Experimental Investigation on Water Cooler Test Rig With And Without Diffusers

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Abstract. Refrigeration is a process of maintaining the temperature lower than the surroundings. It can be achieved with the help of components of refrigerator and the refrigerant. Refrigerant is a substance maintaining the temperature lower than the atmosphere. VCR is widely applied in daily as well as in large scale industry to produce a refrigeration effect. The diffuser is a passage that will increase the pressure energy by changing the kinetic energy at the inlets. The main objective of this project work is to design a water cooler testrig system with two different angled diffusers of divergence angle of 13°, 16° are planned for the equivalent inlet and outlet dia. In this project we are evaluating the various constraints such as refrigeration effect & coefficient of performance (COP) with and without diffusers at condenser inlet. The 16° divergence angleof diffuser given the better coefficient of performance was 23.15.

1 Introduction

1.1 Working principle of water cooler test rig

Refrigerator works on Clausius statement i.e., "it is impossible to transmission of heat from a chiller body to a warmer body without aid of any exterior device. Simple water cooler test rig system with p-h diagram as shown below.

A broad variety of research is already being performed to study the coefficient of performance of the water cooler test rig system. The diffuser which is placed before the condenser inlet is responsible for increasing the coefficient of performance in the water cooler test rig. In this literature to make the project at the lowest cost and get more COP.

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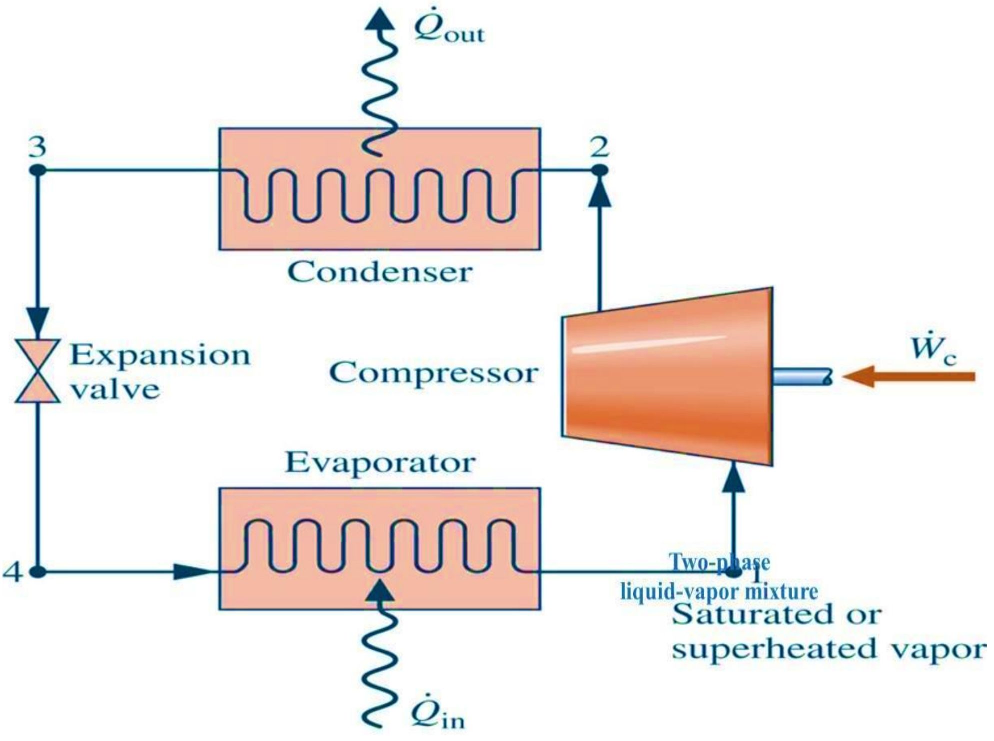

