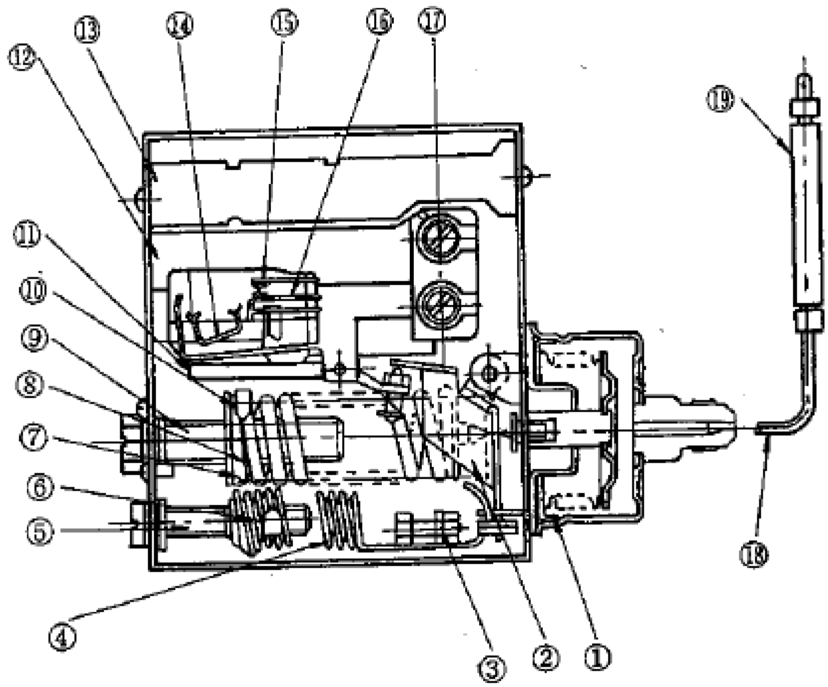
A typical thermostat will have a set point adjustment and a differential adjustment. Changing the set point adjustment will affect the cut-in and cut-out points an equal amount. The differential adjustment affects the cut-out point only.

Fig. 2-23 shows Solenoid valves in Ship's stores refrigeration system.



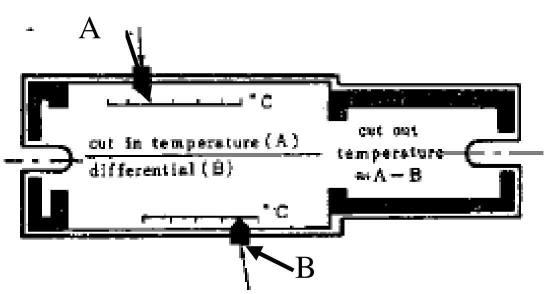
[Fig. 2-23 Solenoid valves in Ship's stores refrigeration system]

Fig. 2-24 shows a thermostatic switch (thermostat).



[Fig. 2-24 Thermostatic switch (thermostat)]

Description of parts: 1) Bellows, 2) Bakelite operation plate, 3) Stopper, 4) Temp. Differential adjusting spring, 5) Temp. Differential adjusting screw, 6) Temp. Differential indicator, 7) Temp. Adjusting spring 8) Temp. Adjusting spring holder 9) Temp. Adjusting screw, 10),Temp. indicator, 11) Bakelite operation plate, 12) Bakelite board, 13) Reinforcing plate, 14) Spring, 15) Fixed contactor, 16) Removal contactor, 17) Capillary tube, 18) Thermo bulb
Fig. 2-25 is a scale plate of a thermostatic switch.



[Fig. 2-25 Scale plate]

Cut in temperature: (A)
Differential temperature: (B)
Cut off temperature: (A) − (B)

"Cut in temperature" means that the electric contactor is closed" and "Cut off Temperature" means that the electric contactor is opened".

2.8 Charging and removing of refrigerant & oil:

1) Charging refrigerant:

To add refrigerant to an operating system, proceed as follows:
(1) Measure the weight of a refrigerant bottle by scale.
(2) Hook up the refrigerant bottle backward and prepare the charging pipe.
(3) Connect the charging valve and purge air from the charging pipe by refrigerant before flare nuts of charging valve is tightened.
Note: The connection point is normally before dryer.
(4) The bottle is put down. It means that the refrigerant is supplied liquid state.
(5) After making sure that each flare nut is tightened satisfactorily, open the charging valve and stop valve of a refrigerant bottle.
(6) Close the stop valve after the receiver for pump down.
(7) Start compressor and charge additional refrigerant
(8) Continue charging until required amount of refrigerant has been charged.
(9) After charging is complete, stop the charging valve and stop valve of a refrigerant bottle.
(10) Disconnect the charging pipe and store a refrigerant bottle.
Note: Refer to Fig. 2-12 Ship's stores refrigeration system diagram.

2) Removing refrigerant:

If the refrigerating system is charged excessively with a refrigerant, the HP pressure rises, and liquid refrigerant is returned to the compressor, when the expansion valve is not properly adjusted, thus not only the suction line but also the compressor are coated with frost. In such a case, the excess refrigerant must be removed.
With all refrigeration system valves in their normal operating positions, proceed as follows:
(1) Shut off liquid supply to evaporators and carry out pump down. Close dryer by-pass valve, open dryer inlet valve and check that dryer outlet valve is closed.
(2) Measure the refrigerant bottle. Place on deck at an angle slightly above horizontal with bottle valves at high end. The position of the bottle should better be lower, if possible, than charging valve.
(3) Connect the stop valve of a refrigerant valve with the charging pipe and purge air.
(4) Open the stop valve of a refrigerant valve and the charge valve. Liquid refrigerant will flow into the refrigerant bottle.
(5) In this time, the bottle outside is cooled by ice and so on. It makes the lower pressure than condenser.
(6) Close the stop valve of a refrigerant valve and the charge valve, when required amount of refrigerant has been removed.
(7) Disconnect the charging pipe and store a refrigerant bottle.

3) Purging non-condensable gases:

Air and non-condensable gases, if present in the system, are pumped through the system and discharged by the compressor into the condenser. These gases are trapped in the condenser and cause excessive condensing pressures and the HP gas pressure to become abnormally high.
Purging of air and non-condensable gases is carried out by the following procedures:
(1) Close the liquid refrigerant stop valve and collect as much condensed refrigerant as possible in the condenser. Maintain cooling seawater flow of the condenser.
(2) Stop the compressor and maintain this condition for several hours if possible.
(3) Open purge valve on the top of condenser and slowly release gases.
(4) Since it is difficult to tell if excessive refrigerant is being purged with the non-condensable gases, purge slowly and check the condenser continually for the presence of non-condensable gases as explained above to minimize refrigerant loss while purging.

4) Adding oil:
When adding oil into the compressor, it is important to prevent air and moisture from entering the system.
The supplying procedure is carried out by the following procedures:
(1) Connect the charging pipe of LO into the oil-charging valve and supply new oil into an oil pan for exclusive use for refrigerant oil.
(2) Open the oil-charging valve just a crack and purge air in the charging pipe by gas pressure in the compressor.
(3) After purging air, close the oil-charging valve.
(4) Close the suction valve and open the delivery valve of the compressor and then start it.
(5) After confirming that the vacuum in the compressor reaches about 200mmHg, stop the compressor.
(6) Open the oil-charging valve slowly while checking the oil level and oil is easily supplied into the crankcase of compressor by vacuum.

5) Removing oil:
Proceed as follows to remove oil from a compressor crankcase:
(1) Connect the charging pipe of LO into the oil-charging valve.
(2) Stop the compressor.
(3) Open the oil-charging valve and remove oil by refrigerant gas pressure in the crankcase.

6) Crankcase heater:
A large capacity refrigerator compressor is equipped with the heater inside the crankcase.
The purpose of crankcase heater is to prevent the mixing of the refrigerant gas into the lubricating oil. When the compressor is stopped for long time, the refrigerant mixes into the lubricating oil. At the starting time, crankcase pressure goes down, the mixed refrigerant gas will go out from lubricating oil as same as the boiling and goes to suction of compressor together with the lubricating oil. This condition makes reduction of the oil in the crankcase. In bad cases, compressor is tripped due to low oil pressure or it results in damage to the bearing.

The crankcase heater prevents the above situation. The gas is difficult to mix into the liquid at high temperature condition.

7) Valves:

The valves for refrigeration plant are different from ordinary valves.
The main characteristics are
(1) They are equipped with sealing seat, which is not only front seat but also back seat
(2) They are normally kept in full open or full close position and not in intermediate open position.
Note: Full open position makes closing the back seat and thus decreasing the pressure of gland for valve spindle.
(3) They are equipped with special gland seal that is necessary to loosen before operation. After operation, gland seal tightening screw is fastened to prevent the leakage of refrigerant from the spindle gland.

3. Reefer Container:

3.1 Outline of Reefer Container:

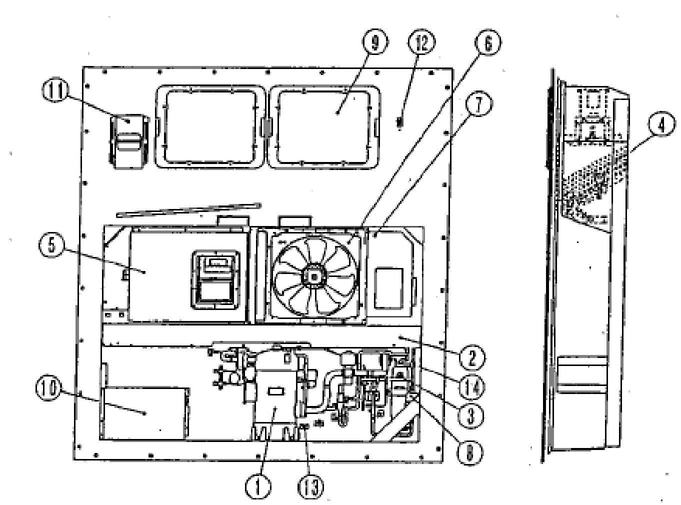
Refrigerated containers are fitted with self-contained electric heating and cooling units. This typical unit is mounted flush with the front face of a standard-sized container. Cooling is provided by a refrigeration system with a semi-hermetic reciprocating or scroll type compressor and an air-cooled condenser.

Axial flow fans are installed to provide ventilation across the evaporator and condenser, Fig. 2-13 shows the airflow through the unit. Heating and defrosting are accomplished by electric heating elements, located in the evaporator section. The heating and cooling cycles are controlled automatically by a thermostat, while the defrost cycle is initiated by a timer or a differential pressure switch monitoring the air pressure across the evaporator. The evaporator fan is switched off automatically during the defrost cycle. Electric power to run the units can be supplied from the ship's electrical system.

Some units are built with a diesel as the primary drive and an electric motor backup. The units can be carried across land by trucks.

Fig. 3-1 is a front panel of Reefer Container.

1) Compressor
2) Air-cooling condenser
3) Liquid receiver
4) Evaporator
5) Control box
6) Cooling fan of Condenser
7) Recorder box
8) Dryer
9) Access panel
10) Electric cable box
11) Ventilator
12) Thermometer insertion hole
13) Gas Sampling ports
14) Liquid moisture indicator



[Fig. 3-1 is a front panel of Reefer Container]

3.2 Safety device:

1) High / Low pressure switch (HLP):

HLP controls starting and stopping of the compressor drive motor by detecting the gas pressures at the suction side and discharge side.

If the discharge gas pressure rises abnormally to the high setting pressure, it opens the circuit to stop the motor and if it drops to the low setting pressure, it closes circuit to resume running automatically.

Furthermore, if the suction pressure drops to the setting vacuum, it opens the circuit to stop the motor and if the suction pressure rises to the setting pressure, it closes the circuit to resume running automatically.

2) High pressure switches (HPS):

If the discharge gas pressure rises abnormally to the high setting pressure, it opens the circuit to stop the motor.

3) Oil pressure protection switches (OPS):

OPS opens the circuit for the LO pump contained in the compressor when the pump fails, and stops the compressor.

If the pressure difference between the pump discharge pressure and the crankcase pressure reaches the setting pressure, it opens the circuit.

4) Water pressure switch (WPS):

If the amount of the cooling water for the water-cooled condenser is sufficient (pressure difference between water inlet and outlet is over the setting pressure), WPS opens the circuit for the air-cooled condenser fan motor to stop it.

In other words, this switch allows a selective use of the two types of condensers automatically. The reefer containers on deck, where no cooling water is available, are cooled by air fans. Where as those in cargo holds, where the cooling water is available, are cooled by the cooling fresh water after stopping the air fans.

5) Compressor thermostat protection (CTP):

If the compressor motor temperature rises, this switch opens the circuit to stop the compressor motor for preventing overheat.

