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COMBINED EFFECT OF REFRIGERATION WITH NANOPARTICLES (Al_2O_3) IN VCR SYSTEM

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ABSTRACT

Nano refrigerant is nothing but the combination of nano-particle with the refrigerant for the sake of better refrigeration process. It has been observed that, as compared to alternative refrigerant, there is better improvement in heat transfer capacity of the refrigerant after addition of nanoparticles. The use of nano-particles along with the conventional refrigerant with vapour compression cycle is relatively a new idea, where nano-refrigerants, so obtained are found to have their improved thermo-physical properties over the conventional refrigerants. Nano- particles can be used along with refrigerant in order to improve the performance of vapour compression refrigeration system. In this paper, alumina (Al2O3) nanoparticles of 50 nm diameter are dispersed in refrigerant R134a to improve its heat transfer performance to have theirimproved thermal & physical properties over the conventional refrigerants.

Keywords**:** Refrigeration test rig, Vapour Compression Cycle, Refrigeration performance, Nanoparticles, Nanorefrigerant.

1. INTRODUCTION

Refrigeration is the process of removal of heat in a space, substance, or system to lower and/or maintain its temperature below the ambient one (while the removed heat is rejected at a higher temperature). In other words, **refrigeration** means artificial (human-made) cooling. Energy in the form of heat is removed from a low-temperature reservoir and transferred to a high- temperature reservoir. The work of energy transfers traditionally driven by mechanical means, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to air conditioning units. Refrigeration has had a large impact on industry, lifestyle, agriculture, and settlement patterns. The idea of preserving food dates back to at least the ancient Roman and Chinese empires.

In past time only refrigerants were used in refrigeration process and they were having a global warming coefficient at high level. Now, as time change the modern techniques are coming into existence with the help of them the refrigeration process become more efficient and safe as compare to previous in atmospheric prospective. Nanofluid is an advanced kind of fluid, which contain nanometer sized (10-9 m) solid particles known as nanoparticles. Nanoparticles enhance the property of normal fluid. In past five years, nano- refrigerant has become more popular for large number of experimental vapour compression systems because of shortage in availability of energy and environmental considerations. Recent advancements in nanotechnology have originated the new emerging heat transfer fluids called nano-fluids. Nano-fluids are prepared by dispersing and stable suspending nanometer sized solid particles in conventional heat transfer fluids. Past researches have shown that a very small amount of suspending nanoparticles have the potential to enhance the thermo physical, transport and radiative properties of the base fluid. Due to improved properties, better heat transfer performance is obtained in many energy and heat transfer devices as compared to traditional fluids which open the door for a new field of scientific research and innovative applications. The addition of nanoparticles to the refrigerant results in improvements in the thermos physical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system.

Nanoparticles directed the innovative world into a new direction by its ability to influence working properties of fluid. Nano fluids are advanced class of fluids with particles of nano size (1-100 nm). The concept is based on the fact that solids have high heat capacity as compared to fluid. So nano sized particles or nanoparticles are dispersed into a base fluid in order to enhance physical properties of base fluid. The nanoparticle materials are usually of metal, non-metal and their oxides, which enhance the heat transfer performance of base fluids. Hence, there is huge scope of its application in heat transfer area. Recently, some investigations revealed the application of nanoparticles in refrigeration systems and significant improvement in performance has been observed. In refrigeration systems the nanoparticles can be either added to compressor lubricating oil or to refrigerant. Dispersion of nanoparticles into lubricating oil (Nano lubricant) improves the lubrication of compressor or decrease friction of moving parts. Additionally, the in case hermetically sealed compressor fractional amount of lubrication oil is carried away by refrigerant in compressor dome. So, by this means the heat transfer characteristics can be improved and hence performance of the refrigeration system. On other hand when nanoparticles are dispersed in refrigerant (termed as nano-refrigerant), then it directly enhance the refrigerant thermal properties and thereby performance of refrigeration system is found to be improved. The conventional refrigerants have major role in global warming and depletion of the ozone layer. Therefore, there is need to improve the performance of vapour compression refrigeration system with the help of suitable refrigerant.

