Waste Heat Recovery From Refrigeration Plant

Chandan Sanjiv Verma[1], Pratyusha Gajbhiye[2], Shilpa Vinchurkar[3]

[1-2]PG Student, Department of Mechanical Engineering, G.H.R.C.E, Nagpur, Maharashtra, India
[3]Assistant professor, Department of Mechanical Engineering, G.H.R.C.E, Nagpur, Maharashtra, India

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Abstract - *heat is energy, so energy is one of the important issues in terms of the use of refrigerants and the protection of the global environment. This waste heat leads to global warming when the heat in the area rises, and it is not good for the ozone layer, so it affects the environmental conditions. Therefore, it is necessary to take concrete measures to save energy by using waste heat. I tried to use the waste heat from the condenser of the refrigerator. This heat can be used for many household and industrial purposes. With minimal construction, maintenance and operation costs, this system is very useful for home use. This is a valuable alternative approach to improving overall efficiency and reusing waste heat. Technically feasible and economically viable.*

With the aim of saving energy and to reduce global warming effect, our work focuses on the valorization of the waste heat evacuated by the condenser of a refrigeration machine (air-conditioner) for the desalination of sea water. In this paper, we have realized the concept of a new system that combines air conditioning and desalination. The modelling of the heat exchanges of each part of the system is realized. To improve the performance of the system, various experimental tests are represented and discussed.

Key Words: **Refrigeration, desalination, condenser, global warming, etc.**

1. INTRODUCTION

The vapour compressor system employs the main components as Evaporator compressor. Expansion Device and condenser. The heat sucked by refrigetant from evaporator and heat added in compressor is extracted, then it can be useful for other purposes. The amount of heat is directly proportional to the refrigeration capacity of plant. So, the heat utilization can be economical for large capacity plants.

The condenser is key element for our project, The aim of the project is to design a condenser which is a heat exchanger which will cause the heat transfer from the refrigerant to water. The heated water is to be used for low temperature applications. The data required i.e., capacity, refrigerants etc., Nagpur the capacity of plant is 30 TR. The heat transfer from refrigerant to water is assurned to be by natural convection The condensation of refrigerant is film condensation. The basic aim of designing the heat exchanger is to fuel the length of coil for complete condensation of refrigerant, raising the water temperature by 50C.

2. HEAT TRANSFER

The Science of thermodynamic deals with the quantitative transition and rearrangement of energy as heat in bodies of matter Heat transfer is the Science which deals with the rate of exchange of heat between hot cold bodies called the source and receiver. There are three distinct ways in which heat may pass from a source to a receiver. Almost all engineering applications are based on this. These are Conduction. Convection and Radiation.

3. CONDUCTION HEAT TRANSFER

Conduction heat transfer is the process by which energy is transfer of kinetic energy at a molecular level. Energy flow occurs in the direction from areas of higher temperature and higher molecular energy level to area of lower temperature and lower molecular energy level.

$$q=KA\ (dT/dx)$$

Where q = heat transferred in x direction
dT/dx=Temperature gradient in x direction
A=Area normal to ternperature gradient
K=Thermal conductivity.
This equation is called Fourier law.

4. CONVECTION HEAT TRANSFER

Convection heat transfer is the transport of energy to or from a combined action. conduction heat transfer and fluid motion. Convection heat transfer at solid fluid surfaces is of most common interest, but fluid-fluid interfaces are also encountered Forced convection heat transfer involves fluids that are moved by some mechanical means. Free natural convection heat transfer refers to buoyant convection which results from the influence of gravity upon fluids density difference induced by the heat transfer process itself Convective heat transfer coefficients are generally characterized in the terms of 'h', which is employed in

$$q=hA\ (Tl-T2)$$

where, q = Rate of heat transfer
A = Surface area
(T1-T2)= Temperature difference between surface and bulk fluid.

This equation is known as Newtonion law of cooling. The flow regions whether laminar or turbulent, have a major influence on convection heat transfer coefficients are practically applied through certain correlations and require knowledge of thermophysical properties of the fluid, the fluid velocity field, and the surface geometry.

5. RADIATION HEAT TRANSFER

Thermal radiation is a form of electromagnetic energy. It is traveling at the speed of light through Homogeneous media. It is characterized by the frequency range of the electromagnetic spectrum. That includes the visible portions and extends through the infrared. At any particular temperature thermal radiation energy is emitted by a body over a wide band of frequencies.

