Fabrication of Mini Deep Freezing and Cold Storage System

Dr. Rajendra Pohane[1], Ms. Rajan Jagtap[2], Ms. Shubham Fendar[3], Mr. Hitesh Guhe[4], Mr. Aman Parate[5], Mr. Akshay Kumbhare[6], Mr. Harsh Khandale[7]

Professor, Department of Mechanical Engineering[1]

UG Student, Department of Mechanical Engineering[2,3,4,5,6,7]

Priyadarshini Bhagwati College of Engineering, Nagpur, Maharashtra, India

Abstract: *As per technical evolution and latest trends take into consideration here effective created an advanced system i.e.* ***FABRICATION OF MINI DEEP FREEZING & COLD STORAGE SYSTEM.*** *Refrigeration is a basic food preservation technique. The Reverse Carnot cycle, which describes Adiabatic and Isothermal Expansion and Compression, underpins all refrigeration technologies for food preservation. Evaporator, Compressor, Condenser, and Expansion Valve are the basic components employed in these cycles. The Vapour Compression Cycle is the most commonly used cycle. Vapour Absorption Cycle and Gas Cycle are two other cycles. Thermoelectric and Magnetic Refrigeration are two other emerging technologies of refrigeration. In these cycles, several types of refrigerants are utilised depending on their qualities. Refrigeration is utilised commercially as a preservation strategy in a variety of food businesses, such as the dairy and meat processing industries. Cold storage is the one widely practised method for bulk handling of the perishables between production and marketing processing. It is one of the methods for preserving perishable goods in a fresh and complete state for a longer period of time by controlling temperature and humidity in the storage system. Maintaining a sufficiently low temperature is essential to avoid chilling injury to the produce. Also, for most perishables, relative humidity in the storeroom should be kept at 80-90 percent, below (or) above which has a negative impact on the produce's keeping quality. When kept at normal harvesting temperatures, most fruits and vegetables have a very short shelf life. Customized air cooling systems will be in high demand in the future.*

Keywords: Reverse Carnot cycle, evaporator, compressor, condenser, vapour compression cycle, bespoke air cool system

I. INTRODUCTION

The process of eliminating heat from an area or a material is known as refrigeration. It's commonly done by decreasing the temperature artificially, such as using ice or mechanical refrigeration, which is a mechanical system or device developed and built to transfer heat from one substance to another.Because refrigeration is only concerned with the removal or transmission of heat, a thorough grasp of the nature and consequences of heat is essential. In most cases, cold storage is cooled by a refrigerator, which uses a liquid with a low gasification temperature as the refrigerant, causing it to evaporate under low pressure and mechanical control and absorb the heat in the cold storage, ultimately achieving the cooling goal. Cold storage is a facility where food that has a short shelf life and is likely to spoil under normal conditions is kept. Fruits, vegetables, fish, and meat are examples of these. These foods are kept at the right temperature (mostly low) and humidity level for each item. Almost all cold storage rooms are designed with these properties pre-configured based on the contents. Some cold rooms are designed with these properties in mind.the compressor refrigerator is the most common, and it consists of compressor, condenser, throttle valve, and evaporator, among other components According to the evaporation tube device, it can be divided into direct and indirect cooling. The evaporator is installed in the cold storage with direct cooling, whereas indirect cooling uses a blower to draw air from the cold storage into the air cooling device. The advantage of air cooling is that it cools quickly and maintains a consistent Temperature. Cold rooms are divided into three categories: self-contained, remote condensing, and multiplex condensing. Self-contained cold rooms are cold storage rooms with a complete refrigeration system that includes the evaporator and condenser in one unit, similar to a window air conditioner. Cold rooms that are self-contained are usually constructed outside of the buildings they serve. The condenser unit in remote condensing unit cold rooms is located somewhere other than directly adjacent to the room and is not packaged with the evaporator, such as on the building's roof. Cold rooms with remote condensing units are usually built into the structures they will serve and may have multiple evaporators. A centralised system with multiple condensing units and evaporators is used in multiplex cold rooms. Cold rooms are built with insulated walls, floors, and ceilings to help them operate efficiently. The insulation, which is usually foam, is sandwiched between two thin walls, which are usually made of steel or aluminium. Insulating the cold room separates the inside and outside temperatures, requiring less work from the evaporators and condensers to maintain the temperature and saving energy. Cold room floors should be reinforced as well as insulated to support any equipment or product they will hold.