APPLICATIONS OF REFRIGERATION

- Food processing, preservation and distribution
- Chemical and process industries
- Special Applications such as cold treatment of metals, medical, construction, ice skating etc.
- Comfort air-conditioning

INTRODUCTION TO REFRIGERATION SYSTEM

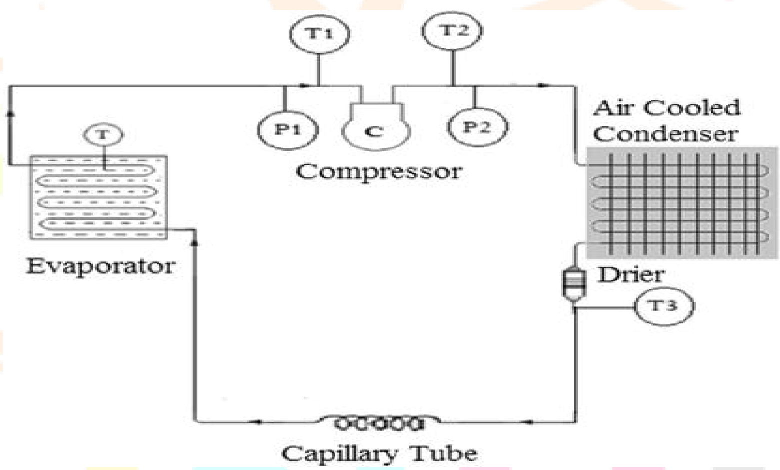

Fig1.1 Refrigeration system

COMPONENTS OF VAPOUR COMPRESSION REFRIGERATIONSYSTEM

1.Compressor : The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve and it is compressed isentropically to a high pressure and temperature and discharged into the condenser through the delivery or discharge valve

2. Condenser: The condenser consists of coils of thin copper pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed by the process of forced convection. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water

3. Receiver: The function of the receiver vessel is to store the condensed vapour-liquid mixture at high temperature and pressure and supply pure liquid refrigerant to the expansion valve so as to get better throttling and controlling effect.

4. Expansion Valve: It is also called throttle valve and the function of this valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature.

5. Evaporator: An evaporator usually consists of coils of copper pipe in which the liquid-vapour refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

INTRODUCTION TO NANOPARTICLES

In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport properties. Nanoparticles are between 1 and 100 nanometers ($1x10^{-9}$ and 1×10^{-7} m) in size. Tubes and fibers with only two dimensions below 100 nm are also nanoparticles. Novel properties that differentiate particles from bulk material typically develop at a critical length scale of 100 nm. They are made from ceramics, metals & metal oxides.

Nanoparticles can be produced from mechanical attrition, pyrolysis, gas condensation, chemical precipitation. Methods like dc plasma jet, dc arc plasma, radio frequency induction plasmas, chemical synthesis, gamma rays and laser ablation are used. Inert-gas condensation is frequently used to make nanoparticles from metals with low melting points. Depending upon application (properties) & cost, specific manufacturing technologies are chosen.

PURPOSE OF USING NANOPARTICLE IN REFRIGERATION SYSTEM:

Nanorefrigerant

Improved thermo-physical properties (H/T Coefficient)

Improved refrigerating effect

Nanolubricant-refrigerant

Enhanced solubility between oil & refrigerant

More oil returns back to the compressor

TYPES OF NANOPARTICLES:

Nanotechnology deals with various structures of matter having dimensions of the order of a billionth of a meter. From the advent of nanotechnology, people realized that certain materials can exhibit different properties based on its size and shape. It all started after the famous lecture, "There is plenty of room at the bottom" given by Richard Feynman on December 29, 1959. Nanomaterials are intermediate between macroscopic solid and of atomic and molecular systems. Nanomaterials have certain properties which make them different from that of the bulk materials, including large fraction of surface atoms, high surface energy, spatial confinement, and reduced imperfections.

Different types of nanoparticles

Nanoparticles can be classified into different types according to the size, morphology, physical and chemical properties. Some of them are carbon-based nanoparticles, ceramic nanoparticles, metal nanoparticles, semiconductor nanoparticles, polymeric nanoparticles and lipid-based nanoparticles.

Carbon-Based Nanoparticles

Carbon-based nanoparticles include two main materials: carbon nanotubes (CNTs) and fullerenes. CNTs are nothing but graphene sheets rolled into a tube. These materials are mainly used for the structural reinforcement as they are 100 times stronger than steel.

