Ice Plants

B TECH 3RD SEM

Introduction

One of the important applications of refrigeration is in ice plant.

Ice plant is used for producing refrigeration effect to freeze potable water in standard cans placed in rectangular tank which is filled by brine.

A good definition of refrigeration is the removal of heat energy so that a space or material is colder than its surroundings.

An ice plant based on same principle as a simple refrigeration system. An ice plant contains various parts such as compressor, condenser, receiver, expansion valve, evaporator and refrigerant accumulator.

A refrigeration is always been a great deal for human being and play a vital role in preserving food , chemical, medicine, fisheries and providing appropriate temperature in working Entity of any industry.

An ice plant has the following components

compressor, oil separator, condenser, receiver, drier, expansion valve, evaporator, chilling Tank, refrigerant accumulator and pressure gauge

Ice plant

The function of an ice plant or **ice factory is to make or form ice in large quantity and in large size**.

The ice making process is quite similar to the one we observe in a domestic refrigerator. The only difference lies in the ice making the stage. In the freezer compartment, the **tray with water when it comes in contact with very low-temperature environment, becomes ice** but in an **ice plant which is a huge commercial factory, it uses separate ice making or ice freezing circuit**.

The cold is produced in one circuit and it is transferred to the water cans by another circuit.

1. Ammonia: It is the primary refrigerant which takes heat from brine. This ammonia changes phase while moving in the circuit.
2. Brine: It is the secondary refrigerant which takes heat from the water and produces ice.

There are three main circuits of working medium in ice plant:

Refrigeration circuit: Ammonia as working medium which actually produces the cold by changes its phase at different location

Cooling water circuit: Cooling water as working medium to remove the heat of condenser

Brine circuit: Brine solution as working medium which transfers the cold from ammonia to water filled cans where ice is to be formed.

Construction

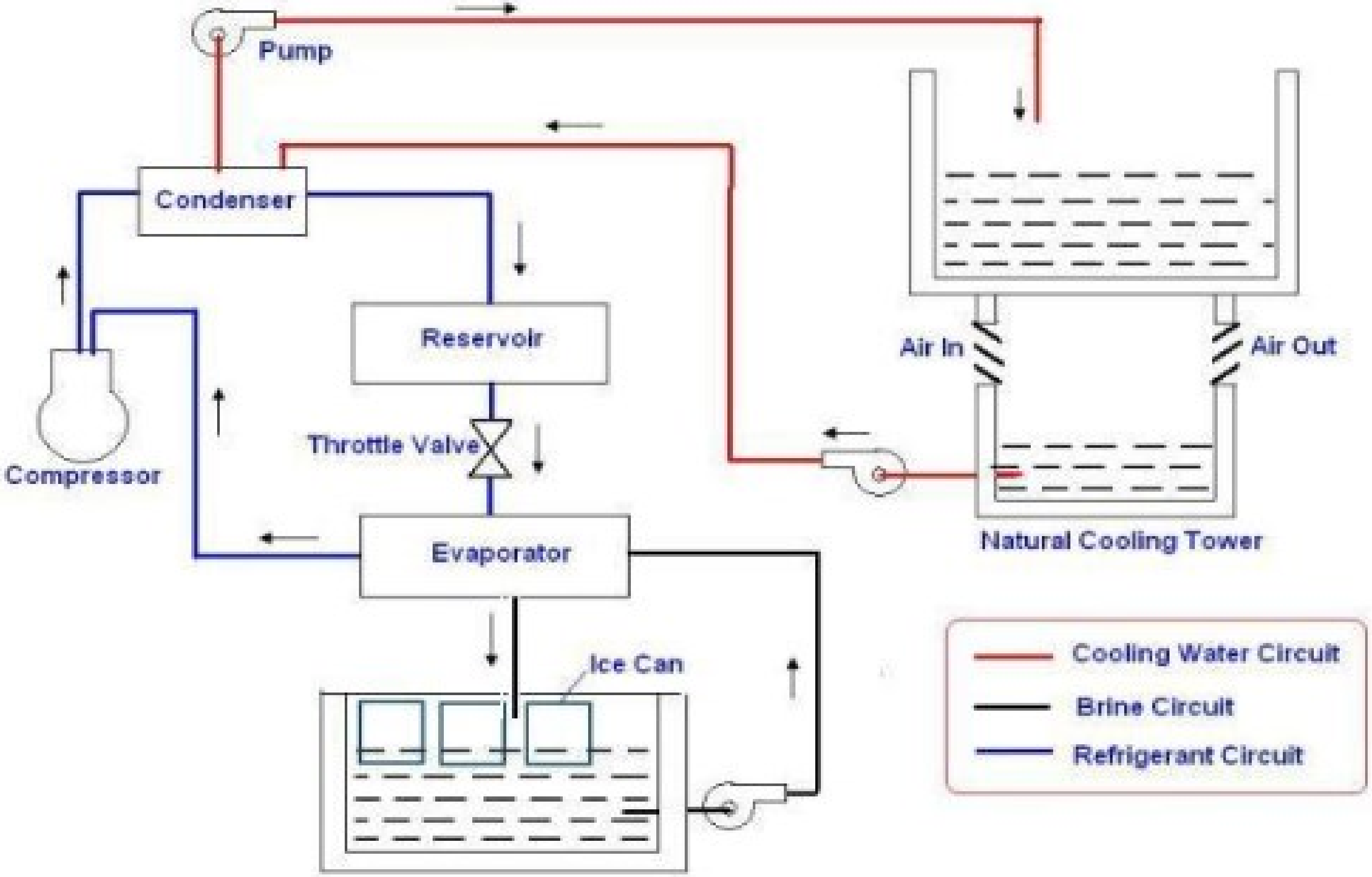
Compressor: Its function is to increase the temperature and pressure of Ammonia vapor coming out from evaporator.