We are working on mini freezer and cold storage system of capacity around 350-400 litres. The system which is completely based on VCRS (Vapour Compression Refrigeration System) where we are using R134a refrigerant to get efficient cooling. We are using two boxes i.e Primary and secondary box.

II. LITEREATURE SURVEY

In study of applied thermodynamics all the while we have been observing heat transfer from a system at higher temperature to that at lower temperature. Now in the study of refrigeration we will be observing various methods of cooling the objects and maintaining the temperature of bodies at values lower than surrounding temperature. According to American society of Heating, Refrigeration and Air-conditioning Engineers (ASHARE) “Refrigeration is the science of providing and maintaining temperature below that of the surrounding (ambient) temperature”.

In the olden days around 2500 years B.C. Indians, Egyptians, etc., were producing ice by keeping water in the porous posts open to cold atmosphere during the night period. The evaporation of water in almost cool dry air accompanied with recitative heat transfer in the clear night caused the formation of ice even when the ambient temperature was above the freezing temperature. Further references are available which support the use of ice in China 1000 years BC. Nero, the emperor, was using ice for cooling beverages. Further, the East Indians were able to produce refrigeration by dissolving salt in water as early as 4th century A.D., of course, on very small scale. The use of evaporative cooling is another application of refrigeration used olden days. The cooling of water in earthen pots for drinking purpose; is the most common example where the evaporation for water through the pores of earthen pot is accompanied with cooling of water. The fore said methods of the production of cooling were not feasible for commercial use due to the very small amount of ice production. Availability of natural ice in limited regions and unavailability of good quality insulation confined the application of ice to those localities only. These all led to the development of the artificial refrigeration side, a few would be presented here. Thomas Harris and John Long got the earliest British parent in 1790. Later on in 1834, Jacob Perkins developed hand-operated refrigeration system using ether (volatile) as the working fluid. Ether vapour is sucked by the hand-operated compressor and then high temperature and pressure either vapour is condensed in the water cooled chamber (condenser). Liquid ether is finally throttled to the lower pressure, and thus evaporation of this liquid in chamber A lowers the temperature of water surrounding the vessel. Finally ice is formed. In this system, ether is used again and again in the cyclic process with negligible wastage.

In 1851, Dr. John Garrie of Florida, a physician obtained the first American patent of a cold air machine to produce ice in order to cure people suffering from the high fever. Instead of air or ether, sulphuric ether was used by Dr. James Harrison of Australia in 1860, the world’s first installation of refrigeration machine for brewery. The steam engine works as a power source which drives the compressor for the pressurization of sulphuric ether vapour, which is, in turn, condensed and is allowed to expand and evaporate in order to produce refrigeration. Dr. Alexander Kirk of England constructed a cold air machine is 1861 similar to that of Dr. Gorrie. The air was compressed by a reciprocating compressor driven by a steam engine running on coal. His actual machine consumed about 1 kg of coal to produce 4 kg of ice (approximately).

In the 19th century, there was tremendous development of refrigeration systems to replace natural ice by artificial ice producing machines. Unfortunately steam engine, a very low speed power developing source, was used to drive the compressor, rendering very poor performance of the refrigeration system.

In the beginning of 20th century, large sized refrigeration machines were under progress. By 1904 about 450 ton cooling system for air conditioning the New York Stock Exchange was installed. In Germany people used air conditioning in theatre for comfort purposes. In around 1911 the compressor speed was raised between 100 to 300 rpm. The first two-stage modem compressor was brought under use in 1915.

During the civil war there was an acute shortage of the supply of natural ice from the north. Hence, Ferdinand Care of the USA developed vapour-absorption refrigeration system ammonia as a refrigerant and water as a absorbent. The system consists of an evaporator, an absorber, a pump, a generator, a condenser and an expansion device. The evaporated vapour is absorbed by the weak ammonia-water mixture in the absorber yielding strong aqua ammonia. The pump delivers this strong solution into the generator where heat transfer from a burner separates ammonia vapour and the weak ammonia water returns to the absorber. On the other hand the ammonia vapour condenses in the condenser before being throttled. The throttled ammonia liquid enters the evaporator resulting in completion of the cyclic process.