CNTs can be classified into single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). CNTs are unique in a way as they are thermally conductive along the length and non-conductive across the tube.

Fullerenes are the allotropes of carbon having a structure of hollow cage of sixty or more carbon atoms. The structure of C-60 is called Buckminsterfullerene, and looks like a hollow football.

The carbon units in these structures have a pentagonal and hexagonal arrangement. These have commercial applications due to their electrical conductivity, structure, high strength, and electron affinity.

Ceramic Nanoparticles

Ceramic nanoparticles are inorganic solids made up of oxides, carbides, carbonates and phosphates. These nanoparticles have high heat resistance and chemical inertness. They have applications in photocatalysis, photodegradation of dyes, drug delivery, and imaging.

By controlling some of the characteristics of ceramic nanoparticles like size, surface area, porosity, surface to volume ratio, etc, they perform as a good drug delivery agent. These nanoparticles have been used effectively as a drug delivery system for a number of diseases like bacterial infections, glaucoma, cancer, etc.

Metal Nanoparticles

Metal nanoparticles are prepared from metal precursors. These nanoparticles can be synthesized by chemical, electrochemical, or photochemical methods. In chemical methods, the metal nanoparticles are obtained by reducing the metal-ion precursors in solution by chemical reducing agents. These have the ability to adsorb small molecules and have high surface energy.

These nanoparticles have applications in research areas, detection and imaging of biomolecules and in environmental and bioanalytical applications. For example gold nanoparticles are used to coat the sample before analyzing in SEM. This is usually done to enhance the electronic stream, which helps us to get high quality SEM images.

Semiconductor Nanoparticles

Semiconductor nanoparticles have properties like those of metals and non-metals. They are found in the periodic table in groups II-VI, III-V or IV-VI. These particles have wide bandgaps, which on tuning shows different properties. They are used in photocatalysis, electronics devices, photo-optics and water splitting applications.

Some examples of semiconductor nanoparticles are GaN, GaP, InP, InAs from group III-V, ZnO, ZnS, CdS, CdSe, CdTe are II-VI semiconductors and silicon and germanium are from group IV.

Polymeric Nanoparticles

Polymeric nanoparticles are organic based nanoparticles. Depending upon the method of preparation, these have structures shaped like nanocapsular or nanospheres. A nanosphere particle has a matrix-like structure whereas the nanocapsular particle has core-shell morphology. In the former, the active compounds and the polymer are uniformly dispersed whereas in the latter the active compounds are confined and surrounded by a polymer shell.

Some of the merits of polymeric nanoparticles are controlled release, protection of drug molecules, ability to combine therapy and imaging, specific targeting and many more. They have applications in drug delivery and diagnostics. The drug deliveries with polymeric nanoparticles are highly biodegradable and biocompatible.

Lipid-Based Nanoparticles

Lipid nanoparticles are generally spherical in shape with a diameter ranging from 10 to 100nm. It consists of a solid core made of lipid and a matrix containing soluble lipophilic molecules. The external core of these nanoparticles is stabilized by surfactants and emulsifiers. These nanoparticles have application in the biomedical field as a drug carrier and delivery and RNA release in cancer therapy.

Thus, the field of nanotechnology is far from being saturated and it is, as the statistic says, sitting on the staircase of an exponential growth pattern. It is basically at the same stage as the information technology was in the 1960s and biotechnology in the year of 1980s. Thus it can easily be predicted that this field would witness a same exponential growth as the other two technological field witnessed earlier.

Air conditioners and refrigerator-freezers are major energy users in a household environment and hence efficiency improvement of these appliances can be considered as an important step to reduce their energy consumption along with the environmental pollution prevention. As per the Montreal Protocol, CFC12 is being phased out following a stipulated time frame. The developed countries have already phased out these substances and the developing countries are to totally phase out the CFCs by 2030 as per the Montreal Protocol. Most of the developing countries are drastically reducing their CFC production and consumption. This demand for a suitable substitute for CFC12 for possible retrofitting of existing systems as well as for new systems.

