Design of a 100 Ton Ice Plant

A Project Study

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DEDICATION

We would like to dedicate this project to our families, our parents, brothers and sisters for their unconditional love and support to us that made us who we are now, what we have accomplished, and in the completion of this project. We would also like to dedicate this project to our classmates for providing moral support and unwavering team work, our teachers, especially our mentor, Eng. Sheila May Escobar for the guidance and knowledge she has provided us, all these without, might not lead us to the completion of this study. And last but definitely not the least, to the Almighty God, to whom we are deeply indebted, for His unfaltering love and guidance we have encountered from the start to the completion of this project, every step of the way.

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And lastly, to our Almighty God, who untiringly gives us the strength and wisdom, all these without, this project would not be possible.

ABSTRACT

This design study is for an ice plant with a capacity of 100 tons of ice per day. The type of ice to be produced is block ice with a mass of 50 kg per block. The design is divided into two (2) separate system of refrigeration for easy maintenance if ever one system breaks down. The decision of separation is economically ideal for, if one system breaks down, the other system will continue to run and the plant will still be in operation.

Summing up, the design will use four (4) freezing tanks (two freezing tank per system), each 12.210 meters in length, 5.18 meters in width, and 1.6 meters in height; eight (8) brine agitators (2 for each tank) each with 1 hp motor power; two (2) water-jacketed compressors (1 for each system) each with 160 hp motor power; two (2) shell and tube condensers (1 for each system) having a length of 4 m and a diameter of 0.8359 m; two (2) cooling towers; one (1) day tank with a 150 m^3 capacity; one (1) deep well water pump with a 1.5 hp power; two (2) expansion valves; water pumps and gate valves. This system uses ammonia as a refrigerant.

The ice plant has a 1576.5 m^2 floor area. The plant's potential location site is at J.Pitong Ledesma St., near Malisbog River, Silay City, Negros Occidental.

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Chapter 1: Introduction

Background of the Study

It has been widely observed that today's environment is drastically changing. The world's ecological aspect has been through the extremes of everything; climate shifts, sea and land level changes, be it rock bottom or high altitudes. And as the summer in our Earth's region is rapidly approaching, the quenching heat is becoming a household name.

In our tropical country, people have different ways of coping up, trying to live with the summer heat: they go to resorts and beaches, going to the highlands and the mountains where the wind and atmosphere is undeniably cooler compared to the down town. But most of the people would rather stay in their homes and have a nice cup of refresher. People tend to stick on drinking their cooled water, thirst quenchers, and anything potable and drinkable with ice cubes, to top that. And with this, the increase in number of people owning their own chillers and coolers is highly observable. But this does not mean you can bring this anywhere you go, you will likely to buy ice blocks to chill your drinks.

This introduces us to the industry of ice making. The hotter the temperature, the hotter the ice making business is. More buyers will seek the comfort of chilled water as the heat increases. Ice blocks are more convenient and faster to cool a drink than to put it on the fridge and wait for it to cool.

Negros Occidental, sure, is not the most populated area in the Philippines but it is one of the crowded and busiest place in the country, following the big cities of Manila, Cebu and Davao . Infrastructures from left to right and busy people occupies the street day and night that can cause people dizziness, vertigo, melt-down, dehydration and other heat-related seasonal ailments.

These factors show the huge demand of ice blocks in the island, specifically on the City of Silay, being a community of a considerably high population and number of food and beverage establishments. As a city of such attributes, a need for a central ice making center is rational and these implicates the demand of the ice making business in the area.

Objectives of the Study

This project study generally aims to design an 100-ton ice plant for the City of Silay to meet the economical and industrial demands of the town and its neighboring cities.

Specifically, this project study also targets to fulfill the following goals:

1. To produce ice blocks that are of good quality at a reasonable price.
2. To meet the demands not only of the City of Silay, but also the neighboring cities of Victorias and Talisay.
3. To provide service that will be of reach to the industries and markets of the city, since the plant is planned to be situated at an economical and community-friendly distance from the city proper.
4. To provide employment to the under-privileged members of the community.

Scope of the Study

This project study is an Ice plant design with a 100 tons of ice per day capacity only. The plant will be located at the City of Silay. This is an ideal location to achieve the objective of this project, to provide ice blocks to the area and to the adjacent communities. The ice plant is only capable to produce an approximate weight of 50 kilograms per ice block.

Chapter 2: Review of Related Literature

The Refrigeration System

Most modern icemakers are designed to work unattended 24 hours a day with only routine inspection and maintenance. The system is therefore designed for reliability, with safeguards against failure or malfunction. Most manufacturers recommend the refrigeration system best suited to their icemakers, but where local installation engineers propose a system, the purchaser should ensure that the contractor is aware of the need for continuous automatic running and for rapid repair after breakdown.

The refrigeration system for an icemaker should be independent of any other refrigeration requirement; it should not be shared for example with a freezer or a cold store. The only exception to this rule is when a complex system is installed and a competent engineer is in fulltime attendance. Manufacturers often recommend a separate system for each icemaking unit, so that in a multiple unit installation there is considerable flexibility, and a reasonable guarantee that at least some of the units are always in production. Choice of refrigeration machinery and of refrigerant is a job for the refrigeration expert, and the advice of the ice plant manufacturer or competent consultant should be sought before making any decision.

Storage of Ice

Manufacture of ice can seldom be matched to meet immediate demand; therefore storage is necessary to cater for peak demand and to allow the icemaker to be operated continuously. Storage also acts as a buffer against interruption of production due to breakdown or routine maintenance.

The size of store required will depend on the pattern of operation, but it is never advisable to store less than 2 days' production, and in most installations it is useful to be able to store 4-5 times the daily production.

