

Heat Exchanger Technology and Applications in Heat Exchanger Engineering

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Abstract: Over the years, all parts of a commercial refrigerator, such as the compressor, heat exchangers, refrigerant, and packaging, have been improved considerably due to the extensive research and development efforts carried out by academia and industry. However, the achieved and anticipated improvement in conventional refrigeration technology are incremental since this technology is already nearing its fundamental limit of energy efficiency. A technology described as 'magnetic refrigeration' which is an evolving cooling technology. The word 'green' designates more than a colour. It is a way of life, one that is becoming more and more common throughout the world. An interesting topic on 'sustainable technologies for a greener world' details about what each technology is and how it achieves green goals. Recently, conventional chillers using absorption technology consume energy for hot water generator but absorption chillers carry no energy saving. With the aim of providing a single point solution for this dual purpose application, a product is launched but can provide simultaneous chilling and heating using its vapour absorption technology with 40% saving in heating energy. Using energy efficiency and managing customer energy use has become an integral and valuable exercise. The reason for this is green technology helps to sustain life on earth. This not only applies to humans but to plants, animals and the rest of the ecosystem. Energy prices and consumption will always be on an upward trajectory. In fact, energy costs have steadily risen over last decade and are expected to carry on doing so as consumption grows. Refrigerants such as hydrochlorofluorocarbons (HCFCs) are present in the ground source heat pump (GSHP) systems and can pose a threat to the environment through being toxic, flammable or having a high global warming potential.

Key words: Absorption cycles, environment, heat pumps, refrigeration cycles, thermodynamic

1. Introduction

One of the most energy efficient methods of domestic heating is to use heat pumps. Heat pumps use electrical energy to reverse the natural flow of environmental heat from cold to hot. A typical heat pump requires only 100 kWh of electrical power to turn 200 kWh of freely available environmental heat into 300 kWh of useful heat [1]. In every case, the useful heat output will be greater than the energy required to operate the pump itself. Heat pumps also have a relatively low carbon dioxide output, less than half that of oil, electric and gas heat production.

Heat pumps for domestic heating are a relatively new concept in Britain; however the technology is widely used in an industrial capacity. Across Europe, hundreds of thousands of domestic heat pump units are in use, and the technology is tried, tested and reliable.

Ideally, a refrigerant will have the following characteristics: Non-toxic - for health and safety reasons. Non-flammable - to avoid risks of fire or explosion. Operate at modest positive pressures - to minimise pipe and component weights (for strength) and avoid air leakage into the system. Have a high vapour density – to keep the compressor capacity to a minimum and pipe diameters relatively small. Easily transportable - because refrigerants are normally gases at SSL conditions they are stored in pressurised

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containers. Environmentally friendly - non-polluting and non-detrimental to the atmosphere, water or ground. Easily re-cycleable. Relatively inexpensive to produce. Compatible with the materials of the refrigeration system - non-corrosive, miscible with oil, chemically benign.

In practice, the choice of a refrigerant is a compromise, e.g., Ammonia is good but toxic and flammable. R12 is very good but detrimental to the Ozone layer [2]. An air-source heat pump is convenient to use and so it is a better method for electric heating. The ambient temperature in winter is comparatively high in most regions, so heat pumps with high efficiency can satisfy their heating requirement. On the other hand, a conventional heat pump is unable to meet the heating requirement in severely cold regions anyway, because its heating capacity decreases rapidly when ambient temperature is below -10°C . According to the weather data in cold regions, the air-source heat pump for heating applications must operate for long times with high efficiency and reliability when ambient temperature is as low as -15°C . Hence, much researches and developments have been conducted to enable heat pumps to operate steadily with high efficiency and reliability in low temperature environments [2]. For example, the burner of a room air conditioner, which uses kerosene, was developed to improve the performance in low outside temperature [3]. Similarly, the packaged heat pump with variable frequency scroll compressor was developed to realise high temperature air supply and high capacity even under the low ambient temperature of -10 to -20°C [4]. Such a heat pump systems can be conveniently used for heating in cold regions. However, the importance of targeting the low capacity range is clear if one has in mind that the air conditioning units below 10 kW cooling account for more than 90% of the total number of units installed in the EU [5].

