International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.1, Jan-Feb 2012 pp-271-275 ISSN: 2249-6645

Reheating Refrigeration System

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Abstract
The title "Reheating Refrigeration System" has the objective to utilize the rejected heat from the condenser of an air conditioner in an economy way.

This will be done by adding an arrangement called "REHEATER SYSTEM" which will have "INSULATED CONDUCTOR" whose one end is in the "HEAT EXCHANGER" at place before the condenser and the other end is in the "REHEATER" at a place after the evaporator and just before the compressor of the refrigeration system. What amount of heat going to the condenser, will be transferred to the reheater by the conductor as there will be some temperature difference in the heat exchanger and the reheater. Owing to this, the temperature and pressure will increase before the compressor in the reheater. Thus the compressor work can be reduced to minimum and the refrigerating effect will tend to increase. So mainly three benefits can be achieved as given as:

1. Utilization of wasting heat.
2. Reduction in work input to the compressor.
3. Better refrigerating effect

Compressor	Discharge Temperature
Screw Compressor (Indirect cooled)	70 → 80 °C
Screw Compressor (Injection cooled)	50 → 60°C
Reciprocating Compressors	85 → 110°C
Boosters (Rotaries & Reciprocating)	75 → 85°C

1. WHY IT IS NEEDED

In the vapour compression refrigeration system (VCRS), for an air conditioner generally a large amount of heat is generated in the refrigerant after its compression in the compressor and that is rejected to the atmosphere through the condenser and thus the heat is wasted. With this, the compressor requires higher power to operate when the cooling rate is needed more. Thus for best practices we need to adapt a project.

It is seen that the discharge gas coming out from the compressor is in a superheated state and some heat can be recovered from this refrigerant gas by de-superheating it before it enters to the condenser. The discharge temperatures in most refrigeration systems are quite high (in the range of 70°C to 100°C).

The superheat can be recycled to heat the refrigerant coming from the evaporator, before the compressor and can be used to increase its pressure thus can reduce the compressor work input to achieve the desired cooling effect.

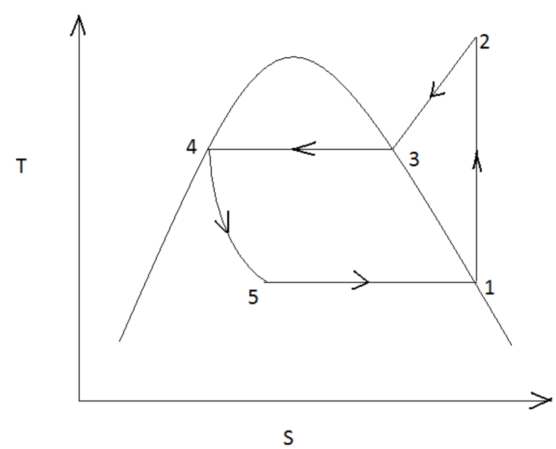

Fig.1 T-s diagram of the VCRS

The discharge temperatures of various types of compressors for refrigerant F22 are generally as follows:

2. REHEATING REFERIGERATION SYSTEM (RRS)

To overcome with this problem, the "Reheating System" is added to the refrigeration system, thus naming Reheating Refrigeration System.

In the reheating system, mainly three components are there;

a) Heat exchanger,

b) Reheater, and

c) Insulated conductor.

The reheater is placed after the evaporator and before the compressor and the heat exchanger is placed after the compressor and before the condenser. Insulated conductor is connecting to both reheater and heat exchanger.