Stowage rates vary with the kind of ice being made, and Table 3 gives the storage space required for the principal types.

Table 3 *Storage space for ice*

type of ice	**space m/tonne**
flake	22-23
plate	17-18
tube	16-20
crushed	14-15
block	

The type of ice storage may range from a simple insulated bin to a large refrigerated silo or bin with automatic loading, unloading and weighing of ice.

Silo Storage

Silos are generally used only for freeflowing subcooled ice, such as flake ice, and an independent refrigeration system for the silo is essential to keep the ice sub-cooled in storage.

It is usual to provide an air cooler to refrigerate the jacket space between the inner lining of the silo and the outer insulated structure; typically the air cooler is located next to the icemaker on top of the silo, and cold air either falls by gravity into the jacket or is circulated by fan.

Ice is removed from the bottom of the silo, gravity flow being assisted by an agitator, usually a rotating chain; this means the oldest ice is always used first. Ice adhering to the silo wall needs to be freed periodically; otherwise this wall of ice becomes permanent, and only the central core of ice in the silo remains freeflowing.

Silo storage is expensive for small amounts of ice; units have been made to hold as little as 10 tonnes, but silos are best suited for storing 40-100 t.

Bin storage

Bins can be used to store any kind of fragmented ice, and may be of any size from a simple box to hold 1/2 tonne to an installation holding 1000 t or more. Refrigeration of the bin is not always essential but, whatever the size, adequate insulation is necessary to reduce meltage; 100-150 mm of cork, or an equivalent thickness in many other suitable insulating materials, should be used.

A simple bin system is suitable for factories making ice for their own use. The icemaker can be mounted above the bin, so that ice flows by gravity to a take off point at the bottom of the bin; thus the oldest ice is used first. Where ice has to be distributed to customers, bins with a capacity of up to 50 tonnes can be made with a sloping floor and so mounted that rapid discharge direct to lorry or conveyor is possible. Some means of access to the bin is advisable in order to be able to dislodge any compacted ice.

Key:

1. Ice makers.
2. Concrete or steel silo
3. Agitator with chain
4. Sliding hatch.
5. Screw conveyor
6. Ice discharge.
7. Jacket cooler unit.

Depth of ice storage in a bin is limited to about 5 m to avoid fusion of ice under pressure; therefore large bins occupy considerable floor space, and usually require some mechanical means of unloading. Rakes, mechanical shovels and movable screw conveyors have all been used to remove ice from large bins. Rakes and shovels normally remove the topmost layer of ice in the bin, leaving older ice untouched at the bottom. It is therefore necessary to clear the bin periodically to remove all the old ice. Screw conveyors work at the bottom of a bin and remove oldest ice first, but an additional mechanism is required to distribute ice uniformly throughout the bin, and the screw drive takes up some space outside the bin area.

Block ice storage

Block ice can be crushed and stored in the same way as other fragmented ice, but it is more usual to store the blocks and crush them as required before delivery of the ice. Because of their weight and shape it is difficult to store blocks other than in a single layer; thus a considerable floor area is required. However there is usually some extra storage available in the icemaker itself, since all of the ice cans are normally kept full.

Handling, Conveying and Weighing

Icemakers located directly above the store feed the ice by gravity. Where an ice-maker produces wet ice, it is advisable to drain off excess water before storing it; this is normally done on a conveyor between icemaker and store. Large bins require some means of distributing ice evenly throughout the storage space; silos and small bins do not require such an arrangement.

Both dished belt and screw conveyors are used extensively for transporting ice. Screws allow both horizontal and vertical movement, but can operate only over a limited distance. Belts are generally used for long hauls, and special ribbed belts can be used on an incline. Delivery into lorry or fishing vessel is by means of a chute that can be moved to distribute the ice evenly.

Pneumatic systems have been used for moving ice, but the method is unsuitable for ice that is to be stored again. The energy used in moving the ice is dissipated as heat which can cause some meltage, and more heat is transferred to the ice from the blown air, unless the air is precooled. In addition the ice is broken down into smaller particles by impact on the duct walls, so that a proportion of the ice at the delivery point appears as wet snow that cannot be stored, for example in a trawler fishroom. The use of pneumatic systems should therefore be confined to distributing ice to the point of use, for instance into fish boxes.

Ice can be weighed automatically on a conveyor belt to within 卤 2 per cent. Elsewhere ice is usually measured by volume, the contents of a standard container having been weighed to determine the density. Weight of crushed block ice supplied is checked by counting the number of blocks delivered to the crusher.

Making Ice at Sea

A number of icemakers arc suitable, with little modification, for use with either fresh or salt water at sea.

Many factory vessels carry icemakers because it would be impracticable to store on board sufficient ice from a shore plant to meet their needs throughout a long voyage. Other vessels carry icemakers where a permanent shore plant would be uneconomic, perhaps because of the seasonal nature of the fishery. Yet other vessels make their own ice because of difficulty and delay in obtaining a regular supply from the port ice plant. But although there are a number of valid reasons for considering manufacture of ice at sea, the prospective owner of shipborne ice plant should bear the following points in mind.

It is rarely possible to match production to demand; therefore some ice storage is still required, and the amount of valuable ship space occupied by the ice plant and the store should be carefully worked out.

There is sometimes insufficient spare power available on board for making ice, and space may have to be found for an additional generator; 30-35 kW would be required for an ice plant producing 6 tonnes of ice in 24 hours, a production rate that would be reasonable for many boats making weekly trips.

