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Experimental analysis of Condenser Inlet Diffuser Concept In Vapor Compression Refrigeration System By Using R404A

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Abstract: *This Paper Describes The Analysis Of Condenser Inlet Diffuser Concept In Vapor Compression Refrigeration System By Using R404a.A Condenser Inlet Diffuser For A Vapor Compression System Is Provided. The Diffuser Includes An Inlet To Receive A Compressed Refrigerant From A Compressor Of A Refrigeration System. The Refrigerant Leaving The Diffuser Having A Higher Pressure Level Than Refrigerant Entering The Diffuser. The Purpose Of A Compressor In Vapor Compression System Is To Elevate The Pressure Of The Refrigerant. In The Conventional Condenser, There Is A Pressure Drop Across The Tubes There By Increasing The Power Consumption Of The Compressor. This Paper Is An Experimental Approach To Compensate The Compressor Work By Providing A Diffuser At The Inlet Of The Condenser. Diffuser Converts The High Velocity Available At The Compressor Discharge Into The Pressure Energy. Diffuser Is A Passive Device Which Recovers The Static Pressure Without Any Work Input. Diffuser Receives Refrigerant From The Compressor Discharge And Increases Its Pressure And Temperature Considerably. By Increasing The Saturation Temperature Of The Refrigerant, The Temperature Difference Between The Refrigerant And The Fluid Flowing Over Condenser Coils Is Increased, So That More Heat Transfer Occurs.*

I. Introduction:

Condensers are an important component used in vapour compression refrigeration systems in HVAC applications. Air cooled condenser is that in which the vapour refrigerant entering the condenser coil is cooled by the surrounding air. As the refrigerant to the flows inside the coils, heat transfer occurs from the refrigerant to the lower temperature fluid circulating outside the condenser coils. The condensed liquid refrigerant from the condenser flows through an expansion device to an evaporator. The two-phase refrigerant in the evaporator enters into a heat exchange relationship with secondary fluid to regulate the temperature of the secondary fluid that is circulated to regulate the temperature of an area inside the structure. The refrigerant liquid in the evaporator undergoes a phase change relationship with the secondary liquid and is returned to the compressor where the pressure of the refrigerant is elevated and discharged into the condenser to complete the cycle. In the present embodiment of the above system, the refrigerant vapour from the discharge of a compressor enters the condenser at relatively high velocity. The direct impingement of this refrigerant can cause damage to the condenser tubes, such as by vibration, pitting and erosion. It also results a phenomenon referred to as "liquid hump". Liquid hump refers to a rise in the level of the condensed refrigerant liquid in the central portion of the condenser as compared to the level at the ends of the condenser thereby reducing the effective heat transfer surface area which can reduce condenser efficiency. Further the high velocity refrigerant causes undesirable splashing of the liquid refrigerant in the condenser. What is needed is a diffuser at the condenser inlet that smoothly decelerates and transitions incoming refrigerant flow, achieving minimum stagnation pressure losses and maximizes the static pressure recovery. With the use of the diffuser at the inlet of the air cooled condenser the static pressure can be recovered thereby reducing the power consumption of the compressor, and thereby improving the system efficiency. If maintaining the same compressor discharge pressure and temperature inside the condenser is higher when using the diffuser of the present invention due to static pressure recovery. Without altering the temperature of the fluid circulating through the condenser coils to cool the refrigerant, the temperature difference between the two is increased, so that less heat transfer surface is needed to reject the same amount of heat. Using the diffuser of the present invention provides an opportunity to use a smaller condenser to achieve the same system efficiency. Use of this diffuser also provides an advantage of reducing the effect of starving in vapour compression systems.

II. Present Work

Steps involved in the present work
1. Manufacturing of DIFFUSER.
2. Incorporating the DIFFUSER into the system.
3. Analysis of the system performance and calculations.

1 .Manufacturing of diffuser

Diffuser is a passive device which increases the pressure energy by converting the available kinetic energy at the inlet. As the velocity of refrigerant is subsonic in the vapour compression refrigeration system the diffuser can be manufactured with the following dimensions. Dimensions for the subsonic velocity (Mach number<1) fluids are given by the NASA.

Area of EXIT / Area of ENTRANCE = 3.5
Diffuser length = (EXIT diameter – ENTRANCE diameter) / 0.525
For a given condenser pipe of bore 3/8" (9.525mm)
Entrance diameter = 5.091mm
Exit diameter = 9.525mm
Length of diffuser = 8.445m

The diffuser with the above calculated dimensions looks like as shown in Fig. 1.

