REFRIGERATION FOR LOCAL FISHING BOATS

MARINE ENGINEERING SECTION
SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

Refrigeration for Local Fishing Boats

Marine Engineering Section, Training Department
Southeast Asian Fisheries Development Center
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Acknowledgement

Our thanks go to the Secretary-General, Mr.Panu Tavaratmaneegul to have confidence and the policy to allow the creation of this technical paper "Refrigeration for Local Fishing Boats"

The aim of this book is to spread the technical knowledge to the fishermen and to interested readers in refrigeration for local fishing boats.

Our thanks also go to the Training Division Head Dr. Yuttana Theparoonrat for giving us valuable suggestions and advice to help make this book successful.

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Suthipong Thanasarnsakorn
Veerachai Chettasumon
Thaweesak Thimkrap
May 2002

Message from the Secretary-General

Marine fisheries development in Thailand created a great increase in marine fish products. However, this rapid development has caused the impact of a decline in marine fisheries resources through over-fishing and over-capacity. It is felt that the government should define policy on fishing activities and give greater guidance on the concept of responsible fishing for sustainable fisheries and ensure its application to fishers. One way is to utilize the catch of fisheries resources to its maximum benefit and value so that the income of fishers may be improve.

During the past seven years (1995-2001), the fisheries production of Thailand has played an important role in the Thai economy with production ranging from 3.4 to 3.6 million metric ton per year becoming one of the top ten fisheries producer countries. The freshness of fish caught is an important factor in fish product production for both export and domestic consumption. Thus, the preservation technique for freshness of fish need all concerned parties to become seriously involved and thoroughly understand this matter.

The Training Department of Southeast Asian Fisheries Development Center has been mandated to train and research in marine fisheries for member countries in the region for more than 35 years. The center has a long history in accumulated knowledge and experiences in this field. The center is a leading and important international organization playing a major supporting role in the fast development of the fisheries sector in this region, which accounts for its position as a major food fish protein supplier globally. The center edits and publishes research and general documents concerning fisheries for continuous distribution to fisheries officers, researchers and fishers.

The purpose of this publication on " Refrigeration for Local Fishing Boats", is aimed to transfer knowledge on refrigeration systems use for local fishing boats to fishers and the public. This publication can stimulated the development of fish preservation in fishing boats to maintain the freshness of fish to be suitable and safe for human food. The development of refrigeration systems in small fishing boat is an important issue in marine fisheries. Fisheries officers, researchers, fishers and people concerned can apply the knowledge gained from this book for practical implementation to attain maximum benefit. The center hopes that this book will benefit the reader and support the achievement of high quality of fish products and will increase of production value for fishers.

Panu Tevarutmaneegul
Secretary-General and Training Department Chief
Southeast Asian Fisheries Development Center

Introduction

In the industrialized nations and affluent regions in the developing world, refrigeration is chiefly used to store foodstuffs at low temperatures, thus inhibiting the destructive action of bacteria, yeast, and mold. Many perishable products may be frozen, permitting them to be kept for months and even years with little loss in nutrition or flavour or change in appearance.

Why do substances become cool? We feel cold when our skin is sterilized by alcohol before we have an injection. This is because the alcohol on the skin is evaporated into the vapor state by the heat, which is absorbed from skin. The heat that is required to evaporate the liquid to vaporize is called latent heat of evaporation. Latent heat is the characteristic amount of energy absorbed or released by a substance during a change in its physical state that occurs without changing its temperature. The latent heat associated with melting a solid or freezing a liquid is called the heat of fusion; that associated with vaporizing a liquid or a solid or condensing a vapour is called the heat of vaporization. For example, when a pot of water is kept boiling, the temperature remains at 100 °C (212 °F) until the last drop evaporates, because all the heat being added to the liquid is absorbed as latent heat of vaporization and carried away by the escaping vapour molecules. Similarly, while ice melts it remains at 0 °C (32 °F), and the liquid water that is formed with the latent heat of fusion is also at 0 °C. The temperature at which a liquid will evaporate is also affected by pressure too. An example of this is that water will boil at about 98 °C at an altitude of 10,000 feet, or will boil at a greater temperature than 100 °C if the atmospheric pressure is raised above normal. The refrigeration cycle is clearly explained in the text of the book, however, some scientific words are used that may not be familiar to you, these are defined in appendix 1.

At present the refrigerants widely used to maintain the quality of products are ammonia or R-22 that is stored under high pressure, in a liquid state. These refrigerants are toxic and flammable and incorrect handling may present serious hazards including explosion, poisoning and fire.

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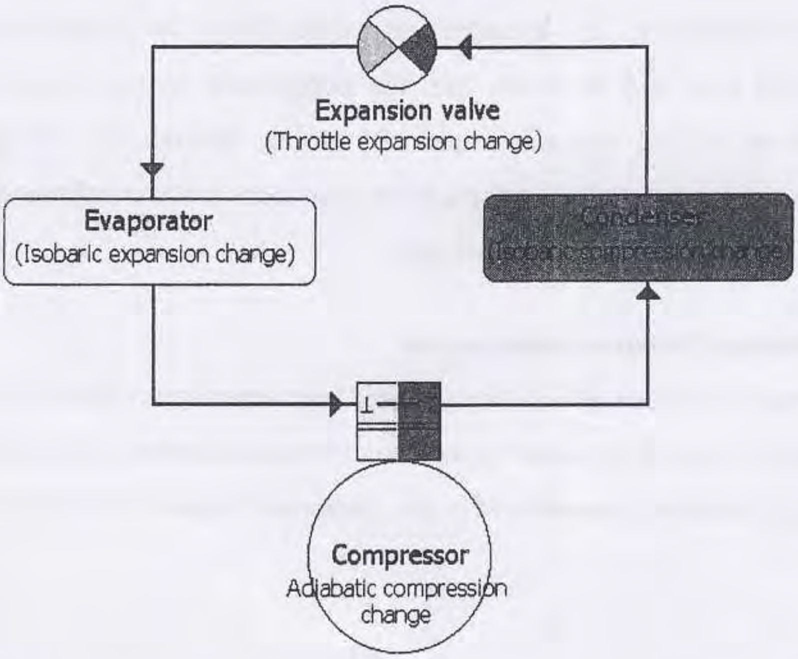
An Introduction to the Components and Thermodynamics of Refrigeration

The basic components of a modern vapour-compression refrigeration system are a compressor; a condenser; an expansion device, which can be a valve, a capillary tube, an engine, or a turbine; and an evaporator. The gas coolant is first compressed, usually by a piston, and then pushed through coiled tubes into the condenser. In the condenser, the tubes containing the vapour are passed through either circulating air or a bath of water, which removes some of the heat energy of the compressed gas. The cooled vapour is passed through an expansion valve to an area of much lower pressure; as the vapour expands, it draws the energy of its expansion from its surroundings or the medium in contact with it. Evaporators may directly cool a space by letting the vapour come into contact with the area to be cooled, or they may act indirectly by cooling a secondary medium like water or brine. In most domestic refrigerators, the coil containing the evaporator directly contacts the air in the food compartment. At the end of the process, the warmed gas is drawn toward the compressor and is recycled again.



Changes in the refrigerant during the cycle

The gas compression refrigerating cycle is the method of compressing a refrigerant gases having evaporated and achieved the purpose of refrigeration at a necessary pressure for liquefaction again by cooling it to liquid, and refrigerant undergoes to the following four static changes.

First change (Throttle expansion)

The refrigerant has cooled close to the temperature of the cooling water. The liquefied in the condenser is expanded through the expansion valve, which is a kind of throttle valve so that the refrigerant passing to the expansion valve, then the pressure and temperature are reduced to those of the evaporator without change in enthalpy.

Second change (Isobaric expansion)

The refrigerant enters through an expansion valve and goes into the cooling room/evaporator where it absorbs sensible heat from its surroundings, it evaporates at a certain pressure, at a temperature relative to the pressure and into a gaseous state. As the refrigerant evaporates, it takes a large amount of sensible heat from the surroundings so that the purpose of refrigeration is achieved.

Third change (Adiabatic compression)

The low temperature, low-pressure gas comes from the evaporator, which is actually the cooled area and is drawn into the compressor to be compressed to the condensing pressure of the refrigerant gas. By going through the compressor, the refrigerant gas has its temperature raised to a level equivalent to the condensing pressure; it is now a high pressure and high temperature gas.

Fourth change (Isobaric compression)

The gaseous refrigerant at high pressure and high temperature from the compressor enters the condenser where it is cooled by water or air and is condensed and liquefied. This change proceeds at a relative pressure and is now becomes a liquid under high pressure.

System and Components

Compressor

The compressor for a refrigeration system is a gas compressor and draws the refrigerant as a gas from the evaporator, which is also the cooled area. The temperature of the gas has increases because it has drawn sensible heat from the material to be cooled. When compressed again the gas is delivered to a condenser where it gives up its adiabatic heat and changes into a liquid.

Compressor can be classified as follows:

1. Medium and low speed vertical type compressors.
2. High speed multi-cylinder type compressors
3. Screw compressors
4. Two stage compressors.

Condensers

A condenser is equipment designed to absorb the heat that is given by the work of the compressor. The cooling substances are water or air, reducing the heat of the gas until it condenses a into liquid refrigerant.

The amount of heat dissipated from the condenser is equal to the sum of heat absorbed by the evaporator and the heat of compression work in the compressor.

In case of marine refrigeration machines, cooling tubes made of steel are internally galvanized, or are made from copper, aluminum and brass are sometimes employed. Where dissimilar metals are used in a condenser, sacrificial anodes made from zinc are fitted to the water jacket to reduce the corrosion caused between dissimilar metals in water. The zinc anodes corrode away preferentially and must be inspected and replaced frequently.

Liquid condenser and receiver

Liquid receivers are close vessels in which the liquid refrigerant at high pressure and normal temperature which has been condensed in the condenser is stored temporally and the volume required depends on the capacity of the refrigerating machine, or the amount of refrigerant charged into the system. If the capacity of the receiver is small, the refrigerant accumulates also in the condenser resulting in a decrease in cooling area and a rise in pressure on the high-pressure side.

The capacity of the high-pressure receiver for a fishing vessel, the system plant should be provided according to the specified items as follows.

1. The liquid receiver shall have enough capacity to accommodate the entire charge of refrigerant.

2. The dimensions of a liquid receiver: the shell diameter should generally not exceed to 1.2 m and the shell length should be 2-4 times the diameter in the case of a horizontal type receiver. While the shell length should be 1.5-3 times the diameter in the case of a vertical type receiver.

3. If there is limited installation space, the system can be divided for installation the sub liquid receiver would have the same shape. There is should be adequate and convenient space for future maintenance.

4. If the capacity requirement cannot meet the criteria above, the capacity should be above 70% of the total charging quantity.

The capacity of high-pressure receivers is obtained by the following equation.

$$V_R = W_L \times K$$

Where:

V_R = Require capacity of the high-pressure receiver

W_L = All capacity of charging refrigerant.

K = Specific volume of refrigerants required there is corresponding to the condensing temperature at 35°C.

Liquid state = 0.86729 m^3/1000 kg

Gas state = 17.2682 m^3/1000 kg

The quantity of refrigerant charging necessary in the system

System configuration	Required refrigerant/Evaporator area Kg/m^3
Dry expansion system	535 - 590
Semi-flooded type system	870 - 960
Brine system (flood type)	1070 - 1180

These specified values correspond to a condensing temperature of 35°C and evaporation temperature of –15°C to -60°C, the calculation must be taken from the inner volume of the refrigeration pipeline.