The cost of making ice at sea can be higher than the price of ice ashore. A vessel owner who opts for making his own ice at sea may not always be able to draw quickly on a shore supply when his own equipment fails. Subsequent delays may be just as frustrating as those incurred in queucing at the shore plant. Seawater ice is somewhat less suitable than freshwater ice for storing fish, and some ice plant manufacturers now offer desalinators to produce fresh water for making ice on board. Although cheap to operate, more space is again required. Finally, water for ice manufacture cannot be taken from a dock or from inshore areas that might be contaminated.

Cost of Ice Plant

It is impossible to generalize about cost of ice plant, since so much depends on local conditions. When a new installation is being planned, it may be necessary to take into account cost of land, buildings, roads, electrical and water supplies, drainage and so on as well as the cost of the icemaking and storage equipment. Annual fixed costs are likely to include depreciation, maintenance, interest on capital, tax, insurance and other overheads, while the main operating costs will include power, labour, water and possibly transport.

Cost estimating at an early stage may well influence the choice of plant size, since many of the costs are largely independent of size, and it may prove more economic for the plant operator to make more than he needs himself and become a supplier.

Maintenance cost may be of great importance in remote areas; although modern plants operate with minimum attention, regular professional maintenance is necessary. Direct comparison of capital and running cost of different types or makes of ice plant is not possible except on so general a basis as to be of little value to a prospective purchaser; each particular project has to be costed individually, using current prices.

Ordering Ice Plant

The more information the prospective buyer gives about local conditions and requirements, the easier it is for manufacturers to submit comparable tenders for the equipment. Initial planning may have enabled the buyer to make some decisions about the type of ice required, location of plant, building layout and so on, and the following check list indicates the kind of information the prospective customer should make available to the manufacturer or supplier.

Type of ice required, intended use, and production rate.
Ice make-up water: temperature, mains pressure, purity and so on.
Cooling water: details of supply if from a separate source.
Electrical supply.
Ice storage capacity required: type required, space available, and ancillary handling equipment needed.
Sketch of site with preferred layout.

**Source: www.fao.org/wairdocs/tan/x5940e/x5940e01.htmA*

Planning for Ice Plants

The first step in planning is to confirm whether an ice plant is actually required. Other ice plants in the area may be a reliable source of suitable ice and, even with the additional transport costs and the manufacturer's profit, they may be able to supply ice cheaper than it can be made by the user. A large installation has many economic advantages over a small unit and it is not unreasonable to expect that it can produce cheaper ice. Other factors, such as being self sufficient, may over-ride an economic disadvantage.

The most important stage in planning is to consider the site of the ice plant, both in relation to the services required for the manufacture of the ice and, to the ease of distribution to the consumer. Ice plants require a power source, and suitable water supplies for both ice manufacture and refrigeration plant condenser cooling. In addition, some plants require a further supply of water for defrosting purposes. The cost of transporting ice is substantial, particularly in heavy traffic areas, and may be the biggest cost to the consumer. Ice plant should therefore be located where the ice is required, or sited to keep transport requirements to a minimum. Advice on layout is usually given by the manufacturer, but this information is only applicable to the type of plant he supplies. For instance, traditional block ice plants require a much larger floor space than modern automatic ice makers. Other ice makers, like the tube ice machine, require a good deal of headroom and are seldom located above the ice storage space, whereas with flake ice machines this arrangement is usual. Silo storage also requires a relatively high building structure, whereas large storage bins need plenty of floor space because of limitations on the storage depth. Space and building height limitations should therefore be considered at an early stage of planning, since any restrictions may preclude the use of some types of plant. For instance, on some sites tall buildings are undesirable for aesthetic reasons.

Classification of Ice Plants

The term ice plant is used in this note to mean a complete installation for the production and storage of ice, including the ice maker itself, that is the unit that converts water into ice together with the associated refrigeration machinery, harvesting and storage equipment, and the building.

Ice plants are usually classified by the type of ice they produce; hence there are block ice plants, flake ice plants, tube, slice or plate ice plants and so on. Ice plants may be further subdivided into those that make dry or wet ice. Dry ice here means ice at a temperature low enough to prevent the particles becoming moist; the term does not refer in this note to solid carbon dioxide. In general, dry sub-cooled ice is made in plants that mechanically remove the ice from the cooling surface; most flake ice plants are of this type. When the cooling surface of an ice maker is warmed by a defrost mechanism to release the ice, the surface of the ice is wet and, unless the ice is then sub-cooled below 0C, remains wet in storage; tube ice and plate ice plants are of this type.

Types of Ice maker

Block ice

Tapered rectangular metal cans filled with water are immersed in a tank containing refrigerated sodium chloride brine. The dimensions of the can and the temperature of the brine are usually selected to give a 24 hour production time, and batches of cans are emptied and refilled in sequence during that period. Ice block weight can range from 12 to 150 kg depending on requirements; 150 kg is regarded as the largest size of block one man can conveniently handle. A block ice plant requires continuous attention and is labour intensive. The icemaker and the store require a good deal of floor space and impose heavy loads on the building structure. For these reasons block ice plants are going out of use, and more modern automatic plants are replacing them.

Rapid block ice

It is possible to reduce the freezing time for blocks considerably, and thus reduce the space required for the icemaker. This is done by reducing the thickness of ice to be frozen; in one type of rapid icemaker this is achieved by passing refrigerant through tubes around which the ice forms and fuses into a block. The blocks can be released by defrosting and harvested automatically, thus markedly reducing the labour requirement, but the storage space required is slightly larger than for the same weight of conventional block ice because the blocks have hollow centres after the tubes are removed.