Fig.1.1. Simple water cooler test rig system

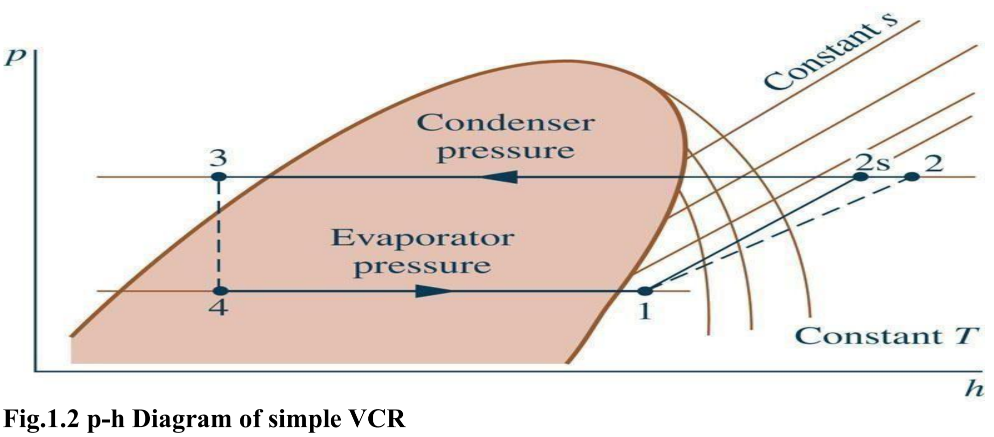

Fig.1.2 p-h Diagram of simple VCR

Saboor (2011) et.al. studied vapour compression refrigeration systems using diffusers at condenser inlets. Diffuser is a passive device to convert the high velocity at condenser inlet to pressure energy. The diffuser increases the pressure the refrigerant receives from the compressor the refrigerant leaving the diffuser is higher than the refrigerant entering into the diffuser. By using this diffuser at the condenser inlet the power feeding of the compressor is decreased. So, the COP of VCR is increasing. So that the performance of the whole system is increased.

Seraj (2017) et.al. have studied in this paper the COP of VCR is enhanced by utilising the diffuser at inlet of the condenser. In this experiment the COP of the refrigeration increased by reducing the compressor effort by a diffuser at the condenser inlet. The diffuser was placed in between the compressor and condenser. The inlet diameter of the diffuser is equivalent to the liquidating tube dia of the compressor and outer dia of the diffuser is identical to the inlet tube diameter of the condenser.

Kumar (2018) et.al. conducted experiment on the VCR is modified by Diffuser at condenser inlet and Heat exchanger at condenser outlet. The diffuser is a passive apparatus to convert the high velocity into pressure energy. Rakesh (2017) et.al. investigated on improving the COP of VCR by arranging a diffuser in amid condenser and compressor. The experiment was carried out by refrigerants R134a. The main parameters are mass flow rates, suction pressure of compressor, refrigerating effect are rated and calculated. These results are validated with the simulation. On simulation the power input to the compressor is decreased by COP improvement.

Saudagar (2012) et.al has studied in this paper to improve COP of VCR. To increase the COP of the system while increasing the refrigeration effect or reducing the compressor work. In this work the COP was increased by decreasing compressor work by using the diffuser at the condenser inlet. Dhanasi (2011) et.al. [7] verified the performance of a domestic refrigerator of capacity 165L, by using R134a, R600a refrigerants wrinkle shaped condenser was used in this experiment. These readings are compared with the existing system. Finally, the wrinkle shaped condenser system has given the maximum coefficient of performance among the existing system %.

Lohote (2016) et.al. [10] studied a VCR is analyzed by using a micro channel heat exchanger. The study of the performance of VCR systems is carried out by different condensers by varying pressure and variation in COP of the refrigeration system, by altering the micro channel heat exchanger. Due to change of pressure, there is change in heat transfer rate of condenser section. The transfer of heat helped to regulate the heat losses happening at thecondenser. The micro channel condenser gives higher performance than the other conventional condensers.

Raghavulu (2022) et al. analysed the tribology and molybdenum disulphide lubricant used as additive for enhancing COP of VCR. In this paper the lubricant considered in the concentration of 0.025%, 0.05%, 0.1% and 0.15%. At 0.05% proportion COP was improved as 20%. Majumder 2022 et al. compared R-134a and R-600a. where R-134a considered as pure refrigerant and R-600a considered as natural refrigerant. The current research examined the pool boiling presentation of refrigerants on the plain aluminium and 2 graphene nanoplatelets reinforced aluminium matrix composite covered aluminium heating exterior with various depth (50 ± 5 μm and 125 ± 6 μm), The trial is directed at a saturation temperature of 10°C and heat fluxes fluctuating from 8.28 kW/m^2 to 75.61 kW/m^2.

Raveendran (2021) et al. focused on energy conservation on VCR using PCM. This paper discovered and designated the development of energy efficiency of the refrigeration system through the application of the phase change material between wall and coil of the evaporator cottage.

