Performance Investigation of Chilling Plant with Refrigerant 22 and Secondary Refrigerant Ethylene Glycol Solution ($C_2H_6O_2$)

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***Abstract* - The demand of cold room is going to increases due to adverse climatic conditions over worldwide so it needs to develop a cold chain which includes harvest cooling (pre-cooling) cold room transport to market. This design of cold storage is adaptive design which is operated on evaporative cooling suitable for preservation of the vegetables, fruit & dairy products. A major use of refrigeration is in the preservation, storage and distribution of perishable foods. Cold room is refrigerated space where low temperatures maintain for preservation of Food. The cold room is designed with refrigeration capacity 1.15 TR. During design these system various design parameter like cooling load calculation, selection of compressor, thermostatic expansion valve, condenser capacity and piping design are considered.**

***Keywords* - lowest temperature, cooling load calculation, Latent heat and sensible heat**

I. Introduction

Cold chain is now recognized as a sunrise sector in India because India has first rank in milk production in word and second number in Fruit and vegetables production. It was absorbed that force evaporation system is used in cold room which is force convection type so achieve the desire temperature into cold room. Improper system design and selection of unsuitable equipment or component leads to high energy consumption, high cooling time and variable temperature in cold room. Vapor compression machines, usually with electrically driven compressors, are the most

commonly used machines for refrigeration and air conditioning for temperatures ranging from 25°C to -70°C.In this system ethylene glycol used as secondary refrigerant because systems that must cool below the freezing temperature of water. Pure ethylene glycol freezes at about −12 °C (10.4 °F), but when mixed with water, the mixture does not readily crystallize, and therefore the freezing point of the mixture is depressed.

II. System Setup

This system is divided into two parts in which first part is refrigeration systems which ethylene glycol as secondary refrigerant and second part is glycol solution circulated in evaporator pipes in cold room. System is operating with ambient temperature 350c and storage temperature 00c. In practice, the cold room will operate for 24 hours daily and which provide storage for dairy product. In this article evaporative cooling is examined for cold room purpose which is an innovating one and not used in any type of cold room. So it will be economical and energy efficient than other types forced circulation cold room. This will help to suggest alternative method of preservation of dairy products fruit and vegetable over the regular system and help to reduce initial cost and operating cost. The salient components of vapor compression refrigeration system used in cold storage system are Evaporator, Compressor, Condenser and Expansion Valve for the vapor compression cycle and another is centrifugal water pump and Evaporative coil in cold room. A typical schematic diagram fig.1 of the refrigeration system is shown below.

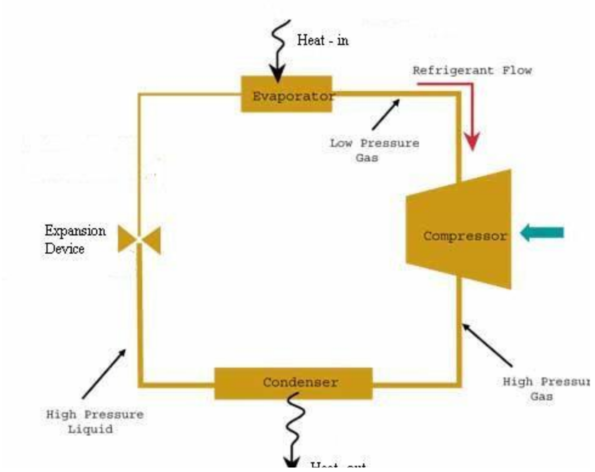

Fig.1 Typical vapor compression cycle

Compressor raises the pressure and temperature of the refrigerant Condenser is rejected heat gained by compressor. Thermostatic expansion valve is use as throttling device which expands the liquid refrigerant and Evaporator is used to absorb heat from the refrigerated space. Then chilled glycol solution is circulated in evaporative coil of cold room with the help of centrifugal pump to achieve desire temperature.

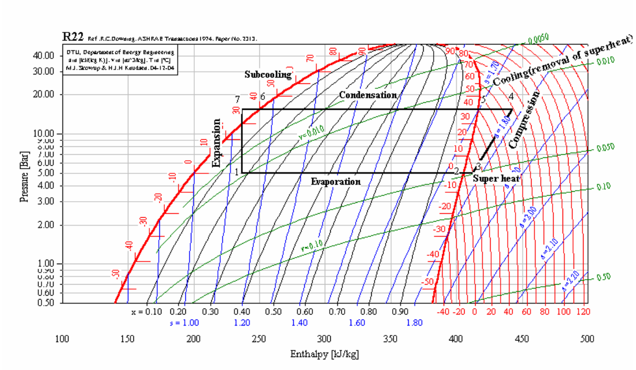

Fig.2 P-h diagram for Vapor compression cycle(R22)