Flake ice

A sheet of ice 2-3 mm thick is formed by spraying water on the surface of a refrigerated drum, and scraping it off to form dry subcooled flakes, usually 100-1000 mm^2 in area. In some models the drum rotates against a stationary scraper on its outer surface; in others the scraper rotates and removes ice from the inner wall of a double walled stationary drum. In some models the drum is horizontal, but more usually it is mounted vertically. No water is sprayed on that part of the drum immediately before the scraper, so that the ice becomes dry and subcooled prior to removal.

Refrigerant temperature, drum or scraper speed, and degree of subcooling are all variable within designed limits so that the capacity of the icemaker and the thickness of the ice can be altered. Typical refrigerant temperature in a flake ice machine is - 20 to - 25*C, lower than in most other types of icemaker, to give rapid cooling and thus make the machine compact. The low operating temperature requires more power, but this is to some extent compensated for by the absence of a need to defrost.

Tube ice

Water is frozen on the inner surface of vertical refrigerated tubes to form hollow cylinders of ice about 50 mm in diameter and with walls 10-12 mm thick. The ice cylinders are released by defrosting the tubes automatically, and are chopped into pieces about 50 mm long by a rotating cutter as they slide out. The cylindrical pieces can be subcooled by storing them at - 5 掳 C, but they may require further crushing before being suitable for some applications in the fish industry.

Plate ice

Water is frozen on one face of a vertical refrigerated plate, and the sheet of ice is released by running warm water on the other face of the plate. The size of ice particle is variable, but the optimum thickness is 10-12 mm. The plates are usually mounted in banks, often above the refrigeration machinery, to form a self contained unit. Water for defrosting has to be heated if its temperature is below

23C. Like most other icemakers the plate ice machine will operate unattended on an automatic timing cycle.

Other icemakers

Machines are available that make ice by methods other than those described here, but the size of unit is usually small, producing at the most only a few hundred kilograms of ice a day; these are suitable for retail and catering services, but are unlikely to be of interest to those providing icemaking services to the catching and processing sectors of the fish industry.

Capacity of Ice Plants

Manufacturers usually quote a wide range of daily output for specific icemaker units, because their capacity can be affected by a number of factors, but this flexibility usually exists only at the planning stage; once the icemaker has been matched to suitable refrigeration machinery under given operating conditions, there is little scope for changing the capacity of the installed unit. Changes in demand are best catered for by reducing running time or by installing multiple units and operating only as many as arc needed.

Since the capacity of both the icemaker and the refrigeration machinery is lower in warmer weather, the size of the plant should be selected for warm weather operation, when demand for ice is also likely to be greatest.

Unit sizes

Most ice machine manufacturers produce a range of standard unit sizes. Since each unit has a variable capacity, depending on the operating conditions, it is usually possible to meet the requirements of each customer under the most favourable conditions.

Some manufacturers produce dual units in which the unit capacity range is apparently extended upwards. However, higher icemaking capacities are usually achieved by using multiple units which may operate with a centralised refrigeration plant or each ice maker may be a self contained unit. Since the system used will have a bearing on the service provided, the choice will depend on the operational requirements. For instance, if the demand for ice is widely variable a number of individual self contained units may be selected in order to accurately match supply and demand.

Ice Plant Requirements

Space

Modern icemakers arc compact in comparison with block ice equipment, but it is not always possible to compare directly the space occupied by different types; for example they may not be available in the same unit sizes. However some guidance on the space requirements for icemakers with a nominal capacity of 50 tonnes a day is given in Table 1; the figures are for icemakers only, and the space for refrigeration machinery, handling and storage will usually amount to far more than for the ice-maker.

Table 1 *Space required for an icemaker producing 50 t/day*

type of ice	floor area m^2	height m
block	190	50
rapid block	30	35
tube	33	66
flake	27	37

Power

Average power and peak power requirements may be different, and both have to be considered at the planning stage. The average power relates to the energy consumed in making a tonne of ice, and this is important in calculating operating cost. Peak power is important to the designer since it will determine what electrical supply is required, and may also affect operating cost if a peak demand factor is applicable.

The energy required to make a tonne of ice is not constant. It varies widely depending on a number of factors, the most important of which are

1. type of icemaker
2. operating temperature
3. make-up water temperature
4. cooling water temperature
5. air temperature
6. size of plant
7. utilization of plant
8. method of refrigeration

Energy consumption figures quoted by manufacturers for unspecified operating conditions should be used only as a general guide. The values given in table 2 show how energy requirements can increase considerably in warm climates.

Table 2 *Energy required to manufacture ice kWh/tonne*

type of ice	**temperate area**	**tropical area**
flake	50-60	70-85
tube	40-50	55-70
block	40-50	55-70

The values in Table 2 are for icemaker and refrigeration machinery only. Some additional allowance must be made for conveyors, crushers and other equipment.

Water

In addition to water for making ice, water may be required for cooling, as in a refrigeration plant condenser, or for heating, as in a warm water defrosting system.

The amount of water required for making ice is roughly equal to the amount of ice being produced plus some allowance for wastage and for prevention of build up of solids in the water circulating system.

Fresh water for making ice for use with fish must satisfy the requirements for drinking water. In addition, the chemical composition of water for making ice must meet the equipment manufacturers' requirements; hard water containing excessive amounts of solids may foul the icemaker and may also yield a soft wet ice. On the other hand pure water may cause problems, particularly in flake ice plants, because the ice sticks hard to the drum; the remedy is to fit a dosing device that puts 200-500 g salt into each tonne of water to improve release of the ice without making the ice detectably salty when used on fish.

It is inadvisable to use shell and tube condensers in a refrigeration system where cooling water is run to waste, unless a plentiful supply of cheap water is available, independent of the domestic drinking water supply; otherwise water costs may be prohibitive, since 15 tonnes of cooling water at 10 捞 C or 60 tonnes at 25 捞 C are required for each tonne of ice produced. Other factors can affect cooling water consumption, and manufacturers' precise figures should be used at the detailed planning stage.

