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A Review on Experimental Investigation of Effects of Magnetic Field between Condenser Outlet and Capillary Tube of Vapor Compression Water Chiller

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ABSTRACT

Current paper presents a review of vapor compression system and modifications made by various researchers to increase performance of vapor compression system. The vapor compression cycle is a well-established refrigeration technique used in most household refrigerators, air conditioners, and many large commercial and industrial refrigeration systems. However, mankind is facing serious problems concerning the global environment, and the emissions of conventional refrigerant fluids such as chlorofluorocarbon (CFC), hydro chlorofluorocarbon (HCFC) and hydro fluorocarbon (HFC) are responsible for ozone depletion or greenhouse effect. Therefore, it is necessary to develop new technologies that can reduce ozone depletion, global warming and increase efficiency of vapor compression system. This article has studied various literatures presenting effect of magnetic field (constant and alternating) on vapor compression water chiller and on the performance of new refrigerant mixtures, effect by changing various parameters of VCC and effect of fault detection techniques on chiller system.

Keywords – ***Magnetic Field, Refrigeration, refrigerants, vapor compression cycle.***

1. Introduction

The Vapor Compression Refrigeration Cycle involves four components: compressor, condenser, expansion valve and evaporator. Circulating refrigerant enters the compressor and is compressed to a high pressure and high temperature. The hot, compressed vapor is then passing through the condenser. In condenser circulating refrigerant rejects heat from the system as it cools and condenses completely. The rejected heat is dissipated by water or air. The condensed liquid refrigerant is passes through an expansion valve where reduction in pressure occurs. Due to the pressure drop, part of the hot gas evaporates.

The refrigerant leaving the expansion valve is a two-phase liquid. This two-phase fluid enters the evaporator**.** Hot room air circulates over the cooling coil by blower fan. Hot air gives its sensible heat to liquid refrigerant, gets cool and liquid refrigerant convert into vapor. This low pressure, Low temperature vapor goes into compressor through suction line again and complete the refrigeration cycle.

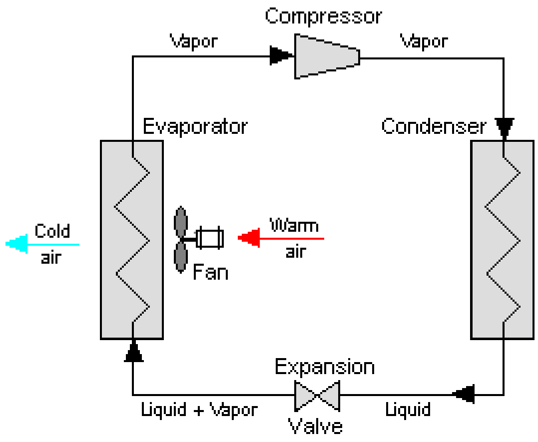


Fig 1: VCC system.

A few examinations have revealed the use of magnetic elements for improvement in the Vapor Compression Cycle and slight changes recommended which will improve the technology [32]. It is based on the magneto caloric effect. Magneto caloric effect means that the temperature of a suitable material changes when magnetized or demagnetized. Main requirements in such cases are that variations must be achievable speedily, repeatedly, reversibly with minimum energy losses [32].

The main purpose of this study is to review the previous papers on VCC, Magnetic Field usages, application, and Various parameters. The methodology adopted for the study is to use literature review technique.

2. Literature Review

Literature survey carried out to identify various technologies used for improving performance of the vapor compression system. Total 54 articles were selected. Only review articles, book chapters and research papers published in journals are identified and total 28 articles are selected.

2.1 Vapor Compression System

G Venkatarathnam et al. Discussed various issues related to changeover of refrigerants being used in vapor compression refrigeration systems. Due to global warming, conventional refrigerants need to be replaced by environment friendly working fluids. Chlorofluorocarbons (CFC's) and hydro chlorofluorocarbons (HCFC's) are being substituted by hydrofluorocarbons (HFC's), hydro fluorooelifins (HFO's), and a variety of mixtures. HFC's that replaced CFC's in the last decade have high GWP and they were the major cause of ozone depletion so need to be phased out. Hydrocarbons have specific practical disadvantages that limit their universal use. The recently proposed HFO has a lower GWP than natural refrigerants, but is flammable. Therefore, refrigerants that fully meet the requirements of safety, stability, energy efficiency and environmental protection cannot be seen.