The required charge of refrigerant for different systems that correspond to the pipe size per unit length of the evaporator and plus 5-10% as illustrated below:

Pipe size	Dry expansion system Kg/m	Semi-flood system Kg/m	Flood system (brine) Kg/m
15A	0.11-0.12	0.176-0.192	0.22-0.24
20A	0.2-0.22	0.32-0.352	0.4-0.44
25A	0.32-0.35	0.512-0.56	0.64-0.70
32A	0.53-0.59	0.848-0.944	1.06-1.18
40A	0.73-0.8	1.168-1.28	1.46-1.6
50A	1.17-1.29	1.872-2.064	2.34-2.58
65A	1.93-2.12	3.088-3.392	3.86-4.24
80A	2.73-3.0	4.368-4.8	5.46-6.0
100A	4.65-5.1	7.44-8.16	9.3-10.2
125A	7.17-7.9	11.472-12.64	14.34-15.8

Evaporator/cooling room

The Evaporator, is actually the cooled space, and is the equipment where the refrigerant absorbs the heat from its surroundings, it is evaporated at low temperature. The evaporators are classified depending on the conditions of the evaporation method as given below:

a. Dry expansion evaporator. This type is designed such that the most of the refrigerant can be supplied from thermostatic expansion valves in the state of a liquid, but this usually contains about 15% gas. Most of refrigerant can be gasified near the outlet. Therefore, the heat transfer efficiencies are not too good, but the amount of refrigerant required is small. Tube coil evaporators and hairpin type cooling coils are most generally employed.

b. Semi-flooded evaporator. This is evaporator is constructed such that the liquid refrigerant is allowed to accumulate inside to some extent; their heat transfer efficiency is higher than the dry expansion evaporator but lower than flooded type evaporators and refrigerant re-circulating evaporators. Tube coil evaporators of the bottom feed type are used in this category.

c. Flooded type evaporators. This type is constructed such that there it is completely filled with liquid refrigerant and the refrigerant gas produced by evaporation may be directly drawn into the compressor without circulating inside the evaporator in the gaseous state. It has excellent heat transfer efficiency, but requires a large quantity of refrigerant inside the evaporator. It is required for fluorocarbon refrigerants to provide a special means to return lubricating oil to the compressor. Evaporators of this type include vertical tube evaporators.

Liquid line filter-drier

The line filter-drier is shaped like a tank, inside which there is a strainer and some of absorbent materials. It is sited in the liquid line before the refrigerant flow control valve (expansion valve) it is commonly installed to keep dust, dirt, metal out of the system and absorbs any moisture entering the refrigerant flow control valve. The installation must ensure that the inlet and outlet ports are correct accordingly to the system flow.

Moisture is absorbed in the drier, otherwise it might freeze in the flow control valve and cause flow problems for the refrigerant in the system. Some filter-dryers are equipped with sight glasses, which indicate the level of refrigerant flow. Many sight glasses are provided with a special chemical, which will change color if the refrigeration system has moisture in it.

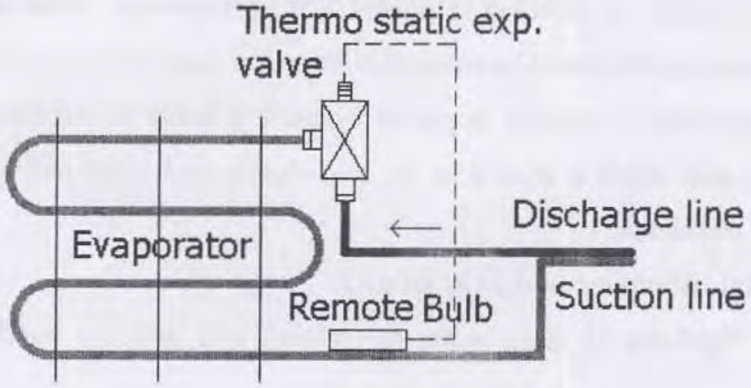
Expansion valve and remote bulb location

The installation of the expansion valve is important, for the best performance the thermostatic expansion valve should be installed as close to the evaporator as possible. There should not be any restriction of any kind between the expansion valve and the evaporator. When it is necessary to install a hand valve on the outlet side of the expansion valve, a hand valve with full-size ports must be used.

Remote temperature sensing bulb location, to extend the performance of thermostatic expansion depends on the proper location and installation of a remote temperature sensing bulb, when an external remote bulb is used it should be clamped onto a horizontal section of the suction line near outlet inside the refrigerated space.

The remote bulb must respond to the temperature of the refrigerant in the suction line to the compressor. It is essential that the entire length of the bulb be in good thermal contact with the suction line. When a steel pipe suction line is used, the suction line should be cleaned thoroughly at the point where the bulb is clamped and should be painted with aluminum paint to minimize corrosion. On the suction line with an outside diameter of less than 7/8" the remote bulb is usually installed on topside of the suction line. For a suction line with an outside diameter over 7/8" the bulb location is at 4 or 8 o'clock on the suction line and will be satisfactory for sensitive valve control.

It is important that temperatures other than the suction temperature do not influence the remote bulb. When the compressor is off, if the temperature of the bulb rises above the evaporator temperature there will cause the thermostatic expansion valve to open allowing the evaporator to become filled with liquid refrigerant and flood back to the compressor when it is started. In some cases where remote bulbs are located in the refrigerated space, the temperature difference between the fixture temperatures of the evaporator is not large enough to open the expansion valve. When there is a necessity to install the bulb outside the refrigerated room, the bulb and suction line must be well insulated for at least 1 foot beyond the surroundings.



Installation Work of Refrigeration System

The connections of refrigeration system pipelines: flanges and welded joints are used in most cases. The screw-in methods are rarely used except on small devices. Welding is the most usual method for connections, because there is no tendency to leakage of refrigerant through vibration, which can occur with flanges and screw-in methods.

A qualified welder is necessary to do the welding on a refrigeration system. The welding of pipelines must have sufficient edge preparation. In particular, welding of pipe of large diameters must be carried out using backing strips to ensure that complete weld penetration is obtained. Further, it is required to clean all welding parts properly both before and after welding.

Piping in the engine room

a. Checks should be made that all equipment is located correctly and according to the drawing.

b. Connections of the liquid separator, oil separator and gas cooler etc. Should be checked and properly marked.

c. Adequate fitting positions and sizes of deck/bulkhead pieces should be checked and questions, if any, should be raised with the parties concerned for proper action.

d. Direction of flow of refrigerant gas and liquid through the suction and delivery pipelines should be checked through to the stop valve.

e. The pipeline should be installed with places for inspection, for easy operation, maintenance or repair to the compressor and other refrigeration devices.

f. When the pipeline is installed in places near passageways, stairs and doors or where it is liable to damage. It should be covered with proper insulation or protection.

g. The pipeline that is installed in places where it is liable to mechanical damage because of vibration and shock it should be secured rigidly and fitted with couplings to absorb the vibration and shock.

h. The principle of piping work is as follows:

- a) Pipelines of large bores for suction and delivery heads should be installed first and smaller ones later.
- b) Pipelines should be installed away from the walls or bulkheads.
- c) Pipelines that require head, slope or the installation of traps for functional purposes, should be installed first with ordinary piping following.

Piping in fish holds and freezing rooms

a. The location and sides of decks/bulkheads between fish holds should be checked and inadequate points if any should be corrected.

b. The position of fittings, length and number of slide bolts should be checked and prepared.

c. Piping work should only be done after the completion of ship hull installation.

d. Pipeline should be installed on the inboard surface of side shell plating and so not project far from the surface of (sparring).

e. After the completion of the pipe work, compressed air should be passed through the thermostatic expansion valve to check if the lines are correctly connected.

f. In blanking off deck/bulkhead pieces, only one side should be fitted with a blind patch.

g. The part of a pipeline that is to be located near doors and hatches, as they are liable to mechanical damage they should be sufficiently covered.

Test and Inspection

After the completion of refrigerant pipe work and before charging with refrigerant or the commencement of pipe installation work, the following tests should be carried out.

Remove all foreign matter inside pipeline by the discharge of pressurized dry air, CO_2 (carbon di-oxide) or N_2 (nitrogen). This is done to remove metal bits, sand, slag, textile fragments and dust remaining in the refrigeration system. At that time hammering of the main parts is done to remove scale and foreign matter more effectively.

a. The pressurized gas should be drawn off at a comparatively low place in the system. In case there is no proper discharge port, it should be discharged through the suction strainer.

b. By-pass valves must be used for thermostatic expansion valves and evaporating regulators etc. to prevent foreign matters from getting into these devices.

c. Dust tend to accumulate in parts of the suction header to which a trap is fitted, the bend of the stop valve located near it should be removed and cleaned internally.

1. Airtightness test

Before testing, there should be checks on the stop valve, safety valve, purge valve drain valve, suction valve and delivery valve of the compressor. All other stop valves should be fully opened.

a. Pressure increase should be made in three sequential stages. Usually, the pressure should first be raised to 5 kg/cm^2 in the whole system (high and low-pressure sides). In the second stage it is raised to 9 kg/cm^2 and should be applied separately to the high and low-pressure sides, after checking that there is no leakage. Finally the pressure is raised to 18 kg/cm^2 and applied only on the high-pressure side.

b. The high and low-pressure sides should be separated at the inlet and outlet manual valves of the thermostatic expansion valve, and the compressor body is pressurized to low pressure.

c. Dry air, CO_2, N_2 gas should be used as the pressurizing gas. The test pressure gauges for high pressure that should be used will cover the range of 25-30 kg/cm^2 and 15-20 kg/cm^2 for the low-pressure side. When conducting airtight tests using CO_2 the cylinder should be located vertically to enable the gas to be sent out under pressure in gaseous state.

d. Leakage detection should be made carefully when the pressure is kept at 5 kg/cm^2 and gas leakage is detected the nearest stop valve should be closed to reduce the pressure to atmospheric before repairing it.

e. Leakage of valves like air vents or drain valves should also be checked carefully. The internal leakage of valves should also be checked and repairs made or they should be replaced.

f. If no leakage of pressurized gas is found at the predetermined pressures, then the system under test should be kept as it is for a determined time. Changes in room temperature and pressure readings should be recorded, and if the temperature changes remarkably, corrections for temperature should be made. It is usually a pressure change of about 0.2 kg/cm^2 relative to a change in temperature of 5 °C.

g. After the completion of air pressure testing, the gas in the refrigeration system should be released through a drain valve, strainer or trap that is located at low levels.

h. If CO_2 or N_2 is used for pressure testing, a special gas receiver should be installed to keep the testing gas to reduce air pollution.

2. Vacuum test

After completion of the airtight test, a vacuum pump should be used to eliminate any non-condensing gas or water content in the refrigeration system. A vacuum pump should be used to reduce the internal pressure of the system to a state of vacuum. The refrigerating compressor must not be used for this purpose.

a. After checking that the system can hold a vacuum and the vacuum pump should be connected to a charging port.

b. A vacuum gauge should be used at this point.

c. Both high-pressure and low-pressure sides should be connected when reducing the internal pressure of the system to a vacuum.

d. During the operation of the vacuum pump, the ambient temperature should be raised to increase the saturated moisture in the air.

e. Even after a high vacuum of about 760 mmHg is reached, the vacuum pump should be continuously run for 6 to 12 hrs to eliminate any air in the system. Subsequently the vacuum pump should be stopped and the system allowed to stand as it is for 6-12 hrs and its condition should be observed.

f. If an abnormal change in the degree of vacuum while the system stands occurs the evacuation of air should be continued until 760 mmHg is achieved. Then the system should be closed, line by lines and the valve near the vacuum gauge be opened to detect the leaking line. The airtight test should be conducted again and after repairing a vacuum test should be made again.

g. Finally a vacuum test on the compressor body should by carried out.

