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Extraction of Green Energy in R & AC System

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Abstract: ***The paper presents trends on recent development of possible substitutes for ecological refrigerants from HVAC&R equipment based on thermodynamic, physical and environmental properties and TEWI (Total Equivalent Warming Impact) analysis. This paper contains a good amount of information regarding the environmental pollution produced by the working fluids of the air-conditioning and commercial refrigeration applications to the ecological refrigerant trend. Overall, it is useful for those readers who are interested in current status of alternative refrigerant development related to vapor compression based refrigeration system for air conditioning, heat extraction sources. The study describes the selection of refrigerants adapted for the utilization based on the thermodynamic, physical and environmental properties and explores the studies reported with new refrigerants in domestic refrigerators, air-conditioners, heat extractors, chillers and in automobile air-conditioners. Additionally, a comparative analysis of the TEWI for possible substitutes of refrigerant R134a used in various air-conditioning, heat extraction sources and refrigeration systems is performed effective manner.***

Keywords: thermodynamic environmental refrigeration air-conditioning heat extractors chillers

1. Introduction

Environmental pollution represents a major risk for all life on our planet (men, flora, fauna), because it consists not only of the local noxious effects of different pollutants but also the imbalances produced on a large scale over the entire planet. Environmental protection represents the fundamental condition of the society's sustainable development and a high priority of national interest that is realized in institutional framework in which the legal norms regulate the development of activities with environmental impact and exerts control on such activities.

The main ease is for environmental protection which is to maintain the ecological balance, to maintain and improve the natural factors, to prevent and control pollution, to promote the development of natural values, to ensure better life and work condition for the present and future generations and it refers to all actions, means and measures undertaken for these purposes.

One of the minor components of the atmosphere, the ozone layer, has a special importance in maintaining the ecological balance. Ozone is distributed primarily between the stratosphere (85e90%) and troposphere regions. Any perturbation of the atmospheric ovonic concentration (which varies between 0 ppm and 10 ppm, depending on the regions) has direct and immediate effects upon life. For most of the states the problems of forming and maintaining the earth's ozone layer, represents a major priority. In this context during the last 30 years, the European Union has adopted a large number of laws and regulations concerning environmental protection to correct the pollution effects, frequently by indirect directives, through imposition of the levels of allowable concentrations by asking for government collaboration, programs and projects for the regulation of industrial activities and productions. The Alliance for Responsible Atmospheric Policy is an industry coalition and leading voice for ozone protection and climate change policies, which maintains a brief summary of the regulations for some countries.

Refrigerants are the working fluids in refrigeration, air-conditioning, and heat extractors systems. They absorb heat from one area, such as an evaporator space, and reject it into another, such as condenser, usually through evaporation and condensation methods. These phase changes occur both in absorption and mechanical vapor compression systems, but not in the systems operating on a gas cycle using a fluid such as air medium. Working fluids escaped through leakages from cooling equipment during normal operation (filling or empting) or after accidents (damages) gather in significant quantities at high levels of the atmosphere (stratosphere). In the stratosphere, through catalytically decompounding, pollution from working fluid leakage depletes the ozone layer that normally is filtering the ultraviolet radiation from the sun, which is a threat to living creatures and plants on earth. Stratospheric ozone depletion has been linked to the presence of chlorine and bromine in the stratosphere. In addition, refrigerants contribute to global warming (also called global climate change) because they are gases that exhibit the greenhouse effect when in the atmosphere.

This paper presents a review on recent development of possible substitutes for non-ecological refrigerants employed in HVAC&R equipment based on thermodynamic, physical and environmental properties and TEWI (Total Equivalent Warming Impact) analysis. This review contains a good amount of information regarding the environmental pollution produced by the working fluids of the air-conditioning, heat extractors and commercial refrigeration applications.

2. Ecological Impact of Refrigerants

The design of the refrigeration equipment depends strongly on the properties of the selected refrigerant. Refrigerant selection involves compromises between conflicting desirable thermo-physical properties. A refrigerant must satisfy many requirements, some of which do not directly relate to its ability to transfer heat. Chemical stability under conditions of use is an essential characteristic. Safety codes may require a non-flammable refrigerant of low toxicity for some applications. The environmental consequences of refrigerant leaks must also be considered. Cost, availability, efficiency, and compatibility with compressor lubricants and equipment materials are other concerns.

Safety properties of refrigerants considering flammability and toxicity are defined by. Toxicity classification of refrigerants is assigned to classes A or B. Class A signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm by volume, and class B signifies refrigerants with evidence of toxicity at concentrations below 400 ppm by volume. By flammability refrigerants are divided in three classes. Class 1 indicates refrigerants that do not show flame propagation when tested in air (at 101 kPa and 21 ⁻C). Class 2 signifies refrigerants having a lower flammability limit (LFL) of more than 0.10 kg m^{-3} and a heat of combustion less than 19,000 kJ kg^{-1}. Class 3 indicates refrigerants that are highly flammable, as defined by an LFL of less than or equal to 0.10 kg m^{-3} or a heat of combustion greater than or equal to 19,000 kJ kg^{-1}.