Condenser: It liquefies the high-pressure and high-temperature Ammonia to high-pressure and high-temperature Ammonia. Here chilled water comes in contact with the high-pressure and high-temperature ammonia and provides the temperature for condensation. The heated water is pumped and again taken to circuit after it has been cooled at natural cooling tower

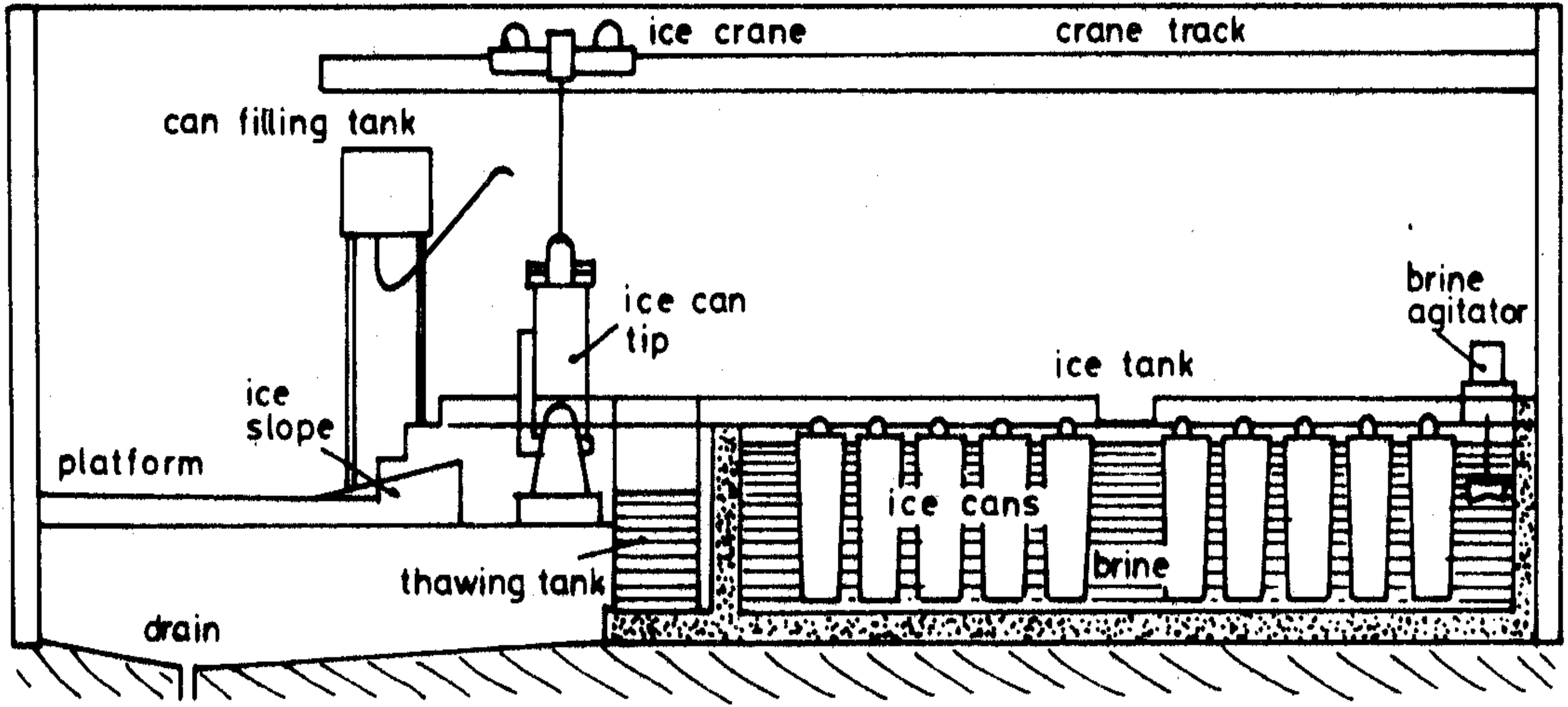
Receiver: It is used to collect the liquid Ammonia from the condenser.

