Review on Cascade Refrigeration Systems and Types of Refrigerants

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Abstract: A refrigerator is a piece of machinery that removes heat consistently in order to sustain a low temperature in a space, and the refrigeration cycle is the cycle that it runs on. Refrigerants are the working fluids that carry heat away and are used in both refrigeration and air conditioning. This paper presents an overview of refrigeration systems before going into detail about cascade refrigeration systems. The effect of refrigerants on the refrigeration cycle's performance**.**
Keywords: Refrigeration, Refrigeration Cycle, Refrigerants, Vapor Absorption Refrigeration, COP

I. Introduction

Refrigeration is a work process involving shifting heat from one location to the next. Domestic refrigerators, industrial freezers, cryopreservation, air conditioning, and heat pumps are just a few of the implementations for refrigeration. A few form of work must be done in order to fulfill the Second Law of Thermodynamics. Mechanical energy is traditionally used, but it can also be done using magnetic properties, lasers, or other methods. Since the turn of the century, the use of refrigeration in the preservation of perishable foods, agriculture, and fisheries has steadily increased [1].
Refrigeration systems are critical in both industrial and residential implementations because they cool or sustain a set temperature. A refrigeration cycle is made up of heat exchange, contraction, and expansion, with a refrigerant flowing through the various units. The refrigerants [2] are chemical compounds with thermodynamic properties that make them ideal for use in refrigeration cycles. They are typically small molecules with lower boiling points as compared to normal (usually less than 273 K). Other properties regarding the safety (including such combustibility or auto-ignition temperature) and impact on the environment (such as ozone depletion or global warming) have an impact on their shortlisting as well.A number of process-related characteristics (such as phase equilibrium characteristics, phase enthalpies, and heats of vaporisation) also have an impact on its performance (such as the Coefficient of Performance, COP). As a result, refrigerant features must be regarded not just for refrigerant shortlisting and/or design, but also for environmental-health-safety (EHS) and procedure performance problems.
Refrigeration systems with one, two, three, or four compression stages [3] have been successfully used in a variety of applications. The number of refrigeration levels is based on number of compression stages needed, the economics, and the kind of of compression. Refrigeration heat loads are related to compressor power in refrigeration system models. The refrigeration models' compressor sections are using the same basic equations as the compressor models previously discussed. Refrigeration systems must use the proper composition, and any makeup gas will have a component mixture.
To know the overall refrigeration loads, the individual unit models use the evaluated compressor suction streams and the heat exchange duties measured by the individual unit models. Depending on the enthalpy discrepancy amongst each refrigerant level, the refrigerant vapour flows generated by these loads are calculated. Compressor discharge pressures are predicted using exchanger designs of the refrigerant condensers.
Refrigeration systems work by repeating a series of thermodynamics processes to return the working fluid to its original condition. A thermodynamics refrigeration cycle [4] takes heat from a cold object and rejects it at a temperature higher. This cycle necessitates work input in order to avoid violating the second law of thermodynamics. The reversed Carnot cycle is the foundation of the perfect refrigeration system. The Carnot cycle is a theoretical construct since it is ideal, meaning it is lossless, frictionless, and heat transfer processes have no temperature variations. In practice, neither of these ideas could ever be realized. As a result, the Carnot cycle serves as a benchmark against which the performance of all the other refrigeration system can be measured.

II. Cascade Refrigeration System.

Almost all refrigeration systems, both commercial and household, operate on a similar concept. They use a vapor compression cycle for refrigerated. However, in some circumstances, using an advanced configuration is more effective. Cascade Refrigeration System [5] is another one of those refrigerated setups. Multiple refrigerated cycles are linked together via an exchanger in the Cascade Refrigeration System. Each refrigeration cycle is referred to as a stage and has its own refrigerant. When compared to conventional refrigeration systems, the cascading system provides for lower temperatures and higher efficiency due to the extra refrigeration system.
The boiling temperatures, freeze points, and critical pressure of the refrigeration systems employed in each cycle vary. This is mostly determined by the lower temperature required and the refrigerated effects required at the evaporator coil.