It was found that, the refrigeration industry will have very little choice but to use flammable refrigerants HFOs, low GWP HFCs, HCs, NH3, etc. The energy efficiency of HFO is slightly lower, and the liquid can be a mixture of medium GWP refrigerants (such as R32) and low GWP refrigerants (such as R1234yf) of choice in future. natural refrigerants appear to be the best choice in the long term [1].

G. Gong et al. Have concluded that the refrigeration system with two condensers is more proficient than single condenser. The study has been carried out for a single stage centrifugal chiller. The cooling capacity of the chiller unit was about 1750 kW. The chiller unit has been set and tested, and the working refrigerant was R22. It was found that, the COP and efficiency of the refrigerating system with two condensers is better than the single condenser [2].

N. K. Sharma et al. Study involves a performance analysis between solar photovoltaic operated vapor compression and vapor absorption refrigeration systems. For the purpose of comparison, two refrigerators compression and absorption refrigeration cycles have been selected. It was observed that the vapor absorption refrigerator takes more time to decrease the temperature of the cabinet in comparison to the vapor compression refrigerator and consumes less power. The vapor absorption system is useful in rural areas having no or less power supply where we want to preserve drugs and food items because it can maintain a constant low temperature between 6-10 °C. The initial investment cost of the compression refrigeration system is higher than that of the absorption system.

If a high cooling rate is required frequently, one should select vapor compression refrigeration system and if only the temperature is to be maintained in the cabinet, then the vapor absorption system is capable with less capital investment than compression system. The Vapor absorption system also performs noise free operation with less maintenance cost [3].

Table 1: Economical Comparison of VCS and VAS [3]

Parameters	Vapor compression System	Vapor Absorption System
Refrigerator Size/Capacity	50 litres	41 litres
Total daily power consumption	2500 W/hr	1500 W/hr
Solar panel Size	425 W	250 W
Refrigerant	R-134a	NH3-H20
Total cost	86000/-	62000/-

Sunil Allam et al. Investigates effect on performance of vapor compression refrigeration system by changing the Condenser and addition of nano particles to the system as a lubricant. The performance of the system mainly depends on the design of heat exchanger hence need to do some changes in the design of condenser. They used spiral condenser made of copper instead of straight iron tube condenser (conventional condenser). The copper spiral condenser (6.35 mm diameter and 5320 mm length copper tube bended in spiral shape) provides more surface area, has more thermal conductivity compared to iron and increases the heat removal rate. An investigation was done by preparation of nano lubrication (addition of polyol-ester (POE) oil mixed with silica (SiO2) Nano powder (1%, 1.5%, and 2% by mass fraction)). The Nano particles have a high heat transfer capability and nano in size makes less chances of particle blockage because of its better nanofluid stability. This nano lubrication helps to increase thermal conductivity of a refrigerant and energy consumption is reduced in compressor which helps to improve the performance of the refrigerator. In market two different types of lubrication oil (Polyol-ester oil and mineral oil) are available. Polyester oil is an artificial oil used in refrigeration compressors and is compatible with R134a, R410A and R12 refrigerants. R-134a doesn't mix well with mineral oil, so it was recommended to use POE oil.

Experimental analysis shows that the COP of Conventional system was 2.78, for spiral condenser without adding any lubrication was 2.86 and for spiral condenser with 2% SiO2 was 3.18. The overall enhancement in COP was 14.36%. It shows that changing the design as well as addition of nano lubrication increases COP. Overall increased heat rejection in the condenser was 6.91%. Overall power consumption of system decreased by 17.4%. The percentage increase in the net refrigeration effect was 8% [4].

Table 2: Comparison of performance parameters [4]

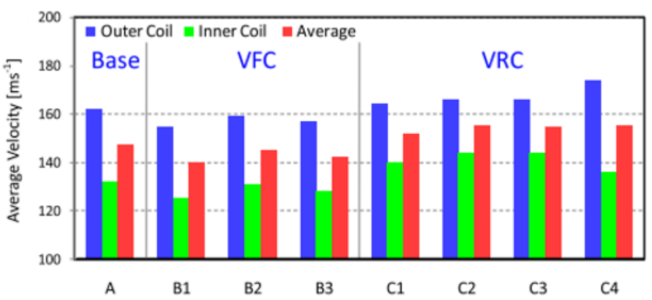
Para-meters	Conventional system	Spiral condenser without lubrication	Spiral condenser with 1% SiO2 Nano Lubrication	Spiral condenser with 1.5% SiO2 Nano Lubrication	Spiral condenser with 2% SiO2 Nano Lubrication
Refrigeration Effect (KJ/Kg)	161	167	169	175	173
Mass flow rate to obtain 1TR (Kg/min)	1.27	1.23	1.21	1.20	1.21
COP	2.78	2.86	3.12	3.16	3.18
Compressor work (KJ/Kg)	57.9	58.3	55.4	55.1	54.8
Power consumption (KW)	1.216	1.112	1.014	1.006	1.002
Heat rejected from condenser (KJ/kg)	217	228	230	229	232