Throttle Valve: It expands Ammonia coming out from receiver to low pressure.

Evaporator: It vaporize the liquid Ammonia from throttle valve by extracting heat from 'brine' and hence brine gets cooled and this brine solution is recirculated to water tank containing 'ice cans filled with water' to absorb the heat of water to freeze it and make ice.



Pump
Condenser
Reservoir
Throttle Valve
Compressor
Evaporator
Ice Can
Air In
Air Out
Natural Cooling Tower
Cooling Water Circuit
Brine Circuit
Refrigerant Circuit

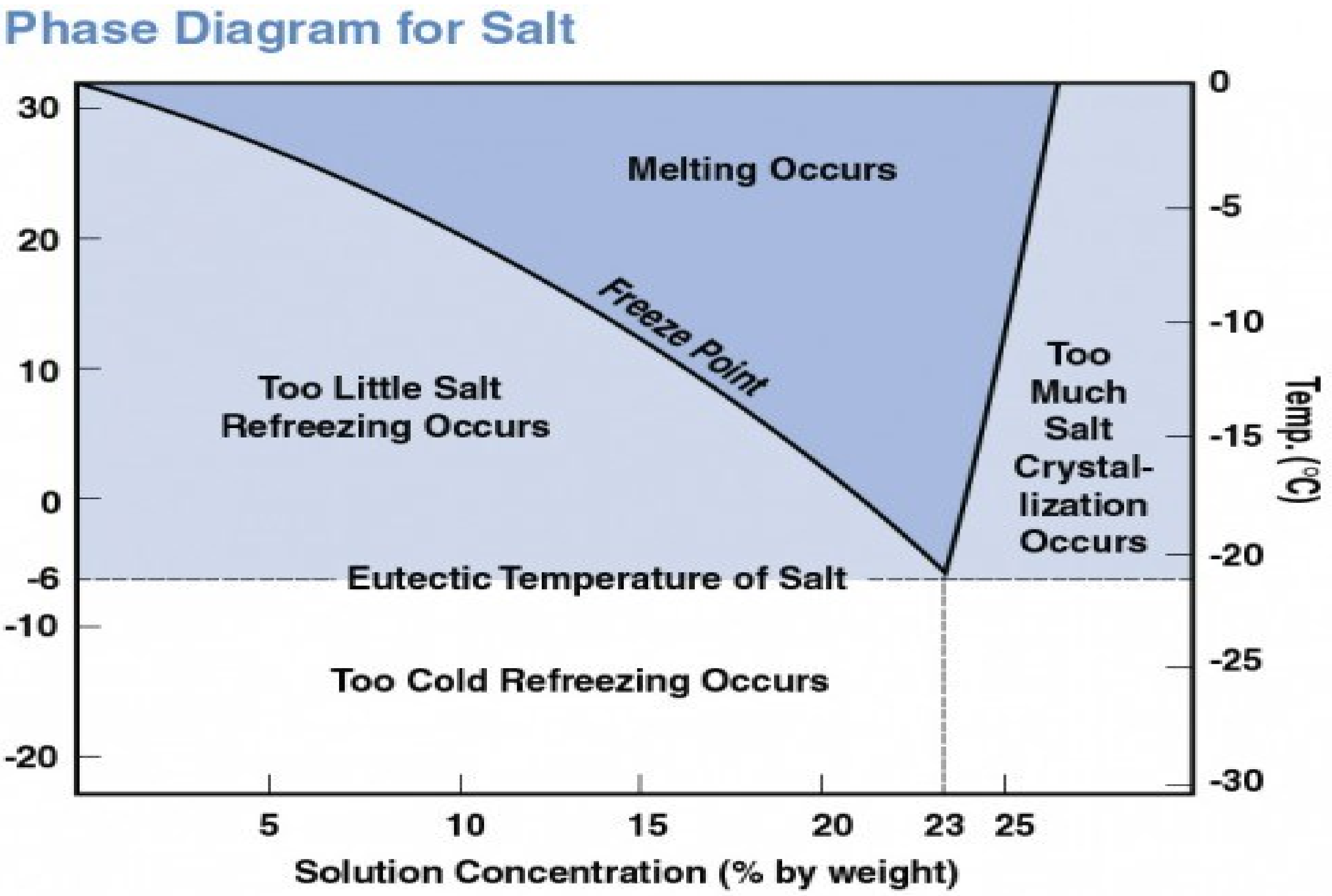

ice crane
crane track
can filling tank
ice can
tip
brine
agitator
ice tank
ice
slope
platform
ice cans
brine
thawing tank
drain

Brines

Brine is a solution of salt in water. Salt content can vary, but brine includes salt solutions ranging from about **3.5% (typical concentration of seawater) up to about 26% (a typical saturated solution, depending on temperature).**

Brine is commonly used in large refrigeration installations for the **transport of thermal energy from place to place**.

In colder temperatures, brine can be used to de-ice or reduce freezing temperatures on roads. In cooking, brine is used for food brining and salting.


Phase Diagram for Salt
Melting Occurs
Freeze Point
Too Little Salt Refreezing Occurs
Too Much Salt Crystal-lization Occurs
Eutectic Temperature of Salt
Too Cold Refreezing Occurs
30
20
10
0
-6
-10
-20
0
-5
-10
-15
-20
-25
-30
Temp. (°C)
5
10
15
20
23
25
Solution Concentration (% by weight)

Brines

Brine is a concentrated solution of salt in water. It can be any solution of a salt in water e.g., potassium chloride brine. Natural brines occur underground, in salt lakes, or as seawater and are commercially important sources of salts, such as chlorides and sulfates of magnesium and potassium.