However, new types and blends of refrigerant with minimal negative impacts are being developed. A

correctly fitted system will also greatly reduce the potential for leakage, which is why using a professional installer is highly recommended. Significant CO_2 savings can be gained by displacing fossil fuels. Even compared to the most efficient gas or oil condensing boilers, a well-designed heat pump with COP of 3-4 will reduce emissions by 30-35%. Further carbon savings can be made if the electricity used to power the pump comes from a renewable energy source such as photovoltaic or a renewable electricity tariff. Also, measures can be taken to reduce the impact of pollution from using grid electricity generated through fossil fuel. For example, one can purchase dual tariff green electricity from a number of suppliers. However, even if ordinary grid electricity is used to run the compressor, the system will still produce less CO_2 emissions than even the most efficient condensing gas or oil boiler with the same output. The term "vapour compression refrigeration" is somewhat of a misnomer, it would be more accurately described as 'vapour suction refrigeration'. Vapour compression is used to reclaim the refrigerant and is more aptly applied to heat pumps. Vapour compression refrigeration exploits the fact that the boiling temperature of a liquid is intimately tied to its pressure. Generally, when the pressure on a liquid is raised its boiling (and condensing) temperature rises, and vice-versa. This is known as the saturation pressure-temperature relationship.

2. Energy Efficiency Considerations in Heat Exchangers Designs

Heat exchangers are devices, designed to efficiently transfer heat, from one medium to another, i.e., water-to-air, refrigerant-to-air, refrigerant-to-water, stream-to-water. Heat exchangers are widely used in power engineering, chemical industries, petroleum refineries, food industries and in HVAC technology. Therefore, heat transfer and the design of heat transfer equipment continue to be a centrally important issue

in energy conservation. With increasing worldwide awareness of the serious environmental problems due to fossil fuel consumption, efforts are being made to develop energy efficient and environmentally friendly systems by utilisation of non-polluting renewable energy sources, such as solar energy, industrial waste heat or geothermal water. The GSHPs are suitable for heating and cooling of buildings and so could play a significant role in reducing CO₂ emissions. Ground source or geothermal heat pumps are a highly efficient, renewable energy technology for space heating and cooling. This technology relies on the fact that, at depth, the Earth has a relatively constant temperature, warmer than the air in winter and cooler than the air in summer.

2.1 Heat Transfer Mechanisms

- Single-phase convection on both sides
- Single-phase convection on one side
- Two-phase convection on other side
- Two-phase convection on both sides

Examples: condensers, boilers, evaporators and radiators (Fig. 1).

Naturally, it would be preferred, for comfort reasons that this index would be small, preferably nil. It may be seen that the variable is directly related to temperature discomfort: the larger the value of the index, the farthest will inside conditions be from expected wellbeing. Also, the use of electricity operated air conditioning systems will be more expensive the higher this variable is. Hence, energy expenditure to offset discomfort will be higher when comparing two index values; the ratio of them is proportional to the expected energy savings.

When the external shade blocks the windowpane completely, the excessive heat gains belong to the lowest values in the set, and the dimensionless index will be constant with orientation. For the climate conditions of the locality, it can be seen that a naked

window can produce undesirable heat gains if the orientation is especially unfavourable, when the index can have an increase of up to 0.3 with respect to the totally shaded window.