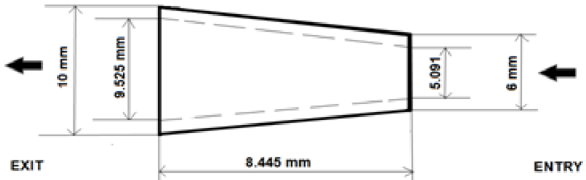


FIG.1 DIFFUSER

2. Incorporating the DIFFUSER into the system

The vapour compression system has the components like compressor, condenser, expansion device and evaporator. To analyze the performance of vapour compression system, pressure gauges, temperature gauges and sight glasses are installed at the exit and the entry of each component as shown in fig..2. The purpose of sight glass is to observe the state of the refrigerant flowing in the refrigeration system. The speed of the compressor can be adjusted with the help of the variable speed drive and voltage regulator as shown in fig. 2.

Diffuser at the inlet of condenser increases the both pressure and temperature of the condenser considerably. Increased pressure in diffuser helps to reduce the compressor work. Temperature of the condenser can be controlled by the fan motor variable speed drive as shown in fig. 2. Diffuser also reduces the condenser tube vibration as it decelerates the refrigerant smoothly.

Vapour compression system with and without diffuser is operated with the help of the hand valves (not shown in fig.). Increased pressure can also be utilized to produce more refrigeration effect with the reduced work input to the condenser.

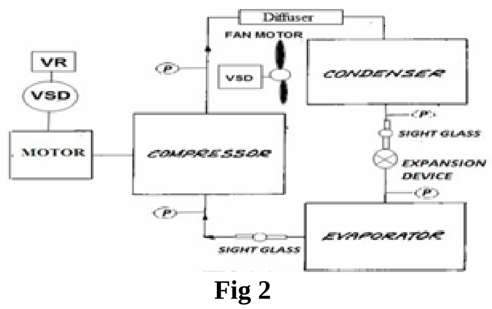


Fig 2

The refrigerant used is R-404A which is also called as Blend Mixture having the boiling point of -47.8^{0}C. 100gm. Of refrigerant is charged into refrigeration system.

Compressor - 1/7 HP hermetically sealed.

Capillary - 0.031" diameter and 7 feet length.

Condenser - 3/16 diameter of 10 m length.

Evaporator - 1/4“ diameter.

Storage - 175 ltrs.

Anaysis of the system performance and Advantages

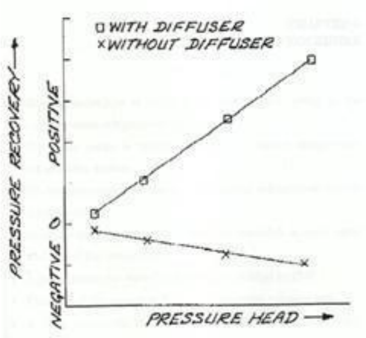


Fig 3

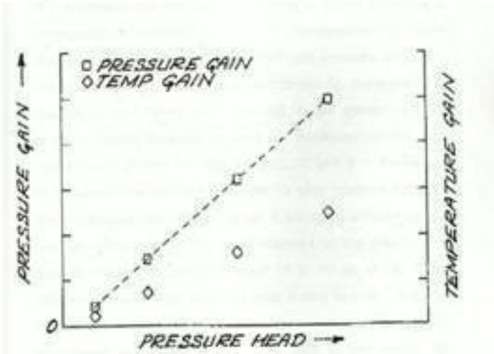


Fig 4

Fig. 3 is a graph comparing pressure recovery of the refrigerant vapour exiting the compressor and entering the condenser between refrigeration systems with and without an inlet diffuser of the present invention.
Fig. 4 is a graph that shows the gain (or differences) in the saturation temperature of the refrigerant in the condenser corresponding to the increase in pressure of the refrigerant exiting the compressor and entering the condenser.
Fig. 5 shows the experimental setup of the present invention.

Advantages:
1. An Advantage of present invention is that it facilitates static pressure recovery of the refrigerant entering the condenser, thereby increasing the pressure of the refrigerant vapour leaving the diffuser compared to the pressure of refrigerant entering the diffuser.
2. An advantage of the present invention is that it increases vapour compression system efficiency.
3. A further advantage of the present invention is that it reduces the tube vibration associated with the operation of the condenser.
4. A yet additional advantage of the present invention is that it reduces the level of liquid hump inside the condenser.
5. Another advantage of present invention is that it increases the heat transfer rate through the condenser i.e., smaller condenser is enough to reject same amount of heat.
6. Arrangement of the diffuser at the inlet of condenser compensates the compressor work.
7. The effect of straving can also be reduced.