The investigational outcomes presented substantial things on system performance such as COP augmented by 7.1%, per energy consumption reduced by 6.7% and temperature disparities were also comparatively lesser inside the freezer cabinet. This projected perception would be beneficial in the event of power failures that are very usual in low grid reliability locations.

Dharpure (2018) reviewed on performance of VCR with different refrigerants. In the current investigation a assessment has been carried out on VCR with straight capillary tube using R134a and a combination of R134a and Hydrocarbon at 28:72 ratio (by mass) as working refrigerant. The complete outcomes of the trials by diverse investigators at various capillary tube diameters using various refrigerants are discussed. Further, the effect of the structure of capillary, length of capillary, diameter of capillary tube has been discussed.

Muhammad (2008) studied to improve the indication COP of a VCR in instrumented automobile air conditioner by designing internal heat exchanger and installing it in the vapor compression refrigeration cycle. In this research two cases considered. Initially, VCR without internal heat exchanger and in the second situation the VCR with heat exchanger. Kalla (2014) investigated few approaches to decrease emission of greenhouse gases. The subsequent decision is pinched that refrigerant blends of HC290/HC600a (40/60 by wt. %) instead of CFC12 and HC290/HC1270 (20/80 by wt. %) instead of CFC22 are found to be substitute refrigerants among other replacements. This research can be useful as it includes a review of the strategy for alleviating global warming.

The above literature survey helped a lot to move work forward. This survey has done on the VCR and the components. The novel survey done on the diffuser. The importance of the diffuser, its functions and updates in diffuser design as discussed in the above. However, this research work is a comparative analysis of COP of a VCR with and without use of diffuser.

2 Materials and methods

The fundamental components involved in the refrigeration arrangement were compressor, diffuser, condenser, expansion valve, receiver and evaporator. All the components play a vital role in the refrigeration process. This research is focused on the investigation on importance of diffuser device.

2.1 Refrigerant

Refrigerant is defined as the working fluid used to remove the heat from the space or products to be cooled in a refrigerating system. Refrigerant produces a cooling effect by absorbing heat from the products or space to be cooled in the refrigerating system. Refrigerant takes heat at a lower temperature and pressure in the evaporator and changes its state from liquid to vapour during evaporation. Refrigerant rejects heat at high temperature and pressure in the condenser and changes its state from vapour to liquid during condensation. In this research work R-134a refringent was used.
Examples of Refrigerants: Ice, Dry ice, Ice-Salt mixture, Sulphur dioxide, Ammonia, Carl dioxide, Water, brines and freons.

2.1.1 Designation of R134a

Chemical Formula for R-134a is CF3CH2F
Here, m=2; n=2; q=4.
Chemical formula correction:(2+0+4) = ((2×2)+2)
$\Longrightarrow 6=6$
Numerical designation= R(2-1)(2+1)(4)=R134

2.1.2 Specifications of ammonia (R-134a)

- Properties: Flammable, irritating, highly volatile and explosive Low running cost, Leak detection is easy, Refrigerant cost is low, small pipe lines are sufficient, Low weight of liquid refrigerant, High efficiency, High COP

- Boiling point is-33.3°C: Freezing point is - 77.8°C.
- Used for evaporator temperatures up to: 70°C.
- Applications: Ice factories, Cold storages, Beverage plants.

2.2 Introduction to diffuser

The velocity of refrigerant is subsonic in VCR. Diffuser smoothly slows down the incoming refrigerant flow and achieves least stagnation pressure fatalities and exploits static pressure recapture.

Fig.2.1 Schematic Diagram of diffuser

2.2.1 Dimensions of a diffuser

Span of diffuser (L) = 20 mm
Ingress outer dia (d1) = 10 mm
Ingress inner diameter (d2) = 6 mm
Exodus outer diameter (D1) = 14 mm
Exodus inner diameter (D2) = 10mm
Divergence angles of diffusers (θ) =13°, 16°