In the beginning of two decades of the twentieth century, the development in refrigeration system was confined to refinement in cold air machines and vapour compression thermoelectric, pulse tube refrigeration systems, etc. The developments are vortex tube, steam-jet refrigeration system, availability of materials of specific properties for thermoelectric materials. The possible use of waste heat or solar energy in case of vapour-absorption and thermoelectric systems has led to development of several commercial units these days especially due to the like hood of future energy crisis, the world is going to face.

III. WORK DONE

3.1 Working Principle

The MFCS System works as a Freezing unit as well as cold storage system. As the refrigeration works on a Revered Carnot Cycle (It has the maximum efficiency for a given temperature limit. Since it is a reversible cycle, all four processes can be reversed. This will reverse the direction of heat and work interactions, therefore producing a refrigeration cycle). The components used are Compressor, Condenser, Capillary Tube aka expansion device, Evaporator Coil & a Thermostat. The system consists of 2 boxes (Primary & Secondary). The material used for those boxes is Stainless Steel (20 gauge) sheet along with the SS Bars (18 Gauge) 1x1 inches as a base frame. The base stand is made of MS where the Compressor & Condenser unit is mounted.

The major factor for cooling the primary box is Evaporator Coils which are mounted between the Primary box (P1 & P2). As the evaporator coils get cooled down, the cooling is passed into the P1 box. Insulation from outside temperature is achieved with the help of a PU Insulation Foam which was sprayed near the evaporator coils.

The refrigerant used here is R-134a, which works efficiently for most refrigeration systems. It has the formula CH2FCF3 and a boiling point of −26.3 °C (−15.34 °F) at atmospheric pressure. This is a non-flammable gas used primarily as a "high-temperature" refrigerant for domestic refrigeration and automobile air conditioners.

Here as the Compressor compresses the refrigerant at high pressure and temperature, it further travels to the Capillary Tube aka Expansion device where the pressure drop causes the refrigerant pressure and temperature to decrease because of the throttling effect. The refrigerant further travels towards the Evaporator coils where it cools down the walls of the primary box & adsorbs heat from the surroundings, resulting in its state changing from liquid to vapour. From evaporator

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coils, the refrigerant (vapour) flows to the condenser where it removes heat from the refrigerant. Between the condenser and compressor unit, the Filter & Drier is fitted to remove any impurities and moisture content from the vapour refrigerant before entering the compressor to the prevention of any damage. We have mounted Dual Capillary Tube which spits evaporator coils into 2 parts. This is done to achieve maximum cooling efficiency and save the compressor from excess loading.

The cooling temperatures expected for the Primary Box is around -5 to -10 °C, similarly, the Secondary Box is around 5 to 10 °C. The Primary Box works as a deep freezer unit where the evaporator coil helps to achieve a negative temperature range. The Secondary box is connected to the Primary through the air ventilation channels. These channels are covered in plastic pipes for insulation. There are in total 2 ventilation channels. 3 inches of BLDC motor fans are fitted in those plastic pipes so that the air can circulate from the primary box to the secondary. As the air is circulated through these ventilation channels between these boxes, the secondary box gets cooled down due to cool air coming from the deep freezing unit of the primary box.

The temperature range expected for the Secondary box is around 5-10 °C. This can help keep fruits and vegetables fresh and increase their storage span as compared to the traditional refrigerators.We can use the primary box for storage by keeping the secondary box disconnected. This is done with the help of the doors that covers the ventilation pipe system. These doors are manual. i.e hand operated. To activate the secondary box, the ventilation doors need to be opened and the motor inside the pipe switched on, individually. As this is a closed cycle & any leakage is prevented with the help of gaskets, we tried our best to keep the system's efficiency as high as possible.

In further scope, if added an additional evaporator to the evaporator coils system, this system can be converted into a proper size cold storage room.

