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Review

Recovery energy from the separated and gravity type of heat pipe exchanger in China

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The national and international circumstance and the application of heat pipeline exchanger were simply introduced in this study, while an application of the separated and gravity types of heat pipeline exchanger was discussed at the recovery energy of the electrical factory, the desulphurisation unit, the construction industries and the air-conditioning system, respectively. Their heat pipeline exchanger's utilization not only effectively decreased energy loss and reduced equipment corrosion and environmental pollution, but also improved the factory's competition, with great benefits reached by the industry.

Key words: Heat pipe exchanger, separated type, gravity type, China.

INTRODUCTION

Heat pipe as a patent technology was named as a "heat element" by USA Gaugler Company in 1944. Grover, firstly pointed out heat pipe as a patent technology in 1963 and he publicly published their experimental results, while Cotter described the theory of heat pipe in detail in 1965 (Shen et al., 2000; Zhang, 2010). Heat pipe is a very high heat transfer element, which can continually transfer energy internally. Its thermal conduction arrives at 10^3 and 10^4 of the metal. Heat pipe exchanger has much more advantage than other exchangers, such as having high heat transfer, having even temperature at the heat pipe surface, finishing heat transfer of solid-solid or solid-liquid, low pressure loss, no requirement for heat offset, safe operation, compaction construction, no mixture of heat flow with cold flow, controlling corrosion, etc (Guo et al., 1998; Luo, 2010).

It can show special advantage for solving the energy problem, for example, it can be obtained by good economic income and social benefits via the use of heat energy, recovery residual energy, saving feedstock and decreasing capital (Le Mingchong et al., 1996; Jiang, 2010). Heat pipe exchangers, having special exchanger , were gradually being developed since 1970, and it could become one of the important saving energy. However, this was studied at Nanjing Industry University in 1973, where the No.1 heat pipe exchanger was researched with the Nanjing refinery plant. The different heat pipe exchangers were widely used, for example, the separated heat pipe exchanger had high heat transfer, long distance heat transfer and can be easily set up, etc., and its advantages are separately heating and condensation sectors (Yang et al., 2001). Moreover, a lot of researches were done on the heat pipe exchanger, but in this paper, the economic advantage of the different separated heat pipe exchanger and the gravity of the heat pipe exchanger will be discussed.

ECONOMIC ADVANTAGE OF SPECIAL HEAT PIPE EXCHANGER

Appliance of the separated heat pipe exchanger at the recovery energy of the electrical factory

There are a lot of flue gases given off (100000 m^3/h) at the large electrical factory, and its heat pipe is between 10 and 20 m, while the single pipe transfer power is 20 kW. There is difference in the making and transportation of this heat element and in the installation and

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Table 1. The separated heat pipe residual recovery unit.

Type	The separated heat pipe residual heat recovery unit
Heat source	Burning residual heat
Cold fluid	Water
Cold wind temperature	200 - 600℃
Steam pressure	5×105 - 1.4×106 Pa
Recovery heat	4650 kW (4000000 Kcal/h)

Table 2. The separated heat pipe exchanger at the desulphurisation unit.

Type	The separated heat pipe exchanger
Heat fluid	Flue gas
Cold fluid	Air
Heat fluid's temperature	250 - 350℃
Cold fluid's temperature	120 - 220℃
Recovery heat	5800 kW (5000000 Kcal/h)

maintenance of it. The pipe diameter has to increase and reduce the compaction of the heat pipe because of transferring high power and transforming limit and stiff requirement. The single heat pipe exchanger cannot reach the technology requirement because the hot fluid is not allowed to be discharged from the heat pipe exchanger. The separated heat pipe exchanger gradually takes the place of the single heat pipe exchanger at the recovery energy of the electrical factory. The work mechanism of the separated heat pipe exchanger shows that, the heat fluid is firstly heated to go up at the evaporation sectors and then condensate at the condensation sectors; the condensation liquid goes back to the evaporation sectors due to gravity; no condensation gas separated pipe is installed at the condensation sectors; there is a discharge valve above the condensation sectors; no condensation gas can be discharged outside at anytime and the condensation liquid can go back to the evaporation sectors because of the potential energy.

