

# Analysis of Applying Air-cooled Heat Pump to Supply Heat in North Area of China During Winter

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**ABSTRACT** introduces some cases of the usage of heat pump in supplying heat respectively in Beijing, Tianjin, Yantai, Xi'an and so on. At the same time analyzes some questions during the course of using heat pump to supply heat.

**KEYWORDS** Air-cooled heat pump Heat supply North area Application •

## 0 INTRODUCTION

The air-cooled heat pump have double functions: supplying heat in winter and refrigerating in summer. Therefore it can save boilers and boiler rooms. It takes on some features no population and high energy utility coefficient when heating, that can be fitted outdoors and need not be equipped with a special room, reducing the invest of construction, saving the invest of the cooling water system because of not using the cooling tower, controlled by the computer during the course of operation, convenient to install and manage, maintained simply and so on. So far it has been applied extensively in the south areas of the Changjiang River. Considering staying longer and cooler in the north winter. The heat pump will decrease lower and even not work as usual. Therefore it is still kept in the phase of probing in the north area of the Changjiang River.

• However, the heat pump are used extensively work constantly in foreign countries, particularly American and north European chilly districts. In our country there are some literatures about the range of the heat pump usage ruled in the area of the Changjiang River valley in 1994. But in 1995 some producers firstly broke through this range and sell products to some cooties in the Yellow River Valley. In Sequence the heat pump makes for the north area steadily. Today there are some project examples in Beijing, Jiaodong and north -west zones. Now select five zones including Beijing, Yantai, Tianjin, and Xian as practical examples to analyze some questions as following:

## 1. APPLICATION OF HEAT PUMP IN HEATING PROJECT EXAMPIES THAT USE HEAT PUMP IN NORTH AREA

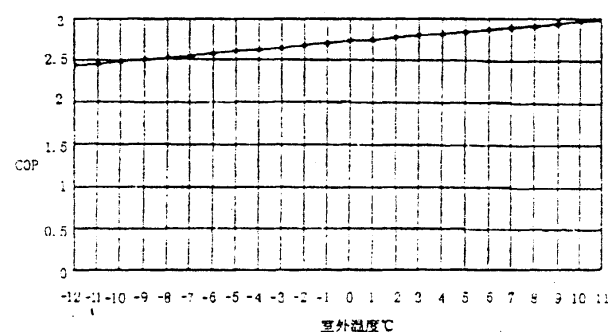
### 1.1 Utility bureau cadres' training center of Beijing

This item is selected as a trial of using heat pump in the office building of Beijing by the air-conditioning department of the architecture science research institute of China. It is the top of a teaching building in the training center and belongs to a standard office building, lying in the north-east district of Beijing. Cold load is  $68.6 \text{ w/m}^2$  and heat load is  $63.9 \text{ w/m}^2$ . It can made in the USA Teling company is selected. The can be kept between supply heat for 120 days (2280 h) and the heat area is  $418.3 \text{ m}^2$ . The amount of consuming electricity an supplying heat is respectively 12242.5 kWh and 30387 kWh. In the supplying season HSPF reaches 2.482. In this item WCH155 type air-cooled heat pump 18-20 °C in 8 hours' work and at night kept in

ventilating and not in heating. When it is off work, the are still kept in working in order to maintain 6°C in the office room. Likewise on Sunday and Saturday and holiday the temperature is also kept in 6°C

The result of application reveals that the heat pump can work constantly and be controlled. On the other hand it takes on the ideas of saving energy and at the same time it can detect different demands of users so that many consumers fell satisfied. During the course of operation actual temperature in the room can reach the designing demand such as comfortable standards and healthy standard. The practical operation proves that the heat pump can satisfy the need of winter heating in Beijing. The curve of relations of actually determined temperature and COP is shown as figure 1. •

The saving energy significance of air-cooled heat pump mainly reflect in two aspects : 1.higher comprehensive energy utility coefficient.2.The flexible regulation can reduce the consume of energym<sup>2</sup> per. Table 1 gives three different comparisons of heat pump, direct-fired and thermoelectricity. The result of technology economic is shown as Table 1.The air-conditioning invest s300-400 yuan/kWh. Heating price is 10.13 yuanm<sup>2</sup>(in the heating season office ) and 18.41 yuanm<sup>2</sup> ( all the day in the heating season) •