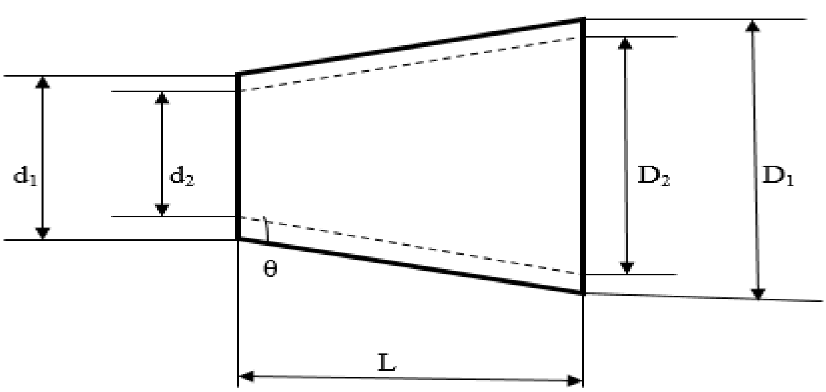

Fig. 2.2 Diffuser line diagram

2.3 Experimental setups

The experimental arrangement of the diffusers in the water cooler test rig as exposed below

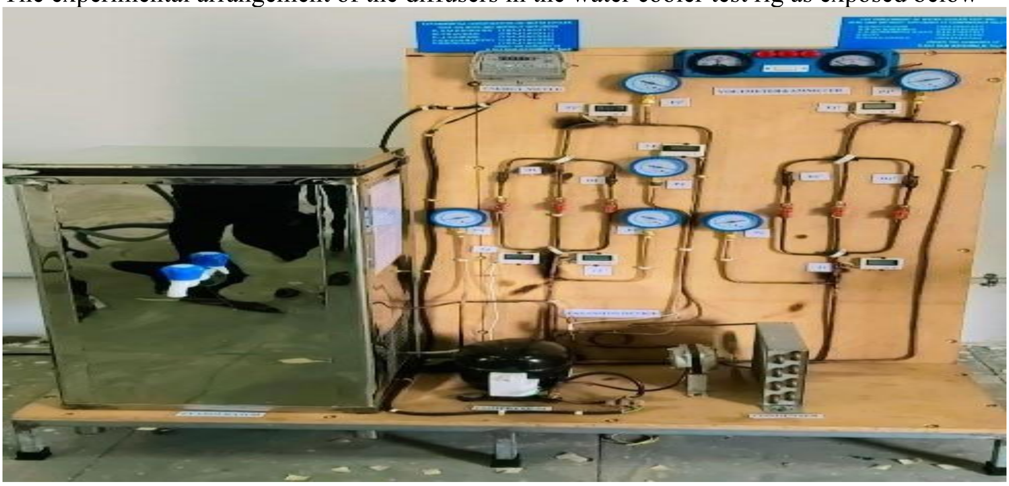

Fig.2.3 Experimental test rig with and without diffuser at condenser inlet

Fig.2.4 13° diffuser at condenser inlet

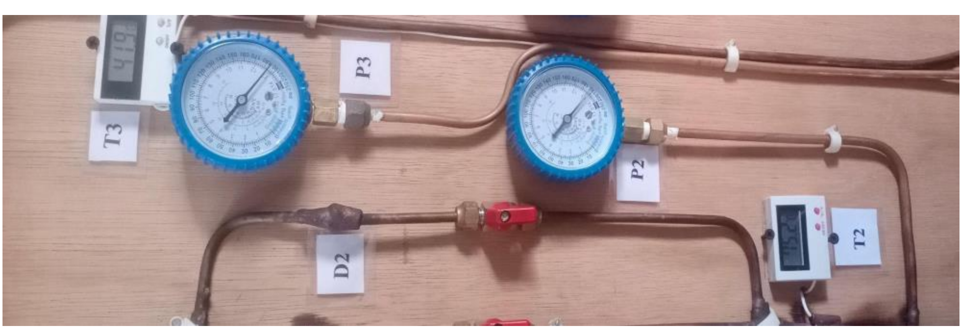

Fig.2.5 16° diffuser at condenser inlet

3 Results and discussion

The impartial experimental results and their analysis were mentioned below

3.1 Readings of without diffuser

The Pressure and temperature readings which are observed in the experimental investigationof water cooler test rig without any diffuser are noted in the below table.

Table 3.1: Pressure and temperature readings of Water cooler test rig system without anydiffuser

S.No.	Position	Pressure (bars)	Temperature (^{0}C)
1	Compressor (P_1),(T_1)	11.7	68.8
2	Condenser (P_2),(T_2)	11.2	38.6
3	Expansion (P_3),(T_3)	1.2	-4.2
4	Evaporator (P_4),(T_4)	1.1	29.7

3.2 Reading of 13° diffuser

The Pressure and Temperature reading of 13^0 diffusers at the condenser inlet which are observed inthe Experimental investigation of the water cooler test rig are noted in below table.