3. Leakage test using refrigerant

a. After the completion of leakage test with vacuum, the refrigeration system should be charged with refrigerant until an internal pressure of 4-5 kg/cm^2 is reached. The system should then be checked for gas leakage using a leakage detector or by using foam to check for bubbles.

b. The fluorocarbon refrigerant should be charged by passing it through a drier into the system.

c. All stop valves other than drain, and air vent valves should be fully opened.

d. Gas leakage detection should be carefully made in sufficient numbers and several times.

e. The equipment and communicating pipelines on the low-pressure side should be checked for gas leakage as long as possible because they are thermally insulated.

f. A warning sign stating, "Unauthorized entry is forbidden" should be posted at the work site.

Handling of the Refrigeration System

A check of whole system before operation and running the compressor should be made as follows:

a. Check the direction of the cooling water pump shaft, check that there is sufficient pressure and volume and no leakage while the water pump is running.

b. Cooling water should pass through the condenser and other accessories like the oil cooler or compressor jacket as necessary.

c. Check for tightness of pipeline, bolts and those fitted to the compressor.

d. Checks should be made on the closing and opening of valves that are attached to each component of the pipeline.

e. If the volume and quality of lubrication oil is sufficient should be checked, if shortage is found, additional oil should be added.

Operation procedure

After the compressor is started the system will exhibit more or less transient phenomena, the pressure, load and temperature of every part, including voltage, current, liquid level, sound and vibration will change. When these factors settle to their normal values checks should be made according to the following schedule.

a. Monitoring of the indicated pressure and temperature on the high and low-pressure sides of the compressor.

b. Oil pressure, temperature and quantity.

c. Voltage and current within ± 10% of rated values.

d. The temperature of the main components likes the compressor cylinder head, bearings, shaft bearings and body.

e. The difference in cooling water temperatures between the inlet and outlet of the condenser.

f. The quantity of circulating refrigerant in the system.

g. Leakage of the refrigerant.

h. Inspection and adjustment of the automatic equipment like the LPS, HP, OPS,and WPS.

Normal operation

a. In the normal operational state, the delivery pressure gauge should indicate a pressure corresponding to the temperature, the temperature should be higher by 4-7°C than the cooling water inlet temperature. In the case of a direct expansion valve type, the suction temperature should be 7-15°C lower than the holding temperature of the freezing room. Where a brine system is used, the suction temperature should be 4-6°C lower than the temperature of brine. The oil pressure is set to 1.5 – 2.5 kg/cm^2 higher than when operating at low pressure.

b. The discharge gas temperature should be at 100°C or below for a system using R-22.

c. The suction gas should be 5-10°C higher than the evaporating temperature of the refrigerant.

d. In the case of two stage compressors, the high-pressure side should be kept about 5°C higher than the medium pressure.

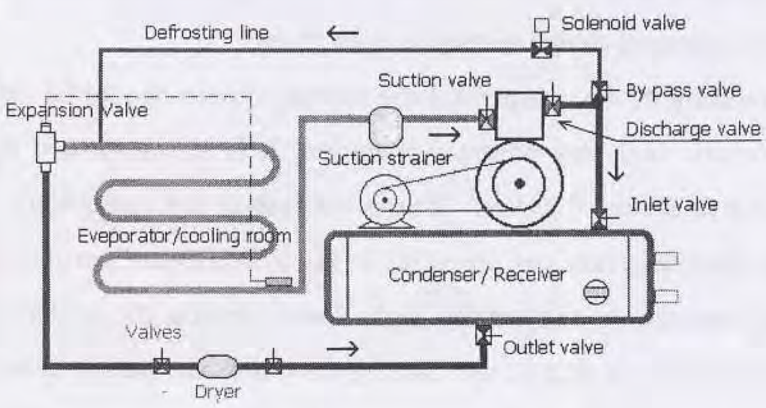
e. The temperature in the cylinder head of the compressor should be kept at 120°C or below.

f. The difference in temperature between the inlet and outlet of the cooling water to the condenser should be maintained at 3°C, and 2-3°C of the outlet. The brine temperature should be lower than the inlet of brine temperature.

Defrosting

Defrosting of the evaporator/cooling room is accomplished in different ways, these can be classified as either natural defrosting or supplementary heat defrosting. This is accordingly to the source of heat is used to melt frost from the evaporator. Stopping the system for some period of time does natural defrosting. Where supplementary heat defrosting is used, heat from a source other than the room temperature like water, brine, electric heater coils or hot gas from the discharge of the compressor can be used.

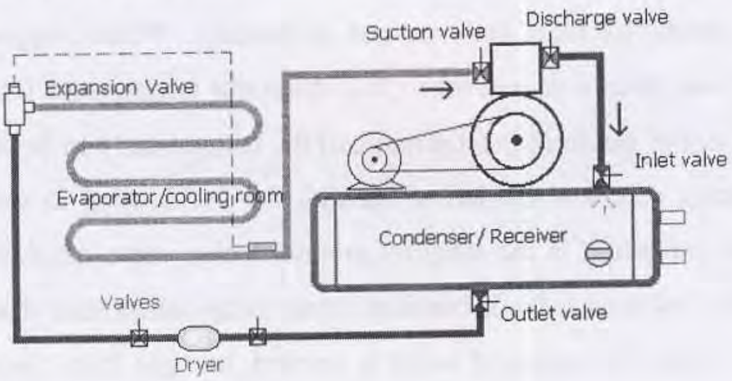
Thus defrosting means a method of melting the ice frosting in the space of the evaporator. Hot gas defrosting is the simplest method and is often employed. A by-pass valve equipped with a solenoid valve is installed between the compressor discharge and the inlet of evaporator. When the solenoid valve is opened, hot gas from the discharge line enters the evaporator, gives up its heat to the ice in the evaporator, then the refrigerant passes to the cold evaporator, and condenses into a liquid state in the evaporator. Finally the refrigerant is returned to the compressor with the refrigerant in a gaseous state.



The hot gas method has some disadvantages. The system may possibly cause a slug of liquid refrigerant to return to the compressor and cause damage. To avoid this problem occurring a suction strainer should be used between the evaporator and the suction valve on the inlet of the compressor.

Pump down

When a refrigerating plant is to be kept standing for an extended period of time, if the refrigerant remains in the evaporator, storage room, liquid cooler, and low pressure pipe line and should be collected in the high-pressure liquid refrigerant receiver. This method provides a reduced a high-pressure, which is caused by the surrounding temperature. It is loaded and forced into the low-pressure portion of the refrigeration system like the evaporator section, couplings, seals and low-pressure devices. These devices may be rendered defective or broken by the high-pressure. Therefore taking care of them should be given great attention.



Handling pump down

The collection of the remaining refrigerant into the low-pressure portion to be kept in the liquid refrigerant receiver can be achieved by running the compressor. This is called a "Pump Down". The principal of this method is now given:

During the running of the compressor the control system should be switched or in the position of automatic high-low pressure operation. It is recommended that the low-pressure should be set to at least 0 kg/cm^2. This is because of the compressor motor stops automatically when the refrigerant gas pressures in the low-pressure portion become zero and when the high pressure is abnormally high. Thus, closing the outlet valve of the condenser/receiver activates the shut down. Closing the condenser outlet valve stops liquid refrigerant discharging into the expansion valve and evaporator portions of the system. This condition is only when the remaining refrigerant evaporates and is drawn by compressor into the receiver until the low-pressure section becomes zero, the low-pressure switch will cut-off and stop the compressor motor automatically.

This operation should be completed two or three times to ensure that there is no refrigerant in the evaporator.

System Refrigerants

The refrigerant R22 is most commonly used in ordinary fishing boats. R-22 has more advantages than R-12. It has a boiling point, at atmospheric pressure, of –40.8°C and is used for low temperature refrigeration. In an industrial freezer, the evaporator temperature is down to -87°C (this being the boiling point below atmospheric pressure).

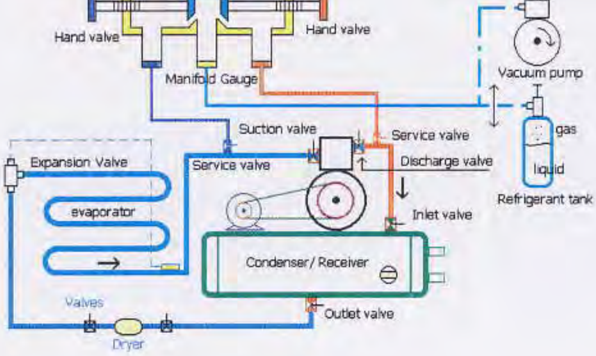
For a system using R-22 an oil separator should be used and should be provided with automatic or manual oil return lines. To ensure the return of oil to the low-pressure side of compressor and maintain the oil level in compressor crankcase, especially in a system with a low-pressure oil separator is very important to prevent the lubricating oil physical properties changing because of low temperatures.

The advantages include lower temperature of evaporation. The R-22 compressor is smaller than the R-12 compressor by approximately 30% and the total requirement of R-22 is about 65% of the amount of R-12 needed. Therefore pipe sizes for R-22 are usually smaller than for R-12.

R-22 will be phased out in the early part of twenty-first century. However it is currently being employed. The refrigerants of choice will be, R-502 or R-410A.

Charging of the refrigerant

In the case of newly installed systems, before charging the refrigerant into the system, checks and tests of the pipeline connections and the system should be made as given earlier. The preparations for the charging of refrigerant should be made as follows:



Vacuum procedure

a. Connect a vacuum pressure gauge to the manifold at the middle portion (yellow color) and directly connect the suction of a vacuum pump. The low-pressure port of the manifold gauge (blue color) connect to the low portion at the accessories or service valve, and the high pressure port (red color) of the manifold gauge connect to the discharge high-pressure portion at the service valve of the compressor.

b. Adjust the low and high-pressure hand valves at the pressure manifold gauge to the middle position (half open), to keep both sides (high and low-pressure sides) open.

c. Open both sides of the accessory valves (high and low-pressure).

d. Switch on the vacuum pump until the low-pressure on the manifold gauge indicates the system pressure to be at absolute vacuum pressure (29 in. Hg.).

e. Turn off both valves at the manifold gauge of the high and low-pressure sections, and after both valves are completely closed then switch off the vacuum pump.

f. This condition must be observed to remain constant at 29 in. Hg.

g. Remove the middle connection (yellow color) from the suction of vacuum pump and connect it to the refrigerant tank.

Make sure the connecting line is free of any air content by opening the valve of the refrigerant tank and loosening the flange nut at the middle portion of the manifold valve. This causes the air and moisture content in the rubber hose to escape from the line because of the refrigerant pressure, then tighten the flange nut and prepare for charging the refrigerant while using a weigh-scale to measure the refrigerant charging weight.

h. Open the refrigerant valve tank for charging the refrigerant into the system until the low-pressure switch cuts-in and the indicating lamp indicates a normal condition.

i. Make sure the cooling water and lubrication oil are sufficient.

j. Start the compressor and maintain the low-pressure in a range between 1.0-1.5 kg/cm^2 The charging of the refrigerant should be observed using the liquid level indicator on the liquid receiver tank, until it reaches a certain level then close the refrigerant tank valve to stop charging more refrigerant.

Prime-mover

There are two types of prime mover considered for driving the compressor either an electric motor or engine is used. The following considerations are used to choose a compressor-motor.

Electric motor

a. Motor construction. Drip proof, force ventilation squirrel cage induction motor is commonly used, because of high performance and low cost.

b. Voltage and power systems. Generally, a three-phase motor is better in load characteristics and is compact in size, it has a good starting efficiency compared with a similar size single-phase motor. The common voltage used is 380 volts for three-phase and 220 volts for single-phase systems.

c. Rated output of the motor should be 20% above the shaft horsepower of the compressor and also condensing and evaporating temperature should be considered.

d. Motor speed. When belt drive is used, the motor speed should in the range of 100 – 150% of the compressor speed this case depends upon the reduction ratio between the motor and the compressor speeds. However, the slip ratio is one factor to be considered and an allowance must be made.