**Figure 1\ Practical determined temperature**

**Table 1 Compared results of some ways of supplying heat**

Ways of Supplying heat	Heat pump	Extensive boiler room	Direct-burning Units	Heat Electric factory
Comprehensive utility efficiency	69%–74%	50%–60%	80%–85%	70%–75%
Consuming coal (Kg/m <sup>2</sup> )	13–24	23–30	11–18	22–27
Virgin invest	low	Highest	Lowest	higher
Cost of operation	lowest	Highest	Low	higher

## 1.2 Holiday village of Huairou green source in Beijing

Holiday Village lies in the mountain area of Beijing'huairou,Which covers 500 acers. Total

construction area is 12000 m<sup>2</sup>. It includes such as A, B, C, D construction, a restaurant, a swimming pool and a bowling guy. Subsidiary buildings have a boiler room, a reserved room and so on. Considering that Huairou lies in the mountain area in Beijing suburb and temperature is 3-4°C lower than that in Beijing, outside dry-bulb temperature -15°C is selected as a calculation standard in winter. Through calculation, total cool load is determined as 1583 kW and total heat load is 1328 kW. •

Due to the buildings located too scatter and in the mountain districts, it is divided as some independent such as guesthouse, coffee guy, restaurant, swimming pool, bowling guy and so on. The independent air-conditioning system of air-cooled heat pump is designed to refrigerate in summer and supply heat in winter. In this system Chinmate HTP-S serial air-cooled whirled pole type heat pump are selected as a master mechanics, which can work efficiently at -15°C. The capability of refrigerating ranges from 35 ton to 200 ton. Respecting the occurrence of the lowest -20°C climate, off-electricity, the frozen precaution, stopping working because of no guests, the life water is served as the subsidiary heating resource, which is handed merely out of the construction hot water pipes and flows through board type exchanged-heat controlled by a computer. Since it was put into operation in 1998, the system has suffered from three bigger chilly currents. When temperature is lowered to -13-15°C, the can work in good shape all the time. Particularly the system can operate much better in the condition of using the hot life water to serve as a subsidiary heat resource. Once outside temperature reaches about -4°C, HTP-S134 type heat pump turns two heat pumps into only one and temperature may reach about 43°C and indoor temperature may be maintained at 21°C-22°C level. In the Table 2, some data is given :

**Table 2 Some data of practical operation of the heat pump at lower temperature**

Parameters	temperature (°C)
Weather forecast of Beijing	-2-11
Determined temperature in Huairou	-15
Out-let water temperature	45
Returned water temperature	40
Evaporating temperature (1.3Kg/cm <sup>2</sup> )	-21
Condensing temperature (18.0Kg/cm <sup>2</sup> )	49
Inside room temperature	22

In case of the occurrence of terminal temperature (below -1°C) and stopping working to maintain, a subsidiary heating system should be fitted in the air-conditioner water system. When it is designed in the power of the heat pump, the designer should emphasize the freezing precaution of the water system except for considering terminal temperature and the load lacing. •

### **1.3 Auto literature and spree center of Tianjin •**

The item covers an area of 2724 m<sup>2</sup>, which has KTV, round stage, restaurant and guesthouse and so on. In 1993 the first phase of the air-conditioning project adopts two SJC-05H type air-cooled (cold load 5.1 kW, heat load 17.9 kW) in the KTV and restaurant's new breeze system. The heat pumps are used to not only supply heat in winter or transist reasons but also offer about 40-50°C hot water for new breezing. Because it is operated in transist seasons and temperature is not too low, the system can get very good effect. Thereby in 1994 the second phase of the guesthouse air-conditioning adapted project adopts two SJC-15C type heat pump

again as the air-conditioning cooling and heating resource. The heat pump are all fitted on the top of house and need not a special room. •

#### 1.4 Yantai bazaar building

It lies in the thriving section which covers an area of 348000 m<sup>2</sup> and has an sale area of 20000 m<sup>2</sup>. The building is divided into new and old sections. The old has not air-conditioning. Though the old has these, the capacity of the master mechanics can't accommodate the demand of all system and thus need take some steps to expand the capacity. It is obvious that the system does not operate usually in winter and need be considered together. It is very difficult to locate the place of the refrigerator room because, on the one hand, three sides face the main traffic roads and the south side is near to resident districts, on the other hand, a about 500 m<sup>2</sup> backyard must be left for a garage and a safe passage way.

