

Building HVAC Practices and Preferences

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Introduction: In buildings, the application of HVAC system has mainly two aims: the first, to satisfy the requirements of air temperature and humidity raised by production technology, and to prevent from indoor and atmospheric pollution by waste air produced during production; the second, to satisfy the demand for working and living comfort of people, which is demonstrated more clearly in civil buildings. The latter will be mainly dealt with in this paper.

1. HVAC for residential building entering into an era with more diversity

The residential building in China is one of the buildings most earliest adopting HVAC, however its development has been slow. The basic mode is that central heating is mainly adopted in northern areas, while various families buy air conditioner according to their own financial capacity in the southern areas. In recent 10 years, following the improvement of living standard, HVAC system for residential buildings has gain great development, appearing with the feature of multi-system and multi-model existing concurrently. Extensively speaking, HVAC system can hardly be separated. In northern areas, it requires not only heating in winter, but also cooling in summer in many areas; in southern areas, in addition to cooling in summer, heating in winter is also required according to comfort standard. At the same time, the indoor air quality has caused attention of many people. Better ventilation is regarded as an important measure to ensure people's health.

In the aspect of central heating system, the biggest change being carried out is household-based heat metering and household or room temperature controlling. According to the document issued by the Ministry of Construction, from October 2000, corresponding measures should be taken to the newly built residential buildings. Therefore, traditional one-pipe series-loop heating system has begun to change. The position to place household thermometer is preserved in many new designed and constructed buildings and room temperature adjustment is also in consideration, for example the application of household single or two- pipe system by using common water supply and return riser, etc. Except traditional radiators, Due to its advantages of higher comfort, energy efficiency and non-occupying usable area, floor panel heating system by low- temperature water plastic pipes has been used widely.

Another obvious characteristic is the variety of energy forms for housing HVAC. In addition to central hot water heating, household gas-fired hot water heater has been began to use since 1995, due to its convenience for measuring energy consumption and easiness for independent operation of various households. Electric heating is even simpler. Household electric hot water boiler, electric heating film and electric cable floor panel heating have been gradually used from 1998, following the reform of electric power system and the adjustment of electric power policy.

However, direct consumption of electricity, a high potential energy as source of heating exists certain defects in practice. Firstly, it will greatly increase the demand for electric

supply. Secondly, annual fee is evidently higher than that of water heating. Under the same condition, electric heating fee will be about double or triple that of hot water heating. Therefore, when electricity is taken as source for heating, the optimum way is to adopt heat pump, the COP value of which is between 2~3 in different areas. The effect of electric saving is obvious.

Air source heat pump is one of the early used HVAC units in housing. In most of the southern areas, it can be used for cool supply in summer and heat supply in winter. It has got wide spread use. In northern areas, even if there is central water heating system, many houses are equipped with air-cooled heat pump, so as to supply heat before and after heating season as a supplementary heating means and supply cool in summer.

Domestic water-source heat pump cold and hot water units have been began to used in recent one or two years. Through refrigerating cycle, underground water are made better use to meet the demand of cold and hot water for air conditioning, then cooling or heating rooms through terminal units. Obviously, compared with air-source heat pump, its COP value is even bigger and there is no limit from the outdoor temperature, therefore it is a better way for energy saving and environmental protection. In areas with proper condition, it is better to popularize its use. Due to comparatively low temperature of hot water supplied (about 50 °C), when it is used for whole-year HVAC energy of buildings, it is better to adopt forced convection heat exchangers, such as fan coil unit or air handling unit as the terminal devices; if it is used only for heat supply in winter, it is proper to use in combination with hot water floor panel heating system.

2. Application of HVAC system for commercial buildings

2.1 Indoor air system

Looking from current situation, indoor air conditioning system has mainly two forms: terminal air conditioner (fan coil unit) with fresh air system and all-air system. The former is mostly used in small rooms of some buildings requiring temperature control independently. It is also widely used in some buildings with lower story height. Due to its reliable operation, convenient use and less investment, it is often used in guest rooms of hotels, typical floors of ordinary office buildings and other locations. At present, this is one of the largest used air conditioning systems in China.