3.3 Defrost device and Control circuit:

Defrost can be carried out by the following method.

1) Defrost timer

Defrost is carried out by setting time of the defrost timer in the circuit.

2) Manual defrost

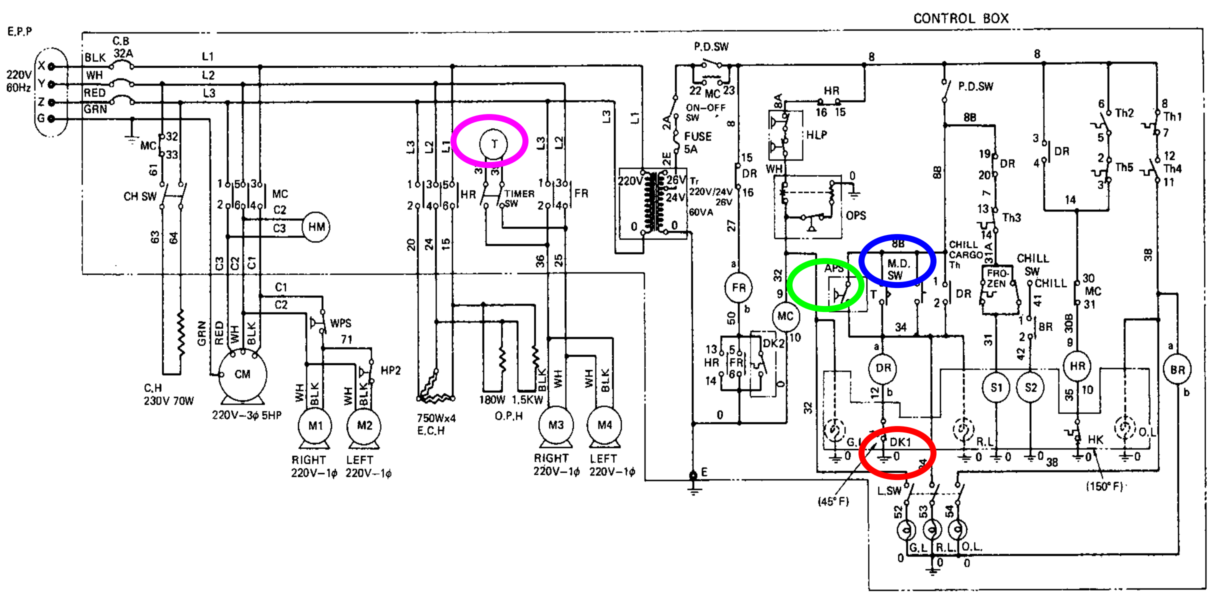
Defrost is carried out by manual signal.

3) Air pressure switch (APS)

APS issues the signal to start defrosting on detecting the specified pressure difference across the evaporator.

If the evaporator is covered with a frost coat, resistance is created for the airflow and thus a pressure difference evaporator. When this pressure difference reaches approximately 15mmAq or more, it closes the circuit to start defrosting.
Thermostat to stop defrosting (DK) is fitted at upper portion of the evaporator and serves to open the circuit to stop defrosting when all the frost on the evaporator has melted down (when the temperature of the fitted section becomes approximately 7℃).

Fig. 3-3 shows an electric control circuit of MITSUBISHI Reefer Container.



[Fig. 3-3 an electric control circuit of MITSUBISHI Reefer Container]

CB: Circuit breaker, E.P.P.: Electric power plug, CM: Compressor motor
MC: Main contactor, WPS: Water pressure switch, HP2: Press. Switch for Condenser fan stop, M1, M2: Condenser fan motor, HR: Heater relay,
E.C.H.: Evaporator coil heater, H.H.: Hose heater, D.P.H.: Drip pan heater,
FR: Fan relay, M3 & M4: Evaporator fan motor, Tr: Transformer, F: Fuse,
ON-OFF: unit on-off switch, HLP: High low pressure switch,
OPS: Oil pressure switch, M.D.SW: Manual defrost switch, T: Defrost timer,
A.P.S.: Air pressure switch, DK1: Thermostat to stop defrosting,
Th1-Th5: Thermostat, S1: Liquid solenoid valve,
S2: Hot gas by-pass solenoid valve, G.L.: Green lamp, R.L: Red lamp,
O.L.: Orange lamp, L.SW.: Lamp switch, HM: Hours meter,
C.H.SW: Crankcase heater switch, C.H.: Crankcase heater,
HK: Thermostat to prevent a heater from overheating

3.4 Check points of Reefer Container at loading on board:

After loading on board, the duty engineer should check the operating condition as quickly as possible.

The setting temperature and ventilation of Reefer Container is shown in the following things.

1) Reefer container list (Temperature and Ventilation)
2) Stowage plan (Temperature)
3) Temperature recording sheet (Temperature and Ventilation)
4) Setting of the controller in Reefer Container (Temperature)

Note: The unit of temperature is centigrade and Fahrenheit. It's necessary to check the above temperature unit.

If it is found that any condition, mentioned above in points 1～4, does not match, contact the terminal operator and confirm right temperature and ventilation.

Moreover, if it is confirmed that there is an abnormal condition in the temperature recording sheet or abnormal condition in operation and Chief engineer judges that safe transportation to the destination cannot be performed, consider unloading or complete repair.

3.5 Check points of Reefer Container at sea:

In principle, the duty engineer should check the condition of Reefer Containers twice a day (Morning and afternoon) or customer request (One of the ice cream Maker requires 4 times a day) and record each temperature in Monitoring Log. When the check is impossible due to rough seas or weather conditions, the reason and effect should be recorded.

If PCT (Power Cable Transmission) Monitoring System is installed on board, the monitoring check with this system can be recorded once a day.

Check items are as follows.

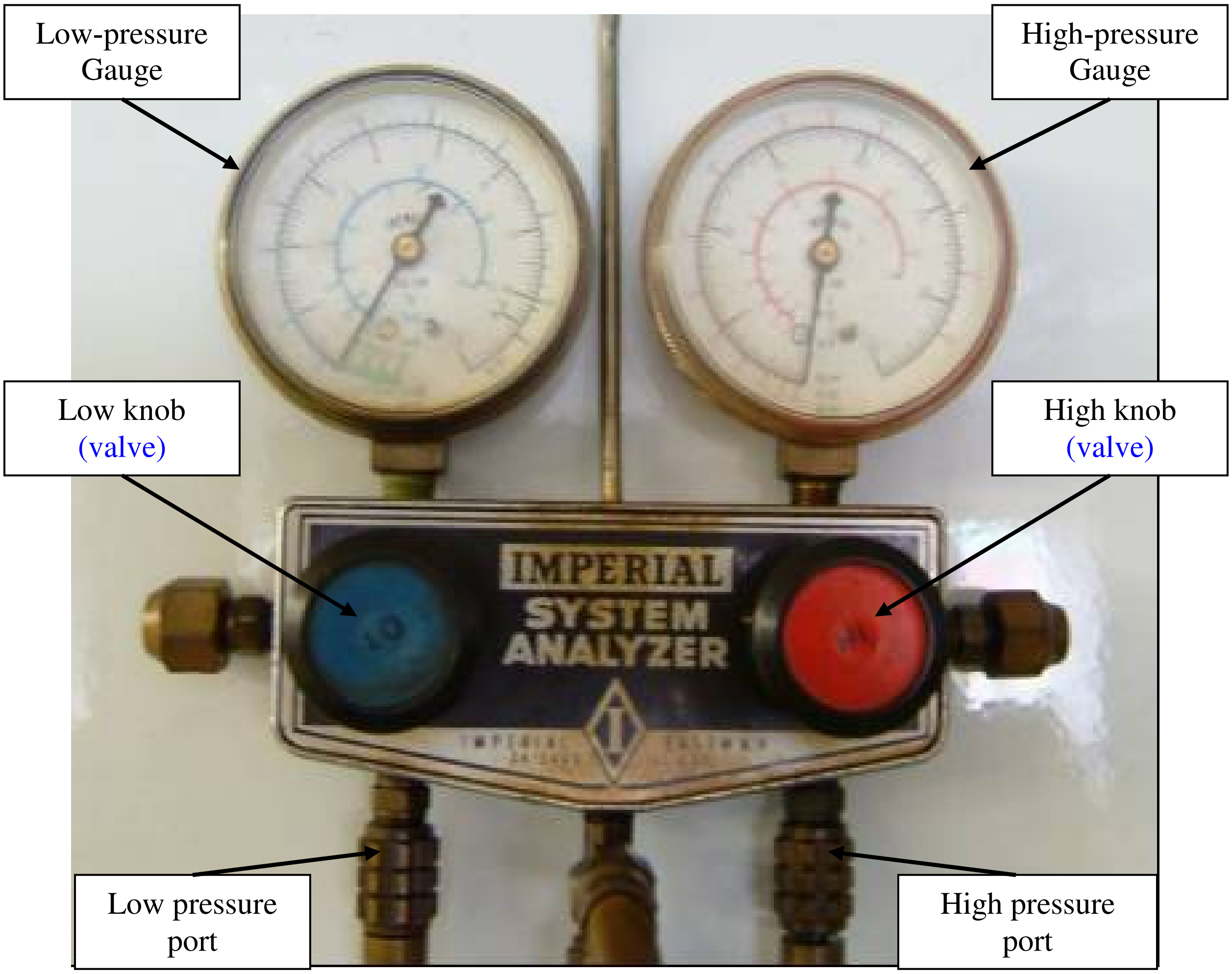
1) Difference between the setting temperature and present temperature
2) Trend of temperature in the recording chart
3) Running condition of the temperature recording chart
4) Defrost condition
5) Running condition of the refrigeration unit
6) Leak of oil and refrigerant, etc.
7) Abnormal vibration and sound
8) Electric equipments (Power plug, cable, etc.)

If abnormal condition is found, appropriate repair should be carried out. According to "Guideline of Management for NYK Container", it must be reported and recorded.

3.6 How to use the gauge manifold:

1) Outline of a gauge manifold

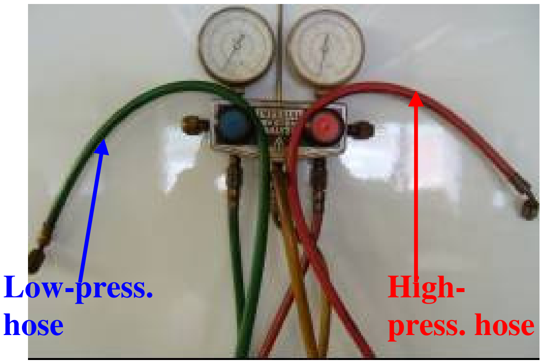
Fig. 3-4 shows a gauge manifold.



[Fig. 3-4 Gauge manifold]

The right gauge (red color) is a pressure gauge for high-pressure (delivery) side and the left gauge (blue color) is a compound gauge for low-pressure (suction) side.
The hose of Low-pressure port is connected to the low-pressure side of a compressor And the hose of High-pressure port is connected to the high-pressure side of it.
After connecting these hoses to both sides and purging air, each pressure is indicated. Both knobs should be closed in this condition.
The center hose is used for charging and removing refrigerant, or feeding oil.
The Fig. 3-5 shows Low & High-pressure connecting hose and a charging or air-purge hose.

Before using the gauge manifold valves, make yourself well familiar with the construction and correct handling procedure.