Brine can be used in:

1. Preservation of food
2. Heat transfer
3. Vapor absorption

At 212°F (100°C), saturated sodium chloride brine is about **28% salt by weight, whereas at 0°C (32°F), brine can only hold about 26% salt.** The thermal conductivity decreases with increasing salinity and increases with increasing temperature.

Brine solution is used as a cooling medium in steel heat exchangers. This can cause corrosion, which can be reduced by reducing temperature, changing the composition of brine and removing dissolved oxygen from brine.

Brine is known to corrode stainless steel, as is bleach. A strong brine, such as calcium chloride, is highly aggressive toward metals and alloys. Corrosion rates in brine solutions are higher than those in distilled water, while the rate and nature of the attack vary from one material to another.

Brine Tanks

Brine tanks are usually fabricated with 6mm Mild steel sheet with tie rods welded end to end.

The depth of the tank is such that brine level is around 25 mm higher than the water level in the cans.

The **tanks is well insulated from the four sides and from the bottom.**

The insulated wooden lids are provided to cover the top segments, to facilitate the removal or replacing the cans.

The brine temperature is maintained by the plant from **-10 to -11^{o} C**

The ice of the water frozen below **-12^{o} C can crack therefore brine temperature are kept higher**.

Ice cans

The ice- cans are fabricated from **galvanized steel sheets and are given chromium** treatment to prevent corrosion due to chemical reactions.