Table 3.2: Pressure and Temperature reading of 13° diffuser at condenser inlet.

S.No.	Position		Pressure (bars)	Temperature (^{0}C)
1	Compressor inlet (P_1),(T_1)		1.3	35.6
2	Condenser inlet	Diffuser inlet (P_2),(T_2)	12.6	73.5
		Diffuser outlet (P_2), (T_2)	12.9	41.9
3	Condenser outlet (P_3),(T_3)		12.6	41.8
4	Evaporators inlet (P_4),(T_4)		1.1	-3.8

3.3 Readings of 16° diffuser

The Pressure and Temperature reading of 16^0 diffusers at the condenser inlet which are observed inthe Experimental investigation of the water cooler test rig are noted in below table.

Table 3.3: Pressure and Temperature readings of 16° diffuser

S.No.	Position		Pressure (bars)	Temperature (^{0}C)
1	Compressor inlet (P_1), (T_1)		0.8	38.2
2	Condenser Inlet	Diffuser inlet(P_2), (T_2)	11.7	56.4
		Diffuser outlet (P_2), (T_2)	12.06	51.3
3	Condenser outlet (P_3), (T_3)		11.6	40.1
4	Evaporators inlet (P_4), (T_4)		0.9	-8.9

3.4 Refrigerating effect and cop for without and with diffuser condition at condenser inlet

The calculated Refrigerating effect, work done and cop of the water cooler test rig with and without diffuser at condenser inlet are noted in the below table.

Table 3.4: RE and cop for without and with diffuser condition at Condenserinlet

Constraints		Refrigeratingeffect (KJ/Kg)	Work done (kJ/kG)	COP
Without diffuser		160.56	13.7	11.7
With diffuser	13°	158.54	11.35	14
	16°	162.29	7.01	23.15

3.5 Diffuser at condenser inlet

In this one discusses the results of diffusers testing at condenser inlet, two diffusers are tested at condenser inlet. The 13° divergence angle of the diffuser is given the maximum Coefficient of performance at condenser inlet.

It will be fixed at the condenser inlet. Below discuss the pressure,temperature and coefficient of performance with varying divergence angles.

3.5.1 Effect of divergence angles on pressure

Graph depicted the divergence angles with respect to pressure at diffusers, as shown below.

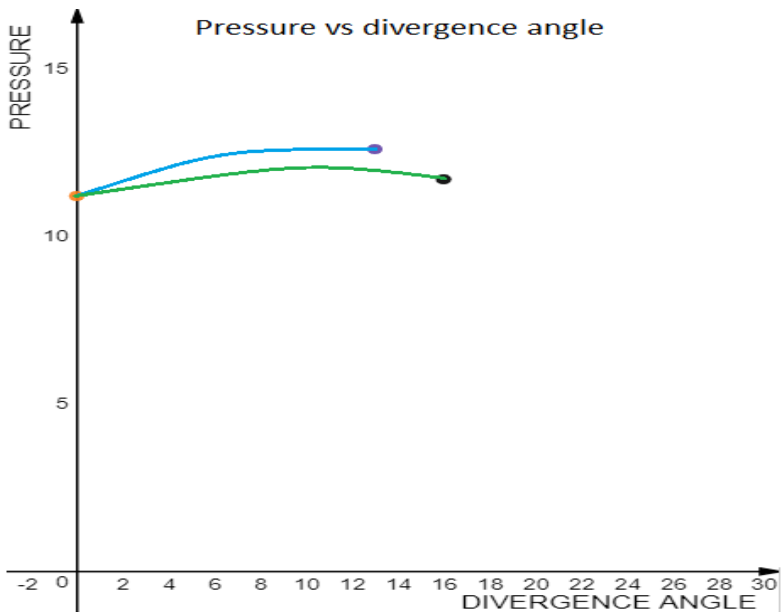

Fig.3.1 Pressure with respect to diverging angle

It is found that, primarily the pressure without any diffuser is 11.2 bars. When utilizing the 13° divergence angle of diffuser pressure increases to 12.6 bars and at 16° divergence angle the system gives pressure of 11.7 bars.

3.5.2 Effect of divergence angles on temperature

Graph depicted the temperature with regards to divergence angle, as shown below.