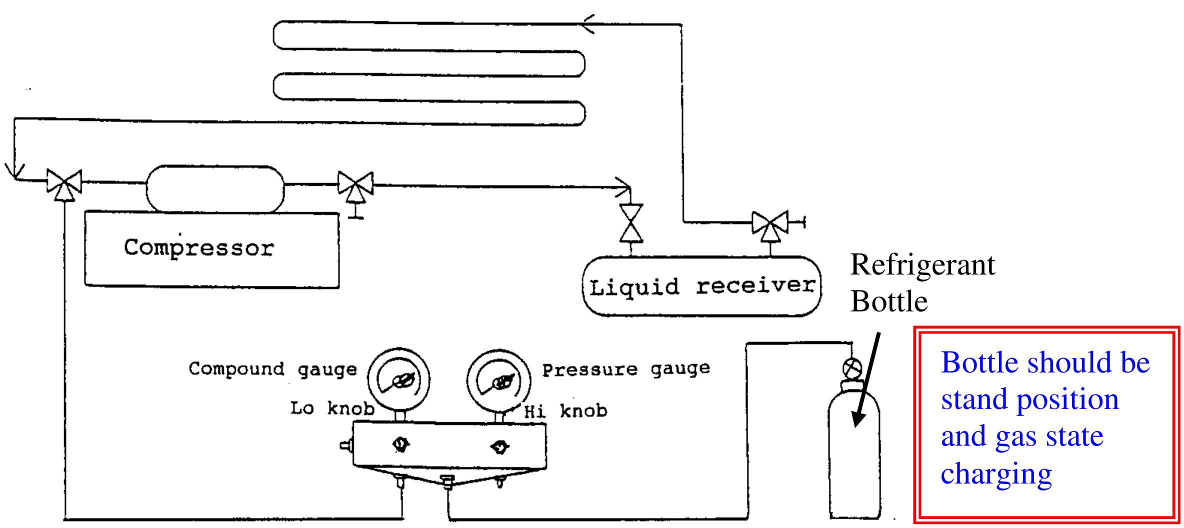
[Fig. 3-5 High & Low-pressure connecting hose and Charging hose]

3.7 How to Charge the refrigerant gas:

Charging with gas condition:

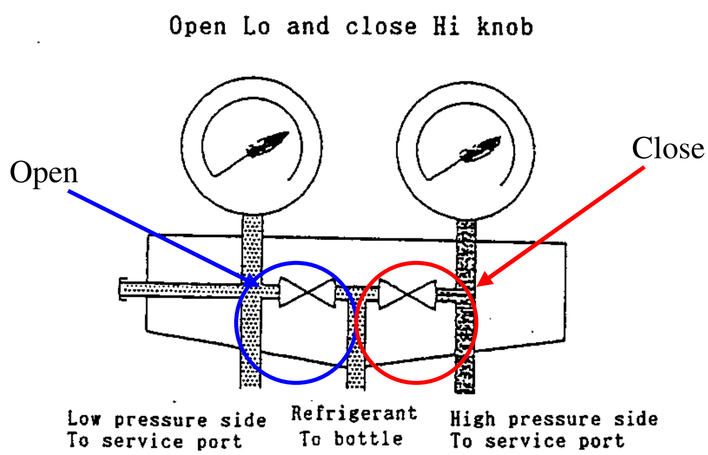
a) Close High and Low knobs.
b) Connect Low-pressure connecting hose to LP check joint and then connect Charging hose to the refrigerant bottle as Fig. 3-6 Gas charging.
c) Purge air in each hose.
Open Low pressure knob and purge air. After confirming purging air certainly, tighten the connection to the refrigerant bottle.
d) Open Low knob.
e) Open the refrigerant bottle valve and start the unit.
f) After confirming sufficient charging, stop the unit. Close all valves and disconnect each hose.

Note: To charge gas, keep refrigerant bottle in the upright position.



[Fig. 3-6 Gas charging]

Fig. 3-7 shows the condition of gauge manifold during gas charging.



[Fig. 3-7 Gas charging condition of the gauge manifold]

3.8 Charging refrigerant oil to compressor:

Observe the following procedure:

a) Close High and Low knobs.

b) Connect Low-pressure connecting hose to LP check joint and High-pressure connecting hose to HP check joint. Connect Charging hose to the refrigerant oil bottle as shown in Fig. 3-8 Refrigerant oil charging.

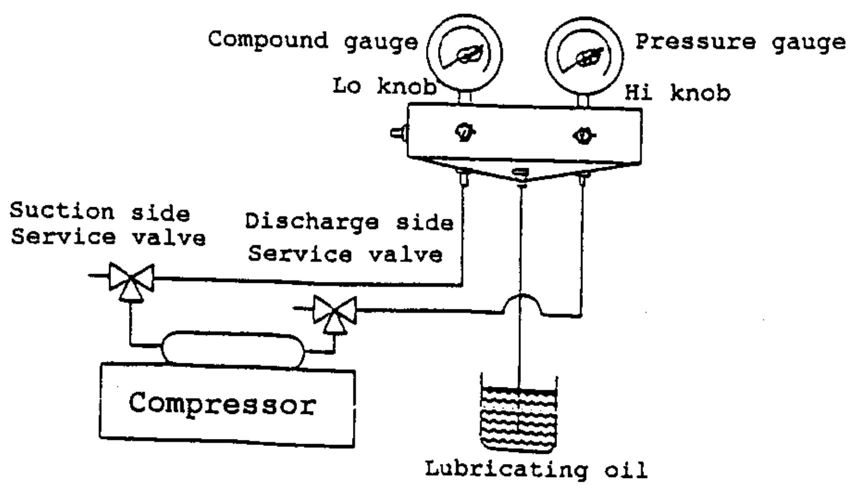
c) Slightly open Low knob and purge air in the line with the suction side refrigerant.

d) Close condenser outlet service valve.

e) Keep running the compressor till the LP switch comes into function.

f) Supply LO from compressor suction side by slightly opening Low knob. At this moment, keep High knob valve close.

Note: This is a general guideline for charging oil and Maker's instruction book to be referred always before carrying out this operation onboard.

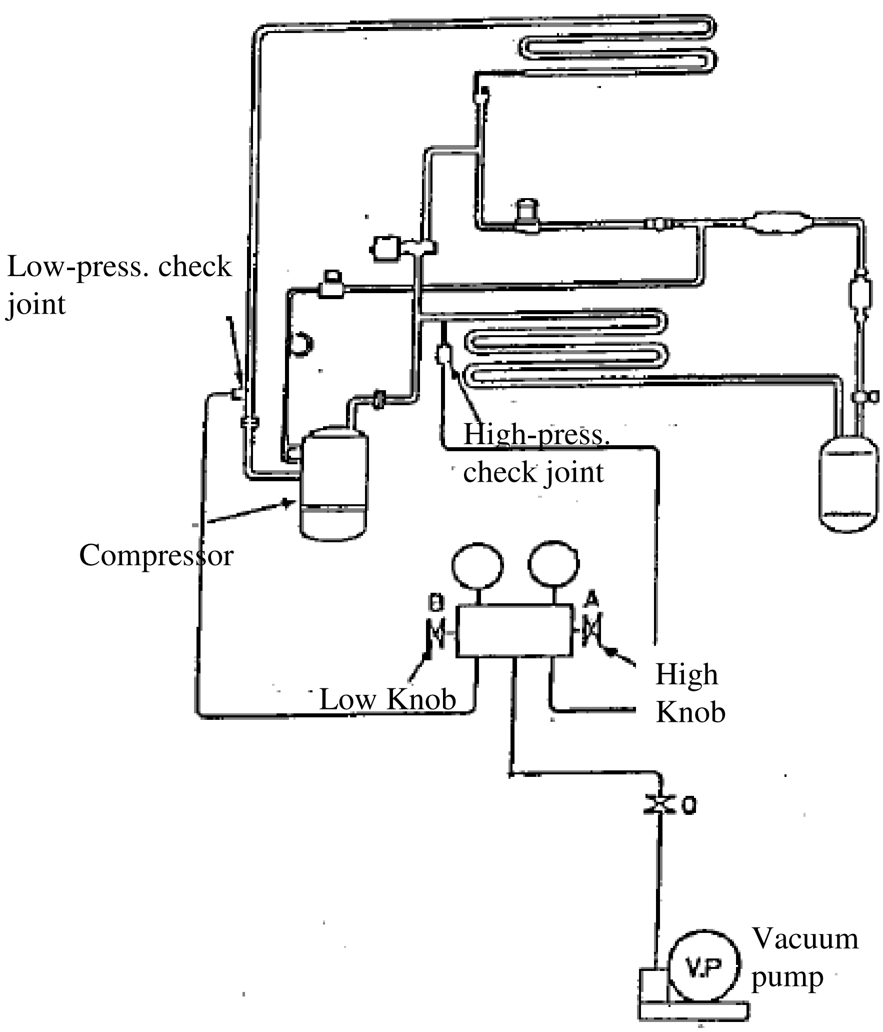


[Fig. 3-8 Refrigerant oil charging]

3.9 Vacuum pump op

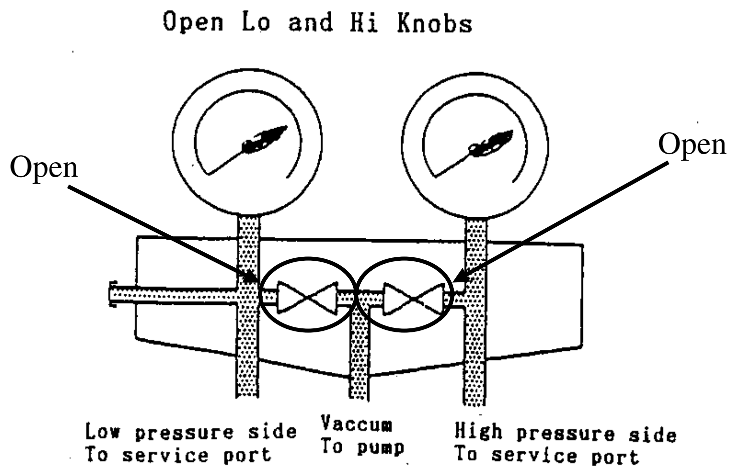
Observe the following procedure:
a) Close High and Low knobs.
b) Connect Low-pressure connecting hose to LP check joint and High-pressure connecting hose to HP check joint. And connect Charging hose to the vacuum pump as Fig. 3-9 How to use vacuum pump.
c) Open High and Low knobs and the suction valve of vacuum pump (O) and start the pump.
d) Continue the operation until 760mmHg.
e) Stop the vacuum pump and close High and Low knobs and the suction valve of vacuum pump.
f) Keep this condition for 5 minutes and confirm that the vacuum value does not change.

3.9 Vacuum pump operation



[Fig. 3-9 Vacuum pump operation]

Fig. 3-10 shows the condition of gauge manifold during vacuum pump operation.



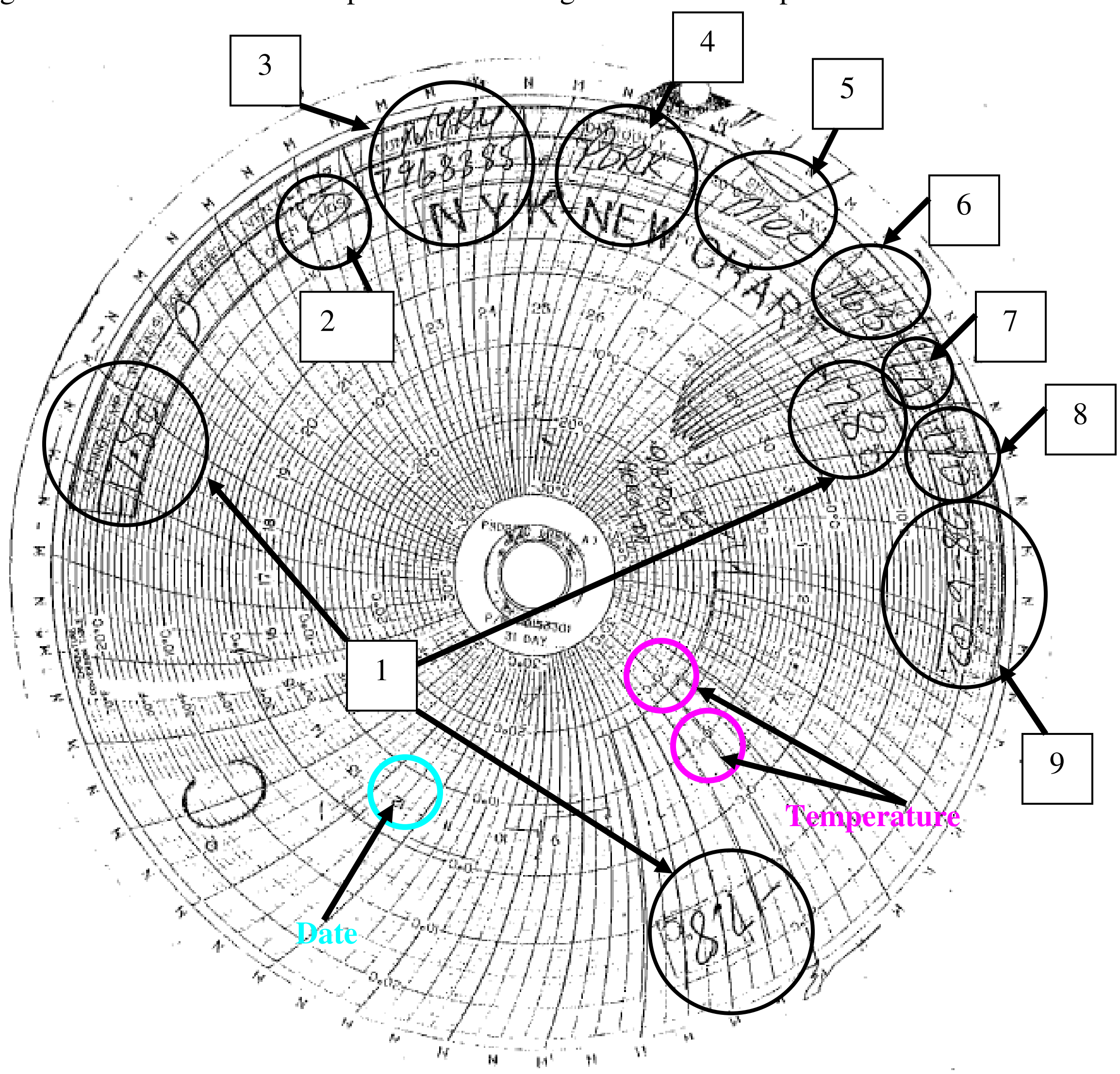
[Fig. 3-10 Condition of gauge manifold during vacuum pump]

3.10 How to read temperature recording chart:

It is important to read the temperature recording chart to judge the condition of Reefer Container during transportation. The condition can be read from the temperature trajectory on the chart.