It also prevents corrosion from **reaction with ammonia** in case of leaks from the system.

Water in the ice cans cools rapidly to temperature **of 3-4^{o} C but takes much more time to reach 0^{o} C**

The rate of freezing decreases substantially as the thickness of ice layer increases. This is due to the higher resistance offered by the ice layer to heat flow from brine to water.

Ice Types

Block ice

The traditional block ice maker forms the ice in cans which are submerged in a tank containing circulating **sodium or calcium chloride brine.**

The dimensions of the can and the temperature of the brine are usually selected to give a freezing period of between **8 and 24 hours.**

Too rapid freezing results in brittle ice. The block weight can vary from **12 to 150 kg**, depending on requirements; 150 kg is considered the largest size of block one man can conveniently handle. The thicker the block the longer the freezing time.

Ice Types

Blocks less than 150 mm thick are easily broken and a thickness of **150 to 170 mm is preferable to prevent the block toppling**. The size of the tank required is related to the daily production.

A travelling crane lifts a row of cans and transports them to a thawing tank at the end of the freezing tank, where they are submerged in water to release the ice from the moulds.

The cans are tipped to remove the blocks, refilled with fresh water and replaced in the brine tank for a further cycle. This type of plant often requires continuous attention. **A shift system is operated by the labour force - 10 to 15 workers for a 100 t/day plant**. Block ice plants require a **good deal of space and labour for handling the ice.**

The latter factor has been the main reason for the development of modern automatic ice-making equipment (flake and tube ice). Compared to other types of ice plants, block ice plants are more prone to producing contaminated ice if high hygiene standards are not scrupulously observed at all times.

Ice Types

Block ice still has a use, and sometimes an advantage, over other forms of ice in tropical countries. **Storage, handling and transport can all be simplified if the ice is in the form of large blocks**; simplification is often obligatory in small-scale fisheries and in relatively remote situations. With an appropriate ice-crushing machine, block ice can be reduced to any particle size but the **uniformity of size will not be as good as that achieved with some other forms of ice**. In some situations, block ice may also be reduced in size by a manual crushing method.

Flake ice

This type of machine forms ice 2 to 3 mm thick on the surface of a cooled cylinder and the ice is harvested as **dry subcooled flakes usually 100 to 1,000 mm^2 in area.**

In some models, the cylinder or **drum rotates and the scraper on the outer surface remains stationary**. In others, the **scraper rotates and removes the ice from the surface of a stationary drum**.

One distinct advantage of the rotating drum method is that the ice-forming surfaces and the ice release mechanism are exposed and the operator can observe whether the plant is operating satisfactorily.