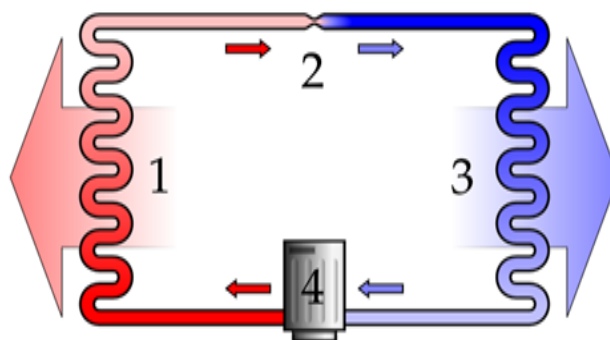


Fig. 1 Diagram of a phase change heat pump: 1) condenser coil 2) expansion valve 3) evaporator coil and 4) compressor.

2.2 Brief Methodology of Heat Exchanger Design Based on the Log Mean Temperature Difference (LMTD) and Effectiveness

A heat exchanger is usually referred to as a micro heat exchanger (μ HX) if the smallest dimension of the channels is at the micrometer scale, for example from 10 μ m to 1 mm. Beside the channel size, another important geometric characteristic is the surface area density ρ (m^2/m^3), which is defined as the ratio of heat exchange surface area to volume for one fluid. It reflects the compactness of a heat exchanger and provides a criterion of classification. Note that the two parameters, the channel size and surface area density, are interrelated, and the surface area density increases when the channel size decreases. The exchangers that have channels with characteristic dimensions of the order of 100 μ m are likely to get an area density over 10 000 m^2/m^3 and usually referred to as μ HXs [6-10].

The concept of multi-scale heat exchanger is expected to have the following characteristics [18]:

- A relatively significant specific heat exchange surface compared to that of traditional exchangers;
- A high heat transfer coefficient, as heat transfer is taking place at micro-scales and meso-scales;
- An optimised pressure drop equally distributed between the various scales;
- A modular character, allowing assembly of a macro-scale exchanger from microstructured modules.

3. Discussions

Some difficulties still exist. On the one hand, the properties of flow distribution in such an exchanger are still unknown [11]. A lot of research work still needs to be done for the equidistribution optimisation. On the other hand, 3-D modelling of heat transfer for such an exchanger requires a thorough knowledge of the hydrodynamics and profound studies on elementary volume (smallest scale micro channels). Finally, maintenance problems for this type of integrated structures may become unmanageable when fouling; corrosion, deposits or other internal perturbations are to be expected. Figs 2-4 show the connections of the heat exchanger, water pump, heat rejection fan expansion valve, and the power supply to heat injection fan (Fig. 5).

Renewable energy is the term to describe a wide range of naturally occurring, and replenishing energy sources. The use of renewable energy sources and the rational use of energy are the fundamental inputs for a responsible energy policy. The energy sector is encountering difficulties because increased production and consumption levels entail higher levels of pollution and eventually climate changes, with possibly disastrous consequences. Moreover, it is important to secure energy at acceptable cost to avoid negative impacts on economic growth. On the

technological side, renewables have an obvious role to play



Fig. 2 Shows the heat exchanger.

In general, there is no problem in terms of the technical potential of renewables to deliver energy and there are very good opportunities for renewable energy technologies to play an important role in reducing emissions of greenhouse gases into the atmosphere—certainly far more than have been exploited so far. But there are still technical issues to be addressed to cope with the intermittency of some renewables, particularly wind and solar. However, the biggest problem with relying on renewables to deliver the necessary cuts in greenhouse gas emissions is more to do with politics and policy issues than with technical ones. The single most important step governments could take to promote and increase the use of renewables would be to improve access for renewables to the energy market. That access to the market would need to be under favourable conditions and possibly under favourable economic rates. One move that could help-or at least justify-better market access would be to acknowledge that there are environmental costs associated with other energy supply options, and that these costs are not currently internalised within the market price of electricity or fuels [12].



Fig. 3 Shows the connections of the heat exchanger, water pump, heat rejection fan and expansion valve.

It could make significant difference, particularly if, appropriate subsidies were applied to renewable energy in recognition of environmental benefits it offers. Cutting energy consumption through end-use efficiency is absolutely essential. And this suggests that issues of end-use consumption of energy will have to come onto the table in the foreseeable future.