All-air system is at present mainly used in some large space, such as lobbies, multi-function halls, conference halls, restaurants, gymnasiums and recreational halls, as well as exhibition halls, etc. These rooms need only uniformly controlled temperature and humidity. The air handling units are usually installed in mechanical rooms and the air is supplied to air conditioning zone through ducts. Therefore, it is safe in use (no pipes in air conditioning zone), less maintaining work and convenient in management and control. At the same time, this system enables to lead in all-fresh air and to fully use natural cooling source, the fresh air to supply cooling to rooms during transient season. It is obviously advantageous to save HVAC energy consumption and supply indoor air of better quality.

As one of the all-air systems, VAV system is composed of concentrated air handling units, air supply facilities, tightly sealed air ducts and terminal boxes. When the load of air conditioning changes, the terminal boxes can automatically control air volume supplied to each room according to room temperature and make the main fan change rotary speed and supply volume. Therefore, it has not only the advantage of fan coil unit with fresh air system

and constant volume all-air system, but also saves obviously energy consumption of air supply fan, presenting bright future of wide application. Although certain use in some high class office buildings began in 1995 and obtained obvious energy saving and economic effect, there are still some problems which is needed to research and solve. Anyway, comparatively bigger initial investment has some influence on its range of utilization.

2.2 Piping system

In some comparatively large-scaled buildings, piping system of concentrated cooling and heating source has been mostly adopted with higher comprehensive economic effect. Viewing from the installation of pipes, in order to save initial investment and reduce areas and spaces occupied by pipes and equipments, two-pipe system has been adopted in most buildings. Hot water supply in winter and chilled water supply in summer are realized by hand or automatic change-over valve on the main pipe. Since the end of 80s of 20th century, due to enhance of comfort required by people, four-pipe system has been adopted for some buildings. The chilled and hot water are simultaneously supplied separately to each air handling unit, which well meet the requirement of heat supply and cool supply to different areas in a building (Due to differences between facing directions of buildings or internal and external areas in buildings, hot load occurs in some spaces while cool supply is needed in other spaces). Although four-pipe system needs more investment and more occupied space than two-pipe system, it has been well received by many users due to its flexibility and comfort. So we have reasons to believe that this system will be gradually increased.

In chilled water piping system, due to the fact that the constant volume system itself exists defects in load balance, energy adjustment and energy saving, the range of utilization is less and less. It has some use only in small-scaled buildings or buildings without fixed application time (for example gymnasiums). At present, the widely used piping system is still primary pump variable volume system. It has the advantage of simple system, stable operation, less investment and convenient handling. It is more practical for use in various buildings and has better operation effect, especially for office buildings. Generally office building have unified cooling load, bigger coefficient at simultaneous use of air handling units. However, for some large-scaled comprehensive buildings or building groups, due to bigger characteristic differential of resistance of terminal water circuit, or smaller terminal coefficient at simultaneous use and obvious non-linear characteristics of air conditioning system when terminals are in low load operation causing unbalance between chilled water supply and cooling capacity supply, primary pump system exists certain defects in energy consumption and in meeting requirements, while secondary pump system with variable volume has good performance. In recent years, secondary pump system has gain more and more use, which has also demonstrated this point. At present, what we shall do is to further research performance of air handling units and whole chilled water system, investigate and sum up the performance of the air conditioned buildings under operation and to make perfection of automatic control system, thus enabling its advantages even more outstanding in practical operation.

2.3 Cold and heat sources

In one commercial building, energy consumption of HVAC system is equal to 50%~60% of the total energy consumption of the building, in which cold source machine accounts for about 50%~70% of total energy consumption for air conditioning of HVAC system in summer.

It is obvious that the efficiency of cold source device has direct influence on building economic effect. Reasonable adopting and operating cold source machine is of great importance to building energy saving and economic effect. It is so to heat source. Take as example one commercial building in Huabei area, under the condition that heat consumption in winter is about the same of the cooling consumption in summer, measured by primary energy unit, energy consumption in winter will be twice of the energy consumption (electric power converted directly to energy consumption) for cooling supply by centrifugal chiller in summer. Therefore, cold and hot sources are of the same importance.