2.2 Vapor Compression Cycle for Water Chiller System

Jia Yang et al. Presents the function of a water mist system to improve the energy efficiency of air-cooled chillers. To improve the chiller performance, a water mist system was coupled to the air-cooled condensers of twin refrigeration circuits was developed and validated. The air entering the condenser and the capacity of the air-cooled chiller vary depending on the mist pre-cooling system. When water mist was sprayed into the air stream entering the condenser, the air temperature will drop and was capable of pre-cooling the ambient air before entering air-cooled condensers. With designed water mist generation rate under HPC, condensing temperature dropped by up to 7.8 ^{0}C and the chiller COP increased up to 21.3%. With the optimal water mist generation rate under HPC, the temperature of the entering condenser air dropped by up to 8.8 ^{0}C, and the chiller COP increased by up to 25.8%. The chiller performance could be improved further under variable condensing temperature control (CTC). Under CTC, chiller COP was increased up to 51.5% with optimal water mist generation rate. HPC is energy inefficient, and should be replaced by CTC [5].

F.W. Yu et al. Developed a mathematical model using multivariate (multiple linear regression) and then validated it using experimental data by using data envelopment analysis (DEA). The analysis tools built into the SPSS v16.0 statistical software to create a multiple linear regression model for a refrigeration system with five chillers, pumps, and cooling towers. The model was used to observe the degree of correlation between weather and operating variables and the system performance (COP). Based on the t-statistics results, the three most significant variables are the load factor, the temperature of supply chilled water and the temperature of cooling water leaving the condenser. Data envelopment analysis was then employed to calculate efficiency. The efficiency of the system studied was found to be 0.76 and operation could reduce the electricity consumption by 5.34% in relation to the existing operation. It is hoped that multivariate and data envelopment analyses would form a standard tool to assess the operating performance of chiller systems and help to formulate a benchmark for chiller improvement work [6].

Tzong-Shing Lee et al. Proposed new designs of variant fin configuration (VFC) and variant row configuration (VRC) condensing coils to increase the energy efficiency of air-cooled water chillers. To design three VFC condensing coils and four innovative VRC condensing coils for airflow distribution of air-cooled water chillers without increasing the heat transfer surface area. Airflow CFD and heat transfer investigation were used to study the influence of VFC and VRC condensing coils on airflow circulation and heat transfer performance. While the three VFC designs were unable to



Total heat transfer comparison

improve the airflow distribution, the four VRC innovative designs all effectively improved the airflow distribution problem, increasing the average air velocity and heat transfer rate in the coils. The case C4 made the best improvements, especially since its inner and outer coil heat flux ratio of 0.977 was nearly uniform. Case C4 increased the average air velocity and overall heat transfer rate than base case A by approximately 10.3% and 5.3%, respectively [7].

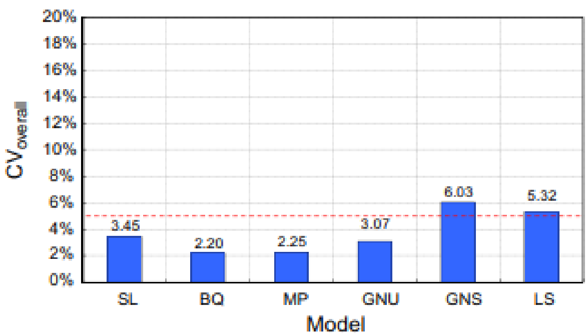
Fig 2: Comparison of Heat transfer and speed for different cases [7].

X. Zhao et al. Observed that when faults occur in the chiller system during initial installation or routine operation, its energy performance is greatly affected. Zhao conducted three FDD (fault detection and diagnosis) methods and its capability to successfully diagnose the faults in chillers. The three FDD methods, including the FDD method based on multiple linear regression (MLR), FDD method based on simple linear regression model (SLR) and FDD method based on decoupling method (DB) were introduced and subsequently evaluated in detail. Multiple simultaneous faults test was conducted. Three FDD methods were verified to notice and diagnose multiple defects, and then three FDD methods were evaluated in detail. Five errors were selected and entered: (1) reduced water flow in the condenser, (2) low water flow in the evaporator, (3) low refrigerant charge, (4) refrigerant overload, (5) The condenser fouling. The decoupling-based FDD has better performance of diagnosing multiple simultaneous faults compared to the MLR FDD method and the SLR FDD method based on quantitative evaluations [8].