In a cascade refrigeration system, there are many cycles. The high temps cycle and the low temp cycle are both included in a two-stage cascade refrigeration system. The refrigeration is also chosen based on the cycle in which it is circulated..
When an extremely low temperatures is necessary, cascading refrigeration is employed. Even if a traditional system can reach that temperature, its overall efficiency will be low. Different refrigeration systems operate independently in a cascade refrigeration system. The sole difference from a traditional model is that all of these devices' refrigerant is combined.
They could even be different refrigerants with different boiling points. Heat exchangers are used to carry out the actual interaction and couplings at the evaporator coils. As a result, cascade refrigeration systems can be employed in temperatures ranging from -40 to -80 degrees Celsius. It can reach a temperature of -127 degrees Celsius..

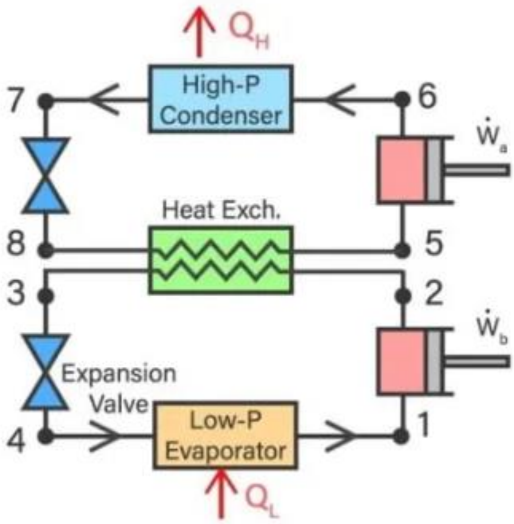

Figure 1: Cascade Refrigeration System

The coupling temperature is the common or intermediary temperatures of the condenser and evaporator at the heat transfer. In generally, the efficiency of a cascade refrigeration system rises as the evaporator temperature rises in the low temp cycling and falls as the evaporator temperature rises in the high temps cycle. Low temperature operations with good energy efficiency is possible with the Cascade Refrigeration System. One of the main reasons is that the refrigerated operating requires less compressor effort than a typical refrigeration cycle.
Using cascade refrigeration, you may obtain exhilaratingly low temperatures (as low as -120 degree C). If a two-stage cascading system is unable to provide the requisite cooling, a third stage (or more) might be added to attain lower temperatures. In comparison to a comparable traditional refrigeration unit, the overall maintenance of a cascade refrigeration system is easier.
Low pressure ratios and reduced lubricating fluid temperatures during operation are two factors for easy maintenance. Cascade systems demand lower compression ratios in each stage than conventional systems. As a result, the temperature of the lubrication oil is reduced, resulting in improved performance.

III. REFRIGERANTS AND REFRIGERATION CYCLE

A refrigerant is a chemical that is used to transmit heat from one location to another in a heat cycle. At room temp, it's usually a gas. Most typically found in air conditioners, refrigerators, freezers, and automobile air conditioners, as well as many other objects that cooled and sometimes heated. Fluorocarbons, particularly chlorofluorocarbons (CFCs), have been used as refrigerants in the past, and they're being phasing out due to their ozone-depleting impacts. Ammonia, sulfur dioxide, and non-halogenated hydrocarbons like propane are other typical refrigerants utilized in various application. The majority of refrigeration systems found in end-of-life equipment deplete the ozone layer and cause global warming.

The following are the two types of refrigeration systems:

Primary Refrigerants: Primary refrigerants are working forms of media or heat carriers that directly participate in the refrigeration unit and cool the substance by absorbing latent heat. Ammonia, SO2, CO2, Methyl chloride, and other primary refrigerants are explanations.

Secondary refrigerants are circulation substances that are chilled by primary refrigerants before being used for chilling. Ice, solid CO2, and other secondary refrigerants are examples.
Chemical Properties of Refrigerants, Physical Properties of Refrigeration systems, and Thermodynamic Properties of Refrigeration systems are the three types of refrigeration characteristics.

There are several different types of refrigeration system, but the following two are the most essential.
• Cycle of Vapor Absorption Refrigeration
• Cycle of Vapor Compression Refrigeration

The following are the explanations for the many types of refrigeration cycles.

Cycle of Vapor Absorption Refrigeration:

An absorbers, a generators, and a pumps replaced the condensation process of the vapor compression cycle in the Vapor Absorption process. The technique works on the idea of using two chemicals that can be separate when heating. The two compounds are interchangeable.

- Ammonia (Refrigerant) and
- Water (Absorbent).