Table1. Specification of experimental setup

S. No	Parameters	Description
1	Type of solution	Ethylene glycol solution
2	Refrigerant	R22
3	Capacity	1.5 TR
4	Compressor	Hermetically sealed, Reciprocating, two cylinders.
5	Condenser	Finned coils, Air cooled
6	Expansion device	Thermostatic expansion valve
7	Evaporator	Bare tube type

III. Component Selection Criteria

3.1 Compressor

Compressor selection of compressor totally depend on heat load calculation of the system, Evaporating temperature and suction temperature because evaporating temperature of compressor affects the volumetric efficiency of compressor. Evaporating temperature decreases the volumetric efficiency of compressor decreases. It is also depend on types of refrigerant used into the system. For above system as per cooling load 1.5 TR hermetically sealed compressor selected. The specification of compressor is given into the table.

Table2. Compressor specifications

No.	**Parameter**	**Unit**	**Value**
1	Capacity	TR	1.528
2	Evaporating Temperature	^{0}c	7.2
3	Condensing Temperature	^{0}c	55
4	Suction Pressure	bar	5.23
5	Discharge Pressure	bar	21

3.2 Condenser

Selection of condenser totally depend on its heat rejection factor, cooling capacity, Temperature difference between refrigerant and atmospheric.

The condenser load is given by formula,

Condenser load = Compressor capacity × heat rejection factor (6)

Heat rejection factor obtained by condensing and evaporating temperature of system. The condenser capacity is determine using following formula

$Q = Uo \times Ao \times \Delta T$ (W) (7)

Where, Uo = Overall heat transfer coefficient based on outside area (W/m^2 ˚C).
Ao = Outside area of tube (m^2).
ΔT = L.M.T.D for condenser (°C).

3.3 Thermostatic expansion valve

Selection of thermostatic expansion valve and its orifice depends on the pressure drop down, refrigerant type, evaporating temperature, liquid temperature entering the valve, mass flow rate of refrigerant, pressure drop across the valve and selected accordingly.

3.4 Evaporator design

During the designing, Material of evaporator, velocity of refrigerant, thickness of wall and contact surface area & Temperature difference are some parameters which affect the cooling capacity of evaporator. Evaporator temperature and Condenser temperature is important which give the cooling capacity of the component. This can be calculated as using formula.

$$Q = U_o A_o (T2 - T1) \quad (W) \quad (8)$$

Where,
Uo = Overall heat transfer coefficient (W/m2)
A_o = Area of evaporator surface in (m2),
T2 = outside the evaporator Temperature (°C),
T1= inside the evaporator Saturation temperature (°C)
Following table give the various values for evaporator coil designed for experimental purpose.

Table3. Evaporator coil calculation.

Sr.No	Parameter	Unit	Value
1	Mass Flow Rate of refrigerant	kg/min	1.5
2	Velocity of refrigerant	m/sec	0.1586
3	Reynolds Number		18891.7
4	Heat transfer coefficient at refrigerant side	w/m^2k	430.86
5	Overall Heat transfer coefficient	w/m^2k	261.5
6	LMTD for Evaporator	˚C	10.34
7	Length of evaporator coil	meter	30.74

IV. SELECTION OF SECONDARY REFRIGERANT

Ethylene glycol is a clear, colorless, odorless, and liquid with a sweet taste. It is hygroscopic and completely miscible with many polar solvents such as water, alcohols, glycol ethers, and acetone. Ethylene glycol is the most widely used as secondary refrigerant for cooling-system antifreeze, although methanol, ethanol, isopropyl alcohol, and propylene glycol are also used. The brine used in some commercial refrigeration systems is an antifreeze mixture; it is typically a water solution of Ethylene glycol or propylene glycol. Following are some of the thermal properties of ethylene glycol.

Table 5 Thermal properties of ethylene glycol.

Boiling point at 101.3 kPa	197.60 °C
Freezing point	-13.00 °C
Density at 20°C	1.1135 g/cm^3
Refractive index, n_D20	1.4318
Heat of vaporization at 101.3 kPa	52.24 kJ/mol
Heat of combustion	19.07 MJ/kg
Critical temperature	372 °C
Critical pressure	6515.73 kPa
Critical volume	0.186 L/mol
Flash point	111 °C
Ignition temperature	410 °C
Lower explosive limit	3.20 vol%
Upper explosive limit	53 vol%
Viscosity at 20 °C	19.83 mPa.s
Cubic expansion coefficient at 20 °C	$0.62\times10^{-3}K^{-1}$

Ethylene glycol is also commonly used in chilled water air conditioning systems that place either the chiller or air handlers outside or systems that must cool below the freezing temperature of water.

Benefits

- Effective against pipe burst to a minimum temperature of -73°C
- Helps preventing corrosion of components
- Improves the heat transfer
- Safe and easy to use
- No residual product
- Ideal also for systems where contact with potable water is possible
- Chemically stable; it will not have effect on other chemicals already in the systems

Table 4 Concentration of glycol in water.