Air cooled condensers can be used on small plants, but for most commercial installations evaporative condensers, or shell and tube condensers with a cooling tower, are more likely to be supplied. Evaporative condensers and cooling tower cooling systems normally use less than 1/2 tonne of water for each tonne of ice, plus some small additional allowance if an overspill is necessary to prevent build up of solids in the recirculated water.

Water for defrosting plate icemakers has to be of the same high quality as water for making ice. About 2 tonnes of water is required for each tonne of ice if the water is run to waste, but consumption can be reduced to almost nothing by making a closed circuit and reheating the water between defrosts.

REFRIGERANTS

Refrigerants are used in the process of refrigeration.Refrigeration is a process whereby heat is removed froma substance or a space.
A refrigerant is a substance that picks up latentheat when the substance evaporates from a liquid to a gas. This is done at a low temperature and pressure. A refrigerant expels latent heat when it condenses from a gas to a liquid at a high pressure and temperature. The refrigerant cools by absorbing heat in one place and discharging it in another area.

CLASSIFICATIONS
Class 1 refrigerants are used in the standard compression type of refrigeration systems. Class 2 refrigerants are used as immediate cooling agents between class 1 and the substance to be refrigerated. They do the same work for class 3. Class 3 refrigerants are used in the standard absorption-type systems of refrigerating systems.

Class 1. This class includes those refrigerants that cool by absorption or extraction of heat from the substances to be refrigerated by the absorption of their latent heats. Table 6-1 lists the characteristics of typical refrigerants.

Class 2. The refrigerants in this class are those that cool substances by absorbing their sensible heats. They are air, calcium-chloride brine, sodium-chloride (salt) brine, alcohol, and similar nonfreezing solutions.

Class 3. This group consists of solutions that contain absorbed vapors of liquefiable agents or refrigerating media. These solutions function through their ability to carry the liquefiable vapors. The vapors produce a cooling effect by the absorption of their latent heat. An example is aqua ammonia, which is a solution composed of distilled water and pure ammonia.

COMMON REFRIGERANTS

Sulfur Dioxide

Sulfur dioxide (SO_2) is a colorless gas or liquid. It is toxic, with a very pungent odor. When sulfur is burned in air, sulfur dioxide is formed. When sulfur dioxide combines with water it produces sulfuric and sulfurous acids. These acids are very corrosive to metal. They have an adverse effect on most materials. Sulfur dioxide is not considered a safe refrigerant.

Sulfur dioxide is not considered safe when used in large quantities. As a refrigerant, sulfur dioxide operates on a vacuum to give the temperatures required. Moisture in the air will be drawn into the system when a leak occurs. This means the metal parts will eventually corrode, causing the compressor to seize.

Sulfur dioxide (SO_2) boils at 14°F (−10°C) and has a heat of vaporization at boiling point (1 atmosphere) of 172.3 Btu/1b. It has a latent-heat value of 166 Btu/lb. To produce the same amount of refrigeration, sulfur dioxide requires about one-third more vapor than Freon and methyl chloride. This means the condensing unit has to operate at a higher speed or the compressor cylinders must be larger. Since sulfur dioxide does not mix well with oil, the suction line must be on a steady slant to the machine. Otherwise, the oil will trap out, constricting the suction line. This refrigerant is not feasible for use in some locations.

Methyl Chloride

Methyl chloride (CH_3Cl) has a boiling point of −10.6° F (−23.3°C). It also has heat of vaporization at boiling point (at l atmosphere) of 177.8 Btu/lb. It is a good refrigerant. However, because it will burn under some conditions, some cities will not allow it to be used. It is easy to liquefy and has a comparatively high latent-heat value. It does not corrode metal when in its dry state. However, in the presence of moisture it damages the compressor. A sticky black sludge is formed when excess moisture combines with the chemical. Methyl chloride mixes well with oil. It will operate on a positive pressure as low as −10°F (−23°C). The amount of vapor needed to cause discomfort in a person is in proportion to the following numbers:

Carbon dioxide -100
Methyl chloride -70
Ammonia -2
Sulfur dioxide -1

That means methyl chloride is 35 times safer than ammonia and 70 times safer than sulfur dioxide.

Methyl chloride is hard to detect with the nose or eyes. It does not produce irritating effects. Therefore, some manufacturers add a 1 percent amount of *acrolein*, a colorless liquid with a pungent odor, as a warning agent. It is produced by destructive distillation of fats.

Ammonia

Ammonia (NH3) is used most frequently in large industrial plants. Freezers for packing houses usually employ ammonia as a refrigerant. It is a gas with a very noticeable odor. Even a small leak can be detected with the nose. Its boiling point at normal atmospheric pressure is −28°F (−33°C). Its freezing point is −107.86°F (−77.7°C). It is very soluble in water. Large refrigeration capacity is possible with small machines. It has high latent heat [555 Btu at 18°F (−7.7°C)]. It can be used with steel fittings. Water-cooled units are commonly used to cool down the refrigerant. High pressures are used in the lines (125 to 200 lb/in.2). Anyone inside the refrigeration unit when it springs a leak is rapidly overcome by the fumes. Fresh air is necessary to reduce the toxic effects of ammonia fumes. Ammonia is combustible when combined with certain amounts of air (about one volume of ammonia to two volumes of air). It is even more combustible when combined with oxygen. It is very toxic. Heavy steel fittings are required since pressures of 125 to 200 lb/in.2 are common. The units must be water cooled.