Its main advantages are: (1) good and suitable for the large heat pipe exchanger unit; (2) it can furnish heat transfer between the cold and heated fluid; (3) it can fully separate the cold and heated fluid; (4) it can transfer heat between one fluid and many fluids; (5) it can be easily set up; and (6) it can adjust the heating surface ratio of the heating and condensation sectors. Table 1 shows the separated heat pipe residual recovery unit, which can recover energy (about 4650 kW or 4000000 Kcal/h) in the operation of Laioning electrical plant. Consequently, good financial benefit and potential favourable social impact could be obtained.

Utilization of the separated heat pipe exchanger at the desulphurisation unit (Wang, 2001, 2002)

In order to protect the environment and decrease pollution (such as SO2, ash, etc.), the flue gas from the boiler must go through the washing unit and then it will get rid of the ash and SO2 content. As such, it has to satisfy the national standard. Therefore, the flue gas' temperature was kept at 60℃ after wash. The water content in the flue gas has reached a saturation state and the flue gas still contains a little bit of sour gas. When the water begins to condense, it can meet the sour gas to corrode the internal surface at the pipe and chimney. So the flue gas after wash must be heated, in order to avoid corrosion of the pipe and chimney.

Currently, a lot of factories use to heat the flue gas for a second time. It not only increases the fuel investment capital, but also easily causes environment pollution. Using the separated heat pipe exchanger, to heat gas after wash, can save money from burning fuel the second time and further prevent pollution in the second operation. It can be economic and provide protection for the environment. Table 2 indicates the separated heat pipe exchanger at the desulphurization unit. It can save 5800 KW of energy by using the separated heat pipe exchanger and it can be beneficial to the factory and society as well (Table 2).

Appliance of a gravity type of heat pipe exchanger at the construction industries

On flowing through the concrete structure, the flue gas can discharge a lot of energy to increase the internal temperature of the concrete more than the outside temperature. It makes the internal and external surfaces of the concrete to increase the pulling stress. When the pulling stress exceeds the anti-cracking ability, the construction of the concrete will crack to have serious effects on the whole construction and cause weariness (Xie, 1994). Xu Jianfeng (Xu et al., 2003) obtained the different temperature and position temperature distribution

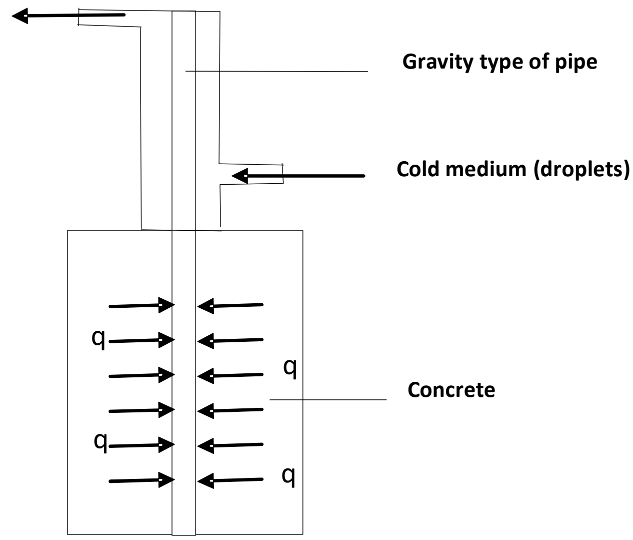

Figure 1. Heat exchange from the gravity type of heat pipe in concrete.