D. Li et al. Discussed Chiller FDD is effective in saving energy and enhances performance by a diagnosis of faults in chillers. Seven faults were studied: The condenser fouling (CF) fault was emulated by plugging tubes into condenser. Reduction of condenser water flow (FWC) and evaporator water flow (FWE) faults were directly simulated by reducing the condenser and evaporator water flow. Refrigerant overcharge fault (RO) and Refrigerant Leakage fault (RL) were emulated by increasing or decreasing the refrigerant charge. Excess oil failure (EO) was emulated by loading more oil than advertised. And the non-condensable in refrigerant (NC) fault was emulated by adding Nitrogen to the refrigerant [9].

N. Cotrufo et al. Study involves decrease in energy performance over the time, mostly due to equipment degradation, changes in use, changes in control settings, sensors errors etc. An effective technique to overcome these issues is the Principal Components Analysis (PCA), a multivariate technique which transforms a data set of inter-correlated variables into another data set of independent new variables, the Principal Components (PCs). This paper focuses on Canada's Montreal's campus water supply system. The central unit consists of two sub-systems (1 and 2), each sub-system has a centrifugal cooler (CH1 or CH2), each with a cooling capacity of 3165 kW, a constant speed pump for cold water and condenser water, and a cooling Tower (CT1 or CT2). If one cooler is insufficient to meet the thermal load, the second chiller is turned on and the two coolers work in parallel. Four different operation modes were identified: operation with both chillers, operation with chiller CH-1, operation with chiller CH-2 and all chillers are turned off. [10].

Lee, Ke-Yang Liao. Have considered empirical model that uses basic data to predict the performance of water chiller. These empirical models were also used to determine energy efficiency and performance of chiller. This study considers six empirically-based models which are simple linear (SL) regression model, bi-quadratic (BQ) regression model, multivariate polynomial (MP) regression model, Gordon–Ng universal (GNU) model, Gordon–Ng simplified (GNS) model and Lee's simplified (LS) model. The first three models are black-box models, while the other three models are grey box models. The difference between these two types of models is that the estimated parameters of grey-box models may be interpreted physically, but the black-box models cannot. CV represents the coefficient of the variation. A smaller CV value represents higher accuracy. It was seen that the BQ, MP, and GNU models had the best prediction capacities, with CV values under 5%. Results show that the bi-quadratic regression model (BQ model), which has the best prediction accuracy with a CV of 2.20%, followed by the multivariate polynomial regression model (MP model) with a CV of 2.25%. Except for the GNS and LS model, all models have acceptable ranges of CV value.



[11,12].

Fig 3: Comparison of overall prediction accuracy [11]

Gschneidner et al. Observed that air-cooled VCC water chiller systems consume a significant amount of energy in overall electrical bills meant for the household purpose. Hence, need to develop techniques to obtain a better efficiency of VCC systems. The study by Brown in 1976 showed that it was possible to use the magneto caloric effect to produce a substantial cooling effect near room temperature. About 15 years later Green et al. built a device which actually cooled a load other than the magneto caloric material and heat exchange fluid. In 1997 Ames Astronautics proof-of-principle refrigerator showed that magnetic refrigeration was competitive with conventional gas compression cooling. Since then, over 25 magnetic cooling units have been built and tested throughout the world. Various near room temperature magnetic refrigerant materials and their effects were observed. The current status of near room temperature magnetic cooling was reviewed [13].

Chiller facts progress Energy- Study involves that a chiller is heat transfer device that runs on vapor compression or absorption cycle and removes heat from water or non-freezing mixture. Water can be cooled up to 20^0C; however, required temperature of water depends upon the application. In air conditioning machines, Chilled water is used in the devices to cool and dehumidify the air flow. Chillers mostly used for industrial applications such as injection moulding, welding, food processing, paper industries and chilled drinking water dispensing units. Chillers can be classified in two types- Centralized (only one chiller satisfies multiple cooling requirements) and Decentralized (for each purpose have its own chiller). The size and capacity of the decentralized cooler is smaller than that of the centralized cooler. The cooling capacity of decentralized chillers was up to 10 tons. The various methods can be used to increase the efficiency of chillers were Controlling the chilled water supply, by lowering the condenser temperature, by chiller sequencing (in case of multi-chillers) and by proper maintenance [14].