Carbon Dioxide

Carbon dioxide (CO2) is a colorless gas at ordinary temperatures. It has a slight odor and an acid taste. Carbon dioxide is nonexplosive and nonflammable. It has a boiling point of 5°F (−15°C). A pressure of over 300 lb/in.2 is required to keep it from evaporation. To liquefy the gas, a condenser temperature of 80°F (26.6°C) and a pressure of approximately 1000 lb/in.2 are needed. Its critical temperature is 87.8°F (31°C). It is harmless to breathe except in extremely large concentrations. The lack of oxygen can cause suffocation under certain conditions of carbon dioxide concentration. Carbon dioxide is used aboard ships and in industrial installations. It is not used in household applications. The main advantage of using carbon dioxide for a refrigerant is that a small compressor can be used. The compressor is very small since a high pressure is required for the refrigerant. Carbon dioxide is, however, very inefficient, compared to other refrigerants. Thus, it is not used in household units.

Calcium Chloride

Calcium chloride (CaC12) is used only in commercial refrigeration plants. Calcium chloride is used as a simple carrying medium for refrigeration. Brine systems are used in large installations where there is danger of leakage. They are used also where the temperature fluctuates in the space to be refrigerated. Brine is cooled down by the direct expansion of the refrigerant. It is then pumped through the material or space to be cooled. Here, it absorbs sensible heat. Most modern plants operate with the brine at low temperature. This permits the use of less brine, less piping or smaller diameter pipe, and smaller pumps. It also lowers pumping costs. Instead of cooling a large volume of brine to a given temperature, the same number of refrigeration units is used to cool a smaller volume of brine to a lower temperature. This results in greater economy. The use of extremely low-freezing brine, such as calcium chloride, is desirable in the case of the shell-type cooler. Salt brine with a minimum possible freezing point of –6°F (−20.9°C) may solidify under excess vacuum on the cold side of the refrigerating unit. This can cause considerable damage and loss of operating time. There are some cases, in which the cooler has been ruined.

Ethyl Chloride

Ethyl chloride (C2H5Cl) is not commonly used in domestic refrigeration units. It is similar to methyl chloride in many ways. It has a boiling point of 55.6°F (13.1°C) at atmospheric pressure. Critical temperature is 360.5°F (182.5°C) at a pressure of 784 lb absolute. It is a colorless liquid or gas with a pungent ethereal odor and a sweetish taste. It is neutral toward all metals. This means that iron, copper, and even tin and lead can be used in the construction of the refrigeration unit. It does, however, soften all rubber compounds and gasket material. Thus, it is best to use only lead for gaskets.

FREON REFRIGERANTS

Freon 13 (CClF3) has a boiling point of −114.6°F (−81.4°C) and is used in low-temperature specialty applications using reciprocating compressors and generally in cascade with Freon 12, Freon 22, or Freon 522.

Freon 22 (CHClF2) has a boiling point of −41.4°F (−40.8°C) and is used in all types of household and commercial refrigeration and air-conditioning applications with reciprocating compressors. The outstanding thermodynamic properties of Freon 22 permit the use of smaller equipment than is possible with similar refrigerants. This makes it especially attractive for uses where size is a problem

Freon 113 (CCl2F.CClF2) has a boiling point of 117.6°F (47.6°C). It is used in commercial and industrial air conditioning and process water and brine cooling with centrifugal compression. It is especially useful in small-tonnage applications.

Freon 114 (CClF2.CClF2) has a boiling point of 38.8°F (3.8°C). It is used in small refrigeration systems with rotary-type compressors. It is used in large industrial process cooling and air-conditioning systems using multistage centrifugal compressors.

Freon 500 (CCl2F2/CH3CHF2) is an azeotropic mixture. *Azeotropic* means that a mixture is liquid, maintains a constant boiling point, and produces a vapor of the same composition as the mixture with CH3CHF2. It is composed of 73.8 percent Freon 12 (CC12F2) and 26.2 percent CH3CHF2. It boils at −28.3°F (−33.5°C). It is used in home and commercial air conditioning in small and medium-size equipment and in some refrigeration applications.

Freon 502 is an azeotropic mixture also. It consists of 48.8 percent of Freon 22 and 51.2 percent of Freon 115, by weight. It boils at −49.8°F (−45.4°C). With Freon 502, refrigeration capacity is greater than with Freon 22. Discharge temperatures are comparable to those found with Freon 12. Freon 502 is finding new applications in low and medium-temperature cabinets for the display and storage of foodstuffs, in food freezing, and in heat pumps.

Freon 503 is an azeotropic mixture of CHF3 and CClF3. The weight ratio is 40 percent CHF3 and 60 percent CClF3. The boiling point of this mixture is −127.6°F (−88.7°C). It is used in low-temperature
cascade systems.

Freon 13B1 (CBrF3) boils at −72°F (−57.8°C). It serves the temperature range between Freon 502 and Freon 13.

**Source: Air Conditioning and Refrigeration (Malestrom)*

Ice Plant Consists of Three Main Circuit:

1. **Refrigeration Circuit** - For ice making
2. **Cooling Circuit** - For cooling water used in condenser
3. **Brine Circuit** - For making ice from water inside cans

Compressors. The function of compressors is to compress the vapor refrigerant to high pressure to the boiling point so that vapor can be condensed at room temperature air or water.

Condenser. It condenses the high pressurized vapor refrigerant to liquid form by rejecting heat to atmosphere. This is the location where heat is released.

Reservoir/Receiver. It receives the liquid refrigerant coming out of condenser and reserves it.

Throttle Valve/Flow Control Valve. It controls the flow of liquid refrigerant and while passing through it, high pressure liquid refrigerant is converted into low pressure liquid so as to be vaporized at evaporator conditions.

