AIR CONDITIONING OF BUILDINGS BY USING AIR-SOURCE HEAT PUMPS AND TUNNEL AIR

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ABSTRACT

This paper presents a new heat pump system in which tunnel air is served as air source.In this heat pump system,tunnel air acts as a heat source from which heat is extracted during heating ,and as a heat sink to which heat is rejected during cooling.Coefficient of performance of the heat pump is always high because the temperature of tunnel air in summer is lower than that of atmosphere air,whereas that of tunnel air in winter is higher than that of atmosphere air.

Energy consumption of heat pumps in which atmosphere air and tunnel air is respectively served as source is compared and analyzed.Results show that tunnel air-source heat pump systems are energy efficient cooling/heating systems and the heating capacity of air-source heat pumps is free from drop in winter.

1. INTRODUCTION

Nowadays,air-source heat pumps find wide application in China because of improving of the people's living standard.In general,an air-source heat pump consists of fan,filters,compressor,evaporator,condenser,short capillary tube ,and controls.The apparatus for changing from cooling to heating or vice versa is often a reversing valve, in which the refrigerant flow to the condenser is changed to the evaporator.Alternatively,air passage through the condenser.An air source heat pump system is composed of heat pumps and piping work;System components include heat exchangers,heat source,heat sink,and controls to provide effective and energy-efficient heating and cooling operations(Manxi 1990).In an air –source heat pump system,outdoor air acts as a heat source from which heat is extracted during heating,and as a heat sink to which heat is rejected during cooling.Since outdoor air offers a universal heat-source,heat medium for the heat pump,air-source heat pumps are the most widely used heat pumps in residential and many commercial buildings.

The weakness of an air-source heat pump is that the heating capacity decreases when the outdoor temperature goes down.

2.ANALYSIS OF TEMPERATURE FREQUENCY

It is vital that the outdoor air temperature frequency is analyzed since the outdoor air temperature

directly affects the performance of air –source heat pumps.The outdoor air temperature frequency in Jinan listed in table 1 are based on detailed records from official weather stations of Shandong Weather Bureau,P.R.China(Yongan 1993).Table 1 provides dry bulb temperature frequency with their corresponding coincident wet bulb temperature frequency.There is 2664 hours in which the outdoor air temperature bellows 7℃ and it accounts for 30% of a year total hours.

Table 1 Temperature Frequency in Jinan

temp. range		core temp.(℃)	wet-bulb temp.(℃)	frequency
(℉)	(℃)			
5~9	-15~-13	-14	-15.2	4
10~14	-12~-10	-11	-12.4	37
15~19	-9~-7	-8.8	-10.3	121
20~24	-6.7~-4.5	-5.6	-6.9	241
25~29	-4~-1.7	-2.8	-3.4	430
30~34	-1.1~1.1	0	-2.9	614
35~39	1.7~4	2.8	-1.4	616
40~44	4.4~6.7	5.6	1.5	601
45~49	7.2~9.4	8.3	3.6	537
50~54	10~12	11	6.7	535
55~59	12.7~15	13.9	8.1	577
60~64	15.6~17.8	16.7	11.4	670
65~69	18.3~20.6	19.4	14.1	725
70~74	21~23	22.2	15.1	795
75~79	24~26.6	25	18.3	899
80~84	26.7~29	27.8	21	691
85~89	29.4~31.7	30.6	22.5	417
90~94	32.2~34.4	33.3	24.4	208
95~99	35~37.2	36.1	26.5	41

3.PERFORMANCE OF AIR-SOURCE HEAT PUMPS

The standard operation condition of the air-source heat pump in winter in China is that the outdoor air temperature is 7℃.In fact,the performance of air-source heat pumps vary with the outdoor air temperature,the temperature of outlet water and so on.figure 1 is the performance curves of the air-source heat pump in winter(Nengzhao 1997).As shown in figure 1 ,the heat capacity of heat pump decreases when the outdoor air temperature falls off in winter.

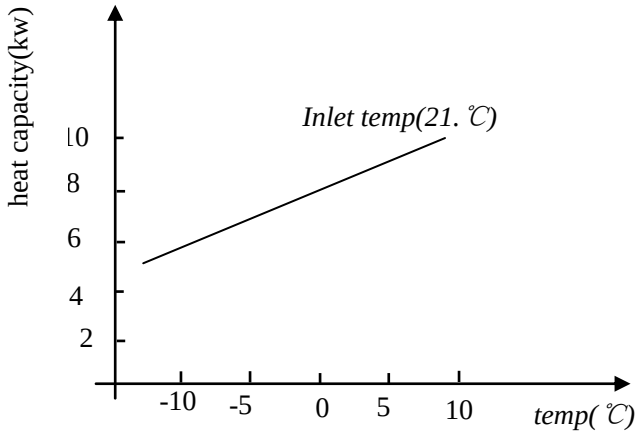

Fig.1 Performance curve of the heat pump

Figure 2 shows the relationship between the heating load and the heat pump capacity in winter .In this figure,line CD represents the building heating load curve at various outdoor temperature and line AB represents the heat pum

p capacity curve at various outdoor temperature in winter.When the heat pump is operated in heating mode, a fall of the outdoor temperature cause a decrease in the evaporating temperature. A lower evaporating temperature results in a lower volumetric efficiency,a small refrigeration effect and a lower density of suction vapor.All these effects result in a smaller heating capacity of heat pump.The fall of the outdoor temperature also cause a rise in space heating load(Shank 2000).The intersection of the heating capacity curve and the heating coil load curve,at point o is the balance point at which the heating capacity of the heat pump is equal to the required heating coil load.When the outdoor temperature drops below this balance point, as shown in figure 2, supplementary heating from the electric or other heat source is required to maintain a preset discharge air temperature.Consequently, the system of heat pump has a low usage factor(ASHRAE 2000).