3.2 CAD Model

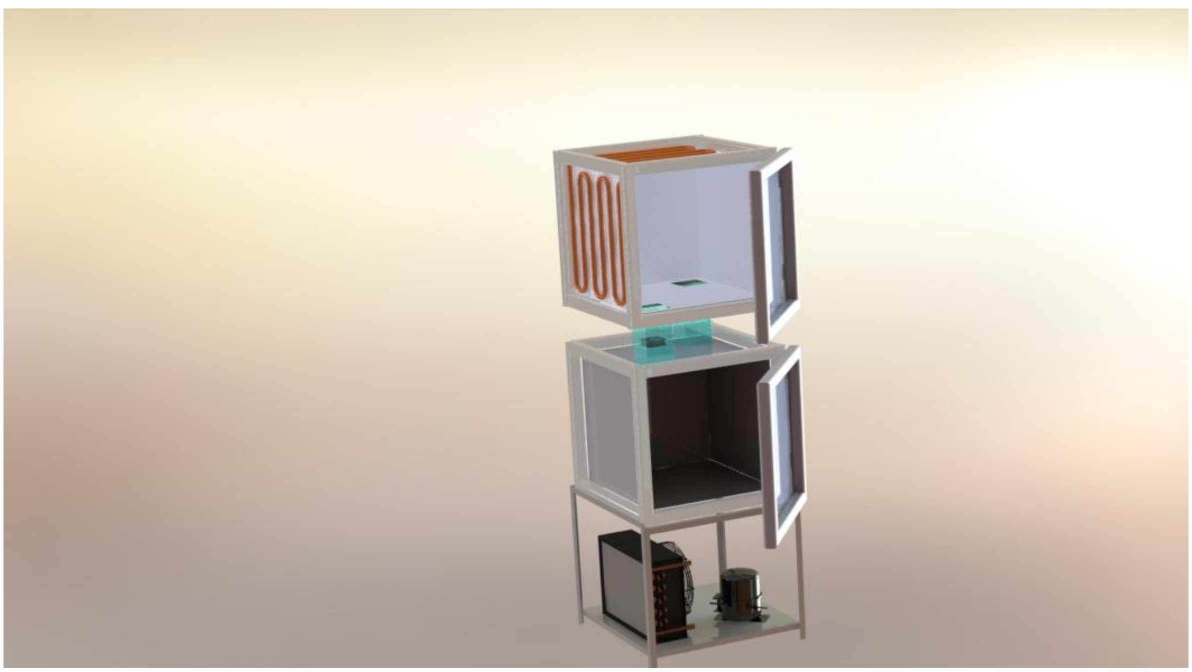

Figure: 3D model of mini deep freezer & cold storage system

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3.3 Calculations

Refrigeration System Performance Coefficient:

R134a Refrigerant is utilised in Mini Freezing and Cold Storage Systems to improve performance.
Temperature of Evaporation (T1) = -15 °C
Temperature of Condensation (T2) = 30 °C
From the graph:
At -15 degrees Celsius,
hf1=186.78 kJ/kg, hg1=392.75 kJ/kg, sf1 = 0.9509 kJ/kgK, sg1 = 1.7337 kJ/kgK, sf1 = 0.9509 kJ/kgK, sg1 = 1.7337 kJ/kgK
At 30 degrees Celsius,
hf2=241.65 kJ/kg, hg2=414.94 kJ/kg, sf2 = 1.1432 kJ/kgK, sg2 = 1.7149 kJ/kgK, sf2 = 1.1432 kJ/kgK, sg2 = 1.7149 kJ/kgK
x1*h = h1=hf1 (fg) - (i)
414.94 kJ/kg h2=hg2
Source: Graph
s1=s2 and h3=h4
186.78 kJ/kg h3=h4=hf=
To locate h1, we must first locate x1.
s1=s2
=sg2 sf1+x1*s(fg)1
x1=0.975 after all values have been entered.
In equation I enter x1.
388.218 kJ/kg h1.

Refrigerating Effect (COP)

Copper Tube Calculation

Systems for Air Conditioning and Refrigeration- With most refrigerants, copper is the preferable Material. It has a high heat transfer capability, is corrosion resistant, and is inexpensive. The formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the formula in the
As it is for all piping, the American Society of Mechanical Engineers Code for Pressure Piping (ASME B31) is used.

Materials.