Evaporator. It cools the refrigeration space by absorbing the heat from the stuffs to be cooled. The absorbed heat is used to convert low pressure liquid refrigerant to low pressure vapor. The low pressure vapor again proceeds to compressor and hence a cycle completes.

Cold Water. It is from cooling tower is used to condense the high pressure vapor coming out from the compressor. Hot water coming out of the condenser flows back to the cooling tower where it is cooled by air.

Ice Cans. These are kept brine tank where in cold brine coming out from evaporator cools the water inside the ice can and convert it to ice. Hence, brine solution act as secondary refrigerant (which does undergoes phase damage).

**Source:*
http://www.mechanicalduniya.com/2015/02/refrigeration-system-construction-working-ice-plant.html

Types of Condenser

Air cooled condensers: Air cooled condensers are used in small units like household refrigerators, deep freezers, water coolers, window air-conditioners, split air-conditioners, small packaged air-conditioners etc. These are used in plants where the cooling load is small and the total quantity of the refrigerant in the refrigeration cycle is small. They are usually made of copper or aluminum coil. In the natural convection type, the air flows over it in natural a way depending upon the temperature of the condenser coil. In the forced air type, a fan operated by a motor blows air over the condenser coil.

Water cooled condensers: Water cooled condensers are used for large refrigerating plants, big packaged air-conditioners, central air-conditioning plants, etc. These are used in plants where cooling loads are excessively high and a large quantity of refrigerant flows through the condenser. There are three types of water cooled condensers: tube-in-tube or double pipe type, shell and coil type and shell and tube type. In all these condensers the refrigerant flows through one side of the piping while the water flows through the other piping, cooling the refrigerant and condensing it.

Evaporative condensers: Evaporative condensers are usually used in ice plants. They are a combination of water cooled and air cooled condensers. In these condensers the hot refrigerant flows through the coils. Water is sprayed over these coils. At the same time the fan draws air from the bottom side of the condenser and discharges it from the top side of the condenser. The spray water that comes in contact with the condenser coil gets evaporated in the air and it absorbs the heat from the condenser, cools the refrigerant and condenses it. Evaporative condensers have the benefits of water cooled as well as air cooled condenser, hence it occupies less space.
**Source:http://www.brighthubengineering.com/hvac/967-refrigerator-and-air-conditioner-condensers/*

Type of Compressors

Piston Compressors. Piston compressors are one of the most widely used types of refrigeration compressors. Reciprocating motion of the piston due to external forces compresses the refrigerant inside the cylinder. There are three types of piston compressors: hermetic, semi-hermetically closed and open-ended. Open piston compressors can be of the same type cylinder or multi-cylinder type. Piston compressors and used widely. It can be used as refrigerants R12, R22, and others.

Rotary Compressors. Rotary compressors has two rotating elements, like gears, between which the refrigerant is compressed. These compressors can pump refrigerant below or moderate the pressure of condensation. Because they can handle small amounts of gas, and produce less pressure, they are used in fewer applications.

Centrifugal Compressor. Centrifugal compressor impeller or blower, which can handle large volumes of gas, but at a relatively low pressure of condensation. It is suitable for work with refrigerants such as R-11, R-113 and other refrigerants.

Screw compressors. Screw compressors are often used in large capacity systems in the range from 20 to 300 tons. Open screw compressors the most often used with ammonia systems. Hermetic screw compressors are used halocarbons with refrigerants. These traps and compress the air, they rotate in exactly the machining of compressor cylinders. Two rotors not in the same form. One male, the other female. The rotor is driven by an electric motor.

**Source: http://www.ref-wiki.com/content/view/31448/28/*

OPERATIONAL DEFINITION OF TERMS

Agitator. It is a device that shakes or stirs the brine solution so the Sodium Chloride concentration will not settle at the bottom when stagnant.

Brine. It is a common fluid used as a secondary refrigerant for the transport of thermal energy from place to place. Most common refrigerant brine uses Calcium Chloride and Sodium Chloride.

Brine Tank (Freezing Tank). A concrete-based pool of brine solution that houses the cans for ice-making process and evaporator coils to perform the freezing process.

Compressors. These reduce the pressure in the evaporator until the liquid refrigerant evaporates to the current temperature and maintain the pressure by drawing off the vapor produced through evaporation of the liquid refrigerant. Another function is to compress the vapor by raising its temperature and pressure to the point at which the vapor can be condensed at the normal temperature of the condensing media.

Condensers. These are heat exchangers in which the refrigerant vapor is cooled and liquefied after compression. The evaporator heat load plus the heat of compression are released into the atmosphere via the condenser by means of a fluid (normally water) or by air.

Evaporator. The evaporator works the opposite of the condenser, here refrigerant liquid is converted to gas, absorbing heat from the air in the compartment.When the liquid refrigerant reaches the evaporator its pressure has been reduced, dissipating its heat content and making it much cooler than the fan air flowing around it. This causes the refrigerant to absorb heat from the warm air and reach its low boiling point rapidly. The refrigerant then vaporizes, absorbing the maximum amount of heat.

Cooling Tower. It is a device commonly used to cool condenser water in power and refrigerating plants.

Day Tank. A cylindrical steel tank or storage elevated in height that stores the water required for the whole refrigeration system in one production cycle.

Expansion Valves. The expansion of the liquid refrigerant fluid from high to low pressure is achieved by passing it through a device known as an expansion valve. Expansion valves meter the liquid refrigerant into the evaporator and maintains a pressure differential between the high-and low-pressure sides of the refrigerating circuit.

Fan Blower . A duct-ed centrifugal fan, especially when used in a heating, ventilating an air-conditioning system.