1) Description in the temperature recording chart

Fig. 3-11 shows an actual temperature recording chart and description.

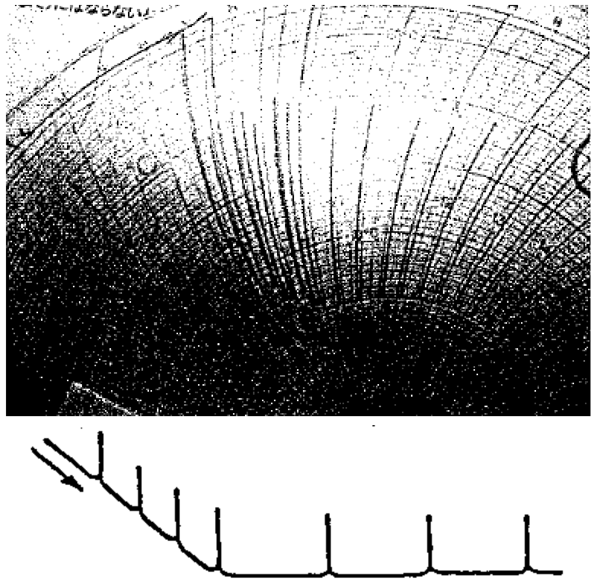


[Fig. 3-11 Temperature recording chart and description]

1) Setting Temperature, 2) Ventilation, 3) Container Number, 4) Commodity
5) Ship's Name, 6) Voyage No., 7) Loading Port, 8) Discharging Port, 9) Loading Port
The chart turns counterclockwise and a date is increasing clockwise.
The vertical line shows a temperature and the center is －30℃ and as temperature point moves outside, it indicates increase in temperature.

2) Typical temperature trajectory on the chart

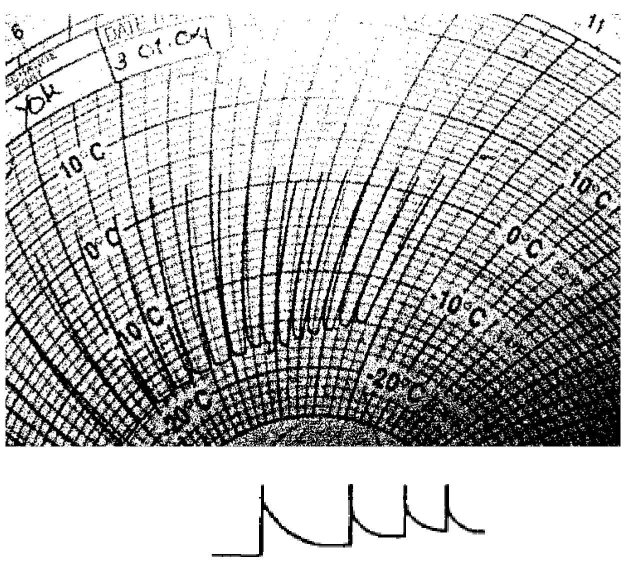
a) Hot vanning (Fig. 3-12)



[Fig. 3-12 Hot vanning]

Because the temperature of a loading cargo is higher than setting temperature, temperature inside the container falls slowly afterwards. This temperature trajectory is normal.

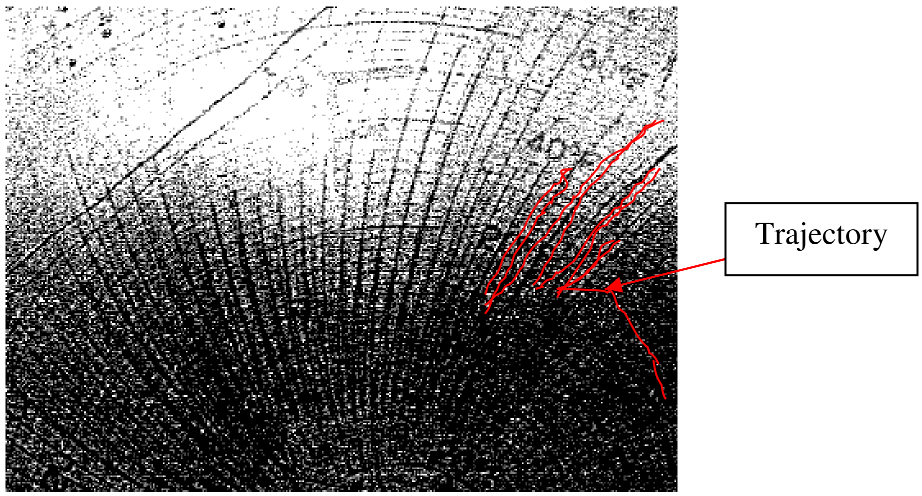
b) Lack of refrigerant (Fig. 3-13)



[Fig.3-13 Lack of refrigerant]

Temperature rises slowly to the setting temperature, once the refrigerating unit runs at full load.

c) Defrost cycle (Fig. 3-14)

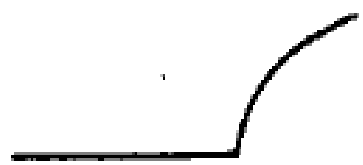


[Fig. 3-14 Defrost cycle

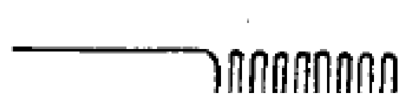
The trajectory during defrost cycle is same as that of during stop condition of a unit and if the defrost interval is automatic, defrost is carried out frequently.

d) Others

(1) A unit is stopped by OPS, etc.



(2) Evaporator fans are stopped.
(Locking or breaking of wire, etc.)



(3) Frost on evaporator coils
(APS, DK, HK)

Note-:
APS: Air Pressure Switch
DK: Defrost Stopping Thermostat

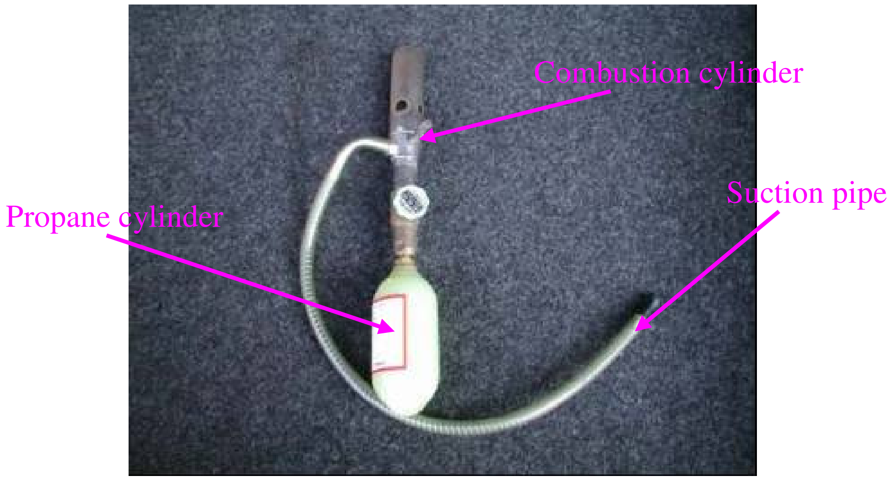
HK: Heater Overheat Protection Thermostat

3.11 How to check leakage of refrigerant:

Refrigerant gas detectors can be used to detect refrigerant gas leakage.
For a gas detector, there are following kinds.

1) Mackinly Refrigerant Gas Detector (Halide Torch Gas Detector)

Refrigerant leak detectors contain a halide torch that uses a propane gas flame to detect refrigerants. If halogenated refrigerant vapors are present, the flame changes from blue to a blue-green color. If gas leakage is big, the flame color becomes violet.



[Fig. 3-15 Mackinly Refrigerant Gas Detector]

Note: The refrigerant combustion gas is poisonous gas, so ensure proper ventilation.

2) Automatic Gas Detector (Electric type):

This detector is controlled by a microprocessor and can detect CFC, HFC, HCFC and also a mixture refrigerant. Leakage can be known by an indicator lamp, meter or sound. Fig. 3-16 shows a sample of Automatic Gas Detector.

[Fig. 3-16 Automatic Gas Detector]

3) Leak Detectors "GUPOFLEX"

GUPOFLEX liquid leak detector is used for detecting gas leaks. This detector detects gas leaks simply by only pressing the button to spray on unit and GUPOFLEX is non-flammable, low degree of halogen and sulfuric liquid detector.

GUPOFLEX spray will produce bubbles by CO_2 gas on the sprayed surfaces.

Fig. 3-17 shows "GUPOFLEX".

[Fig. 3-17 GUPOFLEX]

Instead of GUPOFLEX, Soap water can also be used to detect gas leaks.

3.12 Case Study – Reefer Containers Remain Unplugged After Loading

Sequence of Events

On 01-Aug-15 at 20:40 hrs, our managed vessel arrived at port of Le Havre.

At 21:35 terminal planner came on board delivering loading plan and checking stowage with Ch. Mate. Upon receipt of EDI file, reefer list printed and together with reefer manifests, these were handed over to E/E.

Two reefer units were not included in EDI program file/reefer List by terminal loaded/plugged/un-plugged on 02-Aug.

Since these two units were not included in power stow (EDI files) provided by the planner at Port of Le Havre, they did not reflect in the Reefer list generated by Powerstow. Therefore, vessel staff unplugged these reefers.

Electricians did not verify the number of reefer units with manifest immediately and relied solely on Powerstow print outs of Reefer List.

On 02-Aug at 23:40 hrs, vessel sailed from Le Havre for next port.

After reviewing all manifest on 6th Aug 2015 upon departure of following port of Southampton thoroughly, observed that these two units are included and are live reefers. So vessel staff plugged-in these reefers again. Within one hour of plugging in, temperature reached to its set point.

Cause Analysis

Both Electricians did not verify the number of reefer units with manifest immediately and relied solely on Powerstow Print outs of Reefer List.

Chief officer did not check for any discrepancy between Powerstow printed list and the manifest provided. No efforts were also made to contact local planning office to verify the Edi file.

Corrective Action

Suitable training for electricians will be carried out and electricians will undergo this training at local manning offices in Manila and Mumbai prior joining the vessel.

Joining electricians will be briefed at local manning offices about safe and proper reefer container carriage prior joining.

Also, a confirmation statement will be obtained from vessel after each port as follows,

/////
"We hereby confirm that all the reefers are connected and temperatures set as per the manifest provided to the vessel".
/////

This statement will be signed by the senior staff onboard and electrician and sent to office after every departure port.

3.13 Case Study – Series of Reefer Containers Remain Unplugged After Loading

On 24 Nov 2014, NYKSM received **warning letter** from Global Liner Management Division, NYK Group South Asia Pte Ltd with subject "Series of reefer container unplugging incidents on container vessels".

There were two incidents as below

1) 24 reefer containers found not plugged condition in cargo hold on Vessel A on 14th September, 2014.

2) One reefer container loaded incorrectly with the compressor unit facing the bulkhead side and found not plugged condition on Vessel B on 27th October.

Sequence of Events

<u>Vessel A</u>

14 Sept 2014 in port

There were 24 reefer containers loaded inside the cargo hold which were left unplugged for 19 hours.
Same was noticed only after duty officer realized that that particular cargo hold had reefers loaded previous day and there was no information relayed to electrical officer about these
containers.
The matter was investigated and cause was narrowed down to improper procedure and poor coordination onboard. The reefer manifest used to be left in the ships office for electrical officer and not handed over to C/Eng and E/Off as per the normal procedure.

<u>Vessel B</u>

27 October 2014 - At sea after departure

One reefer container was informed to be left in an unplugged state for 07 days after loading. The said container was loaded with the compressor/ logger side positioned in opposite direction facing the bulkhead and hence unable for ships staff to monitor the parameters or remove the cable for plugging-in. Unfortunately, same was not informed to the terminal for corrective action prior sailing.