2S (tmin - C)/ Dmax - 0.8 P= 2S (tmin - C)/ Dmax - 0.8 (tmin - C)

Where:
P stands for permissible pressure in bar.
S is the maximum permitted stress in tension, while bar is the maximum allowable stress in compression.
tmin = minimum wall thickness (in mm)
Dmax = maximum outer diameter (in mm)
Because of copper's better corrosion resistance, the B31 designation is used for copper tubes.
allows the C factor to be zero.
Thus, the formula is as follows:
P= 2Stmin /Dmax - 0.8tmin - The maximum allowable stress in tension is 502.80 Psi, or 34.66 Bar.
315.9 psi (21.78 bar) and 315.9 psi (21.78 bar) respectively.
For size 34 inch and 14 inch Copper Tube, respectively, according to pressure 54 psi.

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The outside diameter of the tube is now = 22.2 mm, and the thickness of the tube is now = 22.2 mm.
The diameter of the tube is 1.143 mm.
The outside diameter of the tube is now = 9.525 mm, and the thickness of the tube is now = 9.525 mm.
The diameter of the tube is 0.762 mm.
As a result, we used a 14-inch copper pipe.

3.4 Components and Specification

1. Reciprocating Compressor (162 watts).
2. Condenser (with Motor & Fan).
3. Evaporator Coil.
4. Expansion Valve (Capillary Tube).
5. Filter & Drier.
6. Thermostat (Sub-zero).
7. Outer Sheet Metal Body (Stainless Steel).
8. Insulating Material (Polyfoam).
9. R134a Refrigerant.
10. MCB.
11. Wiring Harness.
12. Insulating Pipe covers.
13. Rubber Gaskets.
14. Aluminum Tape.
15. Ventilation Motor Fan.
16. 4.5 Inch Diameter Plastic Pipe.

A. Compressor

The compressor is the heart of the refrigeration system. The compressor acts as the pump that moves the refrigerant through the system. Temperature sensors start the compressor's action. Refrigeration systems cool objects through repeated refrigeration cycles. It works on the principle where it compresses the vapour in the refrigeration system & converts low-pressure vapour into high pressure & temperature of working fluid. The compressor is the pump that enables the flow of the refrigerant. The compressor works by increasing the pressure and temperature of the vaporized refrigerant. There are different types of compressors for refrigeration applications. Reciprocating, rotary, and centrifugal compressors are the most common among refrigeration units.
This compressor employs back and forth piston motion to compress the vaporized refrigerant. Another name for the reciprocating compressor is the piston compressor. This compressor comprises a motor, a crankshaft, and some pistons. The motor rotates the crankshaft, which then pushes the pistons. Each crankshaft rotation achieves actions: suction, compression, and discharge. All these actions are in sequence. As a result, gas displacement is discontinuous and causes vibration. Single-acting reciprocating compressors are those compressors where the refrigerant acts on one side. Double-acting compressors enjoy refrigerant action on two sides of the piston.
a) The Compressor used in our system is a Reciprocating Type compressor, which is a deep freezer compressor.
b) The power consumption is about 162 watts.
c) This type of reciprocating compressor has a cooling capacity of about 180 kcal/hr.
d) The model used is MA72LHEG which is suitable for the cooling area of 400 liters.

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B. Condenser

a) The condenser is a device used in the high-pressure side of a refrigeration system. Its function is to remove the heat of the hot vapour refrigerant discharged from the compressor. Refrigerant while passing through the condenser gives of it's latent heat to the surrounding condensing medium.

b) The condenser is a set of coiled tubes. In the domestic refrigerator, you will find your compressor at the back of the appliance. The condenser cools the vaporized refrigerant turning it back to liquid.

c) Three different phases happen in every condenser. The first phase is called desuperheating. The vapour entering into the condenser is already superheated and super pressurized in the evaporator and compressor. Desuperheating means ejecting the heat from the vapour and turning it into liquid. The next level is changing or condensation state; losing more heat continues in this state where we reach 10% of refrigerant as vapour and 90% as a liquid. The third and last phase is a sub-cooling state. The sub-cooling state is there so as to be sure that not even rising temperatures can bring the liquid refrigerant into vapour again.

d) The Air-Cooled compressor uses air as the external fluid to reject the heat from the system. Air-cooled condensers usually have copper coils where the refrigerant flows. But this is not the whole story; this type is subcategorized into two subsets: natural convection and forced convection.