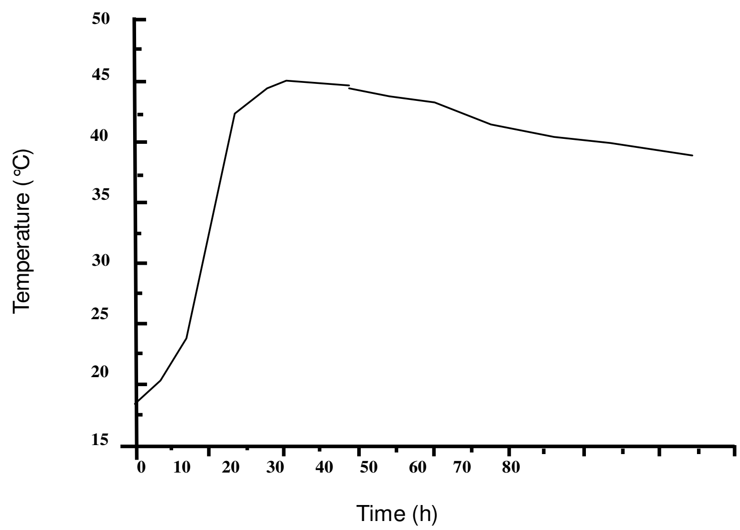

Figure 2. The curve of the concrete construction's temperature with time.

by theoretical analysis and mathematical calculations, and proved that his theoretical model was appropriate. The theory and practice proved that a gravity type of heat pipe exchanger could control the temperature degree of the concrete's internal and surface temperature at the allowable stage.

Figure 1 shows how to exchange heat for the gravity type of heat pipe exchanger. The gravity type of heat pipe is set up at the large concrete construction. The heat energy given off from the concrete passes to the evaporation sectors by conduction. It makes the working medium of the heat pipe to evaporate and exchange the heat energy with the cold medium (droplets) and then, it condensates to liquid and goes back to the heating sectors due to the gravity function. As such, the concrete can transfer the heat energy to the cold medium by this circulation.

The discrete equation will be set up based on the thermal conduction differential equation, while the temperature fields of the concrete during the appliance are calculated, using the finite difference calculus. Figure 2 represents the different initial and terminal conditions, the heating field and the temperature distribution of the concrete construction that are obtained at different times. After the concrete sets, the heat energy given off from the concrete is higher than the heat that is transferred from the heat pipe. So, the heat pipe's temperature quickly increases and the concrete's temperature increases with

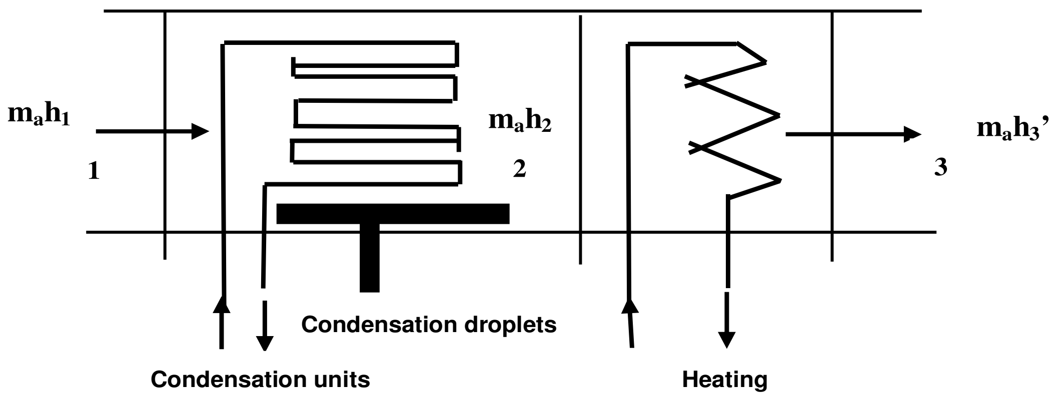

Figure 3. The de-humidity method of traditional air conditioning.

the increase of the heat pipe's energy. When the time increases, the heat energy given off from the concrete will decrease, and when the heat energy given off from the concrete equals the heat energy of the heat pipe and reaches the maximum temperature, the concrete's temperature and the heat energy of the heat pipe gradually decreases. So, the gravity type of the heat pipe can be used at the large concrete construction. However, it can cause a decrease in the concrete's temperature, reduce the temperature degree and improve the stability of the concrete. At the same time, it can decrease the heat pulling stress, reduce the crack and improve the concrete quality (Figure 2).