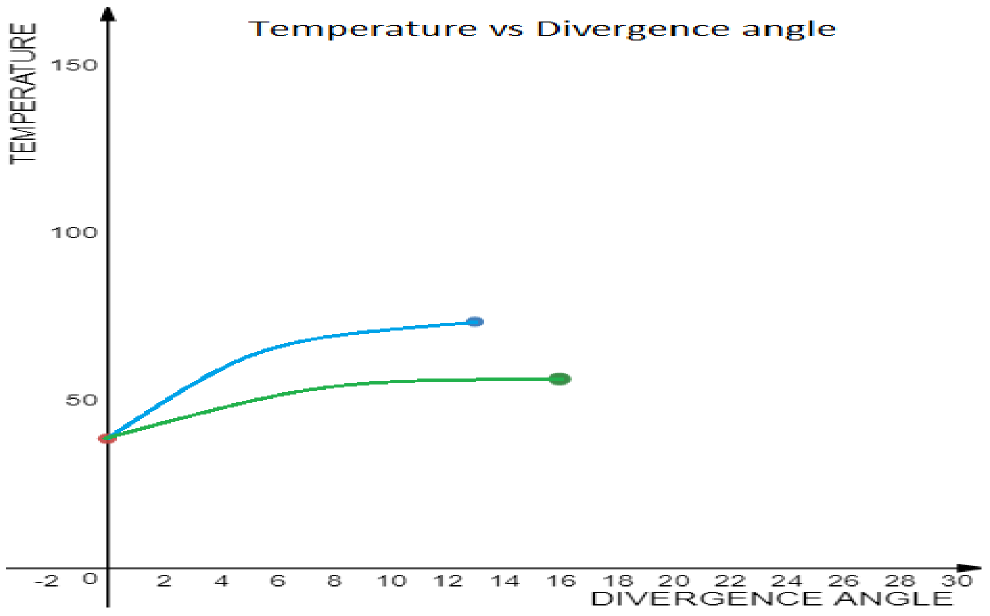

Fig. 3.2 Temperature with regards to diverging angle

Primarily the temperature is 38.6°C without using the diffuser. When using a diffuser of 13^0 it increases up to a certain temperature 73.5^0C. Further decreases to 56.4^0C when using a 16° divergence angle diffuser.

3.5.3 Effect of divergence angles on cop

Graph depicted that the COP with regards to divergence angles, as shown below.

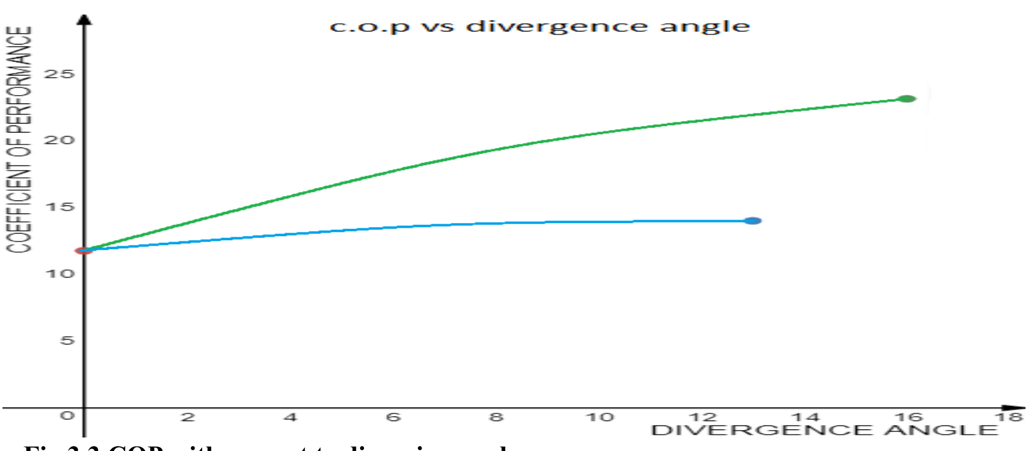

Fig.3.3 COP with respect to diverging angle

Initially the COP is 11.7 without using the diffuser. When using a diffuser of 13^0 it increases up to a certain value of 14. Further it increases to 23.15 when using a 16° divergence angle diffuser. It is detected that supreme gain in COP at diffuser with divergence angle 16° at pressure of 11.7 bars. Hence, some compression work is decreased.

3.5.4 Effect of divergence angles on Refrigeration effect (R.E)

Graph depicted variation of Refrigeration effect with respect to divergence angles, as shown below.