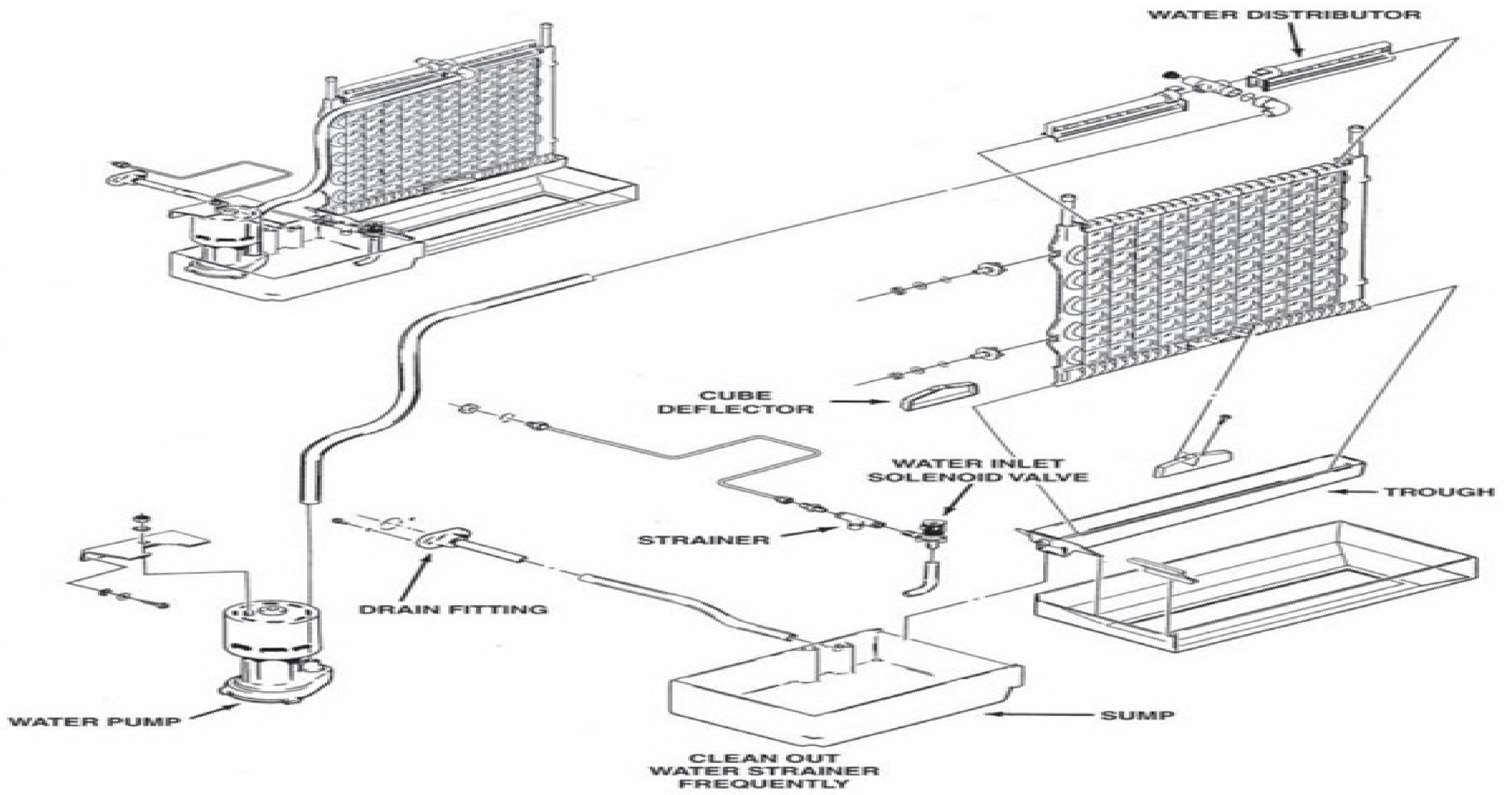
The flakes are usually either bagged directly in plastic bags and stored in a chiller or collected and stored in an automated bin or silo.

Human contact with the ice is minimal. The range of unit sizes for this type of machine now extends from units with a capacity of **0.5 to 60 Tons/24 h**.

Tube Ice

- Tube ice is formed on the inner surface of vertical tubes and is produced in the form of small hollow cylinders of about 50 x 50 mm with a wall thickness of 10 to 12 mm.
- The tube ice plant arrangement is similar to a shell and tube condenser with the water on the inside of the tubes and the refrigerant filling the space between the tubes.
- The machine is operated automatically on a time cycle, and the tubes of ice are released by a hot gas defrost process.
- As the ice drops from the tubes a cutter chops the ice into suitable lengths, nominally 50 mm, but this is adjustable.
- Transport of the ice to the storage area is usually automatic. Thus, as in the flake ice plant, the harvesting and storage operations require no manual effort or operator attendance.
- Tube ice is usually stored in the form it is harvested, but the particle size is rather large and unsuitable for use with fish.

Ice cube making machine



Water treatment for better ice quality

- when a sheet of water is frozen, it should be hard, allowing water applications to freeze quickly, leaving little snow development.
- Both ground sourced and municipally treated waters can contain dissolved minerals, organic matter or the ultimate enemy of ice, "air."
- Ice quality will differ in all parts, depending on the water source. Applying "hard" water or "soft" water will create two completely different styles of ice, which will perform differently under all conditions.
- By understanding the properties of water, the icemaker will be adequately prepared to clarify user concerns on ice consistency.

Water treatment for better ice quality

For good ice making, there are three general types of water contamination that must be considered:

- Organic matter
- Dissolved minerals
- Air

Rainwater will provide a hard durable sheet of ice whereas surface or well waters produce entirely different sheets of ice, due to mineral content. The actual kind of mineral content is vital to ice performance.