Liquid Receiver. A storage vessel designed to hold excess refrigerant not in circulation.

Refrigerant. A substance or mixture, usually a fluid, used in a heat pump and refrigeration cycle. In most cycles it undergoes phase transitions from a liquid to a gas and back again. Many working fluids have been used for such purposes.

Source: https://www.swtc.edu/Ag_Power/air_conditioning/lecture/evaporator.htm
www.wikipedia.com

CHAPTER III:
LOCATION MAP AND PLANT PERSPECTIVE

CHAPTER IV:

DESIGN CALCULATIONS AND ILLUSTRATIONS

CHAPTER V:
PIPING LAYOUT

CHAPTER VI :

TABULATION OF EQUIPMENT SPECIFICATIONS

TABULATION OF EQUIPMENT AND SPECIFICATION

1.	Name of Equipment	: **COMPRESSOR**
	Type	: Single Acting Compressor
	No. of Units Required	: 2
	Materials Handled	: Ammonia Gas (NH_3)
	Design Mass Flow Rate	: 0.3015 kg/s
	Piping Requirements	: inlet size = 3 in NPS outlet size = 2 $^1/_2$ in NPS
	UTILITY REQUIREMENTS	
	Electric Motor	: 160 HP
	Other Equipment	: Water Jacket
	Cooling Water	: 30℃ maximum temperature
	Volume Flow Rate	: 0.2168 kg/s (cooling water)

2.	Name of Equipment	: **CONDENSER**
	Type	: Horizontal Shell - Tube
	No. Of Units Required	: 2
	Materials Handled	: Ammonia Gas (NH_3), Water (H_2O)
	Design Mass Flow Rate	: 0.3015 kg/s
	Piping Requirements	: inlet size = 2 $^1/_2$ in NPS outlet size = 2 in NPS
	Shell Dimension	: D=0.836 m, L=4m
	Tube Dimension	: OD=48.26mm, ID=40.9mm, L=3.55m
	Recommended Materials of Construction	: Steel

3.	Name of Equipment	: **LIQUID RECEIVER**
	Type	: Cylinder
	No. Of Units Required	: 2
	Materials Handled	: Liquid Ammonia (NH_3)
	Design Mass Flow Rate	: 0.3015 kg/s
	Piping Requirements	: inlet size = 2 in NPS outlet size = 1 in NPS
	Dimension	: D=0.4m, L=1.3965m
	Recommended Materials of Construction	: Steel

4.	Name of Equipment	: **EVAPORATOR**
	Type	: Trombone-type coils
	No. Of Units Required	: 4
	Materials Handled	: Ammonia Gas (NH_3)
	Operating Conditions	: -14℃
	Design Mass Flow Rate	: 0.3015 kg/s
	Piping Requirements	: inlet size = 1 in NPS outlet size = 3 in NPS
	Coil Diameter	: D=0.75 in,
	Total Length	: 1520.37m/tank
	No. of Coil Rows	: 138 tubes/tank
	Recommended Materials of Construction	: Steel

5.	Name of Equipment	: **HOISTING WINCH (OVERHEAD TRAVELLING CRANE)**
	No. Of Units Required	: 1
	Materials Handled	: Ice block in cans
	Wire Rope Diameter	: $^3/_4$ in
	Drum Sheave Diameter	: 22.5 in
	UTILITY REQUIREMENTS	
	Electric Motor	: 4 HP

6.	Name of Equipment	: **COOLING TOWER**
	Type	: Forced Draft
	No. Of Units Required	: 2
	Materials Handled	: Water (H_2O)
	Operating Conditions	: Water entering temp=30℃ Water leaving temp=25℃ Air entering temp=26℃ Air leaving temp=32℃ Barometric Pressure=101.325 kPa
	Recommended Materials of Construction	: Steel
	UTILITY REQUIREMENTS	
	Air Flow Rate	: 8.637 kg/s
	Make-up Water Flow Rate	: 0.139 kg/s

7.	Name of Equipment	: **DAY TANK**
	Type	: Cylindrical
	No. Of Units Required	: 1
	Materials Handled	: Water (H_2O)
	Operating Conditions	: Suction Pressure=55 kPa
	Dimensions	: D=5.7m, H=6m
	Capacity	: 150 m^3
	Recommended Materials of Construction	: Mild Steel

8.	Name of Equipment	: **DEEP WELL PUMP**
	Type	: Centrifugal
	No. Of Units Required	: 1
	Materials Handled	: Water (H_2O)
	Operating Conditions	: Water temp=26℃
	Piping Requirements	: Inlet size=100mm NPS Outlet size=125mm NPS
	Volume Flow Rate	: 100L/min
	Recommended Materials of Construction	: Mild Steel
	UTILITY REQUIREMENTS	
	Electric Motor	: 1.5 HP

9.	Name of Equipment	: **COOLING WATER PUMP**
	Type	: Centrifugal
	No. Of Units Required	: 2
	Materials Handled	: Water (H_2O)
	Operating Conditions	: Maximum Water Temp=30℃
	Recommended Materials of Construction	: Cast Steel

UTILITY REQUIREMENTS

Electric Motor	: 10 HP

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On-the-Job Trainee at Ryonan Electric Philippines Corporation
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Internship at Cadiz City Engineer's Office
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FAVORITE QUOTATIONS

"Just because you're a trash doesn't mean you can't accomplish anything. It's called Garbage Can not Garbage Cannot for a reason."

John Paulo **Superficial Pecaoco**

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Internship at Central Azucarera de La Carlota, Incorporated
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FAVORITE QUOTATIONS

“Unless you did your best, there is no room for a loser or a weakling.”