6. REFRIGERANTS

A refrigerant is a substance which will absorb the heat from the source (at lower temp.) and dissipate the same to the sink (at higher temp.) either in the form of latent heat or in the form of sensible heat.

The important properties an ideal refrigetant should possess are:

1) Positive evaporating pressure: -
leakage of atmospheric air into the system is prevented due to positive evaporating pressure.

2) Lower condensing pressure: -
lower condensing pressure permits the use of light weight equipment and piping of the high-pressure side of the system.

3) High critical temperature: -
The critical temperature of the refrigerant should be high as compared to the condensing temperature. Due to this power consumption will be less.

4) Low freezing temperature: -
Freezing temperature of the refrigerant should be low enough as compared to evaporating temperature to prevent solidification and choking to the pipeline and valves.

5) Specific heat of liquid should be low to increase the C.O.P.

6) High latent Heat Vaporization: -
To extract more amount of heat from the cooling material (cooling chamber) per unit weight of refrigerant.

7) Low specific volume: -
To reduce the size of compressor.

PROPERTIES OF SOME IMPORTANT REFRIGERANT

1) Ammonia:
It has condensing pressure (about 12bar), high evaporating pressure here Iatent heat (1212 kj/kg at 15C). Its critical temperature is 132.6C and critical pressure is 116 bar and freezing temperature is -77.8C (low). It has large latent heat, and it has moderate working pressures.

2) Carbon-Dioxide (C02):
It has specific volume and therefore suitable for ships where space is a vital consideration. The critical point of CO2 is and dry ice (solid C02) boils at -78.5C at is 81C atmospheric pressure. It has low critical temperature (31C) which is below condenser temperature and freezing point is sufficiently low (-110C). It is cheap non-toxic, non-corrosive and non-flammable. The disadvantage of CO is high working pressure (70 bar) due to which power required is greater and C.O.P is less.

3) Air:
Air is available free of cost, it is nontoxic and non-flammable. It has low C.O.P. Dry air is used in aircraft air-conditioning where low weight is more important that the efficiently.

4) Freon-11 or Trichloro-monofluro-methane CCI3 (F):
It is colorless. non-corrosive, non-toxic and non-flammable liquid. Commercial name is F-11. At atmospheric pressure its boiling temperature is 23.8C which is relatively high. It has a freezing temperature of -111C and a critical temperature of 197.8C. Due to low operating pressures and high volumes, centrifugal compressors are used with this refrigerant. It is used for air conditioning and water chilling applications.

5) Dicholoro Difluro-methane-freon 12 (CCl2F2):
Its commercial name is F-12. It is colorless, odourless and non-toxic. Boiling ternperature is 29.8C at atmospheric pressure. It has high critical temperature (111.5C) and low freezing temperature of -157.8C. Its latent heat of vaporizations is low and dielectric strength is high. Its specific volume is small as compared to that of ammonia.

6) Difluro-monochloro-methane (CHCIF2) Freon 22:
It boils at -40C at atmospheric pressure. It is denser compared to ammonia and its evaporating temperature is low. It is used in small and medium commercial plants.

There are various methods of refrigeration:

1) Ice refrigeration
2) Evaporative refrigeration
3) Refrigeration by expansion of air.
4) Refrigeration by throttling of gas.
5) Vapour absorption system.
6) Vapour compression system.
7) Steam jet refrigeration.

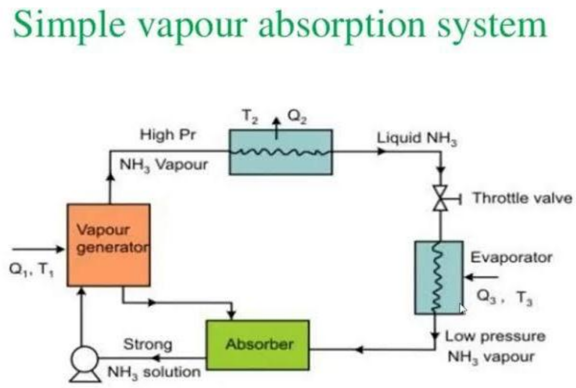
Dry ice refrigeration.