S. Joseph Sekhar et al. (2004) presented two potential substitutes, namely, HFC134a and HC blends are available as drop in substitutes for CFC12. HC (hydrocarbon) refrigerants do have inherent problems in respect flammability. HFC134a is neither flammable nor toxic. But HFCs (hydro fluorocarbons) are not 15 compatible with mineral oil and the oil change is a major issue while retrofitting. They carried out an experimental analysis in a 165 liters CFC12 household refrigerator retrofitted with ecofriendly refrigerant mixture HFC134a/HC290/HC600a without changing the mineral oil. Its performance, as well as energy consumption, is compared with the conventional one. As the system has been running successfully for more than 12 months consumption by 4 to 11% and improve the actual COP by 3 to 8% from that of CFC12. The new mixture also showed 3 to 12% improvement in theoretical COP. The overall performance has proved that the new mixture could be an eco-friendly substitute to phase out CFC12.

Satnam Singh et al. represented a review on behavior of Nano- refrigerantinvapour compression cyclewith different concentration of Nano-particles. The experimental studies revealed that the performance of such systems gets improved by using Nano refrigerants. It is observed that using a Nano-refrigerant with higher concentration is not always true.

T.Coumaressin et al. studied performance of a refrigeration system using nano fluid and concluded CuO nanoparticle with R134a refrigerant can be used as an excellent refrigerant to improve the heat transfer characteristics of a refrigerant. Heat transfer coefficients were evaluated using FLUENT for heat flux ranged from 10 to 40 kW/m2, using nanoCuO concentrations ranged from 0.05 to 1% and particle size from 10 to 70 nm. The results indicate that evaporator heat transfer coefficient increases with the usage of nanoCuO.

Kuljeet Singh et al. carried out an investigation into the performance of a Nano refrigerant (R134a+Al2O3) based refrigeration system.It has been found out that the improvement in coefficient of performance (COP) is maximum (7.2 to 8.5%) with 0.5% Al2O3 (% wt.) nanoparticles. When the mass fraction of nanoparticles increased to 1% in refrigerant COP is found to be lower than even from pure R134a. Further, increased mass fraction of Al2O3 (1%), lowers down the pressure and temperature after expansion of the Nano refrigerant in the expansion valve. In addition to this the specific heat of refrigerant gets decreased. So these both factor will results in decrease in the refrigeration effect, hence COP. Improvement is found to be maximum by using Nano-refrigerant R134a+0.5% Al2O3 keeping refrigerant flow rate as 6.5 LPH.

N. Subramani et al. done experimental studies on a vapour compression system using nano-refrigerants. It was found that, the R134a refrigerant and mineral oil mixture with nanoparticles worked normally (ii) Freezing capacity of the refrigeration system is higher with SUNISO 3GS + alumina nanoparticles oil mixture compared the system with POE oil (iii) The power consumption of the compressor reduces by 25% when the nano-lubricant is used instead of conventional POE oil (iv) The coefficient of performance of the refrigeration system also increases by 33% when the conventional POE oil is replaced with nano-refrigerant (v) the energy enhancement factor in the evaporator is 1.53.

D. Sendil Kumar et al. Nano Al2O3-PAG oil was used as nano refrigerant in R134a vapour compression refrigeration system and it was found that addition of nano Al2O3 in to the refrigerant shows improvement in the COP of the refrigeration system. Usage for Nano refrigerant reduces the length of capillary tube and cost effective. The system performance was investigated using energy consumption test and freeze capacity test. The refrigeration system performance was better than pure lubricant with R134a working fluid with 10.32% less energy used with 0.2%V of the concentration used.

2. MATERIALS & METHODS

COMPONENTS FUNCTION

COMPRESSOR: The function of compressor is to remove the vapour from the evaporator and to raise its temperature and pressure to a point such that it can be condensed with available condensing media.

In VCR cycle, the vapour at low temperature and pressure enters the compressor where it is compressed isentropically and subsequently to its temperature and pressure increase.

Fig 3.1 Compressor

CONDENSER: The function of condenser is to provide the heat transfer surface through which heat passes from hot refrigerant vapour to condensing media.

In VCR cycle, the vapour after leaving the compresser enters the condenser where it is condensed into high pressure liquid.