Utilization of the gravity type of heat pipe exchanger at the air conditioning system

There is hot climate and high relative moisture in air in the southern area of China, and as such, air conditioners are used in this area. The bedrooms are not good for people because the latent energy of the total heat loads of the air conditioner is immensely great in moist areas. So, the air conditioners have no good effect on the bedroom (Yu et al., 2004; Cai, 2003). The common temperature scope and the relative moisture for people are between 22 and 25℃, respectively. So, it is very important for people to control the air conditioner's temperature and moisture. Figure 3 indicates the de-humidity method. When the cold air goes through the condensation unit, its temperature will decrease below the dew point, to condensate droplets at the surface of the pipe. The air after discharging water will be heated to reach the required temperature.

This method not only wastes a lot of the heat energy, but it also increases the factory investment. If the gravity type of the heat pipe exchanger is used in the system, it can increase to dehumidify and decrease the total heat energy and provide suitable temperature and moisture for people (Wu et al., 1997). Figure 4 shows the application principle of the gravity type of heat pipe exchanger in the air conditioning system. Before the cold air goes into the bed room, the cold air's temperature is very low and it has a high relative moisture content. The temperature of the cold air must be decreased by going through the evaporation sectors (from 1 point), and a lot of condensation droplets are discharged outside. The residual air can exchange the heat energy with the gravity type of the heat pipe exchanger. Finally, the ideal temperature and moisture can be sent to the bedroom (Figure 4). Two methods can be calculated as follows:

(1) Common method:

Condensation sectors energy $Qc = ma*(h1-h2)$ (1)
Evaporation sectors energy $Qh = ma*(h3-h2)$ (2)

(2) Heat pipe exchanger method:

Condensation sectors energy $Qc' = ma*(h1-h2')$ (3)
Evaporation sectors energy $Qh = ma*(h3-h2)$ (4)

$$EH = (Qc - Qc') / Qc = (h2'- h2)/ (h1 - h2) \quad (5)$$

Figure 5 represents the two methods that are contrasted for the heating load and it clearly shows that (h2'-h2) and (h3-h2) are different. This is the saving energy from the gravity type of the heat pipe exchanger. 1, p, 2 and 3 in Figure 5 represent 4 positions for the air flow (before dry, after dry, before condensation and after condensation, respectively). The gravity type of the heat pipe exchanger can improve the refrigerant capacity of the air conditioning system and decrease the operational cost to reach the saving energy.

Conclusions

Based on the aforementioned review, the heat pipe exchanger is one of the highly efficient and widely used elements. Researchers conducted different studies on the theory and practical of the heat pipe exchanger in order