An Engine as a compressor drive

In the case where there is a lack in electrical power a mechanical drive is used in refrigeration plants. An engine is commonly employed to drive the compressor and the engine should be as below:

a. Engine or compressor should have a starting off load device to minimize the starting load to give an easy starting condition, these may be:

- A compressor cylinder unloading system.
- Hot gas bypass system.
- If the two systems mentioned are not available a clutch system may be used instead.

b. Engine power. A diesel or gasoline engine is employed instead of an electric motor. The power of the engine should be about 20% for diesel and 40% for a gasoline engine larger than the compressor needs.

c. Engine speeds. The engine speeds have to be selected as close as possible to the compressor speed and be at the minimum fuel consumption ratio. The important factor is the speed and power utilization point should be taken into consideration when selecting the engine.

d. Direct coupling is recommended for the engine drive. In the case where a belt drive is necessary; the strength of the engine bearings at the drive end should be checked. A thrust bearing is recommended for the bearing assembly.

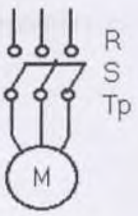
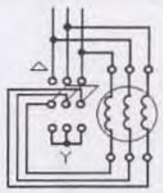
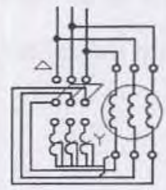
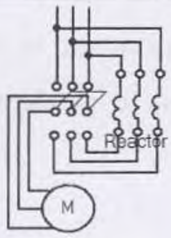
e. An automatic stop device must be provided in the compressor or engine, when the refrigerant pressure becomes abnormal or oil pressure in the compressor and/or engine oil pressure is abnormal. If these devices are not available a buzzer or indicating light can be used to indicate an abnormal situation.

f. The engine and compressor must be built upon a common base or foundation, which is provide with a device like a cushion, rubber or springs to absorb vibration while the system is operating. The flexible pipes should be used for all piping connections between each machine on the common base and the hull to allow flexibility. Each pipe must be clumped adequately at a suitable position and in sufficient numbers.

Electric- motors as compressor drives

In general the compressor motor is a cage type induction motors, but there are disadvantages in the starting as the starting current is about 4-5 times higher than that of the nominal current rating and the starting torque is low.

The starting system must provide sufficient starting torque for a compressor without exceeding current rating of the line.

Item	**Full voltage starting**	**Star-delta starting**	**Compensate starting**	**Reactor starting**
Motor capacity	Low voltage small-medium capacity	Low voltage small-medium capacity	High voltage large-medium capacity	
Phase voltage	V_{ph}	V/1.732	V_{trap} (V_{ph})	V_d (V_{ph})
Starting current	I_s	1/3 I_s	$(V_{trap}^2)\ V_{ph}$	$(V_d^2)\ V_{ph}$
Starting torque	T_s	1/3 T_s	$(V_{trap}^2)\ T_s$	$(V_d^2)\ T_s$
Price of starter	-	Cheap	Expensive	Medium
Principle of the connection diagram				

Small sizes of the compressor motor, less than 5 kilowatts with the delivery valve open, direct full-voltage starting is available because their starting current consumption is not too high because of a low starting torque.

The reduced voltage starting method is used for compressors of large capacity, the starting or combination technique like star-delta, resistance starter, and reactor starter is used in the starting circuit.

Note When starting the motor, it is advisable to reduce the starting torque by using an un-loader, bypass valve or check valve if possible.

Electrical Devices for Refrigeration Control System

Pressure switches

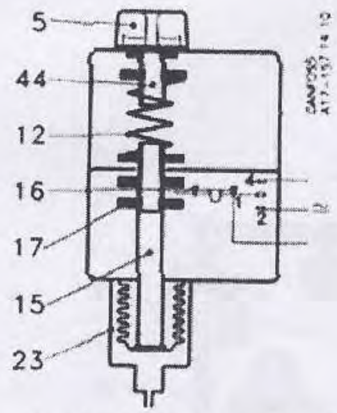
Pressure switches are designed to make or break an electric circuit in response to changes in pressure. Each have their own control range and the selection and installation should be made according to its characteristics, capacity and control function. There are high-pressure switches, low-pressure switches, oil pressure switches, water pressure switches and special ones that are dual pressure switches and are used in refrigeration systems.

The position of their installation in a refrigeration plant should be considered, in the case where the switch is installed near water or moisture, oil and gas ventilation places, a special box like water tight, or explosion proof should be used.

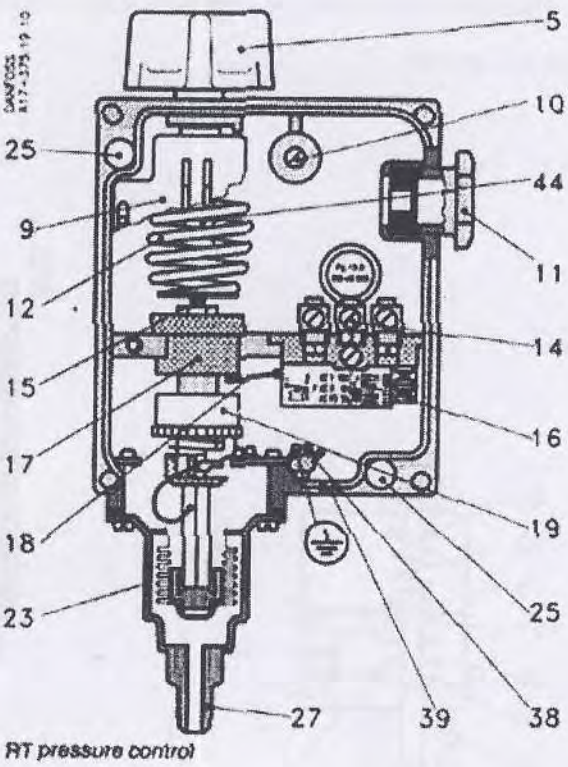
The connections for control purposes, these are limited by the contact capacity. The pressure switch should not be switch directly to the motor or compressor. The control of pressure should be made as an in-direct control by using power relays or magnetic contact breakers to interface with the motor.

High-pressure switch (HPS)

A high- pressure switch serves to break an electric circuit to stop the operation of a compressor by disconnecting the electric supplies. When the pressure on the high pressure side exceeds a predetermine pressure, perhaps because of overcharging the refrigerant, shortage or an abnormal of cooling system, mixing of non-condensing gas or incorrect operation or fire.



Key sketch RT pressure control



RT pressure control

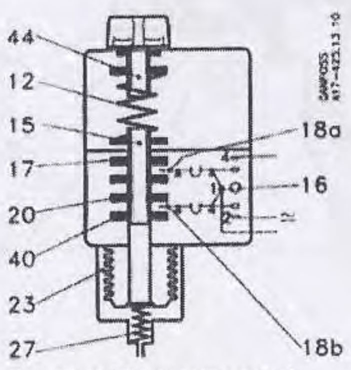
High-pressure switch

5. Setting knob	9. Regulation range scale	10. Loop terminal
11. Pg 13.5 screw cable entry	12. Main spring	14. Terminals
15. Main spindle	16. Switch	17. Guide bush
18. Contact arm	19. Differential setting nut	23. Bellow element
25. Fixing hole	27. Connection	38. Earth terminal
39. Blowout disc	44. Pressure setting spindle	

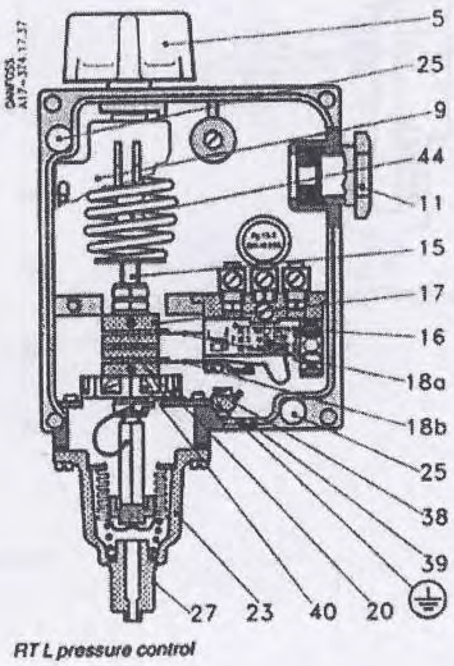
Low-pressure switch (LPS)

A low-pressure switch serves to break the electric circuit the same as the high-pressure switch but this switch responds to the low-pressure side, therefore, this operates when the pressure on the suction side become lower than the predetermined value. Another important function is to make the compressor start automatically when the suction side pressure becomes higher than the set value.

These switches may be combine with a discharge solenoid valve to control the flow of liquid refrigerant.



Key sketch RT L pressure control



RT L pressure control

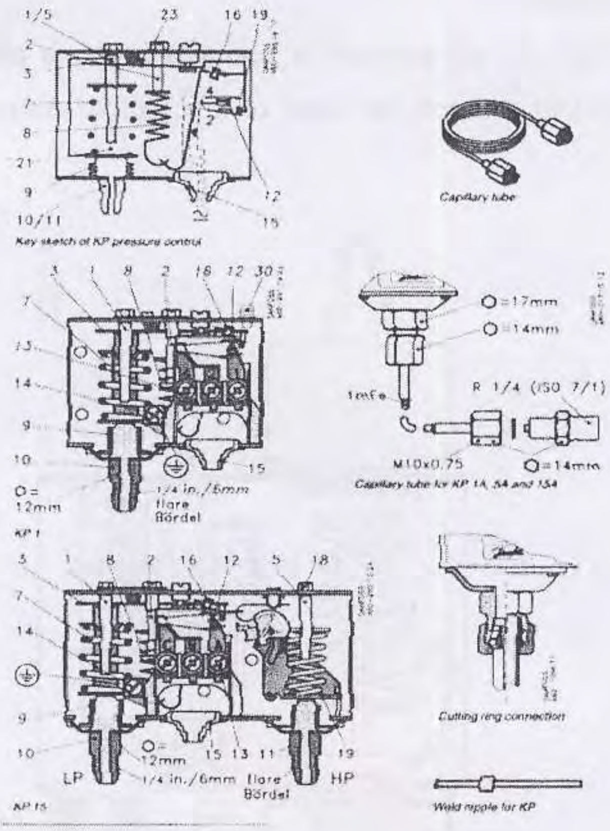
Low - pressure switch

5. Setting knob	9. Regulation range scale	11. Pg 13.5 Screw cable entry
12. Main spring	15. Main spindle	16. Switch
17. Upper guide bush	18. 18a, 18b Contact arm	20. Lower guide bush
23. Bellow element	25. Fixing hole	27. Connection
38. Earth terminal	39. Bole-out disc	40. Neutral zone setting nut
44.Pressuresetting spindle		

Dual pressure switches (DPS)

A dual pressure switch comprises a combination of high and low-pressure switches they are designed to stop the compressor and have the same function as a high or low-pressure switch.

These switches are usually designed to start the compressor when the high-pressure side (discharge side) becomes normal, however some models require to be reset manually when re-starting a compressor.