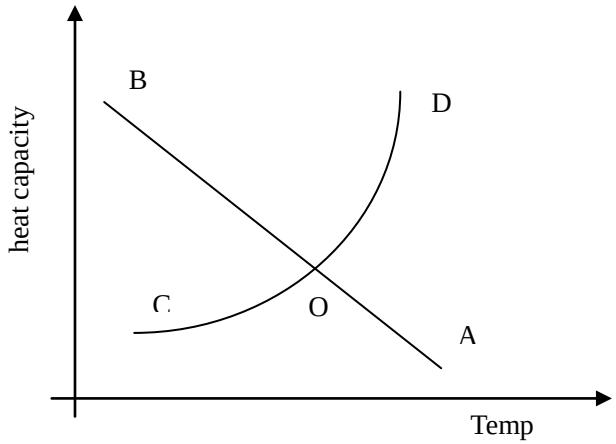

Figure 2 System Performance of Heat Pump

4.HEAT PUMP IN WHICH AIR IN TUNNEL IS SERVED AS SOURCE

There is a tunnel under the earth's surface in Jinan,Shandong Province,P.R.China.Length of the tunnel is 980 m and depth of the tunnel is 6 m.Sectional of the tunnel takes shape of Roman arch and the area of cross section is 4.037 m^2.Inner layer is limestone.There is general soil around the tunnel.Density of soil is 2000 Kg/m^3,coefficient of thermal conductivity is 1.6 w/m.c(Lingquan 1984).

The air temperature of out and in tunnel is measured and the data is listed in table 2.

Table 2 Measured Temperature in Winter(February) (℃)

condition	Parameter	data			
		14/15	15/16	21/22	22/23
outdoor	dry bulb temp.	0.5	8.5	-2.3	-3.0
	wet bulb temp.	-2.3	3.6	-3.0	-3.5
In tunnel point A	dry bulb temp.	4.5	10	1.6	1.75
	wet bulb temp.	0	4.0	-0.8	0.1
In tunnel point B	dry bulb temp.	12.6	13.1	9.9	11.1
	dry bulb temp.	5.9	6.0	5.0	5.6

Table 2 shown that the average dry bulb temperature of outdoor is 0.9℃ ,the dry bulb temperature in tunnel is 8.1℃ ;the average wet bulb temperature of outdoor is – 1.3 ℃,the wet bulb temperature in tunnel is 3.2 ℃.

Figure 3 shown that COP of heat pump in which outdoor air is served as source is 2.5 ,COP of heat pump in which air in tunnel is served as source is 3.3 .COP of heat pump in which air in tunnel is served as source has greatly increased and result of energy conservation is very notable(Ramamoorthy et al 2001).More important is in the absence of supplementary source in this heat pump systems .

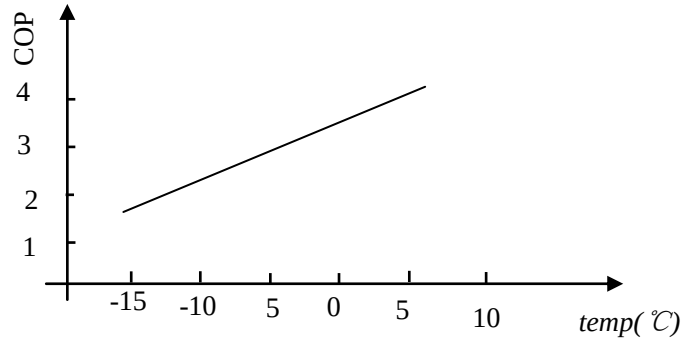

Figure 3 COP vs Temperature

5.DISCUSSION

The heat pump in which air in tunnel is served as source will be used ,only there is a tunnel .If there were no tunnels ,there would be no tunnel air source heat pump systems .There were a lot of tunnels during the 1960s~1970s in China .Now there is a few tunnels in China .However air in caves is also served as air –source heat pump source .

6.CONCLUSIONS

6.1 Dry bulb temperature in tunnel is 7℃ higher than that in outdoor ,and wet bulb temperature in tunnel is 4.5℃ higher than that in outdoor in winter in Jinan, Shandong Province ,P.R.China .

6.2 Heat capacity that tunnel air source heat pump generates can meet the needs of building in winter ,and supplementary source can be eliminated .

6.3 COP of heat pump in which air in tunnel is served as source is 32 per cent higher than that of outdoor air ,and operating costs of this heat pump systems may be greatly decreased .

6.4 Air in the tunnel ,cave,underground,air-raid shelter and others can be served as the air-source heat pump source .

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