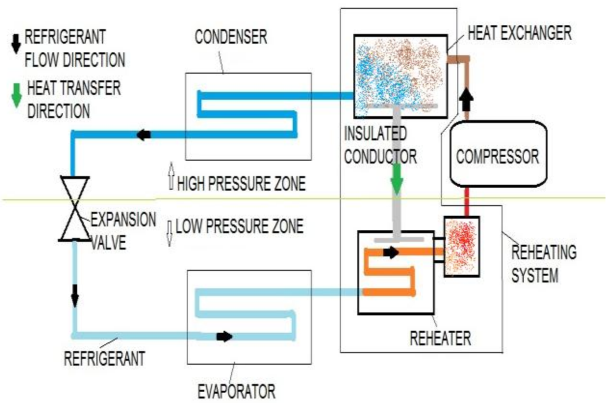

Fig.2 Reheating Refrigeration System

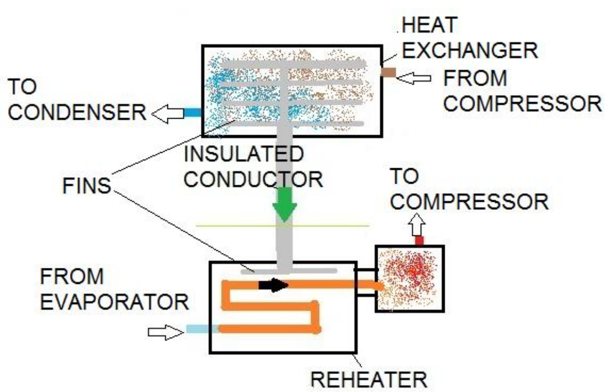

Fig. 3 Reheating system

The heat exchanger is that device which facilitates the heat transfer from the compressed refrigerant coming in it, with the fins of the conductor, which is within it, by the conduction mode. The heat exchanger adapted is a box type device in which the refrigerant only flows and transfers the heat due to temperature difference.

The heat exchanger focuses to increase heat exchange rate. If the fins are achieving higher heat from the refrigerant, means, will be in higher temperature and the refrigerant looses maximum heat to the fins. Then the effectiveness of heat transfer will be Maximum. For better storing of the refrigerant in the heat exchanger, for higher temperature achievement, it should contain suitable material at inside, of higher thermal conductivity.

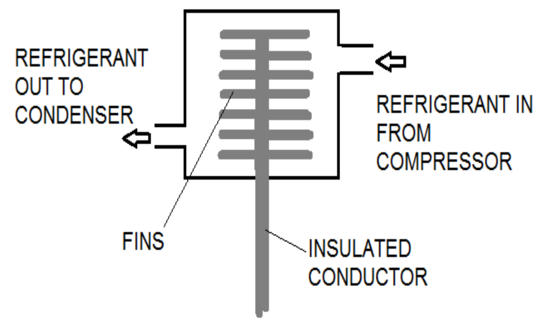

Fig. 4 Heat exchanger

The reheater is that device in which the heat obtained from the heat exchanger is utilized to raise the pressure of refrigerant coming in it, by incrementing the temperature. The refrigerant coming from the evaporator enters the reheater. In the reheater, the fins of the conductor, getting heat from refrigerant in the heat exchanger, transfers the heat to the refrigerant. Thus the temperature of refrigerant increases and the reheater is such designed that it will provide a constant volume system so the pressure would tend to increase. Now the pre-pressurised refrigerant will be forwarded to the compressor.

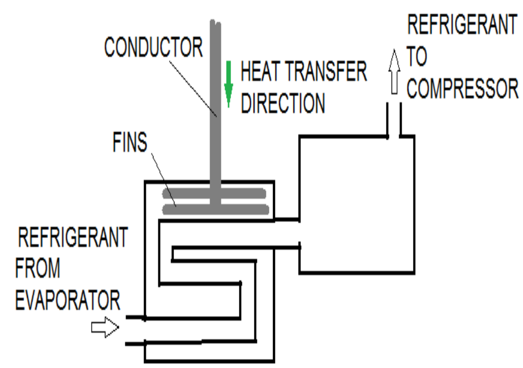

Fig.5 Reheater

The insulated conductor being used in the reheating refrigeration system, transfers the heat from the Heat exchanger to the Reheater. The conductor is insulated so that heat loss to the surroundings may be reduced. The conductor will have fins at its ends. Fins at one end will be inside the heat exchanger and the fins at other end will be inside the reheater. The material should of higher thermal conductivity like copper, aluminium etc.

4. ASSUMPTIONS MADE

i. One dimensional heat flow

ii. Steady state heat dissipation

iii. No internal heat generation

iv. Homogeneous and isotropic material, thermal conductivity of the material is constant

v. Uniform heat transfer coefficient on the entire surface

vi. Thickness of the fin is small as compared to width and length

vii. Negligible radiation exchange with the surrounding.

5. THE PROCESS

When the heat is gained by the refrigerant in the evaporator, the refrigerant gets evaporated as it will have lower boiling point generally below 0°C and its density becomes lesser and it goes towards the compressor but as there is reheater before the compressor the refrigerant will come to the reheater .For the first stage, in the reheater the refrigerant will normally enter and goes out to the compressor. In the compressor the pressure of the refrigerant is increased with the temperature. Now the refrigerant enters the heat exchanger, where the heat of the compressed refrigerant is given to the conductor as it is having lower temperature (conductor is in contact with the temperature of refrigerant at the reheater). The rest amount of heat of refrigerant is rejected to the atmosphere in the condenser and it comes in the liquid phase. And it goes to the evaporator passing through the capillary tube where its pressure is reduced.