This was not realized or reported by duty officer or electrician. The daily reefer container temperature readings were logged down and reported as per set temperature by electrical officer for the next seven days which apparently were <u>false readings.</u>
In this case, fortunately, ship's staff was able to power up the container with great difficulty due to compressor side facing the bulkhead.

Cause Analysis

Vessel A

Failure to follow the procedure
C/O did not hand over reefer manifest to D/O, CE and E/O as per procedure.

Lack of Situational Awareness
Deck/Officer, CE and E/O did not ask or did not check with C/O.

Inadequate supervision
C/E did not inquire about the number of reefers being loaded.

SMS Procedures and Instructions + Inter Departmental Communications
Communication among on board officers failed and procedure was not complied.

Vessel B

Subject reefer was not checked by E/O.
However; he did not report the fact and hid the truth by Falsifying temperature record for one week.

Inadequate supervision
Incorrectly loaded reefer container with power unit facing the bulkhead was not noticed by the duty officer.

SMS Procedures and Instructions + Inter Departmental Communications
Procedure was not complied by Duty officer and E/O did not communicate with any body and recorded false reading.

Corrective Action

To include reefer check items in vessel visit check list and same to be discussed by Vessel Manager and HSEQ Manager visiting container vessels.

To include in briefing check list.

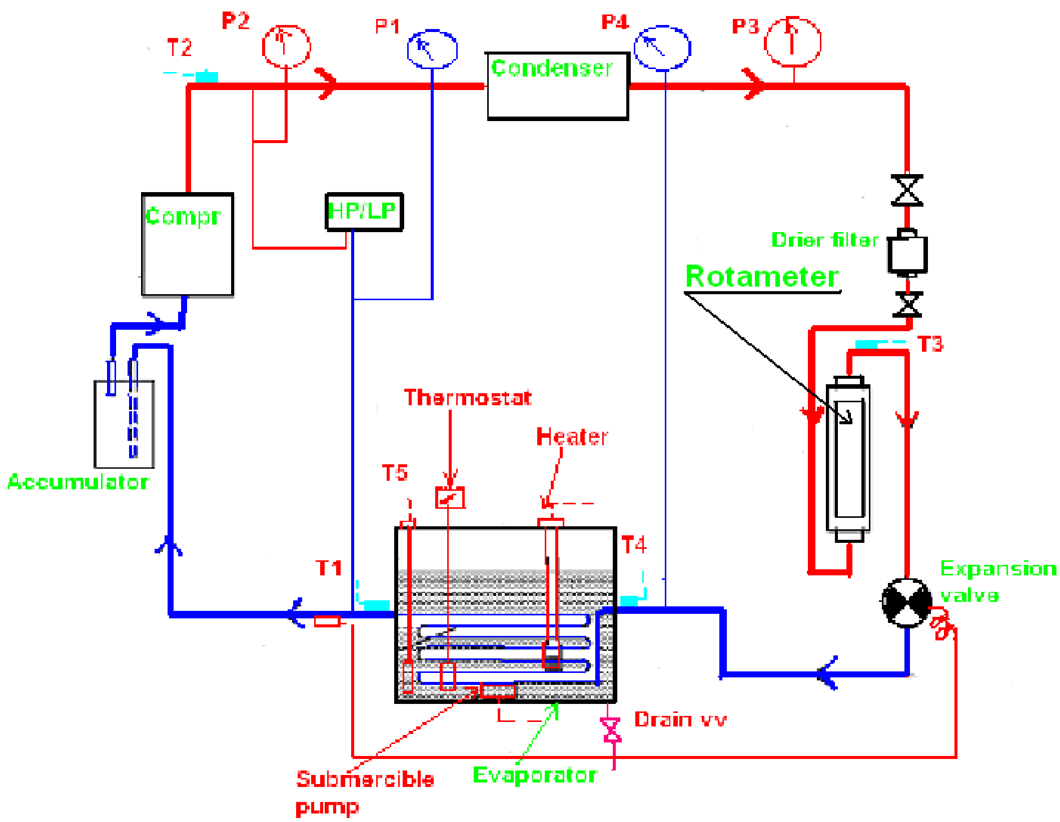
Veseel to send reeferlist to charterers and NYKSM after departure port duly signed by Master , CO, CE and EO.

Daily reefer temperature monitoring to be carried out once by the electrician and any other staff onboard in order to avoid any discrepancies in reefer monitoring.

4. Simulator Training:

4.1 System layout:

The Fig.4-1 below shows the general layout for simulator.



[Fig. 4-1 System layout]

T1: Temperature sensor for monitoring Refrigerant temperature at Suction
T2: Temperature sensor for monitoring Refrigerant temperature at Discharge
T3: Temperature sensor for monitoring Refrigerant temperature before expansion
T4: Temperature sensor for monitoring Refrigerant temperature after Expansion
T5: Temperature sensor for monitoring Refrigerant temperature of water
P1: Suction pressure
P2: Discharge pressure
P3: Pressure after condenser or before expansion valve
P4: Pressure after expansion valve

The system is provided with following components:
- Water Tank (Test Chamber)
- PT-100 Temperature Sensors (5 Nos.)
- Control panel
- Heater: 230 V, 1Ph, 1 Nos. (Mounted inside the tank/chamber)
- Refrigeration components like compressor, evaporator, condenser, receiver, etc.
- Air heater insulated with glass wool on receiver vessel.
- Water Tank is provided with an agitator (submersible pump) for uniform cooling of the medium.
- Following Instruments/Items are mounted on control panel:
-- Temperature Indicator
-- Rota meter for R134a (for indicating refrigerant flow rate through the system)
-- Mains Switch
-- Switches, Toggle type
-- Pressure gauges (compound gauge -2 Nos; glycerin filled-2 Nos)
-- Thermostat
-- Mimic with Test Points
-- Indicator lamps for different switches.

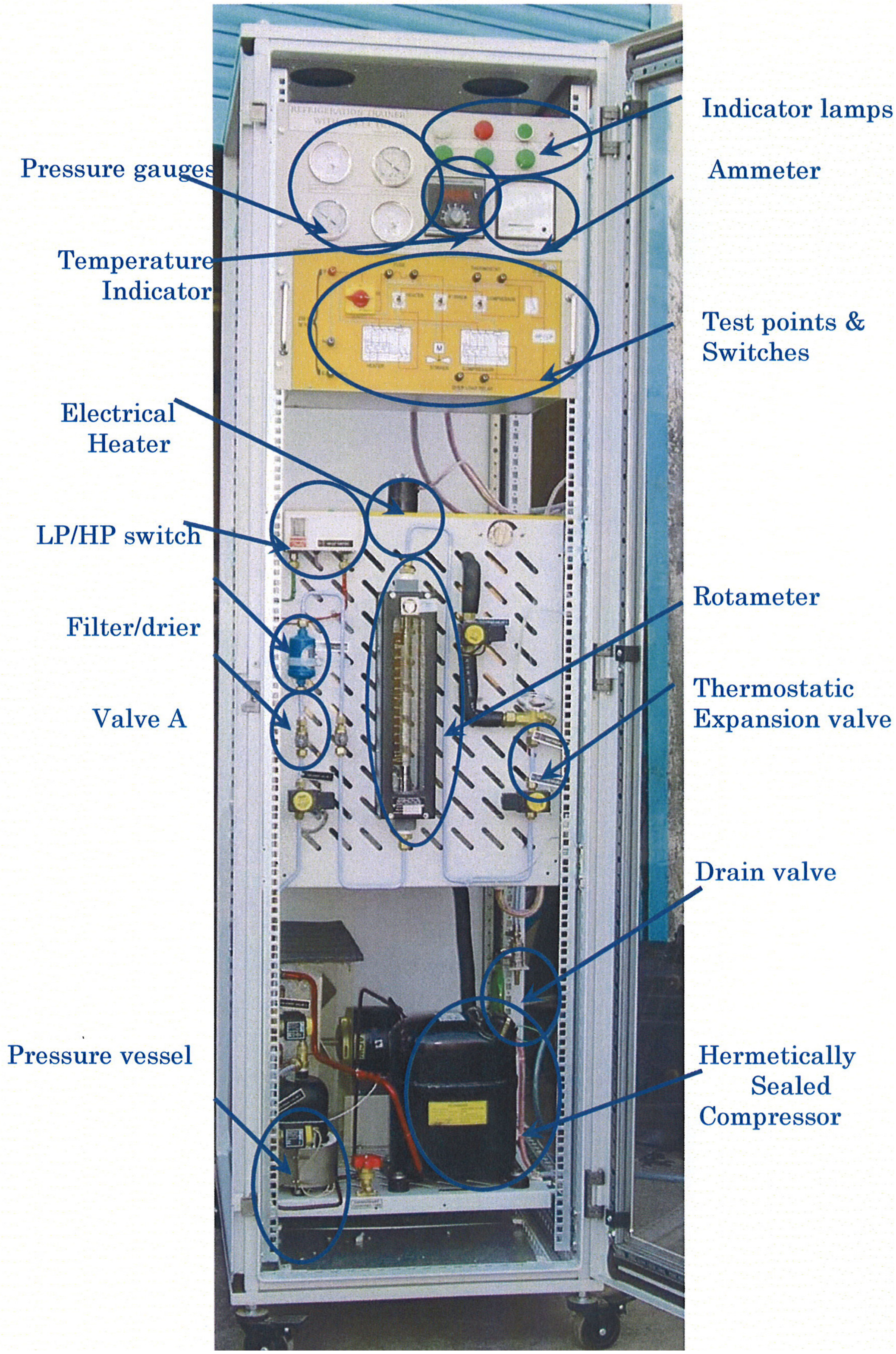
- R-134a Piping System consists of:
-- Hermetically sealed compressor with Electrical Motor
-- Air cooled condenser fan & motor for forced draught cooling
-- Expansion device

4.2 Description of System:

The electric supply is 230 V 50 Hz.
The compressor is used for pumping the refrigerant through the system.
The condenser is the forced air-cooled type for which condenser fan and motor has been provided.
Thermostatic Expansion Valve is provided as an expansion device for evaporator.
Heater is provided to load the system.
An air heater with thermal switch is fixed around the receiver vessel so that there must not have any phase change of refrigerant (from gas to liquid)
A temperature indicator with multi-point selection switch has been provided to get the various temperatures viz.
T1 Refrigerant Temperature at Suction
T2 Refrigerant Temperature at Discharge

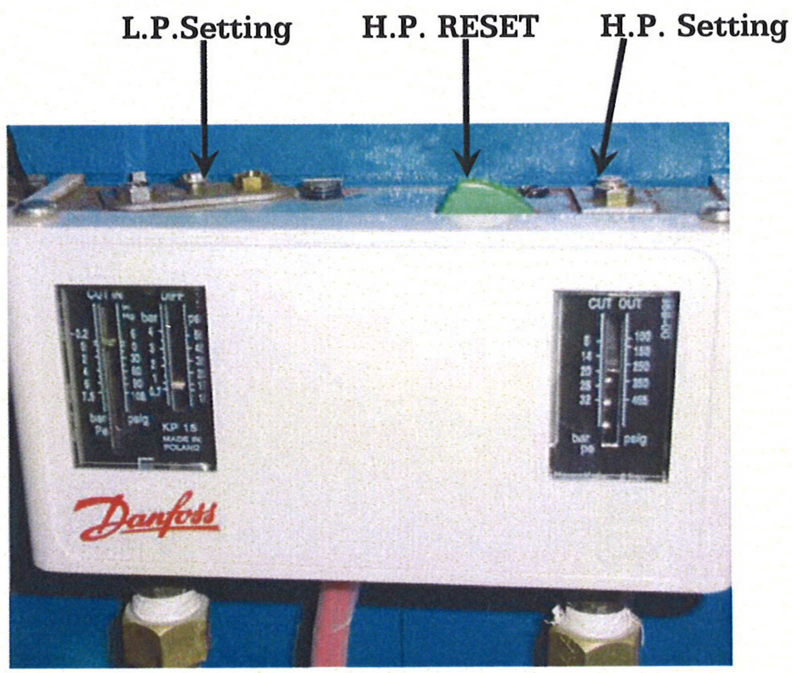
The selection of any of the temperature can be made by rotating the selection switch to the respective channel.
There are four pressure gauges for indicating R-134a pressures at compressor suction P1, compressor discharge P2, after condenser P3, after thermostatic expansion P4.

The Picture below shows arrangement of components in the simulator.