Dual Pressure switch

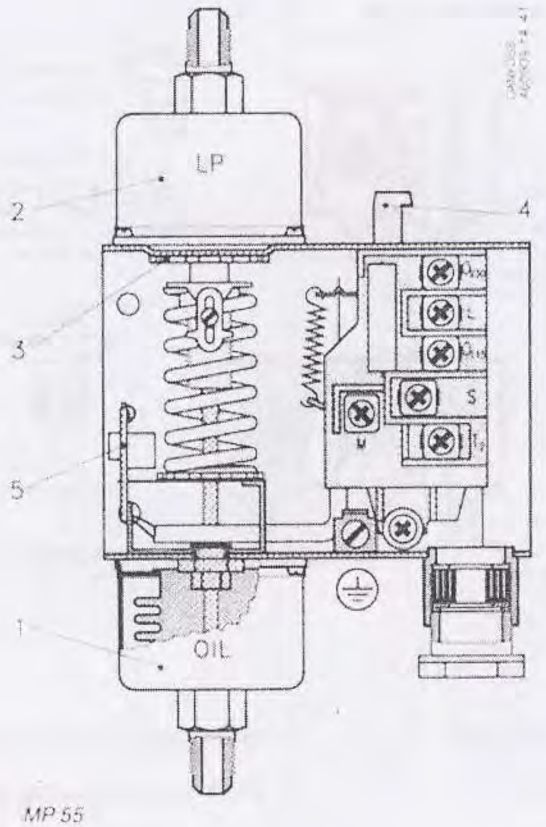
1. Low pressure setting spindle, LP
2. Differential setting spindle, LP
3. Main arm setting spindle, HP
5. High pressure setting spindle, HP
7. Main spring
8. Differential spring
9. Bellows
10. LP Connection
11. HP Connection
12. Switch
13. Terminal
14. Earth terminal
15. Cable entry
16. Tumbler
18. Locking plate
19. Arm
30. Reset button

Oil pressure protection switches (OPS)

This switch is used to stop the operation of a motor compressor to protect the compressor when the oil pressure become lower than the proper value in forced lubrication type compressors.

The operation of this switch that it senses the difference between oil pressures and the low-pressure when the suction pressure becomes lower than a predetermine value. The setting value is between 2-3 Kg/cm^2 higher than the suction pressure. This switch operates after a predetermined time delay of about 20-30 seconds. If the switch has turned off it is required to be reset manually.

Commonly, when the oil pressure is becomes below a predetermined value, a special alarm function that monitors the lapse of time before cutting-off the compressor motor.



Oil pressure switch

1. Connection to pressure side of lubrication system. Oil
2. Connection to suction side of refrigeration plant, LP
3. Setting disc
4. Reset button
5. Test device

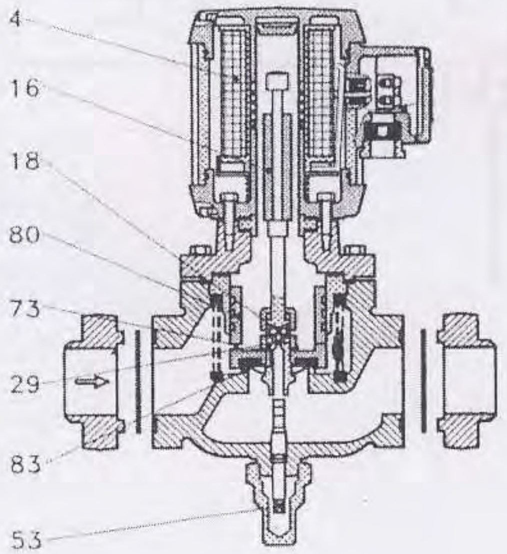
Water pressure switch (WPS)

The water pressure switch serves to detect a reduction in the flow rate of the cooling water or brine cooler. The cooling water switch functions to cut off the compressor motor circuit prevent abnormally high pressure and high temperature at the compressor discharge side. It thus prevents the freezing of the brine coolers.

Solenoid valve

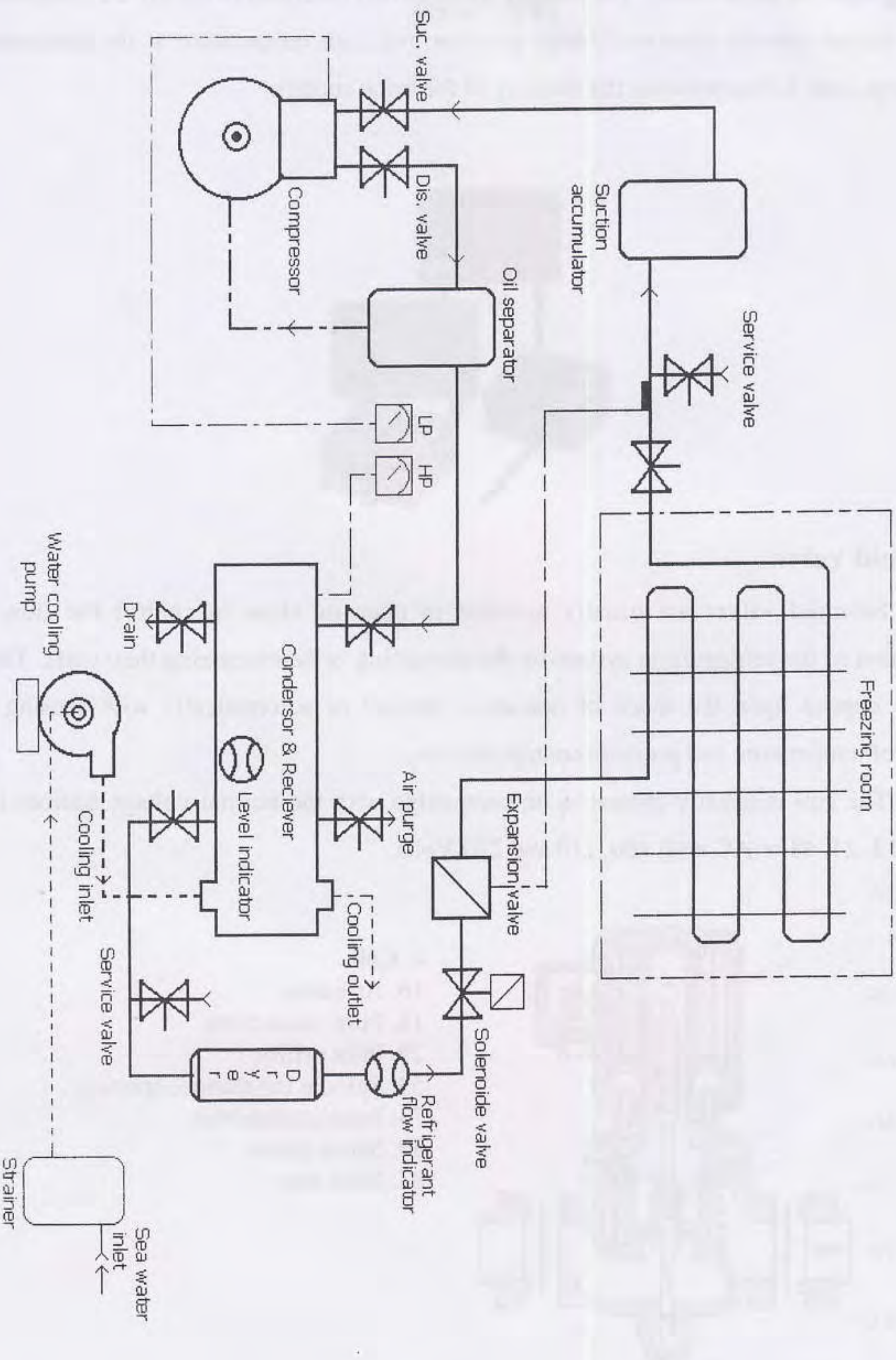
Solenoid valves are usually installed to open or close to control the flow of refrigerant in the refrigeration system by the energizing or de-energizing their coils. These actions depend upon the mode of operation, manual or automatically with sensing by means of temperature and pressure control devices.

The coil is usually chosen to be compatible with the normal voltage sources like DC at 12, 24, 48 or AC with 100, 110 and 220 Volts.

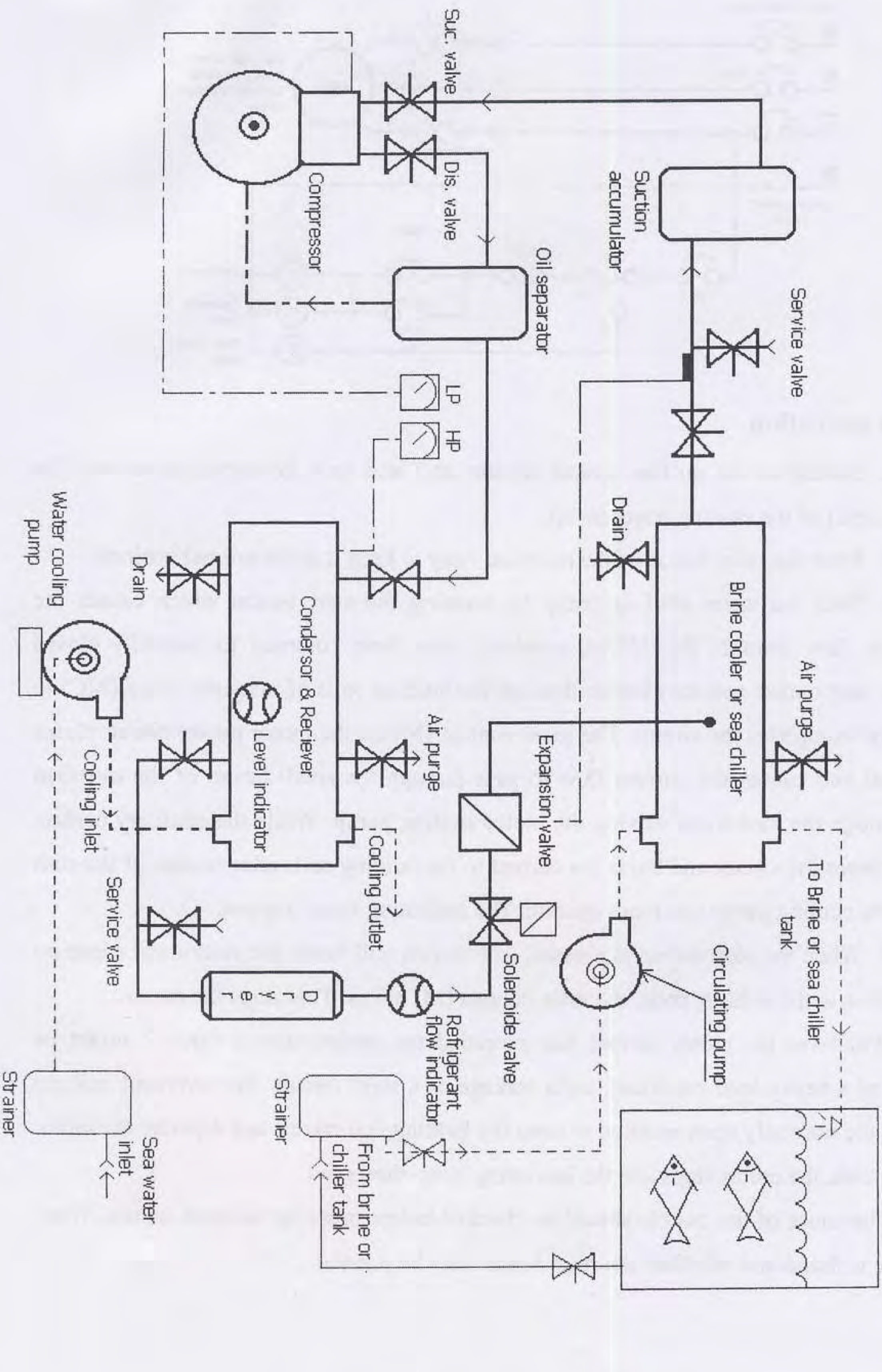


4. Coil
16. Armature
18. Pilot valve plate
29. Pilot orifice
53. Spindle for manual opening
73. Equalization hole
80. Servo piston
83. Main seat