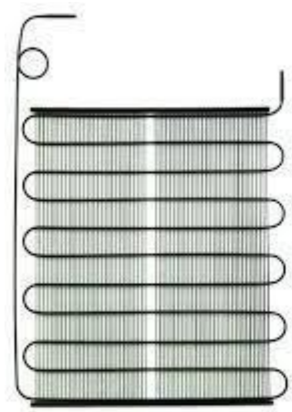

Fig 3.2 Condenser

EXPANSION VALVE: Its function is to meter the proper amount of refrigerant to evaporator and to reduce the pressure of liquid entering the evaporator so that liquid will vaporize in the evaporator at desire low temperature and take out sufficient amount of heat. In VCR cycle, the high pressure liquid from the condenser enters the expansion valvewhere it is throttled down to low pressure and low temperature.

Fig 3.3 Expansion Valve

EVOPORATOR: An evaporator provides a heat transfer surface through which heat can pass from refrigerated space into vaporizing refrigerant. The low pressure vapour from the evaporator enters the suction line of the compressor.

In VCR cycle, the low temperature and pressure from the expansion valve enters the evaporator where it extracts heat from surroundings or circulating fluid being refrigerated and vaporizes to low pressure vapour.

Fig 3.4 Evoporator

PRESSURE GAUGE: It is an instrument used to mesure pressure values in psi lower than ambient atmospheric pressure which is set as zero point in negative value.

(Eg: -15psig or -760mmHg equals total vaccum)

Fig 3.5 Pressure Gauge

TEMPERATURE SENSOR: Thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple producesa temperature-dependent voltagee as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor.

Fig 3.6 Thermocouple

REFRIGERANT: R134a is also known as Tetrafluroethane (CF3CH2F) from the family of HFC refrigerant which is now been used as a replacement for R-12CFC refrigerant. It exist in mostly in gas form and expose to environment as boiling temperature -14.9deg F or -26.1deg C. The refrigerant is not 100% compactible with lubricants and mineral based refrigerant currently used in R-12.

Fig 3.7 Refrigerant R134a

GAS WELDING:

Oxy-fuel welding (commonly called oxy acetylene welding, oxy welding, or gas welding in the U.S.) and oxy-fuel cutting are processes that use fuel gases and oxygen to weld or cut metals .French engineers Edmond Fouché and Charles Picard became the first to develop oxygen-acetylene welding in 1903.Pure oxygen instead of air is used to increase the flame temperature toallow localized melting of the workpiece material (e.g. steel)in a room environment .A common propane/air flame burns at about 2,250K(1,980°C;3,590°F).

Fig 3.8 GasWelding

During the early 20th century, before the development and availability of coated arc welding electrodes in the late1920s that were capable of making sound welds in steel, oxy-acetylene welding was the only process capable of making welds of exceptionally high quality in virtually all metals in commercial use at the time. These included not only carbon steel but also alloy steels , cast iron, aluminium, and magnesium. In recent decades it has been superseded in almost all industrial uses by various arc welding methods offering greater speed and ,in the case of gas tungsten arc welding, the capability of welding very reactive metals such as titanium. Oxy-acetylene welding is still used for metal-based artwork and in smaller home-based shops, as well as situations where accessing electricity would present difficulties. The oxy-acetylene welding torch remains a main stay heat source for manual brazing and braze welding, as well as metal forming, preparation, and localized heat treating. In addition oxy-fuel cutting is still widely used, both in heavy industry and light industrial and repair operations.

In oxy-fuel welding, a welding torch is used to weld metals .Welding metal results when two pieces are heated to a temperature that produces a shared pool of molten metal. The molten pool is generally supplied with additional metal called filler. Filler material depends upon the metals to be welded. In oxy-fuel cutting, a torch is used to heat metal to its kindling temperature. A stream of oxygen is then trained on the metal, burning it in to a metal oxide that flows out of the kerf as slag.

COMPONENTS DETAILS

COMPONENTS	TYPE & RANGE	NUMBERS IN QUANTITY
COMPRESSOR	As given in refrigerator	As given in refrigerator
CONDENSER	As given in refrigerator	As given refrigerator
EXPANSION VALVE	As given in refrigerator	As given in refrigerator
EVAPORATOR	As given in refrigerator	As given in refrigerator
PRESSURE GUAGES	Range 500 & 250kg/cm2	Each one
REFRIGERANT	R-134a	1 unit

TEMPERATURE SENSOR	THERMOCOUPLE of range	1
WELDING	GAS WELDING	As required
NANO PARTICLE USED	AL2O3	0.25gm for sample