New flammability class 2 L has been added since 2010 denoting refrigerants with burning velocity less than 10 cm s^{-1}. Minimizing all refrigerant releases from systems is important not only because of environmental impacts but also because charge losses lead to insufficient system charge levels, which in turn results in suboptimal operation and lowered efficiency.

The average global temperature is determined by the balance of energy from the sun heating the earth and its atmosphere and of the energy radiated from the earth and the atmosphere into space. Greenhouse gases (GHGs), such as CO_2 and water vapor, as well as small particles trap heat at and near the surface, maintaining the average temperature of the Earth's surface at a temperature approximately 34 K warmer than would be the case if these gases and particles were not present (greenhouse effect).

Global warming is a concern because of an increase in the greenhouse effect from increasing concentrations of GHGs attributed to human activities. The measure of a material's ability to deplete stratospheric ozone is its ozone depletion potential (ODP), a relative value to that of R11, which has an ODP of 1.0. The global warming potential (GWP) of a GHG is an index describing its relative ability to collect radiant energy compared to CO_2, which has a very long atmospheric lifetime. Therefore, refrigerants will be select so that the ozone depletion potential will be zero and with a reduced GWP. The most utilized halogenated refrigerants are the family of chemical compounds derived from the hydrocarbons (HC) (methane and ethane) by substitution of chlorine (Cl) and fluorine (F) atoms for hydrogen (H) , whose toxicity and flammability scale according to the number of Cl and H atoms. The presence of halogenated atoms is responsible for ODP and GWP. During the last century, the halogenated refrigerants have dominated the vapor compression-based systems due to its good thermodynamic and thermo-physical properties. But the halogenated refrigerants are having poor environmental properties with respect to ODP and GWP. The second generation of refrigerants, CFCs replaced classic refrigerants in early 20th century. Refrigerants as CFCs (R12, R11, and R13) have been used since the 1930s because of their superior safety and performance characteristics. How-ever, their production for use in developed countries has been eliminated because it has been shown that they deplete the ozone layer. The CFCs and HCFCs represented by R22 and mixture R502 dominated the second generation of refrigerants. Also, the HC and HFC refrigerant mixtures with low environment impacts are considered as potential alternatives to phase out the existing halogenated refrigerants. HC-based mixtures are environment-friendly, which can be used as alternatives without modifications in the existing systems. But HC refrigerant mixtures are highly flammable, which limits the usage in large capacity systems. HFC mixtures are ozone-friendly, but it has significant GWP. HFC mixtures are not miscible with mineral oil, which require synthetic lubricants (such as polyester). Earlier investigations re-ported that HFC/HC mixtures are miscible with mineral oil. It is possible to mix HC refrigerants with HFC to replace the existing halogenated refrigerants.

3. Influence of R134a on Process Efficiency

The design and efficiency of the refrigeration equipment depends strongly on the selected refrigerant's properties. Consequently, operational and equipment costs depend on refrigerant choice significantly. Consists of compressor, condenser, expansion valve and evaporator, connected with refrigerant pipelines. The basic vapor-compression cycle is considered to be one with isentropic compression, with no superheat of vapor and with no sub cooling of liquid. Temperature glide appears during evaporation and condensation at constant pressure. Use of counter flow heat exchangers can sometimes help to utilize that temperature glide efficiently, but problems can appear with leakage of refrigerants from such systems as the initial refrigerant composition and thus properties can be disturbed. The specific compression work w, in kJ kg^{-1}, the specific cooling power q_0, in kJ kg^{-1}, volumetric refrigerating capacity q_{0v}, in kJ m^{-3}.

4.1. Pure Halogenated Refrigerants as Alternatives

The CFC refrigerants of R11 and R12 were substituted by simpler compound refrigerants R123 (HCFC) and R134a (HFC) with a reduced or even zero impact on the depletion of the ozone layer. This alternative is attractivebecause the substitutes have similar properties (temperature, pressure) with the replaced ones and the changes that occur directly on the existing installations are realized with mini-mum of investments. Additionally, the substitution of R123 or R11 refrigerants with R22 or R134a, having molecular masses lower by 50%, leads to reduced dimensions of the refrigeration equipment by 25e30%.For other refrigerants, no simple compound fluids, for example for R502, could be replaced with a mixture of R115 (CFC) and R22 (HCFC) or in some cases only with R22, which is a fluid for temporary substitution. However, all these compounds are considered to be greenhouse gases. As a response to these concerns, even more ecological refrigerants, mainly R1234yf and natural refrigerants. In automotive air-conditioning systems, the refrigerant R12, which could deplete the ozone layer, was replaced by R134a in the 1990s. However, R134a is still a greenhouse gas whose GWP is approximately 1300. During the Kyoto Protocol, R134a was already on the list of refrigerants whose use is restricted. Undoubtedly, the need for refrigerant substitution in automotive air-conditioning systems is very urgent, and R134a should be substituted by an ecological refrigerant in the near future.