Components of Vapor Absorption Refrigeration Cycle:

The components of Vapour Absorption Refrigeration Cycle are Condenser, Expansion Valve, Evaporator, Absorber, Pump, Generator.
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IV. LITERATURE REVIEW

(Gado et al., 2021) The integration of absorbing, adsorption, and desiccant cooling methods into vapor compression cooling/refrigeration systems is comprehensively reviewed in this work. Various hybrid absorption-compression chilling system configurations have been compiled and investigated using energy, maximum exergy, economical, and environment analyses. In comparison to conventional industrial applications, several studies found that such processes might reduce power consumption by 45–88 percent[6]. Furthermore, employing cascading, partly integration, and fully integrated systems, various layouts of hybrids adsorption-compression chiller systems have been thoroughly examined.. The goal of these integrated adsorption-compression cooling system architectures is to improve vapor compression cooling system performance by lowering condensing temps. According to surveys, using large adsorption cooling systems can improve the system until it reaches freezing limitations, however downscaled desorption cooling systems can decrease system performance by raising the intermediary condensing temperatures.

(Gupta et al., 2021) The purpose of having a refrigerator is to keep food products cool, which slows down germ activity. A refrigerator could be powered by mechanical or thermal energy. Thermally activated cool technology are potential options that not only meet the requirement for air conditioners, prime movers, dehumidifying, and refrigerator, but also save environment for future generations. Because of their environmentally beneficial nature, waste heat recovery devices and solar refrigeration systems are becoming increasingly popular[7]. This article examines vapor adsorption systems and vapor absorption systems. Humans' reliance on finite fossil fuels will be reduced if the practice of employing clean solar energy and total waste heating utilisation is implemented. Because of their long-term viability, these technology are garnering a lot of attention.

(Selvnes et al., 2021) This paper provides a comprehensive overview of recent advancements and research investigations in the field of cold thermal energy storage (CTES) employing phase change materials (PCM) in refrigeration systems. A classification of the many types of PCMs used in air conditioning (AC) systems (20 C) to low-temperature food freezing (60 C) is included in the study. An overview of the factors that influence the thermo - physical properties of PCMs, as well as the methodologies used to characterize them, is offered. The current PCMs on the markets in the range of temperature of 10 to 65 degrees Celsius are listed. Finally, research on CTES in refrigerators employing PCMs is reviewed and categorized into applications for food delivery and package, commercial refrigerated, and other refrigeration systems[8]. Because of the widespread use of these devices, predicted future growth, and low cost of utilizing water as the PCM, the data suggest that using ice/water as the PCM for AC applications is by far the most commonly investigated systems.

(Kumar et al., 2020) Ejectors can now be used to save energy in the home and in other modern applications. The ejector has the ability to increase the movement of warmth and create a vacuum[9]. The ejector lacks any form of powerful components. It is possible to increase the framework's coefficient of executing by using an ejection as the underlying expansion device. Dis-cover the low weight gathering H2O with the rapid high weight consolidation H2O ejector, and then convert the blended liquid's motor vigor into pressured vitality. As a result, when the ejector's output weight is compared to the gulf pressures, the ejector's outlet weight is greater. The latest improvements in the concept of operation of ejectors are discussed in this review study, and it is concluded that more research in this important area is required.

(Soni et al., 2021) A thorough comparison of several composites adsorbents created with Silica-gel, Activated Carbon, Extended Natural Graphite, and Zeolite as[10] a parent material has been published. On the basis of thermal conductivity and adsorption capacity, the performance of several composites adsorbent materials has been studied (of water, methanol, ethanol and CO2). A new composite adsorbent based on polymeric binder (silica-gel and expanded natural graphite bound with polyvinyl alcohol) has also been developed, with physical features addressed. Furthermore, three distinct techniques of creating composites adsorbents employing silica-gel, activated carbon, and zeolite with expanding natural graphite were addressed. The composites absorbent of Metal Organic Frameworks has greater heat and mass transport capabilities than the standard absorbent, according to the current study. It has also been discovered that producing high-performance composites adsorbent materials can considerably boost the effectiveness of the adsorption refrigeration unit.