4.3 High Pressure – Low Pressure Cut out Switch:

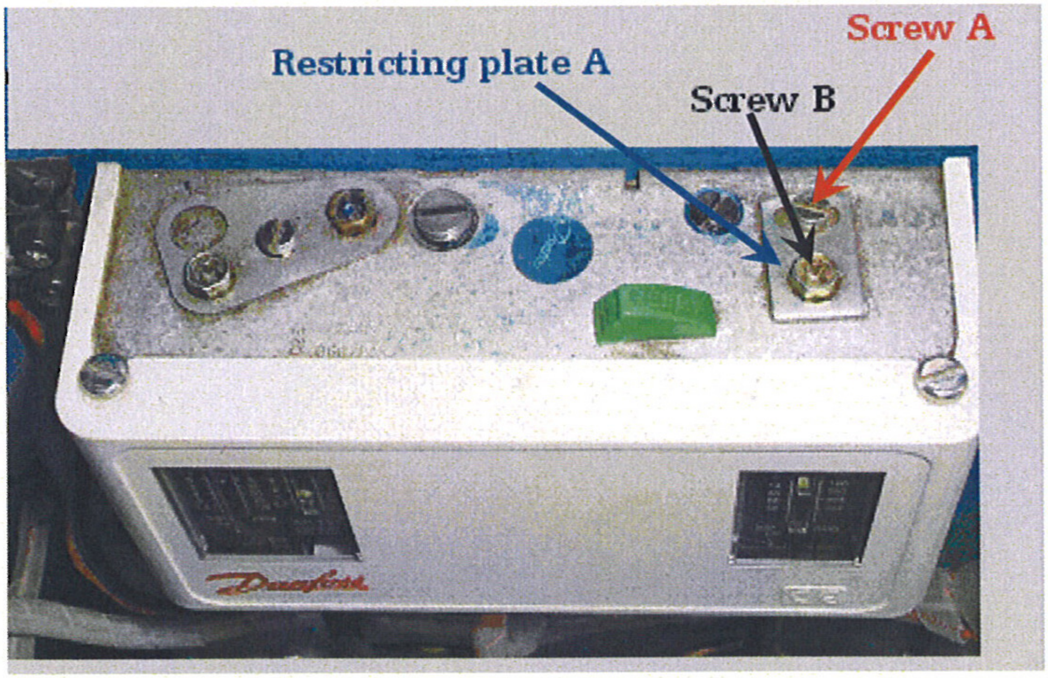
The picture below shows the HP/LP cut-out switch.



Pressure switches have been designed to protect refrigeration and A/C systems against excessively low suction pressures or excessively high discharge pressures.
They can also be used for low-pressure pump down and condenser fan cycling.
Pressure controls do not require special tools. A screwdriver or spanner will do the job.
The wiring diagram is provided inside the rear of the front cover

Operation of High Pressure Switch:
Whenever discharge pressure of compressor becomes more than the critical limit, the compressor is stopped by cutting power supply to the compressor motor, thereby preventing the possible damage.
High pressure cut out consists of bellows connected to condenser side of compressor. As soon as discharge pressure goes beyond the upper critical limit, the bellows move up causing lever to rise and disconnect the connections. Once, the discharge pressure falls below critical limit, the bellows contract. The compressor motor can be restarted after pushing the HP reset button.

How to Set High Pressure Cut-out:
The picture below shows components of HP cut-out.



- To set the high pressure cut-out, remove the screw A as shown in the picture above.
- Remove the restricting plate A.
- Turn screw B clockwise or anticlockwise to set high pressure cut-out. Turning the screw clockwise increases the cut-out value of the high pressure. Turning the screw anti-clockwise reduces the cut-out value of the high pressure.
- After adjusting the high pressure cut-out, replace the restricting plate A and tighten it with screw A so that the setting is not disturbed.

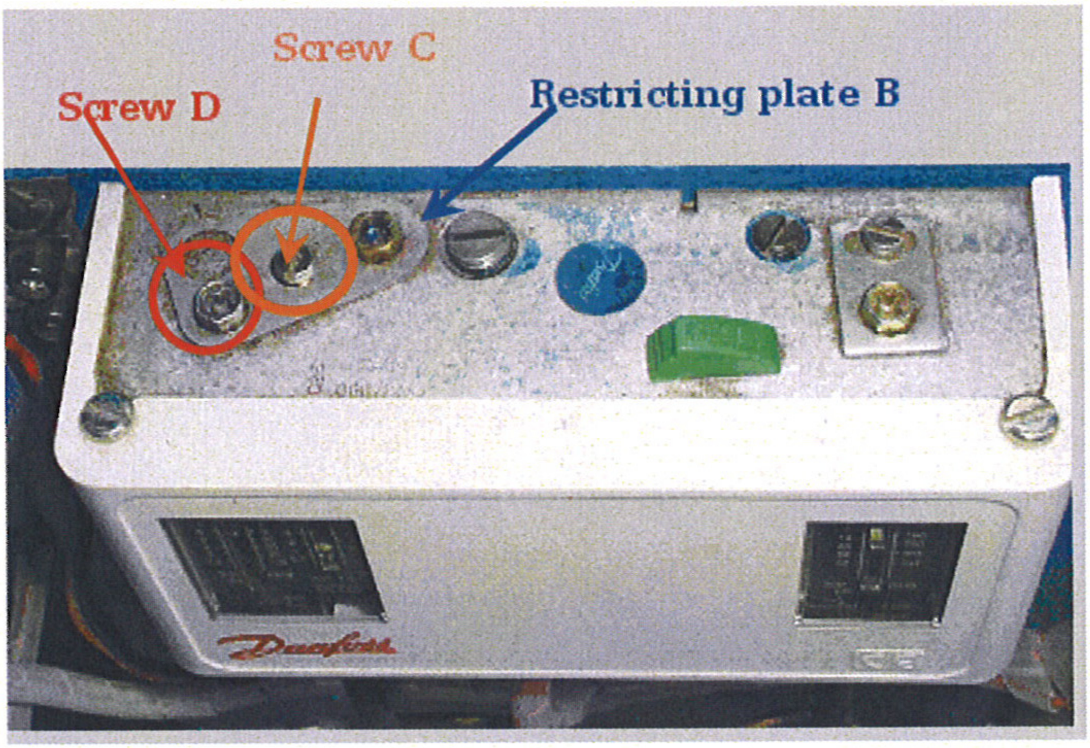
Operation of Low Pressure Switch:
The operation of low pressure cut out is exactly same as high pressure cut out except the compressor motor is switched off, when the pressure in the suction line falls below a predetermined value.

It consists of bellows connected to evaporator side of compressor. When the pressure in the evaporator decreases below predetermined value, bellow gets suppressed and connections are broken.

Low pressure cut out is necessary for a safety control and temperature control. The possibility of reduction in suction pressure of compressor is due to reduction of the load on refrigerating system.

How to Set Low Pressure Cut-Out:

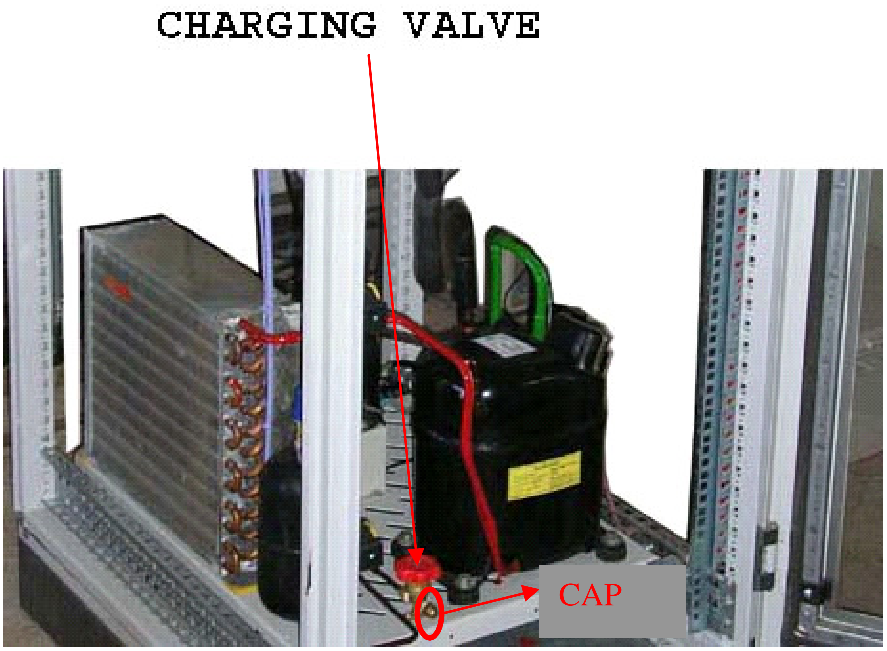
The picture below shows components of LP cut-out.



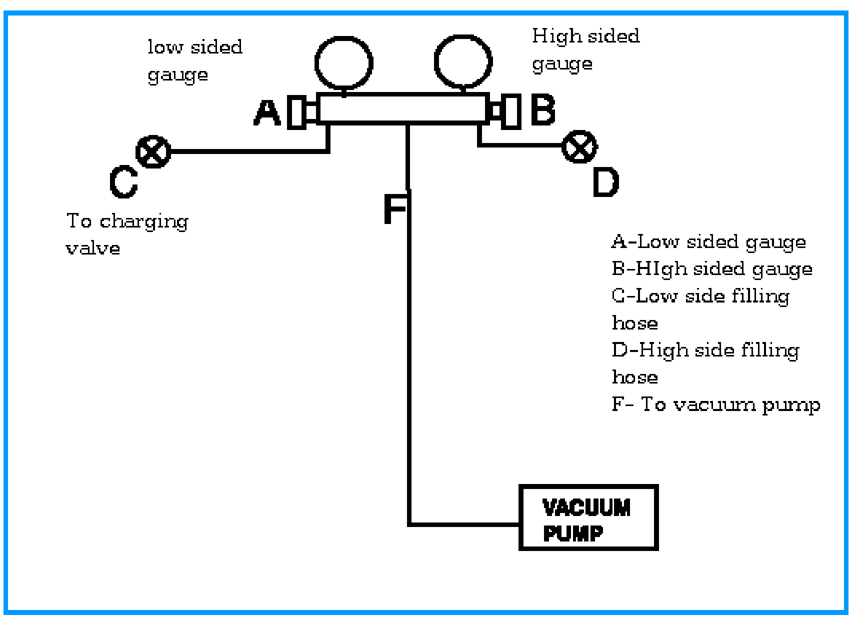
- To set the low pressure cut-out, while compressor is running remove screw C and remove the restricting plate B.
- Turn screw D clockwise or anticlockwise to set low pressure cut-out. Turning the screw clockwise increases the cut-out value of the low pressure. Turning the screw anti-clockwise reduces the cut-out value of the low pressure.
- After adjusting the low pressure cut-out, replace the restricting plate B and tighten it with screw C so that the setting is not disturbed.

4.4 How to Charge Refrigerant in the System (Simulator):

The picture below shows arrangement for gas charging.

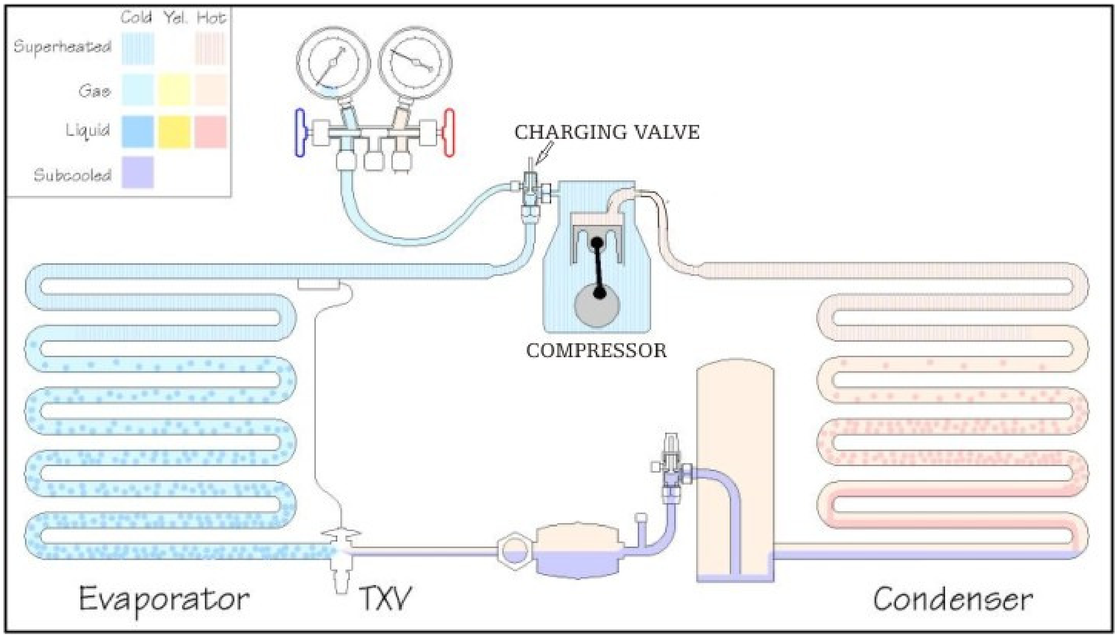


1) Vacuum the system by connecting low sided filling hose C to Charging valve and the other hose F to the vacuum pump. Refer Fig. 4-2.