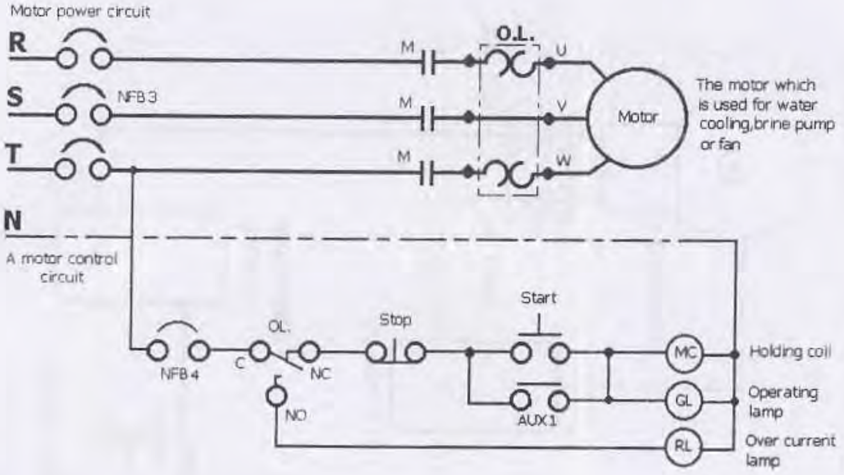
Refrigeration Circuit (Coil Evaporator)



Refrigeration Circuit (Brine System)



Water Cooling Pump or Brine Pump Circuit



Circuit operation

a. Switch on the no-fuse circuit breaker no.3 and no.4 for motor power and the control circuit of the cooling water pump.

b. Press the reset button of the overload relay to keep it in the normal position

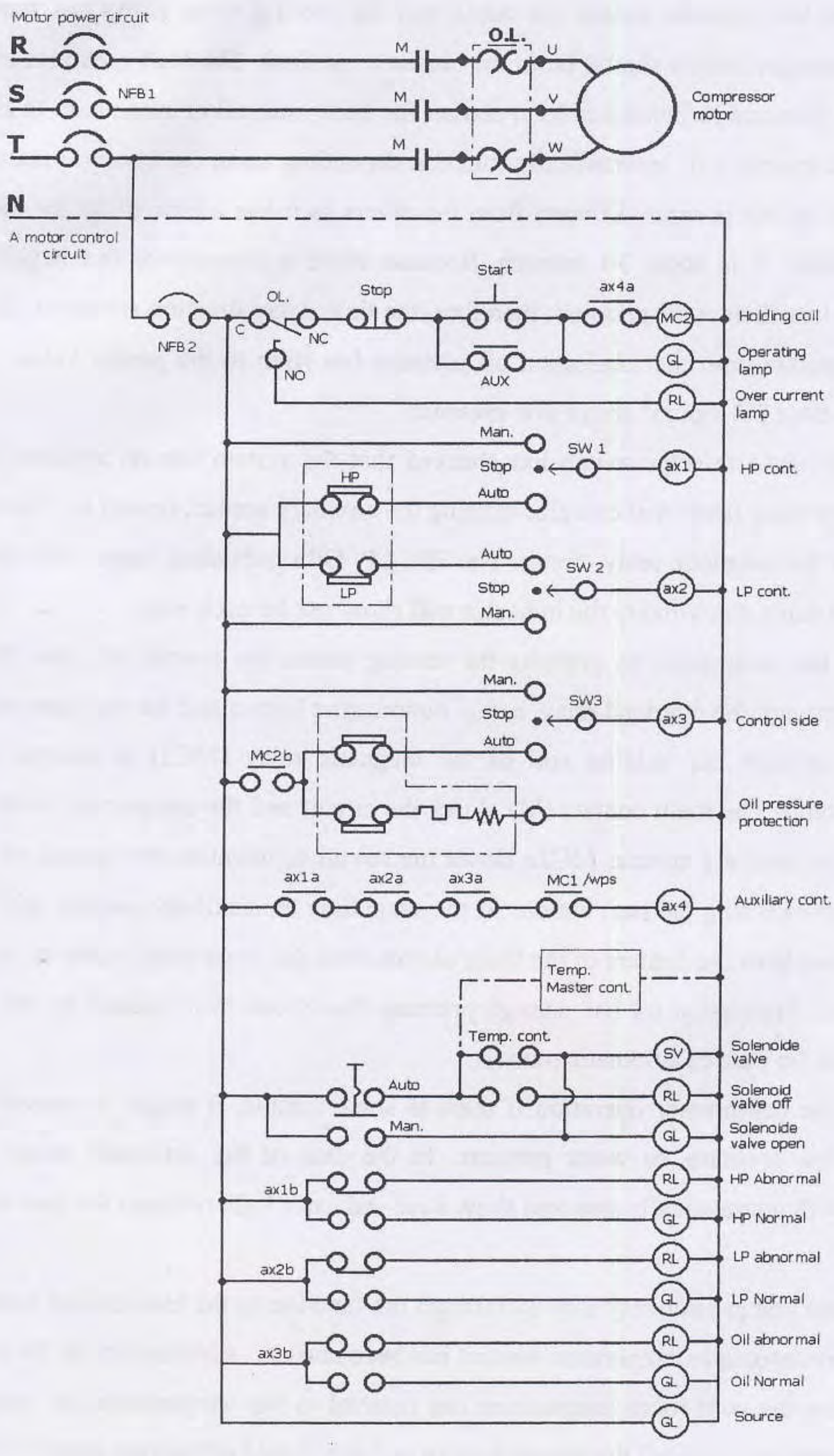
c. Start the water cooling pump by pressing the start button which causes the current to flow from NFB3, NFB4, overload relay from common to normally closed contacts, stop button and start button through the holding coils of magnetic relay (MC) to the neutral completes the circuit. The main contact (M) on the motor power circuit closes the circuit and causes the current flow to pass through the small heater of the overload relay through the motor and driving the motor cooling pump. While the auxiliary contact (Aux1) closes the circuit and holds the current to the holding coils after release of the start button, the cooling pump continues operate. The indicating lamp is green.

d. When the stop button is pressed. The switch will break the circuit and cause no current flow to the holding coils, the main contact (M) opens. This stops the motor.

Whenever the motor current has exceeded the predetermined value it might be because of a heavy load condition, earth leakage or a short circuit. The overload will cut off from the normally open position to open the holding coil circuit and separate the motor power circuit, the motor stops and the indicating lamp shows red.

The cause of the trouble should be checked before pressing the reset button. When the cause is found and rectified, the reset button may be pressed.

Compressor Starting Circuit



Compressor circuit

Switch on NFB1 for compressor power and NFB2 for the compressor control circuit. After the low-pressure switch has cut-in and the cooling water pump has started (MC1b or the pressure switch should be in the closed condition). The high-pressure, low-pressure and oil-pressure switches has been chosen for either manual or automatic. In case of automatic the system will automatically function depending upon the system pressure. The oil pressure switch is some different from the others as it has a time delay for some seconds, in practice it is about 30 seconds. Because while a compressor has begun to revolve there is insufficient oil pressure, therefore, the time delay function serves to allow the system to operate until the lubrication oil pressure has risen to the proper value, the setting point is about 2-3 kg/cm^2 above low-pressure.

After the mode selector switch has checked that the system has no abnormality, then the auxiliary relay (ax4) will energize causing the auxiliary contact (ax4a) to close the holding coils of the magnetic relay circuit. The HP. LP, OPS indicating lamps will show green. If there is some abnormality the indicator will show red for each item.

Starting the compressor by pressing the starting button the current will flow from NFB1, NFB2, through the overload relay, a stop button, start button and the auxiliary relay contact (ax4a) through the holding coil of the magnetic relay (MC2) to neutral and complete the circuit. The main contact (M) closes the circuit and the compressor starts to rotates, while the auxiliary contact MC2a closes the circuit to maintain the current to the holding coil after releasing the start button. At the same time the auxiliary contact (MC2b) is closed and completes the heaters of the timer circuit, then the timer delay starts to count for 30 seconds if lubrication oil has enough pressure the system will operate by the oil pressure function (in case of automatic mode).

During the compressor operation if there is some trouble, it might be caused by high-pressure, low-pressure, or water pressure. In the case of the automatic mode the control system will automatically stop and show a red indicator light red-sigh for each kind of trouble.

The motor compressor may stop by through the function of the temperature control in the case where automatic temperature control has been chosen. Abnormality in the low-pressure, because the cold room temperature has reached to the temperature, the master temperature control will turn off the solenoid valve and stop liquid refrigerant supply to the evaporator and the system has very low pressure and cuts-off the circuit.

To stop a compressor

This system is provided with several mode selector switches and stop buttons. To stop the compressor either pressing a stop button or switch only one mode selector switches to the stop position will cause the control circuit to break the circuit and no current will flow to the holding coils and the main contactor (M) opens and the compressor motor stops.

Refrigeration Designed for Fishing Vessels

The total load of the freezing room (Q_h) is based on the following formula. In case of a flat type however, it may be calculated by multiplying the freezing load by an allowance factor or

$$Q_h = Q_f + Q_t + Q_a + Q_m + Q_w + Q_l$$

Where:

Q_f = Freezing load

Q_t = Wall heat inflow

Q_a = Heat inflow from air change

Q_m = Heat inflow from motor

Q_w = Heat inflow from human bodies

Q_l = Heat inflow from electric lamp

Heat inflow from electric motor

$$Qm = Kw \times \frac{1}{1000} \times 860 \times \frac{h}{24} \text{ kcal/hr.}$$

Where:

Kw = Electric motor power rated

H = Running time of the motor

860 = Constant factor

Heat inflow from room lamp

$$Q_L = w \times 860 \times \frac{1}{1000} \times \frac{h}{24} \text{ kcal/hr.}$$

Where:

W = Power of lamp in watts

H = Operating time

Heat from air change

Heat inflow from air change due to air outside of the fish hold or freezing room

$$Qa = \frac{N_r \times V_r (I_o - I_r)}{V_o} \text{ kcal/hr.}$$

Where:

N_r	=	Number of door opening (time/hr.)
V_r	=	Room or freezing hold volume (m^3)
I_o	=	Enthalpy of outside air
I_r	=	Enthalpy of inside air (freezing room)
V_o	=	Specific volume of outside air (m^3/kg)

Freezing load of freezing room

$$Q_f = \frac{M_f}{H_f} \times C_1 \left\{ (t_1 - t_f) + e + C_2 \times (t_f - t_3) \right\}$$

Where:

M_f	=	Freezing capacity. (The amount of catches loading into Freezing room for each operation (kg))
H_f	=	Freezing time (h)
C_1	=	Specific heat of product before freezing ≅ 0.85 kcal/kg °C
C_2	=	Specific heat of product after freezing ≅ 0.47 kcal/kg °C
t_f	=	Freezing point of product ≅ - 1.25°C
t_1	=	Initial temperature of product ≅ sea water temperature (30°C)
t_3	=	Final temperature of fish (Freezing temperature ≅ -10°C)
e	=	Latent heat of freezing product ≅ 61 kcal/kg °c

Evaporating temperature

$$Et = T - \Delta T$$

Where:

T	=	Temperature of freezing room.
ΔT	=	Range of temperature different in freezing room. ≅ ± 5°c
Et	=	-20 ± 5°c

Condensing heat load (Q_2)

$$Q_2 = Q \times R$$

Cooling area of condenser (F)

$$F = \frac{Q_2}{k \times \Delta T}$$

Where:

Q	=	Refrigerating capacity of compressor (kcal/h)
R	=	Magnifying constant (1.4 – 1.5)
k	=	Overall heat transfer coefficient 450 kcal/m^2 h °C