In the second stage, the refrigerant evaporated in the evaporator enters the reheater and affected by the heat transfer which is by the conductor getting heat from the heat exchanger and the conductor transfers the heat to the refrigerant. The vaporized refrigerant gets heated and its temperature and pressure is increased due the reheater is providing the constant volume system. Now the pressure of refrigerant is higher than that of the previous. This pre-pressurized vapour refrigerant reaches to the compressor where the compressor requires lesser power to get the predefined previous temperature. The refrigerant after getting predefined temperature goes to the heat exchanger where it loses the heat to the conductor again as previously and reaches to the condenser and the further process is similar as previous stage. Thus the cycle is completed.

The processes are:

6-1: heat addition at the constant temperature and pressure in the evaporator

1-2: heat addition at constant volume in the reheater

2-3: isentropic compression in the compressor

3-4: drop in temperature in the heat exchanger at constant pressure

4-5: heat rejection in the condenser at constant temperature and pressure

5-6: pressure drop in the throttle valve isenthalpically

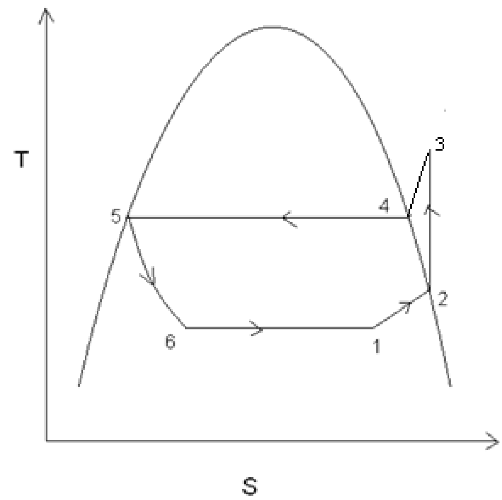

Fig.6 T-s diagram of reheating refrigeration system

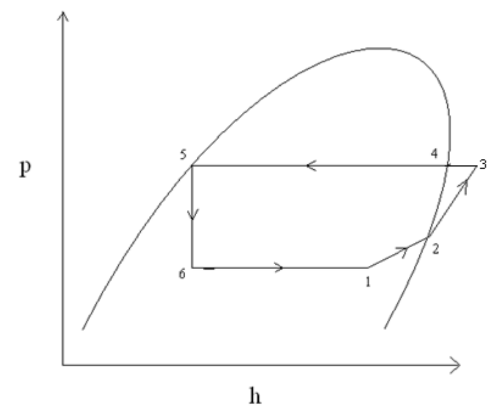

Fig.7 Reheating refrigeration system on p-h diagram

6. GENERAL REFRIGERATION SYSTEM VERSUS REHEATING REFRIGERATION SYSTEM

The cycle analysis of reheating refrigeration system with T-s diagram and p-h diagram are shown in the figures below

In the T-s diagram,

- For simple vapour compression refrigeration system (1):-

  Area under the process 1-2-3-4-5-1 is showing the work input to the system and the area 1-5-A-D-1 is showing the cooling effect of the system.

- For reheating refrigeration system (2):-

  Area under process 6-7-8-9-10-11-6 is giving the work input to the system and the area under 7-6-11-B-C-7 is showing the cooling effect of the system.

Here,

(Work input) $_1$ > (work input) $_2$

(Cooling effect) $_1$ < (cooling effect) $_2$

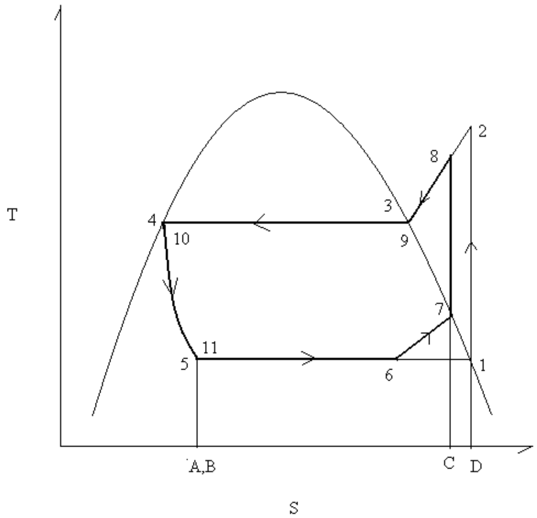

Fig.8 T-s diagram of reheating refrigeration system

In the p-h diagram,

- For simple vapour compression refrigeration system (1):-

Work input to the system = $h_2 - h_1$

And refrigerating effect = $h_1 – h_5$

- For reheating refrigeration system (2):-
- Work input to the system = $h_8 – h_7$
- And refrigerating effect = $h_7 – h_5$