As a result of these conditions, only an 800m<sup>2</sup> top can be used to fit heat pump. Due to adopting heat pump through comparing other schemes, the system saves the cost of constructing a boiler. In this kind of scheme the master is put on the top of house and the boiler keeps invariable as a subsidiary heat resource. 10 PSA100H type air-cooled heat pump are selected and water temperature in winter is determined between 40°C and 50°C. The practical operation proves that the can operate constantly and bear the chilly climate. In the Jiaodong area it may work safe. •

#### 1.5 Xi'an office building

The office building is a new two-stage one, which has three -side outside walls and the north of the top has two windows, the south three windows, the south of the first stage two windows. All of doors and windows are made of aluminum metal. The construction is made of 240mm brick. The SJC-05H type heat pump unit is selected as a master (cold load 16.3kw, heat load 19.5kw). This system is equipped with blower-coil pipes and other subsidiary. The switch of the heat pump and the condition of operation are all on the control of the computer board.

In order to make determined data convinced, the data were got when it is coldest outside. Practical result is shown in Table 3 and Table 4. The data of Table 3 is determined when snow is melting and temperature is -3.3- +2.4°C offered by the weather forecast institute. The data in Table 4 are got after a few days when it 1:30-6:30 before dawn and the temperature is -4.5- +5.9°C provided by the weather forecast institute.

**Table 3 First practical determined data and the calculation result**

Determined states	Outside Temperature (°C)	Outside Relative Humidity (%)	Out-let Water temperature	In-let Water Temperature	Water Volume /10 <sup>-2</sup> m <sup>3</sup> /h	Inside Temperature /°C	heat Volume /W
	Air-conditioner is off work in the first stage						
Normal operation	0.8	75	38.9	29.1	67.9	15.1	7677
Beginning Of defrost	0.8	73	39.0	29.0	67.75	15.2	7817
End of Defrost	0.7	73	39.5	25.5	67.75	10.6	10943

**Table 4 Second practically determined data and the calculation**

Determined State	Outside Temperature (°C)	Outside Relative Humidity ( % )	Out-let Water Temperature	In-let Water Temperature	Water' Volume /10 <sup>-2</sup> m <sup>3</sup> /h	Inside Temperature (°C)	Heat Volume /W
Air-conditioner is off work in the first stage							
Normal operation 2min	-1.2	67	8.4	35.1	26	21.3	9892
Normal operation 25min	-1.2	67	37.3	34.3	26.48	22.9	9164
Defrost	-1.5	65	38.3	35.2	26.48	23.3	9470
All load At the Beginning						20.0 (top)	
Constant Work	-2.4	65	26.5	23.1	26.15	16.0 (top)	10258
Constant Work	-2.5	65	26.5	23.0	26.15	15.9 (bottom)	10590

According to the curve of practical determined room load and heat pump, the balance temperature can be got from them and the result is -2.3°C. Indoor temperature can be maintained in the demand of design, which may be seen from the data of Table 4 in this kind of state.

## 2.ANALYSIS OF SOME PROBLEMS ABOUT AIR-COOLED HEAT PUMP APPLIED IN NORTH ARED

### 2.1 Effect of outside air relative humidity on frosting

The wrong concept of "the lower outside temperature stays the more it frosts" may occur easily in the application of heat pump in the north area. In fact it is contrary. The saturated curve is relatively steep in the range of low temperature while it is even in the range of high temperature. If temperature stays between 4°C and -2°C, the difference of wet content is  $\Delta d=1.89\text{g/kg}$  but it is  $\Delta d=1.2\text{g/kg}$  between -4°C and -10°C. The former data is 1.5 higher than the latter. If there is a 100kw heat pump, which can deal with about 37,000kg air in an hour, the frost content is 44kg in the former while the frost content is 29kg in the latter. Therefore as a heat pump, the worst environment is 0°C- 5°C accompanied with rain or snow instead of lower temperature. For example, in the condition of temperature -8°C and relative humidity 70%, the frost content is not more than that in the bad environment. It is obvious that a conclusion can be drawn from above data, namely in the north area of the Changjiang River the frost content of heat pump in winter is not worse than that in the south area of the Changjiang River. When outside relative humidity is much lower, it offers a good climate condition for the operation of heat pump and sometimes the frost content become even litter, particularly in the north area. So the problems in the north winter lie in not mainly frost troubles but the constant occurrence of frozen because the material of some is not qualified and the efficiency of keeping temperature does not Occurrence work well.