Thermal comfort is an important aspect of human life. Buildings where people work require more light than buildings where people live. In buildings where people live the energy is used for maintaining both the temperature and lighting. Hence, natural ventilation is rapidly becoming a significant part in the design strategy for non-domestic buildings because of its potential to reduce the environmental impact of building operation, due to lower energy demand for cooling. A traditional, naturally ventilated building can readily provide a high ventilation rate. On the other hand, the mechanical ventilation systems are very expensive. However, a comprehensive ecological concept can be developed to achieve a reduction of electrical and heating energy consumption, optimise natural air condition and ventilation, improve the use of daylight and choose environmentally adequate building materials. Energy efficiency brings health, productivity, safety, comfort and savings to homeowner, as well as local and global environmental benefits. The use of renewable energy resources could

play an important role in this context, especially with regard to responsible and sustainable development. It represents an excellent opportunity to offer a higher standard of living to local people and will save local and regional resources. Implementation of the ground source heat pump systems offers a chance for maintenance and repair services. It is expected that the pace of implementation will increase and the quality of work to improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is important and more transparent.



Fig. 4 Shows the connections of the heat exchanger and expansion valve.



Fig. 5 Shows the power supply to heat injection fan.

Various passive techniques have been put in perspective, and energy saving passive strategies can be seen to reduce interior temperature and increase thermal comfort, and reducing air conditioning loads. The scheme can also be employed to analyse the

marginal contribution of each specific passive measure working under realistic conditions in combination with the other housing elements. In regions where heating is important during winter months, the use of top-light solar passive strategies for spaces without an equator-facing façade can efficiently reduce energy consumption for heating, lighting and ventilation. The use of renewable energy resources could play an important role in this context, especially with regard to responsible and sustainable development. It represents an excellent opportunity to offer a higher standard of living to local people and will save local and regional resources. Implementation of the GSHPs offers a chance for maintenance and repair services.

4. Conclusions

The building sector is a major consumer of both energy and materials worldwide, and the consumption is increasing. Most industrialised countries are in addition becoming more and more dependent on external supplies of conventional energy carriers, i.e., fossil fuels. Energy for heating and cooling can be replaced by new renewable energy sources. New renewable energy sources, however, are usually not economically feasible compared with the traditional carriers. In order to achieve the major changes needed to alleviate the environmental impacts of the building sector, it is necessary to change and develop both the processes in the industry itself, and to build a favourable framework to overcome the present economic, regulatory and institutional barriers. Today, buildings are largest consumers of energy. Air conditioning and heating consume about 40% of the power in the buildings. Demand to conserve energy has become necessity as there has been rising costs of energy consistently and this make us to think to go green and innovate the greener concept for buildings. A green building uses less water, optimises energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants.

And, a green home can have benefits, such as reduction in water and operating energy costs of the building. This may also mean refrigerant-based chillers and compressors to be shut off or to be operated at reduced capacity. With the environmental protection posing as the number one global problem, man has no choice but reducing his energy consumption, one way to accomplish this is to resort to passive and low-energy systems to maintain thermal comfort in buildings.

Naturally, it would be preferred, for comfort reasons that this index would be small, preferably nil. It may be seen that the variable is directly related to temperature discomfort: the larger the value of the index, the farthest will inside conditions be from expected wellbeing. Also, the use of electricity operated air conditioning systems will be more expensive the higher this variable is. Hence, energy expenditure to offset discomfort will be higher when comparing two index values; the ratio of them is proportional to the expected energy savings. When the external shade blocks the windowpane completely, the excessive heat gains belong to the lowest values in the set, and the dimensionless index will be constant with orientation. For the climate conditions of the locality, it can be seen that a naked window can produce undesirable heat gains if the orientation is especially unfavourable, when the index can have an increase of up to 0.3 with respect to the totally shaded window.

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