Air-Cooled Chillers- Studied vapor compression chillers with air-cooled and water-cooled condensers. Compressors used in chillers were reciprocating, scroll, screw driven and centrifugal type. The condenser dissipates the latent heat of the refrigerant in the air or water and converts it into a liquid state. In an air-cooled condenser, heat is released into the air. In water cooled condenser heat is rejected in two steps first refrigerant rejects the heat to the water, then hot water is pumped to cooling tower where hot water ultimately rejects the heat to surrounding. Air cooled condenser is selected in case of less operating and maintenance cost, also in freezing environment. If the large water temperature differential is available, then cold water is not directly sent to application, but it is stored as a buffer [15].

2.3 Magnetic Field in Vapor Compression Chiller System

A. Shahsavar et al. Experimentally investigated the effects of both constant and alternating magnetic fields on the laminar forced convective heat transfer of a hybrid nanofluid containing tetra methyl ammonium hydroxide (TMAH) coated Fe3O4 Carbon nanoparticles and nanotubes (CNT) coated with gum Arabic (GA) flow through the heating tube. The experiments were carried out over wide range of parameters such as Reynolds number (548–2190), volume concentrations of Fe3O4 (0.5–0.9%) and CNT (0.25– 1.35%), magnetic field strength (700 Gauss) and alternating magnetic field frequency (10–50 Hz).

Table 3: The influence of magnetic field on several parameters

Parameter	Reynolds number	Fe3O4 + CNT volume concentrations	Improvement in Nusselt number
Without magnetic field	2190	0.5 Fe3O4+1.35CNT	62.7%
With constant magnetic field	548	0.5 Fe3O4+1.35CNT	75.5%
Without magnetic field	¼ 2190	0.9Fe3O4 + 1.35CNT	35.6% and 62.7%
With constant magnetic field	¼ 548	0.9Fe3O4 + 1.35CNT	42.57.6% and 75.5%

The maximum enhancement of 62.7% was achieved in the local Nusselt number for hybrid nanofluid containing 0.5 vol.% Fe3O4 and 1.35 vol.% CNT at Reynolds number equals to 2190 without magnetic field. The magnetic field effect was noticeable in the mixed nanofluid with higher volume concentration and lower Reynolds number. The highest increment of 20.5% in comparison with the case without field was reported in the local Nusselt number for hybrid nanofluid containing 0.5 vol.% Fe3O4 and 1.35 vol.% CNT at Reynolds number equals to 548. The result on heat transfer of constant magnetic field of nanofluid studied was more significant than the alternating magnetic field. The highest enhancements in the local Nusselt number are 35.6% and 62.7% for 0.9Fe3O4 + 1.35CNT at Re ¼ 2190 Without magnetic field. The effect of the constant magnetic field on the heat transfer of the studied nanofluids was more significant than that of alternating magnetic field. [16].

L.D. Jathar et al. Studied four refrigerants (R600, R134a, R404a, R290) and found that R600 was the most effective refrigerant under the magnetic field. R600 is hydrocarbon refrigerant and only hydrocarbon shows improvement in performance under application of magnetic field. Increase in the magnetic field shows increase in COP, RE and decrease in compressor work up to certain limit. When applied to a magnetic field, the performance of R134a refrigerant, which does not contain hydrocarbons, does not improve. As the magnetic field strength increases, the cooling efficiency increases to a certain magnetic field strength. [17].

Priyanka Dangle et al. Reviewed of Effect of magnetic field on refrigeration. With the application of magnetic field up to 3 pairs the refrigerant effect increases and compressor power drops hence improvement in the COP was observed. Beyond the 3 pairs evaporative capacity drops resulting in a drop in the COP [18].

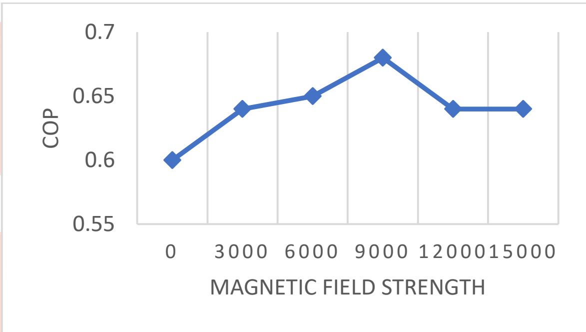


Fig 4: Relationship between COP and Magnetic field strength for R134a [18]

