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Modularly Design for Waste Heat Recovery System in Subway Based on Air Source Heat Pump

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Abstract

It shows that there's an amount of waste heat in subway spaces, and temperature in subway, especially in tunnel, rises year by year. Excess waste heat is traditionally excluded by ventilation and air conditioning systems causing additional power consumption and thermal pollution to the environment. A new scheme is raised in this study to recover waste heat from air in subway tunnel and simultaneously to provide a by-product of air temperature slashing in tunnel. This waste heat recovery system consists of a few modularized air/water heat pumps and a water loop to deliver heat energy to stakeholders. Corresponding to conditions in tunnel and energy usage, working modes for the system are recommended. Mathematical models for major devices of heat pump, such as compressor, condenser, expansion valve and evaporator, are established. Basing on the models, the devices are modularly designed for subway tunnel conditions specifically. Finally, advantages and disadvantages are discussed.

Keywords: Waste heat recovery; Subway; Air source heat pump; Modular

1. Introduction

Subway system consumes a large amount of electrical energy in regular operation. The consumed electrical energy transforms into heat energy and diffuses to subway environment leading to temperature rising in subway space. Exhausting air system, ventilation system, and subway air conditioning system bring out heat energy from subway spaces, so as to guarantee optimal level of temperature for subway regular operation, subway staff, and

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passengers, consuming additional energy. Finally, waste heat would be excluded to surrounding air or soil around causing thermal pollution. Consequently, an efficient energy recovering system is urgent for the purpose of recovering waste heat as well as reducing temperature in subway.

For the past decades, a large number of studies on subway environment focused on piston winds, air quality, fire emergency and thermal comfort characteristics. However, researches on heat recovery from subway are relatively less. By now, researches on waste heat recovery from subway can be classified into two categories that are heat recovery from air in subway and heat recovery from both air and ground around. Studies on heat recovery from both air in subway and ground around mainly included the follows. Geimer[1] investigated absorber tubes installed in tunnel to fulfill heating and cooling of consumers based on heat pump. Liu[2] did some research on the heating system combined subway exhaust heat with geothermal source heat pump. Hu[3] theoretically studied an air conditioning system taking the capillary mat as front-end heat exchanger of ground-source heat pump system by laying it into tunnel walls. All the above WHRS (waste heat recovery systems) based on installing tubes along tunnels or shaft walls were only suitable for new built subways. For this sort of schemes, the site construction was relatively complex, and it is hard to fix when tube leakage occurs. It's desiderating to develop a WHRS that is convenient to be installed, timesaving to be maintained and applicable for both newly built and remodeled subways. Waste heat recovery from air in subway spaces can be divided into two sub-categories, which are directly use of worm air and waste heat energy lifting by ASHP(air source heat pump). Guan[4] developed a novel ventilation system in which exhausted air from platform was not removed out but carried to the hall for heating. Yang[5] introduced an innovative platform screen door system aiming to take the energy saving opportunities for both PSDs (platform screen doors) and APGs (automatic platform gates) by installing controllable slits. The common advantages of these two methods above were worm air directly usage and no additional energy consumption. But there was also common disadvantage that waste heat energy only been used passively. That means stakeholders were strictly limited by low temperature and low specific heat. Waste heat energy lifting by ASHP from subway air could overcome this shortcoming. Kojima[6] installed a WHRS in air exhausting shaft in a Sapporo subway station based on ASHP technology delivering heat energy for district heating and road snowmelt. For the above two programs, waste heat was not captured at original locations, but was extracted from exhausting air near the outlet of exhausting shaft. Only waste heat that carried out by exhausting air from different subway spaces can be recovered. Thus these systems only recovered waste heat, but no cooling by-product could be obtained. Furthermore, owing to the disadvantages of large space occupation, badly influence by outdoor temperature, and poor economy, these schemes were evaluated to be not applicable. Ninikas[7] conducted an annual survey of air flow, air temperature and relative humidity in Glasgow subway. Based on the text data, potential energy and carbon saving was discussed. Yet, it had not been discussed in detail that how ASHP equipments were arranged and how waste heat in tunnel been captured. Gilbey[8] attempted to install air handling units at platforms. Waste heat recovery and platform air cooling were achieved simultaneously. This method was only appropriate for traditional stations. Moreover, positions for installation of air handling units were limited. A scheme combined active and passive using of waste heat from subway air was analyzed by Vasilyev[9]. In the first step, waste heat transferred from exhaust air to supply air taking water as heat transfer medium. In the second step, heat pump was used to lift heat from exhaust air to supply air. To sum up, passive heat capture from subway air was restricted by air temperature and specific heat, while active heat capture using ASHP was prevented from practical application by undeveloped technology, large equipment occupations and poor economy.

2. Proposed heat recovery system

Basing on comprehensive analysis on status of subway heat recovery research, a modularized system consists of a few sets of ASHPs and a water circulating system is developed. Besides waste heat recovery, a by-product of the system is cooling down of subway spaces. The installation locations of ASHP evaporators could be assigned to the tunnel, platform, station hall, staff office, auxiliary room and other areas in subway. One can subjectively choose proper installation locations in accordance with origins of waste heat or requirements of cooling. This study focuses on raising a serious of modularized equipment purposely for subway station tunnel in view of its large amount of available waste heat, relatively high temperature level, and low accuracy requirement to inner temperature in contrast to other waste heat origin spaces in subway.