Area of evaporator (m^2)

$$A = \frac{Q}{k \times \Delta T}$$

Where:

Q	=	Heat load to be taken by evaporator kcal/h
K	=	Heat transfer coefficient kcal/h°c (9 – 12 kcal/h °C natural convection expansion valve)
ΔT	=	Range of temperature different in freezing room. ≅ ± 5°C
		Wall heat inflow ≅ 0.7 kcal/m^2 h °C
		Specific volume of outside air ≅ 0.894 – 0.908 m^3/kg

Heat inflow from air change (Q_a)

$$Qa = \frac{N_r \times V_r (I_o - I_r)}{V_o}$$

Where:

N_r	=	The number of doors open (Time/h)
V_r	=	Room volume (m^3)
I_o	=	Enthalpy of outside air (kcal/kg)
I_r	=	Enthalpy of indoor air (kcal/kg)
V_o	=	Specific volume of outdoor air (m^3/kg)

Cooling water pump

The cooling water pump must have enough flow to be capable of cooling the condenser or other necessary devices like cylinder heads or the oil cooler of the compressor. The required flow rated is calculated by the following formula.

$$V_{pump} = \frac{Q2}{\Delta T} K$$

Where:

V_{pump}	=	Flow rate of cooling water pump (l/h)
Q_2	=	Condensing heat load (kcal/h)
ΔT	=	Different temperature of cooling water in between.
K	=	Allowance coefficient factor 1.1 – 1.25

Electric motors of cooling pumps

$$M_{kw} = \frac{r \times V_{pump} \times H}{6120 \times \eta} \times k$$

Where:

M_{kw}	=	Output of electric motor (kw)
r	=	Specific gravity of sea water (1.0- 1.03 kg/l)
V_{pump}	=	Flow rate of cooling water pump (l/h)
H	=	Total head of cooling water pump (m)
η	=	Efficiency of cooling water pump (60 –70%)
k	=	allowance coefficient (1.2-1.4)

Brine pump

$$V_{brine} = \frac{Q_1}{C \times r \times \Delta T} \times k$$

Where;

V_{brine}	=	Flow rate of brine pump (l/h)
Q_1	=	Cooling load (kcal/h)
C	=	Specific heat of brine (kcal/kg °C)
r	=	Specific gravity of brine
ΔT	=	Temperature different of brine, the value is between outlet and inlet of brine cooler (1 - 2°C)
k	=	Allowance coefficient (1.2 - 1.4)

Example of Calculation

A refrigeration unit is installed in a wooden fishing boat for a freezing room with a capacity of 15 m^3 and storage the same as the room capacity the designed freezing temperature are -30 and -5 °C.

1. Calculation of freezing room

Freezing load (Q_f)

$$Q_F = \frac{1000}{15} \times 0.85\ [(30-(-1.25)) + 61 + (0.47\ (-1.25-(-30)))]$$

$$= 66.67 \times 89.89$$

$$= 5592 \text{ kcal}$$

Heat inflow from air change

$$Qa = \frac{3 \times 15(20.6-(-7.1))}{0.89} = \frac{1400 \text{ kcal}}{24 \text{ hr}}$$

$$= 58.35 \text{ kcal/h}$$

Heat inflow from wall (Q_w)

$$\text{Wall area} = 2(4\times2.5)+(2.5\times1.5)+(4\times1.5)2$$

$$= 39.5 \text{ m}^2$$

$$\text{Heat inflow to wall} = 0.7 \text{ kcal/m}^2\text{/h°C}$$

$$Q_w = 39.5 \text{ m}^2 \times 0.7 \text{ kcal/m}^2\text{h} \times 60°\text{C}$$

$$= 1659 \text{ kcal/h}$$

The total heat for freezing room

$$Q_h = 5592 + 58.35 + 1659 \text{ kcal/h}$$

$$= 7309.35 \text{ kcal/hr}$$

2. Calculation of storage room

After freezing the catch product for about 15 hours, the fish comes to a temperature of about –25 to -30°c and then remove it into the storage room at the same preservation temperature. The storage room capacity is about 15m^2 with 8 tons of catch product. The cooling loads to preserve the catch are calculated as below.

$$Q = \frac{8000 \text{ kg} \times 0.47 \text{ kcal/kg}}{24}$$

$= 156.66$ kcal/hr

The total heat of storage room (Q_h) $= 156.66 + Q_a + Q_w$

$= 157 + 1659 + 58$ kcal/hr

$= 1847$ kcal/hr

The total capacity of the compressor $= 7309 + 1847$ kcal/hr

$= 9156$ kcal/hr

$\approx 36{,}258$ BTU/hr

Condensing heat load (Q_2)

$Q_2 = 9156$ kcal/hr x 1.4

$= 12818$ kcal

Cooling area of a condenser (F)

$$F = \frac{12818}{450 \times 10}$$

$= 2.848 \text{ m}^2$

Area of evaporator (brine)

$$A = \frac{7309}{200 \times 8}$$

$= 4.568 \text{ m}^2$/(circumference of pipeline 0.134 m)

$= 34$ m (length)

Area of evaporator (Hair pin coil)

$$A = \frac{1847}{12 \times 10}$$

$= 15.39 \text{ m}^2$

$= 115$ m (length)

Refrigerant require (Ref_r)

For brine system $=$ Evaporator length $\times$ k

$= 34 \text{ m} \times 1.1$ kg/m

$= 37.4$ kg

For coil evaporator = Evaporator length × k

= 115m × 0.55 kg/m

= 63.25 kg

The total refrigerant require = 37.4 kg + 63.25 kg

= 100.65 kg

High-pressure refrigerant receiver = Total refrigerant required x specific volume

= 100.65 kg × 0.86729 m^3/1000 kg

= 0.08729 m^3

Water-cooling pump

$$V_{pump} = \frac{12818}{2} \times 1.2$$

= 7690 l/h

Brine pump

$$V_{brine} = \frac{7309}{0.811 \times 1.15 \times 1} \times 1.2$$

= 9404 l/h

Electric motor for a cooling pump

$$Mkw = \frac{1.03 \times 7690 \times 1.5}{6120 \times 0.7}$$

= 2.77 kw

Electric motor for brine pump

$$Mkw = \frac{1.15 \times 9404 \times 2.5}{6120 \times 0.7}$$

= 6.31 kw

Initial Conditions in Systems and Boat Profiles

Freezing capacity	=	1000 kg/day (15 hr)
Storage capacity	=	8000 kg
Freezing time	=	15 hr.
Specific heat of catch product before freezing	=	0.85 kcal/kg°C
Specific heat of catch product after freezing	=	0.47 kcal/kg°C
Freezing point of product	=	-1.25°C
Initial temperature of product	=	30°C

Latent heat of product	=	61 kcal/kg°C
Number of door open	=	3 time/day
Room volume	=	15 m^2
Enthalpy of out side air	=	20.6 kcal/kg
Enthalpy of inside air	=	-7.1 kcal/kg
Specific of outdoor air	=	0.89 m^3/kg
Heat inflow through wall	=	0.7 kcal/m^2/h°C
Specific gravity of sea water	=	1.03 kg/l
Specific gravity of brine	=	1.15
Specific heat of brine	=	0.811 kcal/kg°C
Head of brine pump	=	2.5 m

Brine and the Preparation of Brine

Brine is commonly used as a secondary refrigerant. Obviously water cannot be employed as the secondary refrigerant when the system temperature to be maintained is below the freezing point of water (0°C) In this case a brine solution is employed instead of water.

Brine is the name given for a solution when salts are mixed and dissolved in the water. Whenever a salt dissolves in water, the freezing temperature of the brine solution will be lower than the freezing temperature of pure water. Up to a certain point, (the usual value is about 23% max. of salt contents in the water) more salts dissolved in the solution causes a lower freezing temperature of the brine. However, the salt concentration is increased.

Since the specific gravity of the brine increases as the concentration increases, the degree of salt concentration and the thermal properties of the brine can be determined by measuring the specific gravity of the brine with a hydrometer.

Preparation of brine

Brine is the general term given to aqueous solutions of chlorides and organic compounds, which serve to absorb and transfer heat between the evaporator and the object to be cooled.

The brine is required to be of lower than freezing temperature, large specific heat and good heat transfer. It is also required to be non-corrosive in the plant, harmless to the human body or foodstuffs and must be inexpensive.

An aqueous solution of salt (Nacl) or calcium chloride (CaCl) makes the freezing point reduce, if the concentration is increased to some extent so that it is used conventionally as brine. In the case of fishing vessels, salt (Sodium chloride, Nacl) is introduced as the medium of heat transference. The freezing point of the Nacl solution is –21.2°C. For this freezing temperature the salt concentration in the solution is approximately 23% by the weight of solution. Pureness of NaCl powder is greater than 95% as a standard.

Solution contents

In case of fresh water is used to make a brine solution.

Solution Ingredient (Ton/kg)	Brine temperature (°C)	Specific gravity (kg/l)	Brume scale (Scale)
Fresh water/ NaCl 1 / 302	20	1.172	21.177
	15	1.175	21.491
	10	1.177	21.700
	0	1.182	22.218
	-10	1.186	22.630
	-15	1.190	23.039
	-20	1.193	23.344
	-21.2	1.1934	23.384

From the relationship as illustrated above, the same NaCl weight in the solution the specific gravity increases depending upon the decrease of the solution temperature. Therefore, to take good care, both the characteristic temperature and specific gravity should be checked at the measurement point.

Brine solution using seawater

It is convenient and inexpensive in operation, when seawater is used. The seawater is about 1.03 kg/l in specific gravity, this means that there is about 30 kg of NaCl contain in 1 ton of seawater. Therefore 270 kg of NaCl are used to make the brine solution. Generally, the brine is made in a solution tank and after that is transferred to the fish hold. In the case where the area is limited, brine is directly made in the fish hold, a circulating pump is provided to circulate and take care of the solution because of protection for the pile on the floor and the evaporator coils.

The relation between temperature and specific gravity of seawater brine solution

Solution Ingredient (Ton/kg)	Brine temperature (°C)	Specific gravity (kg/l)	Brume scale (Scale)
Sea water/ NaCl 1 / 270	20	1.152	19.035
	15	1.154	19.256
	10	1.156	19.473
	0	1.159	19.796
	-10	1.160	19.903
	-15	1.161	20.010
	-20	1.162	20.117

Result of Survey

From the survey of fisherman in fish freshness preservation at Samutsakhon fishmarket and Samutsakhon fishing village, Samutprakran fishmarket, Bang sa-re fishing port and Rayong fishing port

These may be classified by size of boat and fishing gear as follows:

1. 16 boats using Thai purse seine fishing with lengths between 20 to 30 meters are operating in the gulf of Thailand

2. 4 boats of small-scale trawl fishing with lengths 18 to 20 meters are operating at the mouth of the Chao-praya River and in the gulf of Thailand.

3. 46 boats of large-scale trawl fishing with lengths of 25 to 50 meters are operated in the gulf of Thailand and in overseas fishing.

4. 4 fish carrier boats, these boat are of 5 to 15 members operating in the gulf of Thailand or overseas fishing.

The sample of fisherman using fish preservation may be classified into the methods of fish preservation in two groups and may be described as follows:

Ice preservation method of fish

The fishermen use ice mixed with the sea products or prepared as layers between the ice and sea products, both techniques use a cover of ice on the top surfaces. The consumption ratio of ice and sea product is between 1:3 or 1:1 these ratios depend on the sea products that do not spoil easily. Shrimp or high-grade fish, which is in demand in the market must be taken care of more carefully and will need more ice for freshness. After the product is arranged in a plastic tank, the tanks are carried into the fish hold. Inside fish hold the fishermen arrange them with supporting materials and flake ice to maintain a good low temperature.