P. Thirupathi et al. Experimental research shows that in Vapor compression refrigeration system due to the effect of applying a magnetic field to the liquid pipeline and adding copper nanoparticles to the compressor lubricating oil, the performance was improved. Initially, the efficiency was measured without applying a magnetic field, and then the magnetic field applied to the liquid line was increased from 1 to 5 by increasing the number of magnet pairs. The strength of each pair of magnets was 450 Gauss. Similarly, COP was initially measured without addition of copper Nano particles to lubricating oil and then adding copper Nano particles to the lubricating oil was increased by increasing the percentage of volumetric addition of copper Nano particles were 0.01%, 0.015%, 0.02%, 0.025% to the PAG46 oil. By application of magnetic field, the COP of the system increased up to 40.158% for R134a refrigerant at fourth magnetic pair. By combining magnetic effect and lubrication effect, the COP of the system increased up to 24.54% for R134a refrigerant at fourth magnetic pair by the application of magnetic field on liquid line with the 0.025% volumetric addition of copper nano particles to the compressor lubricating oil (PAG46 oil), when compared to simple VCR [19].

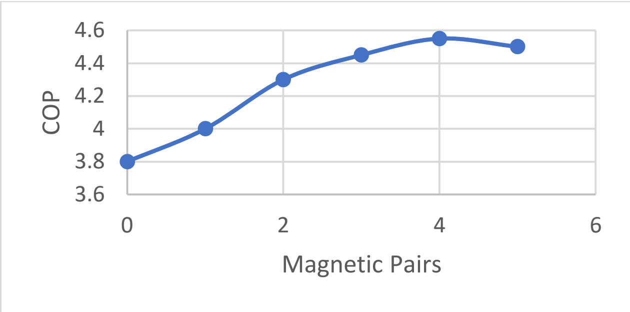


Fig 5: Relationship between COP and number of pairs of Magnet [19]

Ekkes Bruck, V. Khovaylo. Studied that material properties change under the power of MF and magneto caloric properties of Heusler alloys and related compounds such as thin films, melt spun ribbons, and microwires. Comparing magneto caloric properties of thin films, ribbons and microwires with those of the bulk samples, it was noted that, MCE in thin films was inferior to the corresponding bulk materials. This was due to several factors such as spin noncollinear, broadening of the phase transition interval, suppression of magnetic moment at interfaces etc. Among thin films, melt spun ribbons and microwires, the melt-spun ribbons of magneto caloric materials seemed to be the best choice for the purpose of large-scale applications of magnetic refrigeration [20].

Warburg E et al. Discovered the thermal effect of metal iron when applying for it in a varying magnetic field known as MCE (Magneto-Caloric Effect). MCE is defined as heating or cooling of magnetic materials upon magnetic field variation. The magnetic field has a strong influence on physical properties such as an entropy, heat capacity, and thermal conductivity of a magnetic material [21].

Debye et al. Discussed the idea of MCE and suggested achieving an ultra-low temperature by adiabatic demagnetization cooling. The entropy change accompanying the magnetization of paramagnetic substances and its application to obtaining temperatures below 1°K has been discussed. Some suggestions have been made concerning the application of temperatures obtainable to the direct determination of the number of magnetrons in paramagnetic substances, thermal and superconductivity and a method suitable for the determination of heat capacities below 1°K [22].

Silva et al. Mathematically considered AMRR (active magnetic regenerative refrigerator) system which uses magneto caloric materials and materials whose thermal conductivity changes with the applied magnetic field (H) like gadolinium. Results showed that by using gadolinium as magneto caloric material (MCM) and B = 1 T, one can increase the temperature span from 2.5 K up to 11.5 K. Frequency, operating temperature and time of contact between the cold reservoir and the MCM were also recorded. It showed that a fluid is not required for an AMRR system, as long as the system uses materials whose thermal conductivity changes with an external magnetic field. In solid-state AMRR system, temperature achieved was11.5 K, the operating temperature was 303 K, the frequency was 2 MHz, and the contact time between the cold reservoir and last MCM component was 0.5 sec [23].

Samuel and Shawn Used magnetic field up to 12,000 Gauss applied at liquid line and studied the effect of magnetic field on the performance of refrigeration cycle using refrigerant mixtures such as R-410A, R-507, R-407C and R404A. Usage of the magnetic field has a positive influence on the system COP as well as thermal capacity of condenser and evaporator and pressure ratio. The study showed that the effect of magnetic field on the mixture behavior varied depending upon the mixture's composition and its boiling point [24].