(You et al., 2022) The efficiency of the refrigeration system, which can be improved by distributing many nanoparticles in the compressors oils and refrigerants of a vapor compression refrigeration system, needs to be improved in terms of energy conservation and environmental concerns. Similarly, in the field of chilling and air-conditioning systems, one of the most common uses has been the use of nano-refrigerants/nano-lubricants, as well as the use of considerably more effective eco-friendly fluids[11]. The goal of the study is to look at the impacts of nanoparticle in lubricants and refrigerants. Natural refrigeration fluids (refrigerants) are described in this study as the ideal refrigeration fluids (refrigerants) for environmental sustainability and as the ultimate remedy to ozone depleting and global warming challenges.. Hicks refrigerated fluids (refrigerants) are arguably the most well-known substitutes for cfcs and huffs refrigeration fluids in refrigeration and air conditioning applications (refrigerants). The impact of distribution stabilizing of nano lubricants and lubricating mechanisms involved in increasing tribological properties is also investigated in this paper.

(Sharma et al., 2021) In terms of reducing energy consumption, the heat driven ejector refrigeration machine is a better option than a compression-based refrigeration unit. Because exergy is inextricably linked to the second rule of thermodynamics, the program's effectiveness can only be assessed using this law. On the basis of efficient performance, it has been determined that good extractor qualities outperforms other components such as the condenser, generators, and evaporation[12]. The concept of ejector refrigeration systems, as well as its exergy analysis and working fluids, are presented in this research. It delves deeply into ejector technologies and behavior, exergy analysis, refrigerant characteristics, and their impact on the ejection refrigeration unit.

(Talpada & Ramana, 2021) This paper examines the development of new working pairings and nano-refrigerant (a mixture of nanoparticles and refrigerant) that contribute to the improvement of absorbed refrigeration system effectiveness. This research compares absorption refrigeration systems with several new working pairs, taking into account the system's COP and circulation ratio[13]. The influence of nano particles on binaries fluids electrical conductivity, absorption rate, heat transfer rate, boiled heat transfer rate, pressure drop, pumping power, and refrigeration system electrical efficiency were also measured and reported in this research.

(Lv et al., 2022) The goal of this review was to compile the most up-to-date literature on the boiled heat transfer performance of environmentally friendly refrigerants with an ODP of less than 0 and a GWP of less than 2000. This review examined the heat transfer process as well as the impacts of heat flux, mass flow, saturation temperature, and mass transfer resistance on the heat transfer coefficient and pressure drop. Furthermore, a thorough examination of the relationship between boiling heat transfer characteristics was provided, which may be useful in practical applications. Prospects and challenges that need to be addressed for future study were also noted[14]. This study assesses current advancements on the boiling heat transfer performance of single and combined environmentally friendly refrigeration systems, as well as science research gaps that must be addressed.

(Pinni et al., 2021) This review paper includes a comprehensive review of previously published research papers on nano refrigerants, as well as a thorough analysis of the thermal performance of the various nanorefrigerants at various concentration of nanoparticles, as well as a comparing of the[15] thermophysical properties of nano - refrigerant and pure refrigeration system. This paper also discusses the current state of nanoscale materials with refrigeration and their heat transmission capabilities, as well as enhancement potentials, technical applications, and future difficulties.

(Mahmood et al., 2021) This study presents the vapour compression refrigeration technique and its changes that can be utilized to increase the program's performance and minimize its power consumption, based on an exhaustive analysis of practical and theoretical investigations. This study also [16]discusses the issues that can be used as a source of research for future studies and research. The use of vapour injection technology, naturally working fluid, and heat exchanger can increase cooling load, refrigeration effect, and energy usage. According to the findings of this study, a vapour injection approach employing a natural refrigerant like water could provide most environmentally friendly refrigeration unit. The future vision for the vapour compression refrigeration cycle, as well as its novel design technique based on Computational Fluid Dynamics (CFD), are discussed and presented.

V. Conclusion

Refrigeration systems are critical in both industrial and residential implementations because they cool or sustain a set temperature. A refrigeration cycle is made up of heat exchange, contraction, and expansion, with a refrigerant flowing through the various units. This paper provides a literature review of the cascade refrigeration system (CRS). It is an important system that can achieve an evaporating temperature as low as −170 ◦C and broadens the refrigeration temperature range of conventional systems. In this paper we presented an overview of refrigeration systems before going into detail about cascade refrigeration systems. The effect of refrigerants on the refrigeration cycle's performance.

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