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Active low-grade energy recovery potential for building energy conservation

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ABSTRACT

With environmental protection and energy source posing as the biggest issue of the global problems, human beings have no choice but to reduce energy consumption. One way to accomplish this is to increase the efficiency of energy consumption and sufficiently exploit the low-grade energy in our lives. Low-grade energy recovery devices are of significance to meet the needs for energy conservation and green environment requirements such as fresh air pre cooling/heating, water heating, drying clothes and humidifying. These devices are also free of motion parts, non-corrosive and environmentally friendly. Various low-grade energy recoveries powered cooling, heating, drying and dehumidifying systems have been tested extensively; however, these systems are not yet ready to compete with the well-known vapor-compression system. The objective of this paper is to provide fundamental knowledge on the low-grade energy usage systems and present a detailed review on the past efforts in the field of low-grade energy recovery and usage subsystems. Lots of attempts have been made by the researchers to improve the performance of the low-grade energy recovery or usage subsystems. It is seen that, for successful operation of such systems, combination of diverse technologies is essential for more effective and multi-purpose applications.

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1. Introduction

Nowadays, energy security, economic growth and environment protection are the national energy policy drivers of any country. As world populations grow, faster than the average 2%, the need for more and more energy is exacerbated. Actually, people cost their most of life time within buildings. Hence, the purpose behind the building energy consumption is to provide a variety of building services, which include weather protection, storage, communications, thermal comfort, facilities of daily living, aesthetics, work environment etc. That is to say, by the consumption of energy, buildings are to provide an acceptable indoor environment, which allows occupants to carry out various activities.

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Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Therefore, the building sector is a major consumer of both energy and materials worldwide, and that consumption is increasing continuously. Within the buildings, most of energy is for the provision of heating, cooling and air conditioning [1]. For space heating, for example, drawing the boundary as far as the boiler or heat pump implies that the service considered is delivery of heat to a room or building. Extending the boundary to cover an entire building implies that the unit of service is maintaining a desired temperature distinct from the outside. The minimum work needed to achieve this task depends on additional factors such as insulation and the degree of venting with the outdoors needed to maintain air quality [2]. For air conditioning, buildings in warm climates or those with high casual gains may need some form of cooling to maintain a comfortable interior environment [3–7].

The heating or cooling of an enclosed space to maintain thermal comfort is a highly energy intensive process accounting for as much as 60–70% of total energy. In naturally ventilated buildings, one way to achieve this is by precooling supply air, using a form of chiller attached to the inflow vent of the building. Hence, maximum natural energy or recycling waste heat or coolness can be used for creating a pleasant environment inside the built envelope [8]. When the interior is required to be warmer than the outside, the incoming exterior air would be heated. This situation may occur in winter. However, when the exterior temperature is sufficiently high (sufficiently low), as in summer (winter), the room should be kept cooler (warmer) than ambient air environment to achieve indoor thermal comfort, which cannot be implemented simply by the use of natural ventilation. Usually, there are air conditioners or heat pumps employed to achieve that required thermal comfort of indoor air. Absolutely, directly intake of ambient fresh air into the indoor space will greatly enhance the indoor air quality; on the other hand, the heat exchange between fresh air and indoor air unexpectedly increase the heating/cooling load across the buildings. Fortunately, some novel methods or units have been presented in recent years, and these will be reviewed in the present paper.

In addition to the energy consumption by building air conditioning, lots of other facilities, including domestic equipments, traffic tools, and electronics, should 'eat' the fuels, particularly the fossil fuels. As you know, fossil fuels currently supply most of the world's energy needs, and however acceptable their long-term consequences, the supplies are likely to remain adequate for the next few generations. Scientists and policy makers must make use of this period of grace to promote energy conservation or recovery from low-grade heat sources of energy and determine what is scientifically possible, environmentally acceptable and technologically promising [9]. Actually, energy use reduction can be achieved by minimizing the energy demand, by rational energy use, by recovering heat and cold and by using energy from the ambient air and from the ground [1]. In past 20 years, researchers of this paper have created lots of novel heat/cold recovery units; these will be overviewed in the present work.

Therefore, thermal recovery from building air conditioners and low-grade waste heat recovery methods will be reviewed and discussed in the present work. In details, this paper will review technologies of heat and cold recovery and efficient energy use from the ambient air for built environment and services, with most of them being experimentally and theoretically studied by the authors. In Section 2, waste heat and cold recovery in air-conditioning systems for improving indoor environment are introduced; In Section 3, thermoelectric technologies as clothes dryer, ventilator, vehicle air conditioning, electronic cooler and dehumidifier with energy from the ambient air are indicated; finally, conclusions are drawn in Section 4.

2. Waste heat and cold recovery facility in air-conditioning room

The quest to accomplish a safe and comfortable environment has always been one of the main preoccupations of human beings. In ancient times, people used experience gained over many years to make the best use of available resources to achieve adequate living conditions. At late as the 1960s though, house comfort conditions were only for the few. From then onward air-conditioning systems became common in many countries due to the development of mechanical refrigeration and the rise of the standard of living. During recent years research aimed at the development of technologies than can offer reductions in energy consumption, peak electrical demand and energy costs without lowering the desired level of comfort conditions has intensified [10].

In terms of air conditioning, building ventilation is necessary for supporting life by maintaining acceptable levels of oxygen in the air, to prevent carbon dioxide from rising to unacceptably high concentrations and to remove odour, moisture and pollution produced internally. The method of building ventilation is so important in influencing not only the air quality in the occupied zone but also the cooling or heating energy requirement for the space. The ventilation rate required for a given room or a building is determined to satisfy both health and comfort criteria. In modern and retrofit buildings, ventilation is probably the greatest component of the total energy consumption. This is usually in

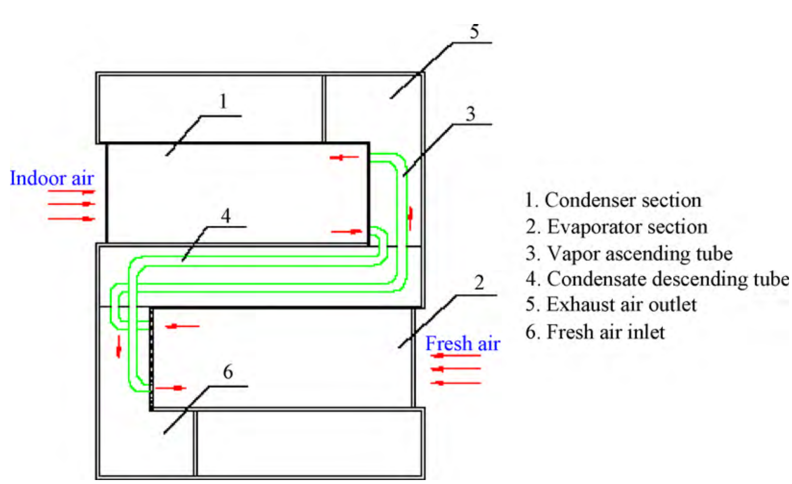

Fig. 1. Schematic configuration of heat pipe heat recovery facility from Liu et al. [7].