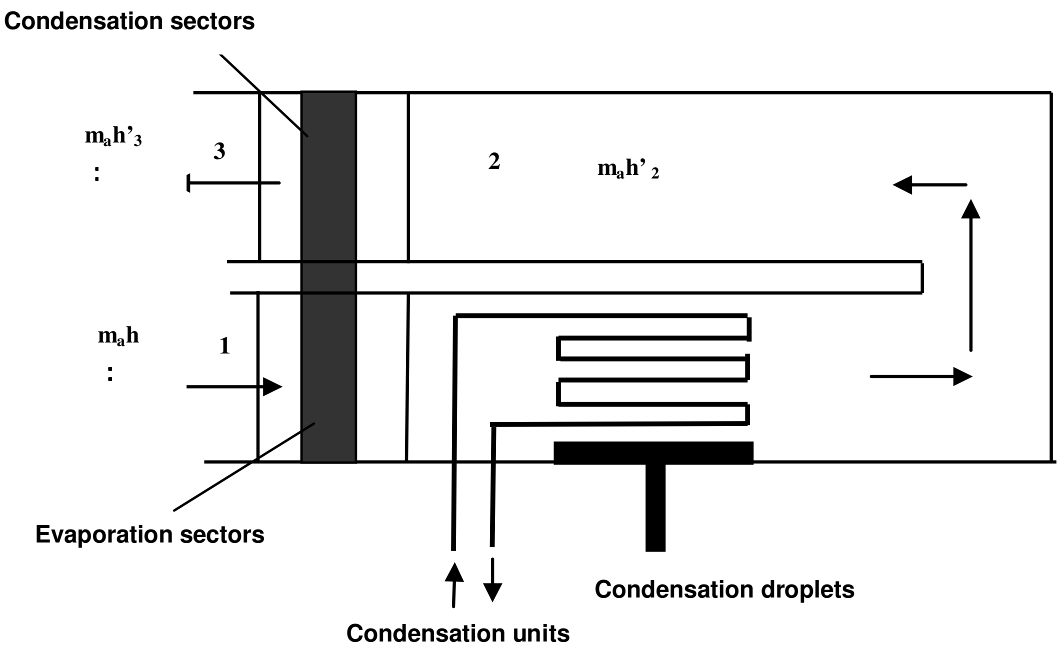

Figure 4. The application principle of the gravity type of heat pipe exchanger in the air conditioning system.

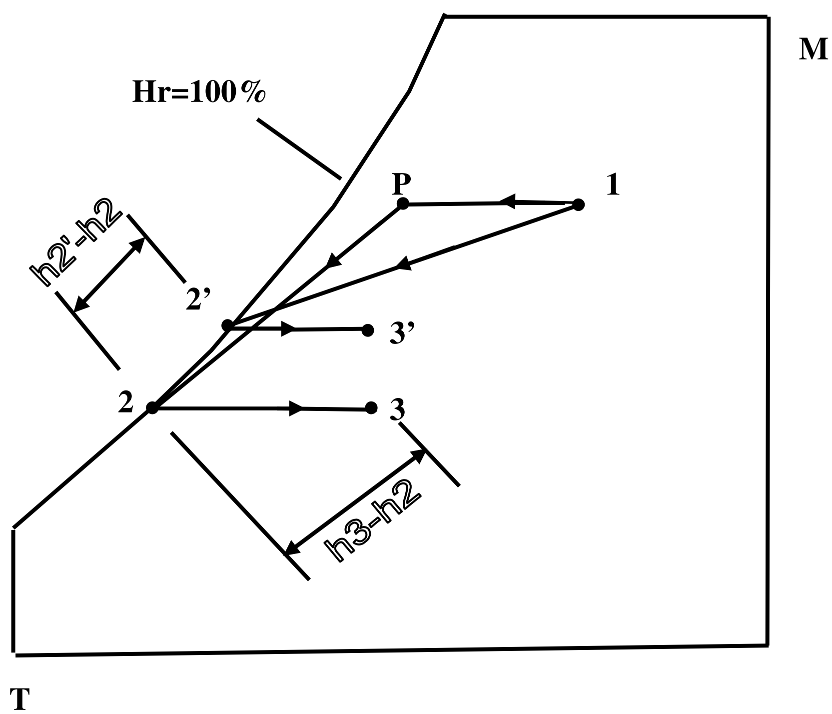

Figure 5. The heating load contrast.

to improve the factory income and reduce environment pollution. An application of the separated type of heat pipeline exchanger was discussed in detail at the recovery energy of the electrical factory and the desulphurisation unit.

However, it can separate both the heat and cold resources and transfer the heat energy from the long distance without an extra power. At the same time, the gravity type of heat pipeline exchanger was introduced at the construction industries and the air conditioning system, and can increase the refrigerant capacity of the air conditioning system and reduce the operational cost to reach the saving energy. Nonetheless, both the separated and gravity types of heat pipeline exchanger will be widely used at the different industries in the future.

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