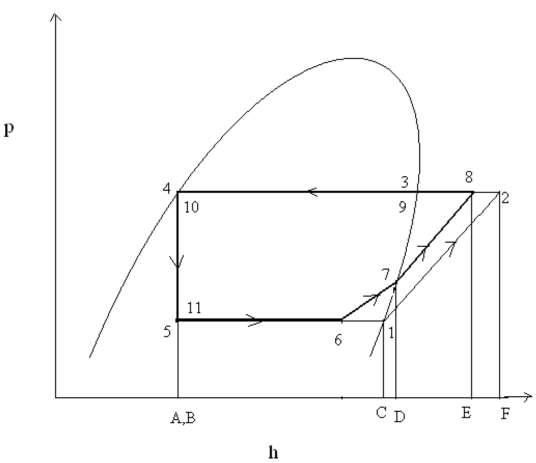

Fig. 9 p-h diagram of reheating refrigeration system

It is clear that

(Work input) $_1$ > (work input) $_2$

(Refrigerating effect) $_1$ < (refrigerating effect) $_2$

Thus it may be concluded that

Coefficient of performance of RRS > Coefficient of performance of simple VCRS

$$\left(\text{since COP} = \frac{\text{refrigerating effect}}{\text{work input}}\right)$$

Therefore the reheating refrigeration system increases the coefficient of performance of the system by simply utilization of the heat wasting in the condenser and providing the economical benefits as low capacity compressor can also be used.

7. BENEFITS

With the adaptation of reheating refrigeration system the following advantages can be achieved:

1. There is saving of wasted heat in the condenser
2. The power consumption in the compressor is reduced to minimum
3. The amount of refrigerant may also be reduced
4. Better cooling effect can be achieved
5. The apparatus are easier to construction and easily available
6. There is no change in the components of the refrigeration system
7. There is no change in the air conditioning parameters.

8. LIMITATIONS

1. The life of the refrigerant may decrease faster as it will gain more heat
2. The distance between the heat exchanger and reheater should be adequate.

9. COST OF REHEATING REFRIGERATION SYSTEM

The reheating refrigeration system does not require changes in other devices of the refrigeration system and the air conditioning parameters, thus it is not bearing the much costs except the cost of reheating system.

The cost for making the reheating system is combination of the cost of heat exchanger, reheater, conductor and insulation. These are having the cost of mainly its material. For higher heat transfer rate, materials having higher thermal conductivity are recommended. Here is list of some materials:

Material	Thermal conductivity (W/mK)
Aluminum	225
Brass	107
Copper	385
Cast iron	55-65
Steel	20-45
Silver	410
Urethane, rigid foam	0.026
Glass fiber	0.043
Soft rubber	0.13
Wood	0.17
Glass	0.78

The total cost for Air Conditioner having Reheating Refrigeration System may be about = Cost of Air conditioner without RRS + Cost of reheating device

Total cost of making the reheating device will be under Rs. 2000. Thus it will have effectiveness with efficiency as well as be economical.

10. ACKNOWLEDGEMENT

The work of "Reheating Refrigeration System" could not have taken shape without the able support of Mr. A. K. Dewangan and Mr. S. Rathore, lecturers of Mechanical Engineering Department, Institute of Technology, Guru Ghasidas Vishwavidyalaya, Bilaspur (C.G.). They were the main sources who have given the right direction to this. We are thankful to Mr. Murari Kumar Lahare, pump operator in NSPCL, Bhilai, for his valuable time to our project. My comrades Mr. Gajendra Kumar Khute, Mr. Ajay Kanwar and Mr. Manoj Dhruw have given their valuable time comlete this task.

11. NOMENCLATURE

COP = coefficient of performance

RRS = reheating refrigeration system

VCRS = vapour compression refrigeration system

h = enthalpy

p-h diagram = pressure- enthalpy diagram

p = pressure

s = entropy

T = temperature

T-s diagram = temperature- entropy diagram

$ = American dollar

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