Temperature maintenance checks must be made because melting of the ice causes high water levels in the fish container or fish hold. If the water level is higher than the proper level the water must be drained off. The product may be damaged by the pitching or rolling of the boats and must be repacked in ice to replace that melted while at sea.

Preservation of large quantities of fish that do not command such high prices in the market.

The preservation of these kinds of catches is that they are directly mixed with ice into the fish hold and supplied with ice at between 1:2 or 1:3 of fish to ice and the water level in fish hold is checked particularly where there is no drain gate arrangement.

For a small-scale shrimp trawl fishing boats. The preservation method uses ice and seawater mixed in the fish hold and arranged with the shrimp mixed with ice in a plastic container. The conditions are monitored and maintained as mentioned above.

Refrigerated fish preservation method

Fishing boats with fish preserved by a refrigeration system are trawl-fishing boats with lengths of about 25-50 meters these boats work overseas with an operational period of over 20 days for example in Indonesia or Australian waters.

The general arrangement of the fish hold and refrigeration system is that an air blast system is used for preservation. The system uses an electric fan to draw low temperature air from the evaporator (unit cooler) to blow around the fish. These are contained in trays and arranged on shelves, each shelf has a pitch of between 30-35 centimeters to maintain the air ventilation and which improves the refrigeration efficiency and preservation coefficient. Therefore, the fish holds are arranged with 2 or 3 sets of electric fans depending upon the size of the fish hold and the way of arranging the fish inside the room. The temperature used is in the range –28 to –35 degree Celsius. Thus, good insulation is used and is mostly the injected foam type insulation of around 8-11 inches thick.

Installation of the refrigeration system

Compressor, the fishing boats have 4 or 6 piston compressors using R-22 refrigerant with the cylinder head cooled by seawater. The electrical power generation system is normally three-phase, 380 volts. An electric motor of 30 horsepower at about 1400 to 1450 rpm is used as the prime mover. The compressor is installed in the engine room or on the fore deck above the engine room. In large sized fishing boats there are often 2 to 8 sets installed, each set being operated independently. There is direct starting without auxiliary devices in the starting system.

The cooling units are air blasters, one set is provided with 2-3 electric fans of about 2-3 hp. which are used as temperature or heat transfer devices. The system arrangement is quite simple with just one thermostatic expansion valve of the compensated pressure type used as the refrigerant control. The refrigerant is supplied through a capillary tube into the unit cooler (evaporator coil) which is divided into 6-8 circuits. The unit cooler is installed as close to the compressor as possible and is installed at the top of the fish hold to improve the air ventilation and system efficiency with few losses.

Problems and the difficulties of fish freshness preservation for Thai fishermen

1. The cost and maintenance cost of a refrigeration system is high. Also the auxiliary devices used in refrigeration systems are costly like the power generator, fish hold, fish hold insulation and the installation cost.

2. The fishing operation time is short at about 5-6 days. Ice preservation is enough to maintain the temperature. If the fishing operation was longer, fish freshness would be difficult and poor.

3. Thai fishermen have no faith in refrigeration systems and lack experience and refrigeration knowledge.

4. In the older fishing boats if there are changes to preserve by using a refrigeration system, the boat must be re-designed in such matters as the ship's hull, engine room, and fish hold all of which are extra expenses. For fish carrier vessels, the refrigeration system must be introduced and installed both together.

Suggestions by the fishermen

1. The attitude and values of the Thai consumer to a frozen product has affect to its price. The fisherman is not convinced about the market system. Daily, fish that are preserved by ice attract better prices than the frozen products. Thus, the fisherman has no guarantee if they improve their preservation method by freezing there will be no benefit because of the cost and operating cost of the refrigeration system. The fuel consumption of fishing boats is the main investment and there is no promotion or support from the government.

2. Cost for the investment of a refrigeration system are quite high and need auxiliary devices like a main generator and auxiliary generator which has more capacity and which is reliable, installation must be arranged and human resources onboard have no experience in refrigeration systems.

3. The period of fishing operation, if the fishing operation is over 20 days, the fishermen might change to refrigeration systems. By an analysis of fishermen operating in the Gulf of Thailand they think ice fish preservation is enough as it can be maintained for about 4-5 days, freshness, taste is unchanged and the fisherman can go alongside at fishing

ports around the coast of Thailand to sell their fish or they can transfer their catch by truck to the fish market.

4. For the boats that use refrigeration systems they must be rich in capital investment and have knowledge. They can communicate to each other about new fishing grounds, rich in resources to serve the consumer.

5. Some of fishermen have a possibility to improve their fish preservation methods to refrigeration systems if in near feature they must spend more time to go long distance fishing.

6. Recently, fishing boats with refrigeration systems are operating in the south of Indonesian waters but it is quite a long sailing time and is far from Thailand.

7. In general, it is about 1 million Baht for one refrigeration system for a new fishing boat because it is easy to make the installation when the boat is built.

8. The temperatures that are used to maintain the freshness of fish is between –28 to –35 degree Celsius so that the product can remain fresh during transfer or transportation.

9. Some fishing boats have more than one refrigeration set installed to improve the reliability and efficiency. In the case where 1 or 2 cold rooms are used, the installation of the refrigeration system is in the middle of boat to avoid heat radiated from the engine room.

10. The price of product does not always depend upon the quality of the product but it sometimes depends on the demand or power of the market.

11. For Thai purse seines refrigeration is not popular. They cannot prepare or cool the temperature before catching because of the operating cost.

12. In general, steel boats keep or maintain low temperatures better than wooden boats.

Some sample of Thai fishing boats from the fish freshness preservation method.

Length of boats (m)	**Number of boat**	**Ice preserve method**	**Refrigeration method**	**Fishing area**	
				Thailand	**Oversea**
10-20	25	25	-	25	-
21-25	5	5	-	5	-
26-30	6	6	-	4	2
31-35	5	5	-	-	5
36-40	8	-	8	-	8
41-45	3	-	3	-	3
46-50	26	-	26	-	26
>50	-	-	-	-	-
Total	78	41	37	34	44

The table of fish freshness preservation of Thai fishing boats at Samutsakhon, Samuthprakran Chonburi and Rayong province

Conclusion

From the survey of about 78 samples of Thai fishing boat are 36 boats with a length between 10-30 meters fishing in the Gulf of Thailand, 34 boats and another 2 boats operate overseas, of those mentioned there are no boats with installed refrigeration systems. 5 fishing boats with lengths between 31-35 meters are operated overseas but still preserve with ice because their fishing grounds are not too far from Thailand.

For the large scale fishing boats with lengths between 36-50 meters operate overseas. Their fishing time is over 20 days and the boats are equipped with air blast refrigeration systems. Each boat is usually provided with more than 2 sets of compressors and auxiliary generators with enough power generating capacity to cover the power demand.

Suggestion by the Associated group

1. The fisherman and the business relationship are confused and the lack of skill in fish preservation, like how to freeze and maintain freezing and the attitude of the consumer. So that some of the freshness preservation methods have been introduced in an incorrect manner like the use of hazardous chemicals mixed with the product. The chemical is toxic and injurious to humans and cause losses in the export business.

2. The preservation of fish product depends upon the scale of fishing and fishing boat. If the fisherman operates overseas, refrigeration is automatically necessary and widely used in the fishing boats.

3. The fisherman lacks education in responsible fishing because the information and promotion methods used are not available on the practical side, like the apparent over catch by fishermen. These matters affect the preservation cost, quality, and price of product.

4. The government must conduct seminars for fishing boat owner groups, the business group who work in the fisheries industry to encourage and disseminate the knowledge to upgrade the preservation methods to keep the freshness and upgrade the value of the sea production and conduct training courses in preservation technology in many ways to fisherman and seafarers.

Appendix

Adiabatic compression

Adiabatic compression is a process of compressing a refrigerant gas in a compressor without removing or adding heat. Therefore this process the heat is increase.

Enthalpy

Enthalpy is the measure of energy by both of temperature and pressure at atmospheric pressure. The enthalpy is symbol by h and unit in calorie (cal) or kilocalorie (kcal). Enthalpy is the sum of energies which, need to change a substance from the initial temperature to the certain temperature is calculated using the following formula.

$$h = C_p \times (T_2 - T_1)$$

Where C_p = Specific heat of substance

T_1 = Initial temperature of substance

T_2 = Final temperature of substance

Example

Compute the enthalpy of heat which, heat up 1 kg of water from 0°C to 100 °C, specific heat of water = 4.187 kcal/kg °C

$$h = C_p \times (T_2 - T_1)$$

$$= (4.187 \text{ kcal/kg °C}) \times (100 - 0\text{°C})$$

$$= 418.7 \text{ kcal}$$

Entropy

Entropy is expressions of the heats transferred for change the mass of substance per degree from absolute temperature or base temperature to some arbitrarily selected temperature (Example 0°C is the base temperature of water). Entropy is available to measure in Btu per pound degree or kilocalorie per kilogram degree and generally used only in engineering calculation, it is usually contain in most engineering handbook.

Isobaric compression

Isobaric compression is the process of change in pressure or volume under the condition of constant temperature.

During compression of the refrigerant gas, heat must be remove at the condenser area in order to maintain a constant temperature. The remove of heat is by air-cooled or water-cooled, and the heat that remove is equal to the heat input by the work of compressing the refrigerant gas.

Isobaric expansion

Isobaric expansion is a process of refrigerant expanded in the evaporator at a constant temperature through the expansion valve while pressure and volume both changes. The pressure will vary inversely with the volume. That is the pressure increase as the gas is compressed and decreases as the gas is expanded.

During expansion the refrigerant gas is cooled and the heat needed to keep the gas at a constant temperature must come from an outside source the heat so obtain must be exactly equal to that given up by the gas during its expansion.

Latent heat

Latent heat is the heat which, applied to any given substance to change in their state at the same temperature and pressure.

Example

1. The heat was required to change the ice at zero degrees Celsius to water at zero degrees Celsius, this heat called " Latent heat of melting"

2. The heat was required to change the water to steam this heat called " Latent heat of vaporization"

3. And the heat was required to cooling the steam to water or to removed the heat is called " Latent heat of condensation"

Sensible heat

If added the heat into a substance and cause the temperature rise as the heat is added. The increase in heat is called "Sensible heat" Likewise, heat may be removed/heat subtracted from a substance, if a substance temperature is falls is again called "Sensible heat"

Therefore, sensible heat is the heat causes a change in temperature of substance.

Specific gravity

Specific gravity is the ratio of mass (kg) of a certain volume of liquid or solid as compare to the mass (kg) of an equal volume of water. The water is given a specific gravity of one. Therefore the objects which float on the water has a specific gravity less than one.

Example

1 liter of water is equal to 1 kg compare with 1 liter of oil is about 0.85 kg.

Solution the specific gravity of oil = 0.85 kg/1.0 kg = 0.85

The oil is specific gravity of 0.85 then the oil must be floating on the water.

Specific heat

Specific heat is the amount of heat that must be added or release to change the temperature of substance by one degree Celsius at atmospheric pressure.

Example

1. The specific heat of water = 4.187 kcal/kg°C and
2. Specific heat of air = 1.0 kcal/kg°C

Specific volume

Specific volume is the volume for comparing a density for any substance of one kilogram at a standard condition (20°c at atmospheric pressure and 30% of relative humidity)

Example

A specific volume of dry clean air is equal to 0.840 m^3. It is means that the 0.840 m^3 in volume of dry clean air at a standard condition is equal to 1 kilogram by weight.

Throttling process

Throttling process in the refrigeration system is the expansion of gas through an orifice or a controlled opening of valve (expansion valve) without gas performing any work as it expands.

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