Table 4: Effect of R-410A, R-507, R-407C and R404A on various parameters [24]

	R-404A	R-507	R-407C	R-410A
Condenser COP	1.18	1.16	1.05	0.90
Evaporator COP	0.32	0.30	0.25	0.20
Compressor Capacity at 0^0C	600W	500W	580W	1000W
Condenser Capacity at 0^0C	700W	580W	600W	900W
Evaporator Capacity at 0^0C	180W	160W	140W	170W
Pressure Ratio	5.8	6.5	5.7	4.5

Samuel Sami. Used energizer MHD (Magneto-Hydrodynamics) technology, for new alternative refrigerant mixtures under various conditions of the magnetic field. Performance of some new alternative refrigerant mixtures such as; 410A, R-507, R-407C, and R404A under various conditions of magnetic field were discussed. The experimental set-up composed of 3-kW compressor, oil separator, condenser, pre-condenser, pre-evaporator, adjustable expansion device, capillary tubes, and evaporator. Three magnetic elements 4000 Gauss each have been employed. The test results demonstrated that magnetic treatment has a positive effect on enhancing the evaporator capacity and improving the compressor performance thus protecting the compressor as well as the coefficient of performance. The study also showed that the effect of magnetic treatment varies depending upon the magnetic field applied [25].

3. Discussion

In one research study four pairs of permanent magnets of 3000 Gauss field strength had installed at exit of condenser of the VCC setup. The comparison of the set-up performance had done with and without application of magnetic field to estimate the improvement in the VCC system. Experiments were carried out on R-600a refrigerant.

3.1 Effect of magnetic field on water temperature

The Fig 6 represent the variation of water temperature with time. The graph plotted without application of magnetic field and with increasing number of magnetic pairs of magnetic field strength 3000 Gauss each. As the intensity of the magnetic field increases, the viscosity of the refrigerant decreases, which increases the mass flow rate of the refrigerant. It shows drop in water temperature (Improvement in cooling effect) with increase in number of magnetic pairs up to the third pair. After third magnetic pair there is decrease in cooling effect [26].

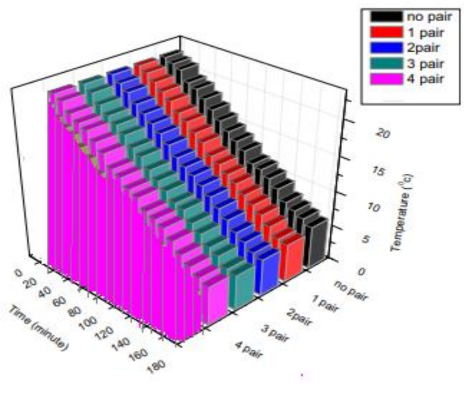


Fig 6: Drop in water temperature with respect to time for variety of magnetic pairs [26]

3.2 Effect of magnetic field on refrigerating effect and power consumption

Fig 7 represent effect of magnetic field on the power consumption of compressor and refrigeration effect. The input power required by the compressor decreases with increase in magnetic pairs. As the strength of the magnetic field increases, the viscosity continues to decrease; therefore, less compressor power is needed to pump the same quantity of refrigerant. As the number of magnetic pair increases, the refrigerating effect also increases up to third magnetic pair, because more amount of refrigerant is circulated per unit time due to a decrease in the specific volume of the refrigerant, leads to increase in the heat transfer rate and refrigerating effect. Beyond certain magnetic field strength, drop in refrigerating effect occurs [26].

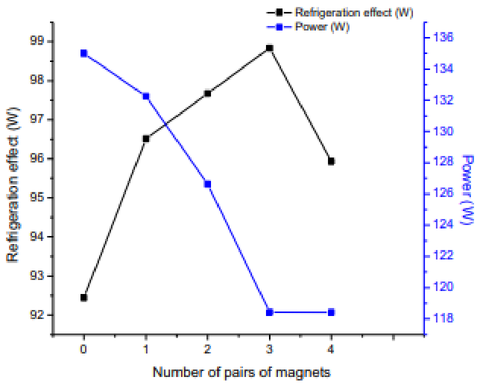


Fig 7: Effect of variety of magnetic pairs on refrigeration effect and power consumption [26]

3.3 Energy consumption in hermetic refrigerator compressor

From Fig 8, it can be concluded that minimum energy is consumed when the third magnetic pair is used. With increasing the magnetic pairs, energy required to run the system decreases. Magnetic field weakens chemical bond present in the refrigerants. Decrease in the viscosity and hence pumping power decreases till third pair. After third magnetic pair complete de-clusterization occurs and beyond third magnetic pair there is no scope for further de-clusterization and hence no decrease in power is observed [26].