C. Evaporator

a) Evaporator is an important component together with other major components in a refrigeration system such as compressor, condenser, and expansion device. The reason for refrigeration is to remove heat from the air, water, or other substance.

It is here that the liquid refrigerant is expanded and evaporated. It acts as a heat exchanger that transfers heat from the substance being cooled to a boiling temperature.

b) Bare-Tube and Plate Surface construction have the entire surface in contact with the evaporating refrigerant inside.

c) The Evaporator Coils used are copper pipes of ¼ inches in diameter.

d) These coils are soldered to the stainless steel walls of the box .i.e between 2 sheets.

D. Expansion Valve (Capillary Tube)

a) Capillary tube can be considered as an expansion device, this device is also known as a metering device it is a throttling device and it is used in air conditioning and refrigeration systems. This device is a fixed restriction type device. It is a narrow tube that connects the conductor directly to the evaporator. So instead of an orifice, a length of a small diameter tube gives the restrictive effect, which is the same as the orifice. Capillary tubes are small diameter tubes the inside diameter of the capillary used in refrigeration is generally about 0.5-2.28mm which means they are very small. It can create a greater pressure drop in the refrigerant flow if the capillary tube is long and has a smaller inside diameter.

b) The pressure of the refrigerant would drop down when the refrigerant enters the capillary tube from the condenser, the pressure is decreased because of the low diameter of the tube. If the diameter is small and has a long length then the pressure drop is achieved. The capillary tube is a non-adjustable device so that the refrigerant flow cannot be controlled, so the flow of refrigerant would change according to the variation in the surrounding. So the capillary tubes are designed for certain ambient conditions. So if we select a capillary tube properly then it can work well for a wide range of conditions.

c) We have used a dual capillary tube system so that the evaporator coil will receive an equal amount of refrigerant flowing inside of it. Thus, to ensure proper cooling of the walls.

d) What are the advantages of the capillary tube :

- It is not expensive.
- It doesn't need any maintenance.

● It would reduce the starting torque needed for the motor because of the same pressure on the two sides of the compressor.

E. Filter & Drier

A filter-drier in a refrigeration or air conditioning system has two essential functions: one, to adsorb system contaminants, such as water, which can create acids, and two, to provide physical filtration. Evaluation of each factor is necessary to ensure proper and economical drier design. Filter driers are devices used in an HVAC system that are a combination of filter and dryer (or drier). A filter is used to remove any particle such as dirt, metal, or chips from entering the refrigerant flow control. The refrigerant flow control device could be a thermostatic expansion valve or simply a capillary tube. The filter is sometimes also referred to as a strainer. It is critical that these particles are filtered out and prevented from going into the metering device. It can cause blockage to the passage flow of the refrigerant in the expansion valve and cause improper operation of the system.

F. Thermostat

A thermostat is a device to detect temperature changes for the purpose of maintaining the temperature of an enclosed area essentially constant. In a system including relays, valves, switches, etc., the thermostat generates signals, usually electrical, when the temperature exceeds or falls below the desired value. R134a Refrigerant is a common refrigerant that is used in many air conditioning applications, usually packaged in blue colour cylinders. Due to the nature of R134a properties which is an HFC (hydrofluorocarbon) refrigerant, it does not have any ozone depletion potential and has a little greenhouse effect.

G. Refrigerant (R-134a)

R134a Refrigerant is a common refrigerant that is used in many air conditioning applications, usually packaged in blue colour cylinders. Due to the nature of R134a properties which is an HFC (hydrofluorocarbon) refrigerant, it does not have any ozone depletion potential and has a little greenhouse effect.

No.	Properties	R134a
1	Boiling Point	-14.9°F or -26.1°C
2	Auto-Ignition Temperature	1418°F or 770°C
3	Ozone Depletion Level	0
4	Solubility In Water	0.11% by weight at 77°F or 25°C
5	Critical Temperature	252°F or 122°C
6	Cylinder Color Code	Light Blue
7	Global Warming Potential (GWP)	1200

III. CONCLUSION

1. The aim is to overcome our project objectives .i.e to enhance food preservation time and prevention of food degradation.
2. Fabrication of Mini Freezing & Cold Storage System is under development.

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