Ethylene glycol freezing point vs. concentration in water

Weight Percent EG (%)	Freezing Point (deg C)
0	0
10	-4
20	-7
30	-15
40	-23
50	-34
60	-48
70	-51
80	-45
90	-29
100	-12

V. RESULTS AND DISCUSSIONS

A simple vapor compressor system is designed for chilled glycol solution which achieve the lowest temperature upto -220c at 50% concentration of glycol solution further circulated into the cold room for achieving evaporative cooling. According to the observation and readings obtained from experimental setup gives Carnot cop of the system is 4.06.its theoretical cop is 2.9 as per calculation. Actual performance of the evaporative cooling is calculated by keeping product load inside the cold room. Actual cop of system is 1.84.Design and adaptation of vapor compressor cycle able to chill 320 liter water in 900 minutes. As mass flow rate of water is increased evaporative cooling time is decreased. Then achieved temperature in chilling tank is supply According to readings and variations in flow rate it was observed that 600 LPH glycol solution at -200C take minimum time to obtain 80C temperatures inside the cold room within 24 hours. Temperature some readings and observation is given below table.

Table 6 Experimental observations for system

Sr. No.	Parameters	Unit	Reading		
1	Condenser Pressure	Bar	13.10	12.26	12.06
2	Evaporator Pressure	Bar	1.03	1.58	1.93
3	Condenser Inlet Temp.	^{0}C	67	64	62
4	Condenser Outlet Temp	^{0}C	28	29	31
5	Evaporator Inlet Temp	^{0}C	-13.3	-12.7	-6.9
6	Evaporator Outlet Temp	^{0}C	8	17	21
7	Mass Flow Rate Of Refrigerant	lph	15	30	75
8	Glycol Solution Temperature	^{0}C	-10	-5	0
9	Time required for 10 rev. energy meter for compressor	sec	6.7	7	7

Table7 Performance analysis of different temperature of antifreeze solution.

Sr. no.	Temperature	5^{0}C	0^{0}C	-5^{0}C	-10^{0}C
1	Carnot C.O.P	5.4	5.375	4.58	4.06
2	Theoretical C.O.P	4.06	3.7667	3.33	2.923
3	Actual C.O.P	1.98	1.9452	1.8657	1.8423
4	Relative C.O.P	0.45	0.51	0.555	0.629
5	Capacity(TR)	0.71	0.63	0.57	0.54

5.1 Graph

Figure 4 shows temperature drop versus Required time graph on which x-axis has temperature drop and y-axis with required time. It shows as time is increases temperature drop is goes on increasing. Temperature drop is also depends on mass flow rate of secondary refrigerant that is the water used into system.

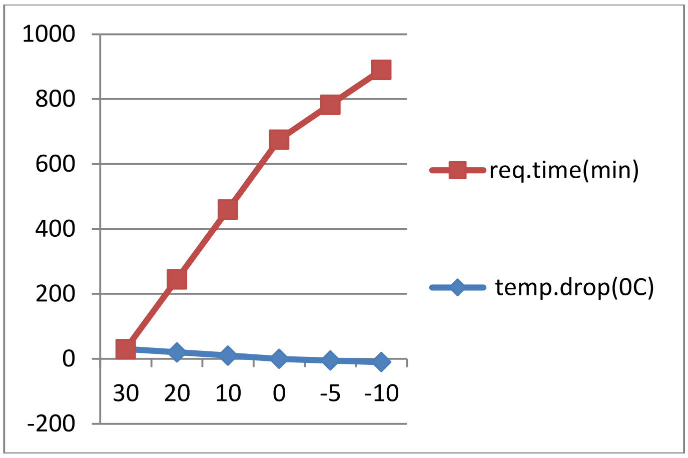

Fig.4 Temperature drop Vs Req. Time graph

VI. CONCLUSIONS

- Design vapor compressor chilling plant able to chill glycol solution 320 liters in 900 minutes with temperature difference 40^0C
- It is found that according to designing the capacity of the chilling plant is 1.15 TR at condensing temperature 62 ˚C and evaporative temperature -14˚C.
- With the help of evaporative cooling the load on refrigeration get reduced which is helpful to save power consumption and economical running of the plant.
- For the cold room can be achieved different temperature as per our need and required.
- In the chiller plant, find the temperature below 0^0C consider the concentration at 30% of glycol solution used as compare 50% concentration used generally in the industry
- At different temp of ethylene glycol solution i.e.$(0,-5,-10)^0$C, calculate the C.O.P. and capacity of plant and analyses that C.O.P.& capacity is decrease and relative C.O.P. is increase.
- Temperature drop of antifreeze solution is less as compare with water as secondary refrigerant.
- Water flow rate inside cold room at 600 LPH is able to lower down cold room temperature from ambient condition i.e. 32 °C to 8°C within 24 hours.

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