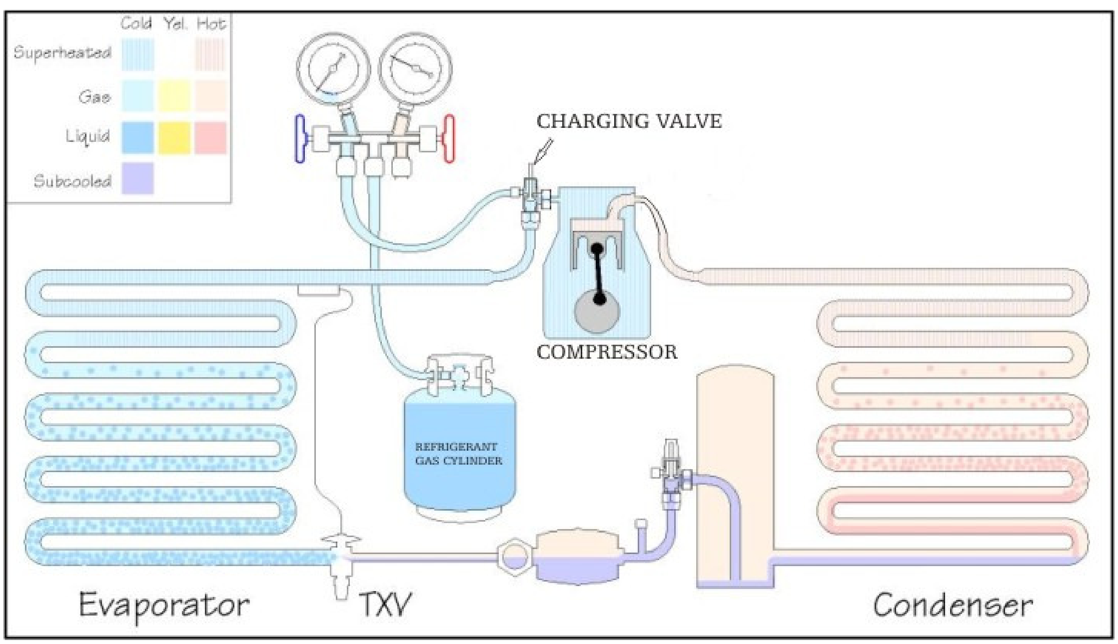
[Fig. 4-2 Vacuum pump operation]

2) After vacuuming the system, close the charging valve. Remove the hose from the vacuum pump. Refer fig. 4-3.



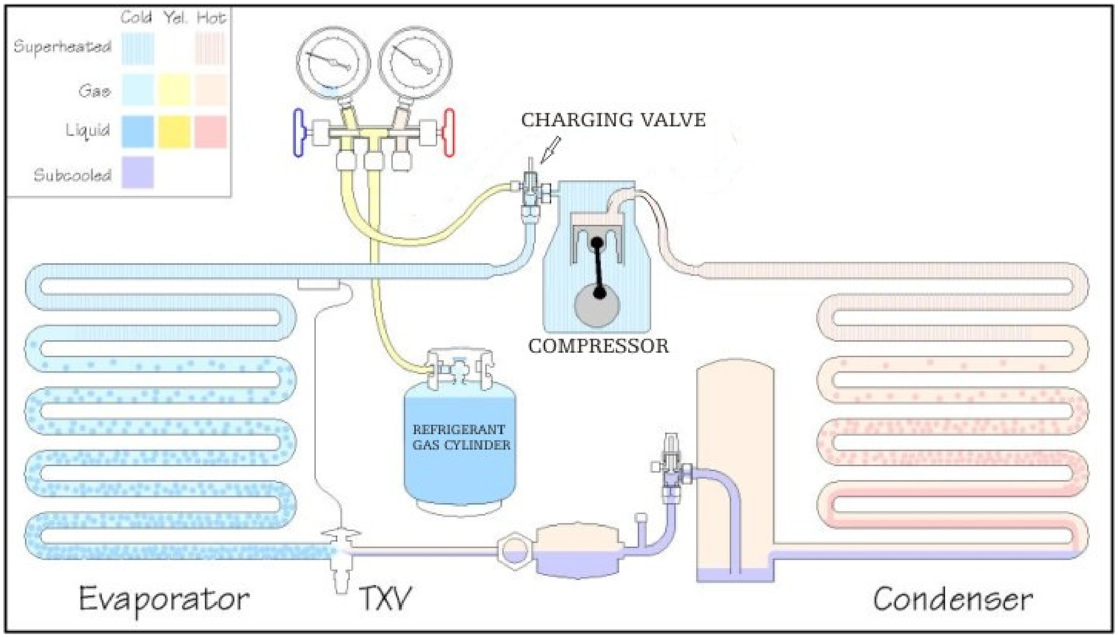
[Fig. 4-3]

3) Connect the other hose F to the refrigerant gas cylinder. Refer Fig. 4-4. Note the total weight of the cylinder and gas in the cylinder (W1).



[Fig. 4-4]

4) Open the charging valve and the valve at the low sided gauge, the refrigerant gas passes through the hose into the system as gas in the cylinder is at higher pressure. Refer Fig.4-5.



[Fig. 4-5]

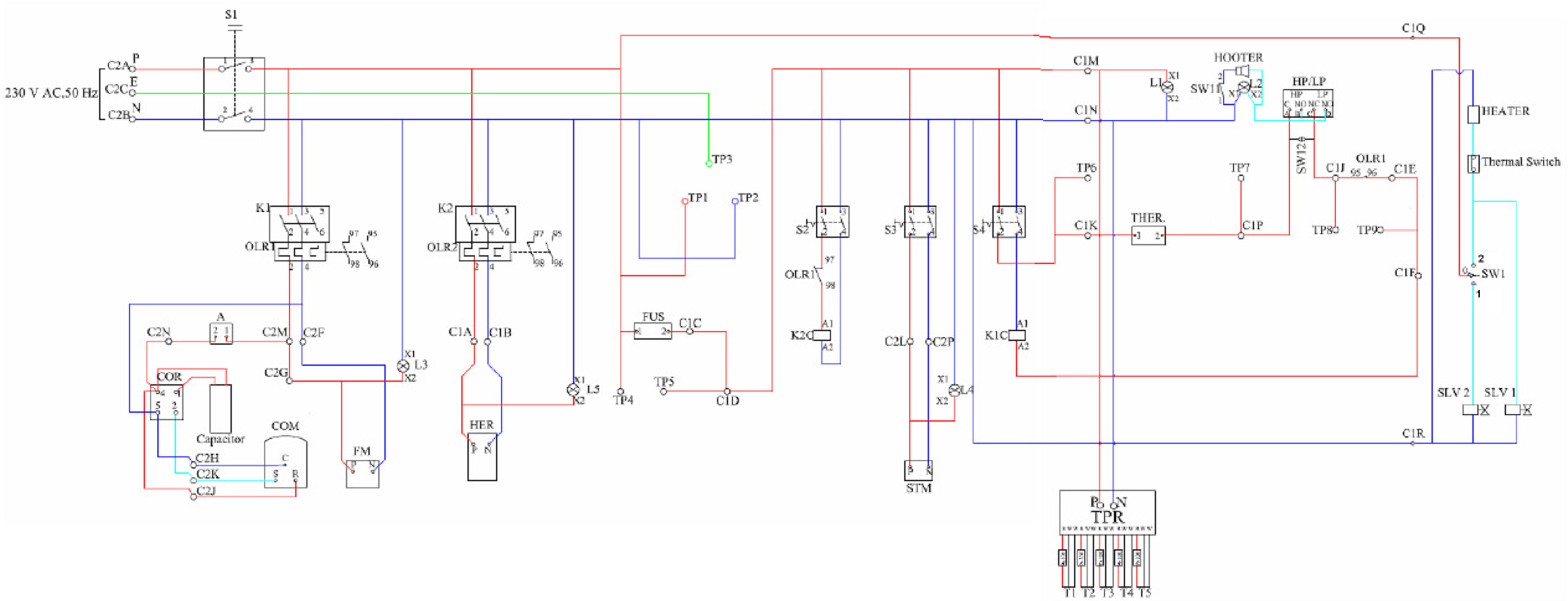
5) Wait for the gas from the cylinder to enter the system. As the gas is charged in the system, the pressure on the low sided pressure gauge starts increasing.
6) Wait till the change in pressure is zero. Note the total weight of the cylinder and gas in the cylinder (W2). Calculate how much gas is charged (W1-W2).
7) Switch ON the compressor. Now, more gas will be charged. Keep the compressor running till desired quantity of gas is charged.
8) Close the charging valve. Wait for 2-3 minutes. Switch off the compressor.
9) Remove the hoses and cylinder.
10) Carry out Leak test.

Note: Amount of gas needed to be charged depends on the capacity of the system and type of gas used. Therefore the gas bottle to be kept standing position and gas state, never put down**.**
Warning:
Never run compressor without refrigerant in system as the compressor relies on refrigerant/oil flow. Any oil displaced during the refrigerant recovery process must be replaced in the system before charging can commence.
Never charge system through the high side with the compressor running.

4.5 Use of Compound Gauges:

Compound gauge is a gauge, whose range starts in negative gauge pressure and ends in positive gauge pressure. That means it can be used to measure both pressure and vacuum
On these gauges, there are two or more scales. One scale indicates pressure. Another scale on the gauge lists the saturation temperature of refrigerant corresponding to the pressure.
Using this compound gauge, we can read the system pressure and corresponding saturation temperature of the refrigerant used
The pictures below show gauges, indicating temperature of R12, R22 and R502.
In the gauges below, regardless of which refrigerant is being used, the scale, designated as PSI, is the one used to check system pressures during operation of Refrigeration system.

Wiring Diagram for Simulator:



P: Phase
N: Neutral
E: Earth
K1: Contactor for Compressor
K2: Contactor for Heater
OLR1: Overload relay for Compressor, range 6-10A
OLR2: Overload relay for Heater, range 6-10A
A: Ammeter
COR: Compressor overload relay, AC85001M
COM: Compressor
FM: Fan motor
FUS: Fuse
K1C: Contactor 1 coil
K2C: Contactor 2 coil
STM: Stirrer motor
THEM: Thermostat
HP/LP: High & Low pressure switch
S1: ON/OFF switch for Mains
S2: ON/OFF switch for Heater
S3: ON/OFF switch for Stirrer motor
S4: ON/OFF switch for Compressor
SW1: ON/OFF switch for solenoid valve
L1: Indication lamps for Mains
L2: Indication lamps for HP/LP fault
L3: Indication lamps for Compressor ON
L4: Indication lamps for Stirrer motor ON
L5: Indication lamps for Heater ON
TPR: Temperature sensor

5. Troubleshooting:

1) Compressor

Malfunction	Possible Cause	Observation	Action
High Compressor Discharge Pressure	Air in system	The discharge or condenser pressure is over the saturated pressure of Refrigerant at the condenser temperature.	• Check for non condensable gases. Purge, if present • Investigate for air ingress and repair, if present. • Check and/or adjust the compressor cut-out setting pressure. It should be adjusted to more than atmospheric pressure.
	Insufficient cooling water flow	The differential temperature between inlet and outlet of cooling water is over 10°C during compressor running.	• Check water supply pressure • Check water-regulating valve Setting and operation. • Check for any obstruction or clogged strainer.
	Dirty condenser or corroded shell baffles	The differential temperature between inlet and outlet of cooling water is below 5°C during compressor running.	• Clean or replace as necessary.

Malfunction	Possible Cause	Observation	Action
High Compressor Discharge Pressure	Refrigerant overcharge	1) The differential temperature between inlet and outlet of cooling water is below 5 centigrade during compressor running. 2) Check the refrigerant level.	• Remove excess refrigerant. • Restore the refrigerant to gas bottle
	Compressor discharge stop valve partially closed	Check the discharge valve opening.	• Open it fully.
	Dirty condenser fins (Air-cooling type)	1) Check the appearance of fins 2) Differential pressure between inlet and outlet of fins is high	• Clean fins.
Low Compressor Discharge Pressure	Excessive or low temp. cooling water flow	Outlet temperature of cooling water is too low	• Check water regulating valve Setting and operation.
	Liquid refrigerant flooding back (Liquid back)	1) Suction piping of compressor is frost condition 2) And suction temperature is as same as saturation temperature at the suction pressure: It means no overheated gas. It is a risk of liquid condition 3) Abnormal sound from compressor	• Check Expansion valve and operation. • Check for open or leaking hand Expansion valve.
	Compressor suction stop valve partially Closed.	1) Refrigerator chamber temperature rises 2) Compressor is frequently starting and stopping.	• Check and open it fully.