Previous studies have considered R152a and the natural refrigerant CO_2as possible substitutes for R134a in automotive air-conditioning systems. However, R152a is a flammable refrigerant, which must use a secondary loop when used in automotive air-conditioning systems. The working pressure required for the CO_2 system is much higher than that for the R134a system. Extremely high pressure leads to a significant change in the present system and thus a higher system cost. Hence, these two refrigerants are far from practical for use as substitutes of R134a in present-day automotive air-conditioning systems.

4.2 Refrigerant mixtures as alternatives

Very limited pure fluids are having suitable properties to provide alternatives to the existing halogenated refrigerants. The mixing of two or more refrigerants provides an opportunity to adjust the properties, which are most desirable. The three categories of mixtures used in refrigeration and air-conditioning applications are zoetrope's, near azeotropes (quasi-azeotropes) and zoetrope's.

Azeotropic mixture of the substances is the one which cannot be separated into its components by simple distillation. The azeotropic mixtures are having boiling points that are lower than either of their constituents. An azeotropic mixture maintains a constant boiling point and acts as a single substance in both liquid and vapor state. Azeotropic refrigerant mixtures are used in low temperature refrigeration applications.

The objective with near azeotropic mixtures is to extend the range of refrigerant alternatives beyond single com-pounds. Near azeotropes have most of the same attributes as azeotropes and provide a much wider selection possibilities. However, near azeotropic mixtures may alter their composition and properties under leakage conditions. Zeotropic refrigerant mixtures are blends of two or more refrigerants that deviate from perfect mixtures. A zeotropic mixture does not behave like a single substance when it changes state. Instead, it evaporates and condenses between two temperatures (temperature glide). The phase change characteristics of the zeotropic refrigerant mixture (boiling and condensation) are non-isothermal. Zeotropic substances have greater potential for improvements in energy efficiency and capacity modulation. However, the major drawback of the zeotropic refrigerant mixture is the preferential leakage of more volatile components leading to change in mixture composition.

4. Ecological Impact Assessment of Possible Substitutes for R134a

The R134a is an interim substitute for halogenated refrigerants. Replacement of R134a in existing refrigeration systems is still actually. Retrofit basically means adaptation of refrigeration system to the new refrigerant with changed safety and control equipment and instrumentation within the system, and with changed system performance. The adaption is not simple, especially in the case when transition from mineral oil lubricated systems (HCFCs) to synthetic oil lubricated systems (HFCs) is necessary. For an indirect evaporation system, the total electric power values are reduced compared with the direct evaporation system, although the evaporation temperature decreases. This trend is explained by the fact that the refrigerant mass flow rate decreases more compared to the increase of the specific mechanical work.

5. Conclusions

This study contains a good amount of information regarding ecological refrigerant trend. Scientific research based on mono-compound substances or mixtures will lead to the discovery of adequate substitutes for cooling applications that will not only be ecological (ODP ¼ 0, reduced GWP), non-flammable and non-poisonous but also have favorable thermo-dynamic properties.

A possible solution is the use of inorganic refrigerants (NH_3, CO_2) and hydrocarbon refrigerants (propane, isobutene, ethylene, propylene) for industrial applications and for household cooling for use in air-conditioning or food storage. Because the hydrocarbon refrigerant represents a high risk of flammability and explosion, these substances will not be often used as refrigerants compared with CO_2 or NH_3. Another advantage of these two substances lies in the fact that they were used for a long time as refrigerants.

The European Partnership for Energy and Environment considers the HFC refrigerants as the best alternative for the refrigerant CFC and HCFC in most of the applications. The HFC refrigerants allow the use energetically efficient applications, offering significant benefits compared with the existing al-tentative. On average, over 80% of the gases that contribute to the greenhouse effect and are used in cooling equipment have the indirect emissions as sources. The high energy efficiency resulted by the use of HFC refrigerants balances in a great measure of the global warming potential. The TEWI index values computed for all the three analyzed system types are lower for indirect evaporation than direct evaporation. A maximum deviation of 20% is obtained for the refrigeration system. The decrease of the evaporation temperature by 15 K for refrigeration and freezing systems results in the TEWI index decrease by 15e37%. The direct effect of TEWI index represents 33e60% of the total value for most of the analyzed refrigerants. The minimal values are for R290, R600 and R152. The direct effect of these refrigerants is approximately 2%.

The new refrigerant generation must offer high efficiency or the change to address low GWP will backfire with increased rather than decreased net GHG emissions. The use of ecological refrigerants plays a crucial role for reducing the environmental impacts of the halogenated refrigerants to protect the environment.

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Author Profile

M. Yaswanth, Student of Final year Mechanical Department, Panimalar Institute of Technology(Affiliated to Anna University), Chennai, India.He received**The National Award in Sustainable Energy Development for the Academic Year 2014, by ISTE** and also participated& won in many National level technical Papers. Hehasan adverse knowledge and interest in the field of Refrigeration and Air Conditioning Systems. Simultaneously he has published a paper in the International Journal and presented 3 papers in international conferences.