Tab 3.1 Components Details

The refrigerator works with vapour compression refrigeration system. In vapour compression system, there are four major components such as Evaporator, Compressor and Condenser and Expansion valve. External energy (power) is supplied to the compressor and heat is added to the system in the evaporator, whereas in the condenser heat rejection is occurred from the system. The refrigerant enters in to the compressor as saturated vapour and is compressed to a high pressure, results in a higher temperature superheated vapour. The refrigerant heat is carried away by the surrounding air in the condenser, results in a saturated liquid. The saturated liquid refrigerant enters in to the expansion valve, results in reduction of pressure of the refrigerant. Finally the refrigerant enters in to the evaporator and draws heat from the region to be cooled. The vapour refrigerant goes back to the compressor to restart the cycle.. The lubricating oil is POE oil (refrigerant oil 68) which is commonly used in refrigeration and air conditioning systems because of its premium quality. Then the readings of P1,P2,P3,T1,T2,T3 are noted and corresponding Enthalpy values are also calculated .then a 0.25 grams of AL2O3 nano particles is added to refrigerant R134A to speed up the process , cooling and to improve the efficiency . the same procedure is again repeated for the nano particle added refrigerant and finally values are calculated.

Nano fluids and nano lubricants are also used to reduce the exergy losses in the compressor indirectly.The addition of Al2O3 nano particles to the base fluid (POE) gave better performance and reduction of power consumption. However, a nano composite particle in domestic refrigerator is very sparse. Then , finally COP is calculated using the given formulae and the graph is plottedto note down the difference and to study the increasein coefficient of performance of refrigerator.