## **2.2. Occurrence of intellect defrosting systems •**

So far there are three types of defrosting systems used extensively: 1. Only controlling time simply. 2. Controlling time by the air temperature. 3. Controlling more comprehensively time by temperature and pressure. Those systems can not optimize defrosting work. Recently Italy RC Company develops an intellect defrosting system (IDEA), which can read mobile data and record some parameters. According to mobile parameters, the system knows when the frost will occur on the coil-pipes and then it begins to defrost by practical need. Thus it can not only avoid unnecessary defrost but optimize the time interval, namely shorten or prolong time intervals on the data of temperature and humidity. The defrosting operation is based on mobile and objective data so that it be free of personal interference and need not any worker to interfere in. In a word the system can save 10%-20% cost of operation and some assumed wrongs never happen because it may optimize the operation of heat pump. A heat pump can be used much longer mainly because of being perished merely. The occurrence of intellect defrosting systems sets a good base for applying heat pump to supply in the north area.

## **2.3 Improvement of the supplying-heat capacity of heat pump in low temperature**

In recent years some producers do lots of study in the heat pump in order to improve the supplying-heat capacity in low temperature and reduce subsidiary heating amounts. The heat pump produced by Trane can operate at  $-17^{\circ}\text{C}$  and be used conveniently. The "Hi-- Re-- Li Recycle" type heat pump, invented by American West House, can work at  $-28^{\circ}\text{C}$ . In 1997 the Japanese RLI Company succeeded in developing special J serial heat pump for cold zones. In order to solve the fault that heating power may reduce when the outside air become much lower, it assumes a refrigerating -jet recycle and adds up the out-gas volume of a whirl compressor and the pressure ratio. At the same time it also assumes liquid refrigeration to promote the jet coefficient. This kind of heat pump can work at  $-20^{\circ}\text{C}$ . The heat pump developed by USA Dunham-Bush company can operate regularly below  $-15^{\circ}\text{C}$ . Some measures may be taken to raise the heating power. Firstly, the defrosting control-technology should be perfected. Secondly, the pipe design of should be promoted and the operation should be kept stable. Finally, the system design should be paid attention so that it can assure the heat pump operates in better environment. Though people have done a great deal of study in raising the work power in low temperature, subsidiary heating system is still assumed to be assure of heating power and keep it from being frozen when the air-cooled heat pump is applied in most north zones in China. •

## **2.4 The warm winter phenomenon effect**

In recent years to people's interest the earth become warmer and warmer. In 1998 the temperature of the earth surface overpass the usual value, which has lasted for 20 years. The warming earth results in unusual climate such as green house effect, Civic Hot Island effect, and some whole world environment problems. In the north area the warm winter phenomenon becomes more obvious. In the Xian zone, in the winter no snow ever occurs in 2000. Thus it leaves much bigger space for the application of heat pump in the north area. As usual temperature still keeps very low before supporting heat in the north area. At this time people feel uncomfortable, so the heat pump can make up for it. •

## **2.5 Architecture tendency of air-conditioning multi-systems**

Nowadays architectures take on different forms and their functions embody different sorts. Therefore the design of air-conditioning systems should tend to multidisciplinary development orientations. The heat pump plays an important role in variable air-conditioning systems because the heat pump

can be fitted flexibly and simply. For example, in some office buildings, on the one hand it is used intensively in the day, on the other hand it can be rented by different stages. Some residential buildings are dispersed and thus it is difficult to manage them. It is not likely for users to consume heat at the same time, too. Obviously heat pump can be assumed in this condition. In some big comprehensive buildings some zones adopt the heat pump system as subsidiary heat because the air-conditioning system is divided into many zones. As a result the system need not a cooling tower and cooling water system. •

### **3 CONCLUSION**

Through above analysis, the application of heat pump can be adopted in the north winter no matter it is considered in technology or economic. Some data determined in the practical engineering prove that the heat pump can be used constantly With the advancement of study and improving work in the heating power of heat pump, in the future the heat pump can be applied extensively in the north area.