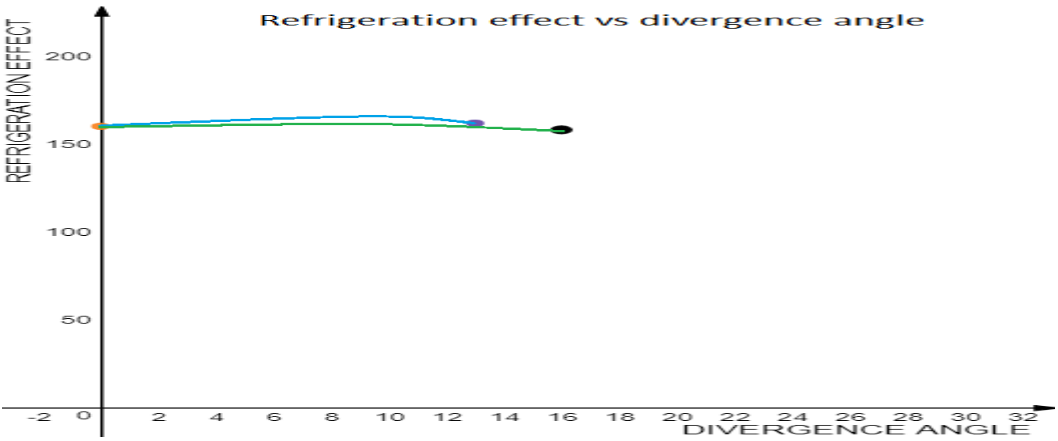

Fig.3.4 Variation of Refrigeration effect on diverging angle

Initially the Refrigeration effect is 160.56 KJ/KG without using the diffuser. When using a diffuser of 13^0it decreases up to a certain value of 158.54KJ/KG. Further it increases to 162.29 KJ/KG when using a 16° divergence angle diffuser. It is detected that extreme gain in Refrigeration effect atdiffuser with divergence angle 16° at pressure of 11.7 bars. Hence, some compression work is decreased.

3.5.5 Effect of divergence angles on Work done (W.D)

Graph depicted the variation of Workdone with respect to divergence angles, as shown below.

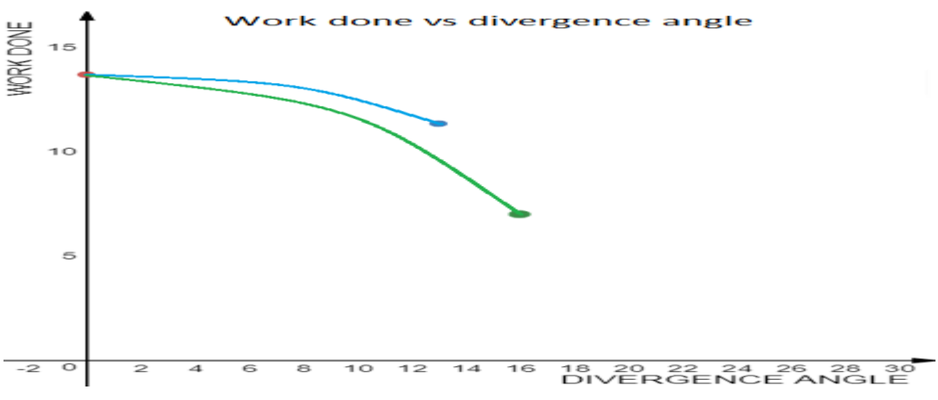

Fig.3.5 Variation of Refrigeration effect on diverging angle

Initially the Workdone is 13.7 KJ/KG without using the diffuser. When using a diffuser of 13^0 it decreases upto a certain value of 11.35 KJ/KG. Further it decreases to 7.01 KJ/KG when using a 16° divergence angle diffuser. Hence, some compression work is reduced.

4 Conclusions

- Investigation has been carried out to place and test the effect of two diffusers of divergence angle 13^0,16^0 at condenser inlets on water cooler test rig systems.
- The 13^0,16° divergence angled diffusers are fixed at the condenser inlet. Diffusers at the condenser inlet with 16° divergence angle gives higher coefficient of performance than the 13° divergence angle diffuser and then normal procedure.
- Diffuser with divergence angle of 16° given the supreme cop (23.15) as associated to 13^0 diffuser. The pressure growths from 0.41 to 0.68 bars and the compressor work are decreased by 6%.
- Percentage of increase in COP is approximately 6%.

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