Malfunction	Possible Cause	Observation	Action
Low Compressor Discharge Pressure	Leaking compressors valves	1) Refrigerator chamber temperature rises 2) Continuous running of the compressor 3) During the pump down operation, the compressor does not stop. 4) After the compressor is stopped due to low suction pressure, the suction pressure soon increases again. 5) Abnormal sound from compressor	• After pump down, remove Cylinder heads and check.
	Low refrigerant charge	1) Refrigerator chamber temperature rises 2) Some part of high pressure liquid piping for example dryer part is cold condition. 3) Suction temperature is higher than the saturation temperature at the suction pressure. It means too much overheated gas. 4) Condenser refrigerant level is too low during compressor running condition	• Check leaking point and charge refrigerant.
	Worn piston rings	1) Refrigerator chamber temperature rises 2) Suction pressure is not reduced during compressor running 3) Lubricating oil is dirty	• After pump down, dissemble and check.

Malfunction	Possible Cause	Observation	Action
High Compressor Suction Pressure	Overfeeding refrigerant	1) Suction temperature is same as the saturation temperature at the suction pressure; It means too low overheated gas.	・Check expansion valve.
	Leaking compressor suction valves	1) Refrigerator chamber temperature rises 2) Continuous running of the compressor 3) During the pump down operation, the compressor does not stop. 4) After the compressor is stopped, the suction pressure soon increases again. 5) Abnormal sound from compressor	・After pump down, remove Cylinder heads and check.
	Compressor unloading at too high pressure. Trouble with the unloading mechanism	1) Compare the suction pressure and compressor load and it may be high suction pressure but low load of compressor 2) Unloading signal is activated but load is still low	・Check setting and operation of capacity control system. ・Check the unloading mechanism
Low Compressor Suction Pressure	Low refrigerant charge	1) High suction gas temperature 2) Frost or cold condition at some part of the high pressure liquid piping e.g. the dryer is frost or cold 3) The refrigerant level is low during the pump down condition	・Check refrigerant amount and add the required amount.

Malfunction	Possible Cause	Observation	Action
Low Compressor Suction Pressure	Restricted flow of refrigerant	1) High suction gas temperature 2) Frost or cold condition at some part of the high pressure liquid piping e.g. if the strainer is clogged, the strainer becomes frost or cold at the restriction part 3) Refrigerator chamber temperature rises	• Check expansion valve. • Check solenoid valve. • Check strainers for clogging.
	Compressor high load operation during low load of refrigeration cycle	1) Compare the suction pressure and compressor load, and it may be low suction pressure but high load of compressor 2)) Unloading signal is activated but load is still high	• Check setting and operation of capacity control system. • Check the unload mechanism
	Low pressure cut-out not stopping compressor	1) The suction gas pressure is below the cut-out pressure but the compressor is still running	• Check setting and operation of low pressure cut-out.
Cold (Sweating Or Frosting) Compressor Crankcase	Liquid refrigerant flooding back	1) Suction piping of compressor is in frost condition 2) And suction temperature is as same as saturation temperature at the suction pressure: It means no overheated gas. It is a risk of liquid coming back at suction side. 3) Abnormal sound from compressor	• Check whether hand expansion valve is open or leaking. • Check expansion valve and its operation.

Malfunction	Possible Cause	Observation	Action
Cold (Sweating Or Frosting) Compressor Crankcase	Too much oil in circulation	1) Crank case oil level is too low 2) Oil separator & return piping are normal condition	• Check for proper oil level.
Compressor will not start	No power to compressor	1) The suction gas pressure is over the setting point of starting 2) No abnormal tripping condition	• Check breaker, main switch, Fuses and wiring.
	Overload tripped Low oil pressure tripped	1) Over current relay is activated 2) Low oil differential pressure switch is activated	• Reset , check and eliminate Cause of no voltage.
	Safety control switch open	1) Abnormal indicator lamp is lit on 2) Each pressure and/or temperature switch is activated 3) Setting point of safety switch is normal or abnormal. If setting is normal but switch is still tripping condition, it is a switch problem	• Check high pressure switch, water failure switch and OPS. • Check switch setting and operation. • Find and eliminate the cause of operation.
	Thermostat set too high	As same as above decisions	• Check and reset.
Compressor will not start	Solenoid valve closed	1) Refrigerator chamber temperature rises 2) Expansion valve is not in frost condition.	• Check power of solenoid. • Check valve for proper operation.

Malfunction	Possible Cause	Observation	Action
Compressor will not start	Lack of refrigerant	1) Refrigerator chamber temperature rises 2) High pressure liquid piping is in frost or cold condition 3) Low Refrigerant liquid level in the condenser or receiver is empty	• If low, repair any leaks and recharge.
Compressor runs continuously	Low refrigerant charge	1) Refrigerator chamber temperature rises 2) High pressure liquid piping is in frost or cold condition 3) Low Refrigerant liquid level in the condenser or receiver is empty 4) Suction gas temperature is higher than normal	• If low, repair any leaks and recharge.
	Solenoid valve leaking	1) Refrigerator chamber temperature is below the setting point 2) Continuous frost at the expansion valve 3) Suction gas temperature is below the saturation temperature at the suction pressure	• Check solenoid valve.

Malfunction	Possible Cause	Observation	Action
Compressor runs continuously	Compressor valves leaking	1) Refrigerator chamber temperature rises 2) Abnormal sound < Discharge valve> ・Discharge gas temperature is higher than the normal condition ・Suspicion pressure rises <Suction valve> ・Suction gas temperature rises ・Discharge gas temperature is below the normal	・After pump down, remove Cylinder heads and check.
	Worn piston rings and/or cylinder liner	1) Refrigerator chamber temperature rises 2) Suction gas temperature rises 3) Crank case temperature rises 4) Lubricating oil is dirty	・After pump down, dissemble and check.
Low Oil Pressure	Insufficient oil in crankcase		・Check oil level.
	Oil filter clogged		・Clean oil filter.
	Defective oil pump		・Dissemble pump and check for wear.
	Defective oil return valve		・Test valve.
	Worn bearings	1) Lubricating oil is dirty	・After pump down, dissemble and check.

2) Condenser:

Malfunction	Possible Cause	Observation	Action
Condensation Temp. High	Air and non-condensable gases present in the system	The discharge or condenser pressure is over the saturated pressure of Refrigerant at the condenser temperature	• Purge non-condensable gases.
	Low cooling seawater flow	The differential temperature between inlet and outlet cooling water is over the 10ºC during compressor running	• Check seawater strainer. • Check seawater pressure. • Check water regulating valve Setting and operation.
	Dirty condenser tubes or fins	The differential temperature between inlet and outlet cooling water is below 5ºC during compressor running.	• Clean them

<Air and non-condensable gases present in system>

Cause:

1) The setting point of Cut-off pressure switch for Compressor is lower than the atmospheric pressure.
If low pressure piping has a hole or is leaking, the system sucks air.

2) High velocity gas flow makes vacuum point at the bend or after valve.
When gas flow is stopped, above point is under positive pressure. In this case, gas is leaking.
When gas flow is high velocity, above point is under negative pressure (vacuum). In this case, air is sucked in.

Note: Normally, there is some amount of leaking refrigerant oil is found near the leaking or sucking points. When the oil leakage is observed at any point in the system, it means that the gas is leaking or the air is being sucked in from that point.

3) Expansion valve:

Malfunction	Possible Cause	Observation	Action
Low Refrigerant Flow	Low condensation pressure	1) Refrigerator chamber temperature rises 2) Discharge and condenser pressure are too low. Differential pressure between high pressure side and low pressure side is low	• If seawater temp is low, adjust Cooling water flow. • Check water-regulating valve.
	Strainer or valve clogged	1) High suction gas temperature 2) Frost or cold condition at some part of the high pressure liquid piping e.g. if the strainer is clogged, the strainer becomes frost or cold at the restricted part 3) Refrigerator chamber temperature rises	• Clean strainer. • If it is clogged by ice, remove moisture.
	Improper operation		• Check and adjust valve.

4) Evaporator:

Malfunction	Possible Cause	Observation	Action
Insufficient cooling	Lack of refrigerant	1) Refrigerator chamber temperature rises 2) High pressure liquid piping is in frost or cold condition 3) Refrigerant liquid level at the condenser or receiver is empty	・Charge refrigerant
	Heavy frost or ice	1) Refrigerator chamber temperature rises 2) Superheat gas temperature at the suction side is below than expansion valve setting: normal is from 5 to 10 degrees 3) Check the evaporator	・Check evaporation temp. Setting. ・Change defrost interval. ・Check drain pan.
	Evaporator fan stop or improper operation	1) Refrigerator chamber temperature rises 2) Superheat gas temperature at the suction side is below than expansion valve setting: normal is from 5 to 10 degrees 3) Check the evaporator	・Check and repair evaporator Fan.

6. Case Studies, Company's instructions, Maker's service information:

Case Studies:

Case 1:

Subject: Problem in lowering Cold room temperature down to the required setting

Reference: Trouble report (AQU-6/2003)
Date of failure: 10/09/2003

Description of event:
The cold room temperature was found not lowering to the required setting. All three Evaporator coils were getting blocked and the Compressor was found cutting off due to low suction pressure. It was suspected that there was moisture present inside the system. The temperature was maintaining between -9°C and -4ºC.
The system was purged and the Drier element cleaned. But, no significant improvement was noticed. Afterwards, a shore workshop attended the vessel at Mizushima to purge and pressure test the system with Nitrogen. After vacuuming, the system was charged with refrigerant gas. Afterwards, the system was tested and found running satisfactorily.

Direct cause of Failure: Presence of moisture inside the system

Countermeasures:

1) To take precautionary measures to prevent ingress of moisture inside the system and maintain the Drier in good operating condition.
2) To adhere to Maker's Instruction manual and PMS regarding maintenance and inspection of refrigeration system and take immediate corrective measures i.e. repair or renew parts, if any abnormality is noticed.

Loss of time: Nil

Estimated Cost of Repair: YEN 450,000/-

Case 2:

Subject: Failure of Air conditioning system Condenser tube

Reference: Trouble report (ORC-6/2003)
Date of failure: 29/06/2003

Description of event:

The gradual loss of refrigerant from the system was observed. During investigation, it was found that the End plate in way of the cooling tubes had eroded. The gas was also observed leaking from a number of tubes. The leaking tubes were plugged with bronze plugs and Devcon sealant. A total of 20 nos. of tubes were plugged, but still it was observed that there was gas leakage from other tubes as well.
The condenser was landed ashore for renewal of leaking tubes and damaged end plate. After repair, the condenser was fitted back. The system was tested and it was found running satisfactorily.

Direct cause of Failure: Erosion of End plate in way of the tubes

Countermeasures:

1) To adhere to Maker's Instruction manual and PMS regarding maintenance and inspection of air conditioning system and take immediate corrective measures i.e. repair or renew parts, if any abnormality is noticed.

Loss of time: Nil

Estimated Cost of Repair: US$ 6500/-

Case 3:

Subject: Air conditioning system Compressor damage

Reference: Trouble report (TRM-003/2005)

Date of failure: 18/08/2005

Description of event:

According to ship's staff, the temperatures of cylinder heads were being monitored everyday during the morning rounds. It was reported that there was no abnormality noticed regarding either the temperatures of the cylinder heads or any other parameters until 17th August 05.

On 17th August 05, the temperature of one unit cylinder head was found higher than other units. The compressor was stopped. On 18th August 05 evening, the compressor was restarted. It was noticed that the L.O. level was decreasing and the temperature of that unit cylinder head increasing. The compressor was stopped. On 19th August 05, the compressor was opened up for inspection and it was found that the Valve plate, Piston and Liner were damaged. The Liner was found badly scored. Since the Liner was integral part of the compressor body, the body was required to be renewed. An undamaged piston was fitted in that unit and the cylinder liner was tested for any leakage with pressurized air. The air was found leaking into the crankcase. The damaged parts were renewed. The system was tested and it was found running satisfactorily.

Direct cause of Failure: Damaged valve plates causing damage to Piston and Liner

Countermeasures:

1) To adhere to Maker's Instruction manual and PMS regarding maintenance and inspection of air conditioning system and take immediate corrective measures i.e. repair or renew parts, if any abnormality is noticed.

Loss of time: Nil

Estimated Cost of Repair: US$ 6000/-