7. VAPOUR ABSORPTION SYSTEM

The absorption refrigeration system is heat operating unit which uses a refrigerant that is alternately absorbed by and liberated from the absorbent. Minimum no. of primary units essential in absorption system includes evaporator, absorber, generator, and condenser figure shows a simplified flow diagram of an ammonia absorption system in which water serves as the absorbent. During the compression stroke the vapour is compressed isentropically to pressure P2 and temperature T2 delivered out from the compressor (P2). P2 shows the vapour in superheated state. The vapour at 2 passes and to condenser in which the cooling water is supplied to remove heat from the vapour. Thus, vapour is first cooled to the saturated temperature at pressure p2 and further removal of heat, condenses it to liquid removing its latent heat till pt3 Thus, to carry out this operation, the saturation temperature corresponding to pressure P2 should by sufficiently higher than the temperature of cooling water for efficient heat transfer.

The high-pressure liquid is now expanded through a throttle valve, of the liquid at 3 throttles to lower pressure P1 and the condition obtained after the constant enthalpy expansion is shown 4 After throttling, we get Iuqid partly evaported at lower temperature T4 and lower pressure p1, thus after the throttle valve we get wet vapour at low temperature. This vapour now passes through evaporator coils immersed in brine or the chamber to be refrigerated. These vaopur absorb latent heat from brine in further evaporating itself. The vaopur may reach condition 1 i.e., dry saturated pressure P, thus completes the cycle absorber.

The strong ammonia solution thus formed is then pumped into the generator. The pump increases the pressure of the solution about 10 kg/cm. The strong solution of ammonia is heated by external means (steam or gas), and in the heating process, the refrigerant vapour is driven out of solution and the same heat is given out to the condenser, where it is condensed to low pressure level by an expansion valve and then returned to the absorber.



The high-pressure liquid ammonia is passing through a throttle valve to the evaporator where it absorbs its latent heat of vaporization and maintains the cold. The dry ammonia vapour is coming out of evaporator which is allowed to mix with the weak solution of ammonia sprayed in the absorber.

This completes the cycle.

8. VAPOUR COMPRESSION SYSTEM

The vapour refrigeration systems now a days one universally used for all purpose refrigeration. It is generally used for all industrial purposes from a small domestic unit of 0.5-ton capacity to an air conditioning plant of cinema hall of 200-ton capacity. The vapour compression refrigeration plant is shown diagrammatically.

COMPONENTS OF VAPOUR COMPRESSION SYSTEM.

The main components of vapour compression system are:

1) Compressor.
2) Evaporator.
3) Condenser.
4) Throttling device.

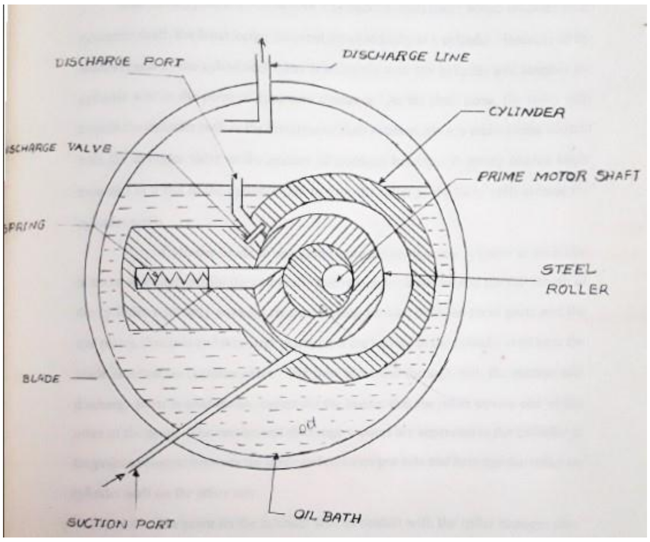
The two types of compressors are generally used in vapour compression

1) Reciprocating compressor.
2) Rotary compressor.

1) Reciprocating compressor:

The reciprocating compressor is the most widely used type being employed in all field of application, it is especially adoptable for used with refrigeration requiring relatively small displacement and condensing at relatively high pressure. Among the refrigerants used extensively with reciprocating compressor are R-12, R-22, R-500, R-502 and R-717Reciprocating compressors are available in sizes ranging from 1/8 hp (approx. 90W input) in small domestic units up to 250 tons or more in large industrial installations. Reciprocating compressor may be single acting or double acting. In single acting compressors, compression of the vapour occurs only on one side of the piston and once during each revolution of crankshaft, whereas in double acting compressors. Single acting compressors are usually of the enclosed type wherein the piston is driven directly by a connecting rod working off the crankshaft, both connecting, and crankshaft being enclosed in a crank case, which is pressure tight to the outside.