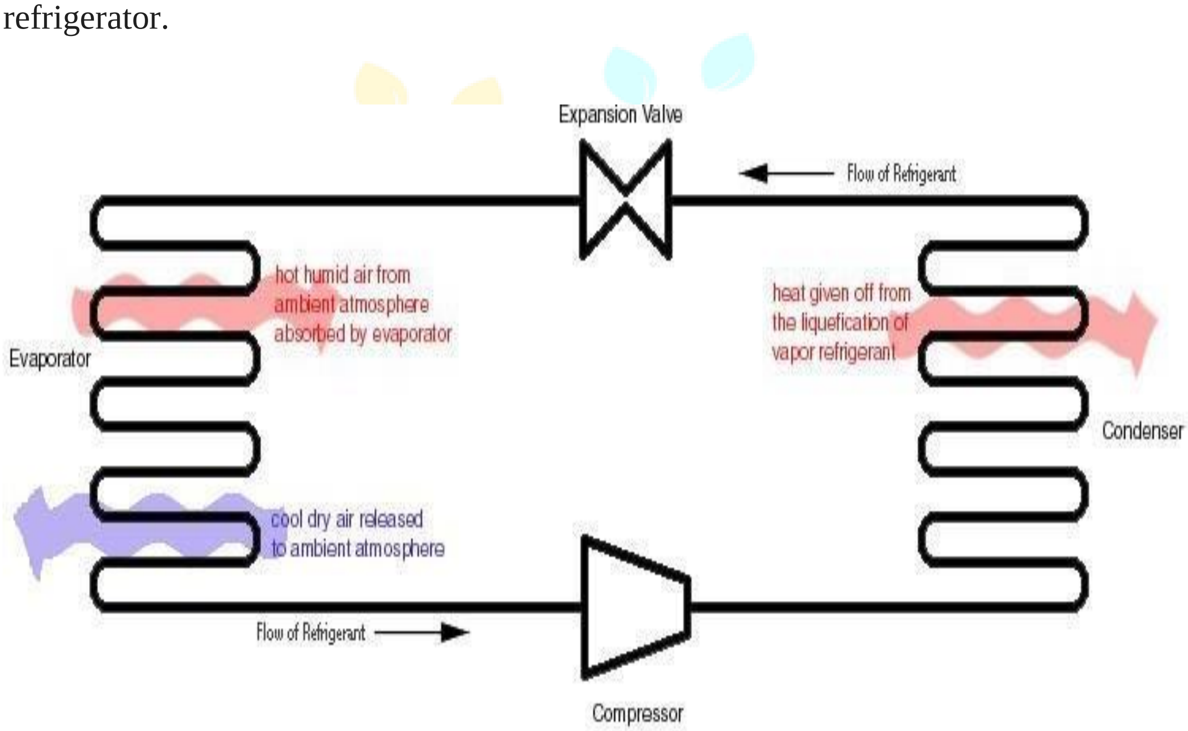

Fig 4.1 Working principle of Refrigerator

FORMULA

The COP of the refrigerator is given by,

$$(COP)_R = \frac{Q_L}{W} = \frac{h_1 - h_4}{h_2 - h_1}$$

Work done on the compressor,

$$W_c = h_2 - h_1 = C_p (T_2 - T_1)$$

Conversion of psi to bar

$$1Bar = (Psi/14.5) + 1.03$$

OBSERVATION TABLE

The readings below shows the reading for normal refrigeration before adding Nanoparticles at the interval of 7 min after start of refrigeration .

PRESSURE , P	**PRESSURE , P**	**TEMPERATURE , T**	**ENTHALPY , h**
Psi	Bar	Degcelcius	KJ/KG
59.46	4.1	50	271
89.92	6.2	44	274
99.31	6.89	39	276

Tab 5.1 Observation before adding Nano Particles

T1 & P1 = After compressor

T2 & P2 = After condenser

T3 & P3 = After Evaporator

T4 &P4 = T1 & P1

The values of pressure p1,p2,p3 was taken from pressure gauges 1,2,3

The values of Enthalpy , h (KJ/KG) was taken from Mollier chart with reference of pressure,P value and temperature ,T value.

PRESSURE,P	**PRESSURE,P**	**TEMPERATURE ,T**	**ENTH ALPY,**
Psi	Bar	Deg Celsius	KJ/KG
29.15	2.01	-10	392
96.55	6.66	33	420
102.1	7.1	25	234

Tab 5.2 Observation after adding Nano Particles

CONCLUSION

From the above , calculation we can conclude that the Coefficient of performance of Refrigerant added with Al2O3 is more efficient than thenormal refrigerant .