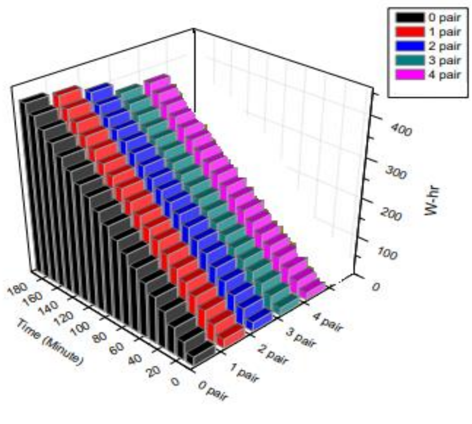


Fig 8: Electricity consumption with respect to time for a number of magnetic pairs [26]

3.4 COP

Fig 9 shows effect of magnetic pairs on COP. When up to 3 pairs of magnetic fields were applied, the cooling effect increases and the power required by the compressor decreases, so an improvement in COP was observed, beyond the 3 pair's evaporative capacity drops resulting in a drop in the COP [26].

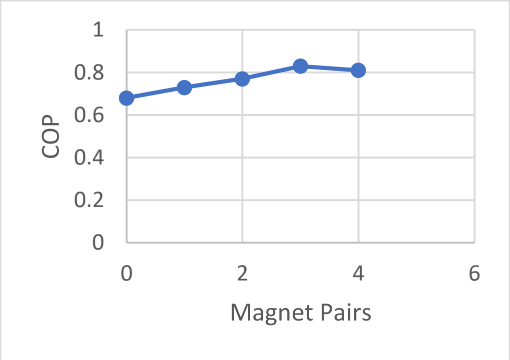


Fig 9: Effect of number of pairs of Magnet on COP [26]

Employing a magnetic field between the condenser outlet and the capillary tube is a new technique that helps in improving efficiency and cooling capacity of air-cooled vapor compression cycle water chiller. There is need of an alternative refrigerant having low ODP and GWP. R600a is promising refrigerant with this respect. The work will be focused on experimental investigations of Effect of magnetic field on R600a refrigerant by comparing the performance with and without application of magnetic field and Effect of magnetic field strength (i.e., varying the applied magnetic field by changing the number of magnet pairs on liquid line) on COP of the vapor compression system. The material, magnetized and attracted by the magnet is called ferromagnetic. These include cobalt, iron, nickel, some rare earth alloys and some natural minerals such as lodestone.

4. Conclusion

The implication of Chlorofluorocarbon and Hydro chlorofluorocarbon refrigerants has an adverse impact on stratosphere layers of the earth such as ODP (Ozone Depletion potential) and GWP (Global Warming Potential). So, these refrigerants need to be replaced with less unsafe ones, having preferably zero ODP and GWP.

The chiller system consumes a large amount of electricity; few methods are utilized to obtain a better efficiency of VCC systems.

COP is the main factor that administers the energy performance of the chiller system and it is important to achieve higher COP.

Working fluid (R600a) reduces ozone depletion potential and global warming potential and hence it tends to be treated as eco-friendly.

Non-Hydrocarbon refrigerants do not show improvement in performance on application of magnetic field.

With the influence of MF Strength, we can determine how the magnetic flux leads to increase in cooling capacity.

Large MCE of magnetic material is investigated for magnetic cooling application, strong magnetic field is required.

Throughout this study, the performance characteristics of some new proposed substitutes under different magnetic field levels have been investigated, analyzed and compared to that of no magnet condition.

COP was initially measured without application of magnetic field, and then magnetic field applied to liquid refrigerant was increased by increasing the number of the magnetic pairs from 1 to 4.

By applying magnetic field in VCC leads to improved evaporator capacity.

Enhancement in efficiency by applying magnetic field.

Water chiller performance enhancement observed with magnetic flux. Energy saving is higher under the magnetic field. Compressor energy consumption decreases with the increase in magnet pairs. Refrigerating effect improved with magnet pairs.

Positive effect of increase in number of magnetic pairs on COP of the refrigeration system up to a certain magnetic field strength. For higher magnetic field strength and beyond cooling performance detreated possibly because of heating of the refrigerant as a result of excessive magnetic field. There is a limit to the maximum field strength which can be applied beyond this limit the performance of the vapor compression system degrades.

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