With out diffuser

P1(Psi)	P2(Psi)	P3(Psi)	P4(Psi)
45	225	225	45
T1(^{o} C)	T2(^{o}C)	T3 (^{o} C)	T4 (^{o}C)
20	51.5	48.5	21.0

With diffuser

P1(Psi)	P2'(Psi)	P3(Psi)	P4(Psi)
45	230	230	45
T1(^{o} C)	T2'(^{o}C)	T3 (^{o} C)	T4 (^{o}C)
18	55.5	48	20.2

Where

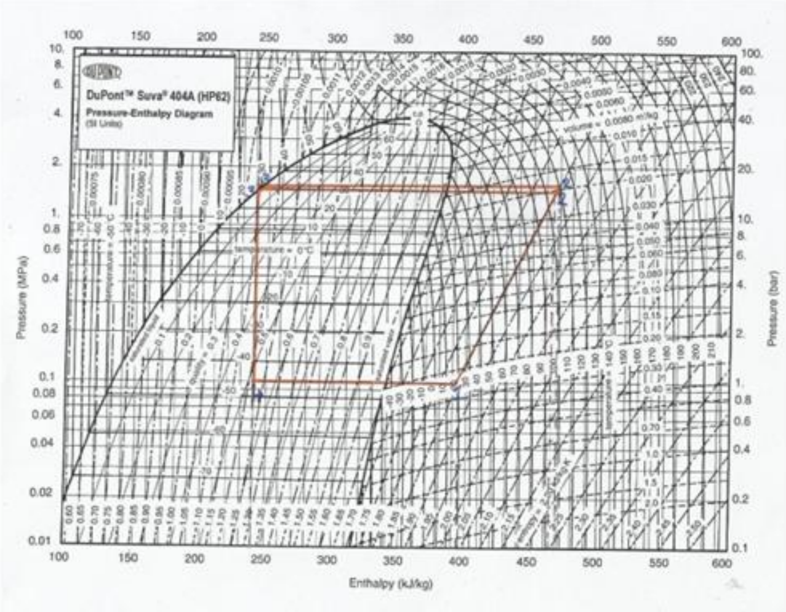
P1 = Suction Pressure
P2 = Discharge Pressure
P2' = Pressure at the exit of diffuser
P3 = Pressure at the exit of condenser
P4 = Pressure at the exit of expansion device
T1 = Suction temperature
T2 = Discharge temperature
T2' = Temperature at the exit of diffuser
T3 = Temperature at the exit of condenser
T4 = Temperature at the exit of expansion valve

NOTE:

1. Net Refrigeration effect is maintained constant with the help of the variable speed drive to the compressor in both the systems of with and without diffusers.
2. Condenser Temperature is maintained constant with the help of the variable speed drive to the fan motor.
3. compression process is assumed to be reversible adiabatic or isentropic.

Compressor work = h2 – h1
Diffuser work = h2'- h2
Refrigeration effect = h1 – h4
For the same refrigeration effect= h3= h3' =h4
Reduction in compressor work = Compressor work – diffuser work
= h2 –h1 - (h2' – h2)

Fig. 5



h3=h3'=h4=242 kj/kg h1=400 kj/kg h2'=469 kj/kg
h2=466kj/kg

From the P-h chart of R-404A as shown the following values can be obtained.

h1 = 400 Kj / Kg
h2 = 466 Kj / Kg
h2' = 469 Kj / Kg
h3=h3'=h4 = 242 Kj / Kg
Compressor Work = h2-h1 = 466-400 = 66 Kj / Kg
Diffuser =h2'-h2=469-466 =3 Kj / Kg
Refrigeration effect =h1-h4 =400-242 =158 Kj/Kg
Reduction in compressor work=66-3 =63 Kj/Kg
$COP_{WITHOUT\ DIFFUSER}$ =
Refrigeration effect / compressor work
= 158/66
= 2.39
$COP_{WITH\ DIFFUSER}$ =
Refrigeration effect / Reduced compressor work
= 158/63
= 2.51
Hence the COP is increased in the vapour compression refrigeration system

III. Results And Conclusions

This invention produces the following results:
Condenser Pressure is increased from 225 psi to 230psi.
Overall COP is increased by 8.24%.
Compressor work is reduced by 4.55%.
Power consumption can be reduced by 4.55%.
Refrigeration effect can be increased by 3.57%.
COP of the system increased from 2.45 to 2.67

IV. Conclusions:

1. Static pressure recovery in the condenser is possible.
2. Compressor work can be compensated.
3. COP of the system can be increased.

4. Power consumption can be reduced.
5. Liquid hump can be eliminated.
6. Condenser efficiency can be increased.
7. If we use variable speed compressor

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