Water is one of the few liquids that are lighter as a solid than as a liquid. This is due to a slight reduction in the degree of hydrogen bonding which holds its molecules together.

Any further reduction in this bonding will degrade the ice.

Highly mineralized water or some free alkalinity will contribute to this and coupled with a “salting out” effect will create a lower density or “slower” ice.

When raw water is freshly applied during the resurfacing process, the heat flow travels from the top down. During the ice resurfacing process, the film on the surface is the last to freeze, thus trapping the entire mineral content directly at the top of the air/ice surface. The effect is a lack of hydrogen bonding and in extreme instances, the dispersion of mineral salts is so concentrated that sometimes a white powder forms.

As the season progresses the skating surface becomes more alkaline and its freezing point will continue to drop.

High pH levels cause a freezing rate to slow, which in turn creates a poor ice surface. "Alkaline results in poor ice"…the higher the sodium content the more evident this becomes

Water Treatment

A pH level below 7.0 is strongly recommended for a quality ice surface.

Water treatment methods are well standardized and each has its own advantages if it is properly used for the intended application in question.

The quality of the water affects energy consumption and ice quality. Water contaminants, such as minerals, organic matter, and dissolved air, can affect both the freezing temperature and the ice thickness necessary to provide satisfactory ice conditions.

Proprietary treatment systems for arena flood water are available. When these treatments are properly applied, they reduce or eliminate the effects of contaminants and improve ice conditions. .

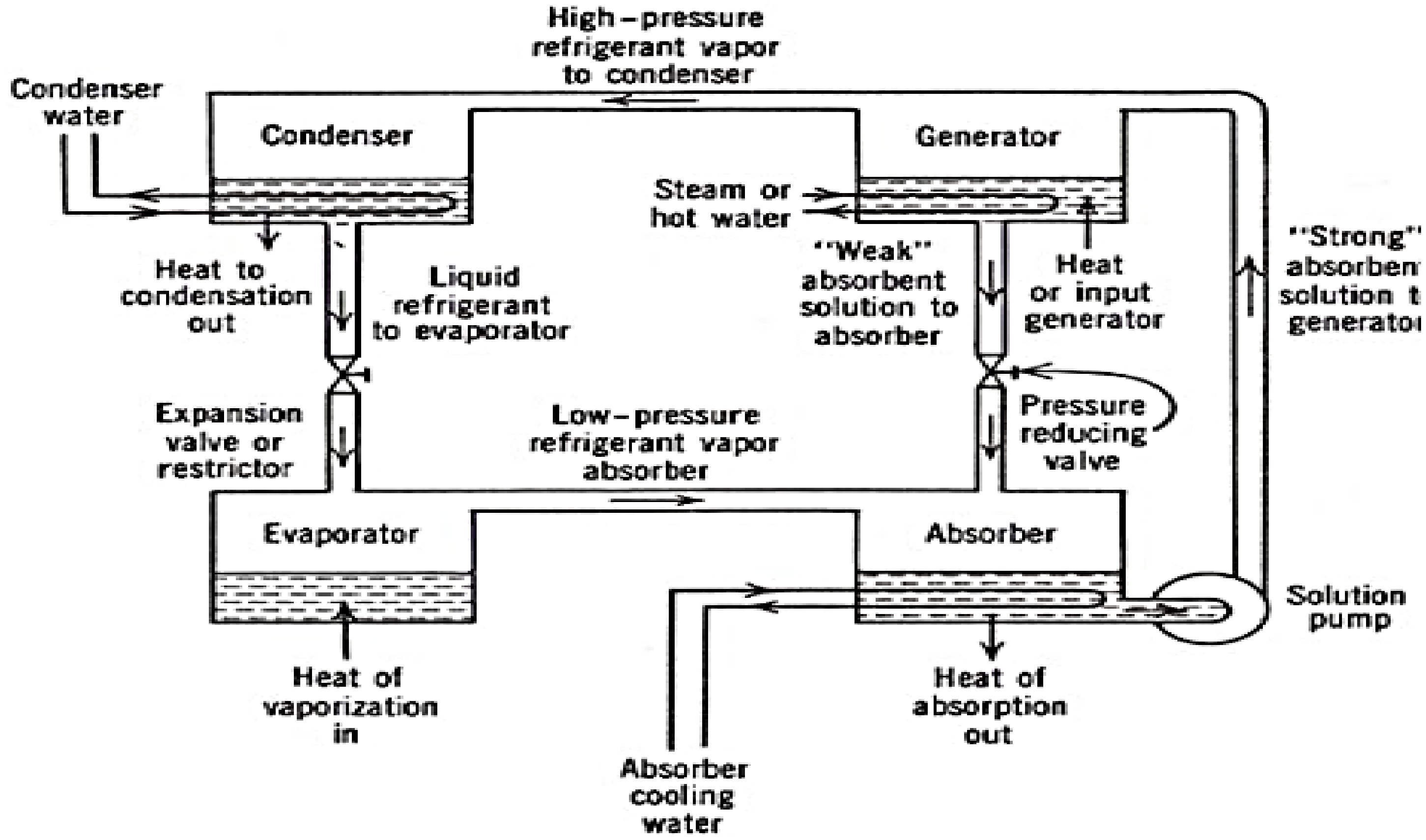
Vapour Absorption Refrigeration System (VARS)