2) ROTARY COMPRESSORS:



Rotary compressors in common use are of four general designs:

i. Rolling piston: -

The rolling piston type employs a cylindrical steel roller which revolves on an eccentric shaft. the latter being mounted concentrically in a cylinder because of the shaft eccentric, the cylindrical roller is eccentric with the cylinder and touches the cylinder wall at the point of minimum clearance. As the shaft turns, the roller rolls around the cylinder wall in the direction of shaft rotation, always maintaining contact with the cylinder valve in the manner of crankpin bearing. A spring-loaded blade mounted in a slot in the cylinder slot to flow the roller as the latter rolls around the cylinder walls. Cylinder heads or end plates are used to close the cylinder at each end to serve as a support for the crankshaft. Both the roller blade extends the full length of the cylinder with only working clearance being allowed between these parts and the end plates. Suction and discharge plates pans are in the cylinder wall near the blade slot, but on opposite sides. The now of vapour through both the suction and discharge ports is continuous, except for the instant that the roller covers one or the other of the ports.

ii. Rotating vane: -

The rotating vane type of rotary compressor employs a series of rotating vanes or blades which are installed equidistant around the periphery of the slotted the rotor shaft is mounted. Heads or end plates are installed on the ends of the cylinder to seal the cylinder and to hold the rotor shaft. The vanes move back and forth radially in the rotor slots as they follow the contour of the cylinder wall when the rotor is turning. The vapour compressed by the reduction in that results as the vanes rotate from the point of maximum rotor allow discharge of the compressed vapour at the desired point during the compression process, that point being the design point of the compressor.

iii. Helical rotary screw: -

The helical rotary or screw compressor is a positive displacement compressor in which compression is accomplished by the enmeshing of two mating helically grooved rotors suitably housed in a cylinder equipped with appropriate inlet and discharge ports. The gas so trapped in the interlobe space is moved box axially and radially and is compressed by direct volume reduction as the enmeshing of the lobes of the compressor progressively reduce the moved port the suction port and sealed in a interlope space.

9. EVAPORATORS

It is most required important part of the refrigeration system. The evaporator is known as cooler or freezer The evaporators are manufactured in different sizes, shapes, and types as per requirements.

The evaporators are mostly divided into two groups:

1) Flooded Evaporators: -

In flooded evaporators, the evaporator (cooler or freezer coil) is always kept filled with liquid refrigerant. This type of evaporator gives high rates so that smaller evaporators can be used for the required capacities. Flooded system provides an advantage of using several evaporators with equal working efficiency in conjunction with one accumulator without using more than one throttIe valve when all evaporators are used for same temperature.

2) Dry-expansion Evaporators.

Liquid refrigerant is fed into the dry expansion evaporator through an expansion device which meters the liquid into evaporator at a rate such that all the liquid is vaporized by the time it reaches the end of the evaporator. The rate at which the liquid is fed into evaporator depends upon the rate of vaporization and increases or decreases as the heat load on evaporator increases or decreases. Flooded type is always filled with liquid, whereas the amount of liquid present in the dry expansion evaporator increases to accommodate the greater load. Thus, the evaporator efficiency is greatest when the load on evaporator is highest.

The evaporators are also classified as per the mode of heat transfer.

1) Natural Convection Evaporators.
2) Forced Convection Evaporators.

NATURAL CONVECTION EVAPORATORS:

These evaporators are used where low air velocity and minimum dehydration of the products are desired. The air circulation by natural convection depends upon the temperature difference between evaporator and the space to be cooled. High circulation rates will be produced with higher temperature differential.

FORCED CONVECTION EVAPORATORS:

These evaporators are used for cooling air by forced circulation of air. The evaporators are more efficient that natural convection evaporators because it requires less cooling surface and higher evaporative pressures can be used which save considerable power input to the compressor. The air velocities of 100 to 200m /min. across the coil face are recommended. These evaporators are provided with fins to increase the heat transfer rates. 80 to 120 fins per meter of coil lengths are recommended when the required temperature is below zero degree and 600 fins per meter are recommended when the required temperature is above zero degree.

10. EXPANSION DEVICES

The expansion device is one of the basic components of a mechanical refrigeration system. It is located between receiver and evaporator (if receiver is not used then it is placed between condenser and evaporator). Filter and drier are provided before the expansion device to prevent any trouble due to moisture and suspended Impurities.