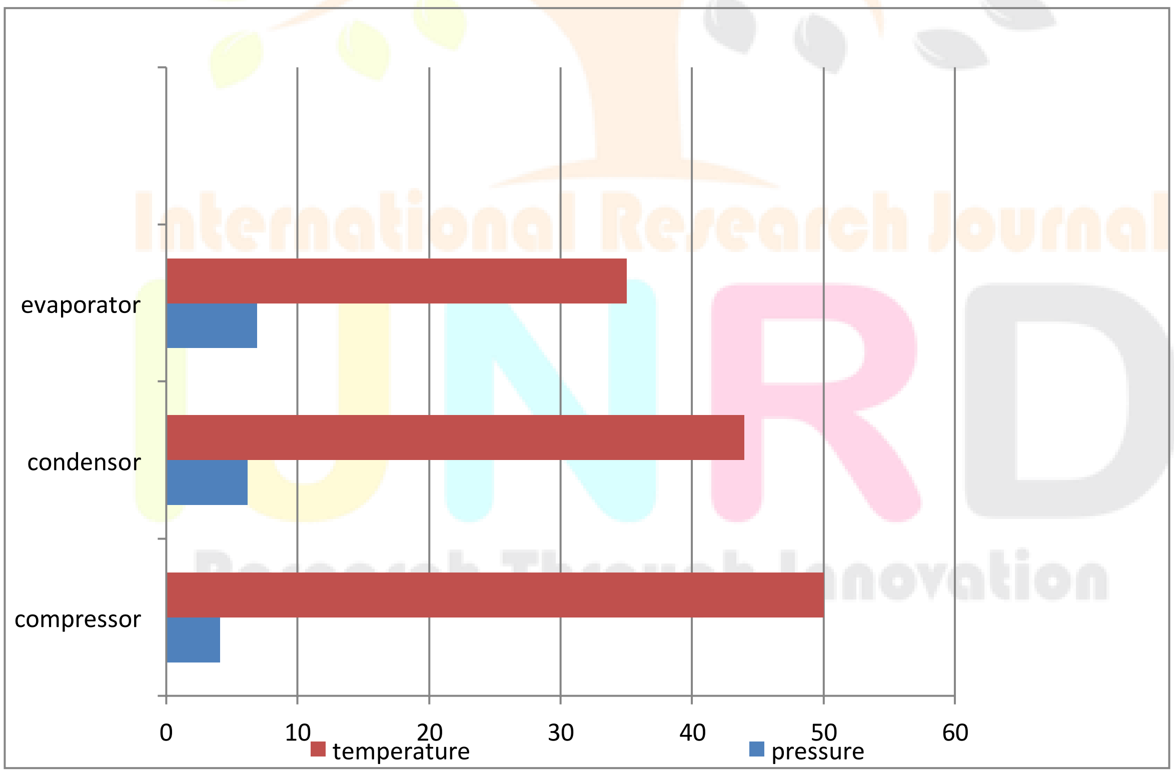

Fig 6.1 Effect on Refrigeration without Nano Refrigerant (Al_2O_3)

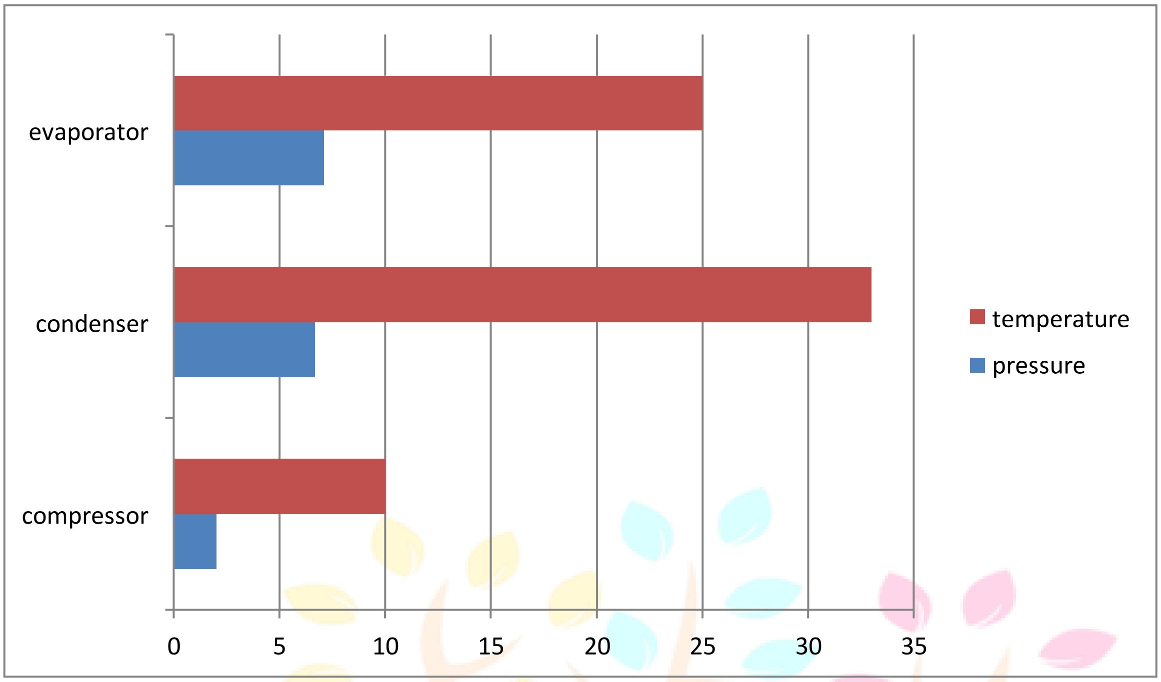

Fig 6.2 Effect on Refrigeration with Nano Refrigerant (Al2O3)

INFERENCE :

From the graph above we can come to conclude that the graph on addition of Al2O3 is more efficient

Fig 7 Experimental Setup

4. CONCLUSION

The refrigerator worked with vapour compression refrigeration system with normal refrigeration and nano particle added refrigeration system is completed successfully. The addition of nanoparticles in refrigerant not only increased th coefficient of performance but also it consumes reduced power for its cooling capacity. This can be implemented anywhere either in domestic or commercial refrigerators. However the attempt it made successful, for further more improvement for the coefficient of performance of refrigerator we can find the properties of other nanoparticles which is more superior than Al2O3 .by finding more superior propertities of nanoparticle other than Al2O3 ,if someothernano particle has very good characteristics than the used nano particles it can be used to improve the performance.

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