The vapor absorption refrigeration system comprises of all the processes in the vapor compression refrigeration system like compression, condensation, expansion and evaporation.

In the vapor absorption system the refrigerant used is ammonia, water or lithium bromide.

The refrigerant gets condensed in the condenser and it gets evaporated in the evaporator. The refrigerant produces cooling effect in the evaporator and releases the heat to the atmosphere via the condenser.

Vapour Absorption Refrigeration System (VARS)



Components of VARS

Condenser: Just like in the traditional condenser of the vapor compression cycle, the refrigerant enters the condenser at high pressure and temperature and gets condensed. The condenser is of water cooled type.

Expansion valve or restriction: When the refrigerant passes through the expansion valve, its pressure and temperature reduces suddenly. This refrigerant (ammonia in this case) then enters the evaporator.

Evaporator: The refrigerant at very low pressure and temperature enters the evaporator and produces the cooling effect. In the vapor absorption cycle, this refrigerant flows to the absorber that acts as the suction part of the refrigeration cycle.

Pump: When the absorbent absorbs the refrigerant strong solution of refrigerant-absorbent (ammonia-water) is formed. This solution is pumped by the pump at high pressure to the generator. Thus pump increases the pressure of the solution to about 10bar

Absorber: The absorber is a sort of vessel consisting of water that acts as the absorbent, and the previous absorbed refrigerant. Thus the absorber consists of the weak solution of the refrigerant (ammonia in this case) and absorbent (water in this case).

When ammonia from the evaporator enters the absorber, it is absorbed by the absorbent due to which the pressure inside the absorber reduces further leading to more flow of the refrigerant from the evaporator to the absorber.

At high temperature water absorbs lesser ammonia, hence it is cooled by the external coolant to increase it ammonia absorption capacity.

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Generator: The refrigerant-ammonia solution in the generator is heated by the external source of heat. This is can be steam, hot water or any other suitable source. Due to heating the temperature of the solution increases.

The refrigerant in the solution gets vaporized and it leaves the solution at high pressure. The high pressure and the high temperature refrigerant then enters the condenser, where it is cooled by the coolant, and it then enters the expansion valve and then finally into the evaporator where it produces the cooling effect. This refrigerant is then again absorbed by the weak solution in the absorber.

When the vaporized refrigerant leaves the generator weak solution is left in it. This solution enters the pressure reducing valve and then back to the absorber, where it is ready to absorb fresh refrigerant. In this way, the refrigerant keeps on repeating the cycle.

The pressure of the refrigerant is increased in the generator, hence it is considered to be equivalent to the compression part of the compressor.

VCRS	VARS
Using high-grade energy like mechanical work.	Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc.
Moving parts are in the compressor. Therefore, more wear, tear and noise.	Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth
The COP decreases considerably with decrease in evaporator pressure.	The system can work on lower evaporator pressures also without affecting the COP.
Performance is adversely affected at partial loads.	No effect of reducing the load on performance.
Liquid traces in suction line may damage the compressor.	Liquid traces of refrigerant present in piping at the exit of evaporator constitute no danger
It is difficult.	Automatic operation for controlling the capacity is easy.