The function of an expansion device is to reduce the condensate pressure down to evaporator pressure and to regulate the flow rate through the evaporator. Some of the expansion devices are

(i) Capillary tube:
It is metal tube of 98 to 285 cms and bore 0.6 to 2 mm. It is used only in small capacity units such as domestic refrigerators, water coolers and small commercial plants. The required pressure drop is caused due to heavy frictional resistance offered by a small diameter tube. The resistance is directly proportional to length and inversely proportional to diameter.
(ii) Automatic expansion valve:

It is known as constant pressure expansion valve. It controls liquid supply to evaporator by maintaining a desire pressure. It works in response to the pressure changes in the evaporator due to increase in load (pressure increases) or due to decrease in load (pressure decreases).

11. LITERATURE REVIEW

[1] S.C Walawade, B.R Barve and P.R Kulkarni they extract heat house hold refrigerator and used as a food warmer, water heater and grain dryer.

[2] Hussam Jouhara, Navid Khordehgah, Sulaiman Almahoud, Bertrand Delpech, Amisha Chauhan and Savvas A.Tassou state that in industrial process lot of heat get lost they are not practically used. They try to use waste heat in industrial process and reduced the energy consumption in industry and save cost.

[3] Muhammad Asim, Michael K.H. Leung, Zhiqiang Shan, Yingying Li, Dennis Y.C. Leung and Meng Ni study and analysis rankine and vapour compression refrigeration cycle for proposed waste heat recovery and for better system performance compared and analyzed the 36 working fluid combination.

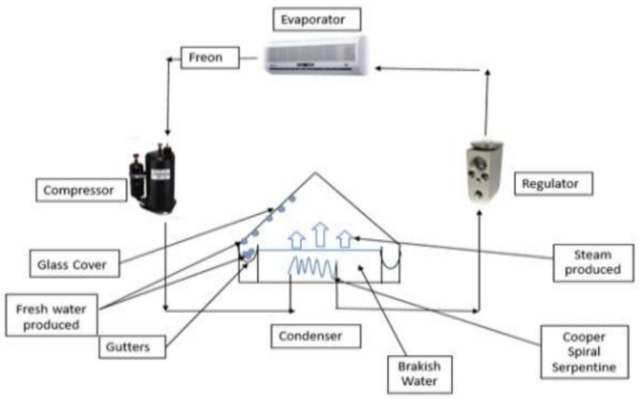
[4] V. Naveenprabhu, F. Justin Dhiraviam, K.M. Gowtham, R. Afsal Tharick and R. Arunkumar they extract heat from refrigeration and make a separate heat chamber to use both heating and cooling process goes simultaneously, it is a cost effective and used everywhere to reduce power consumption.

[5] S.C Kaushik and M. Singh placed a canopus heat exchanger between the compressor and condenser. They investigate it is possible to recover discharged superheated vapor and to increase the temperature of external fluid(water) removing heat from the condenser.

[6] Abdellah Shafieian and Mehdi Khiadani stated role of cooling and AC systems in submarine and water supply for both crew and equipment is essential, at that time large amount of high temperature exhaust fumes discharged from submarine engines provide an better opportunity to recover and apply this waste energy in required applications.

12. APPLICATION

Water distillation is one of the most important low temperature applications. On cargo ships which transfer the meat, fish etc, there is a refrigeration system of sufficient capacity. The sailors the ship is required to travel along distance through sea which take long time. even if far the months together, they must leave the ship. in this situation the major problem is of drinking water. they can store drinking water for so many days. so, for this the distillation of sea water is very good alternative.



13. CONCLUSIONS

This is useful for large capacity plants. As our aim to recover the heat, the heat loss in condenser will be more in large capacity plants. When we will get the sufficient heat, then only we can put it to use for any low tempreature application. We tried by this work to expand the use of air-conditioner systems for water desalination. the waste heat rejected by the condenser and contributed to evaporate water and extract fresh water by condensation of the steam produced while keeping the principal function of air-conditioner to cool. we found that sea water temperature reaches approximate 55°C, distilled water flow rate reaches 3.2 Kg/m2 /Day, these results can be improved by malty solutions like augmentation of the basin surface by adding a second stage, or by acceleration of steam condensation process by adding a bigger condenser for that purpose.

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