Centrifugal chiller is one of the cold source machine of HVAC system popularly used in large-scale commercial buildings. Due to its big capacity, coefficient of performance reaching to 5~6 and less occupied space, it has been well received by many designers and users. Generally speaking, the bigger the capacity of the centrifugal chiller, the higher the efficiency and the capacity per unit weight will be. Therefore, most of the capacity of centrifugal chiller is above 1,162 kW. Although variable speed control has been adopted in some projects, the most used capacity adjusting is to adjust the guide vane at compressor inlet, with a range of 20%~100%. Screw and piston compressor chillers are mostly used in medium and small buildings. Due to its smaller capacity. In order to meet low-load use requirement, centrifugal chillers are often used in combination of one multi-head screw or piston compressor chiller in some large comprehensive commercial buildings. By using the characteristics of small capacity of the latter, not only the operation flexibility of the system is increased, but also the operation fee is decreased. This is a method worth popularizing.

Although in recent years, electric power department of our State has continuously invested in reform of electric power grid, the phenomena of lack of electricity still exists in some large cities. Specially, during the on-peak power supply period, the electric load can hardly satisfy the current development. "Flatten on-peak and filling up valley" of electric power grid has been raised to a new height, therefore time-based preferential electric fee policy has been made in some cities to create some conditions for promoting ice storage of HVAC system. For some non-whole day HVAC Buildings (such as office buildings and exhibition halls), ice making and storage can be carried out at night by using low price electric power, thus less electric power will be used for cooling supply during day time. It will not only have better economic effect for users, but also contribute to balancing electric load of electric power grid. The National Electric Dispatching Center began to adopt ice storage system in 1997. At present, several ice storage systems have been installed in buildings of various places in our country. At the same time, cold air distribution systems have been designed and installed in some buildings by using the characteristics of low temperature chilled water supplied by ice storage system. At present, these buildings have been put into operation (such as Shanghai Children Hospital and Office Building of National Electric Power Company), resulting in increasing of indoor comfort and saving of more energy for HVAC system.

Due to the limit of electric power supply and the protection of atmospheric ozone layer, the adoption of absorption chiller has been gradually increased. The typical one is oil-combustion or gas-combustion (or both combined) direct-burned chiller and hot water machine. It not only can provide chilled water in summer, but also can provide hot water in winter by using the same machine. Therefore, it has been welcome by many building developers and users. However, heating capacity of these machines is limited. For making "one machine with multi-function" into full play, it is proper to use in a building with

approximately the same of cooling and heating capacity. From the viewpoint of region, it is proper to use in buildings in southern part beyond Huabei(including some areas of Huabei). Comparatively low coefficient of performance of the unit is another problem in dispute. From the view of whole HVAC system, even if it is deducted to primary energy source, its efficiency is about 20%~30% lower than centrifugal chiller system used. Therefore, it is better to select after comparison and analysis of the investment and the operation fee of whole-life condition. It is obvious that the application range of this machine is comparatively narrow in the areas of hot summer, warm winter and severely cold areas.

Table 1 is the summarized result of chillers used in sampled 50 projects of a design institute in Beijing from 1990 to 2000.

Table 1

Form of chillers	Centrifugal chillers		Electric refrigerating chillers (including centrifugal chiller)		Absorption chillers		Total	
	Number of unit (Number)	Capacity (USRT)	Number of unit (Number)	Capacity (USRT)	Number of unit (Number)	Capacity (USRT)	Number of unit (Number)	Capacity (USRT)
	90	42168	131	53873	30	139982	161	67855
Percentage	56%	62%	81%	79%	19%	21%	100%	100%
Average capacity of single chiller	469USRT		411USRT		466USRT		421USRT	

From the above table, it can be seen:

- (1). The electric chiller are the main type of chillers used in commercial buildings both for its number of units and installation capacity, which occupy 80% of the market.
- (2). Centrifugal and absorption chiller are more appropriate to places where capacity of single unit is big, while the capacity of single unit of screw and piston compressor chiller is comparatively small (average value being 180 USRT/unit).

Figures 1-3 are results of categorized statistics of chiller of the above 50 projects.

Through the comparison of Figures 1-3,we can see:

- (1). The absorption chillers have been widely used since 1995, which is closely related with electric policy then and the situation of the protection of atmospheric ozone layer.
- (2). The total capacity of chillers used was big in 1995 and 1996, which was related with the situation of capital construction then; following the decrease of public buildings and the increase of residential building after 1997, central air conditioning system has been reduced to some extent.

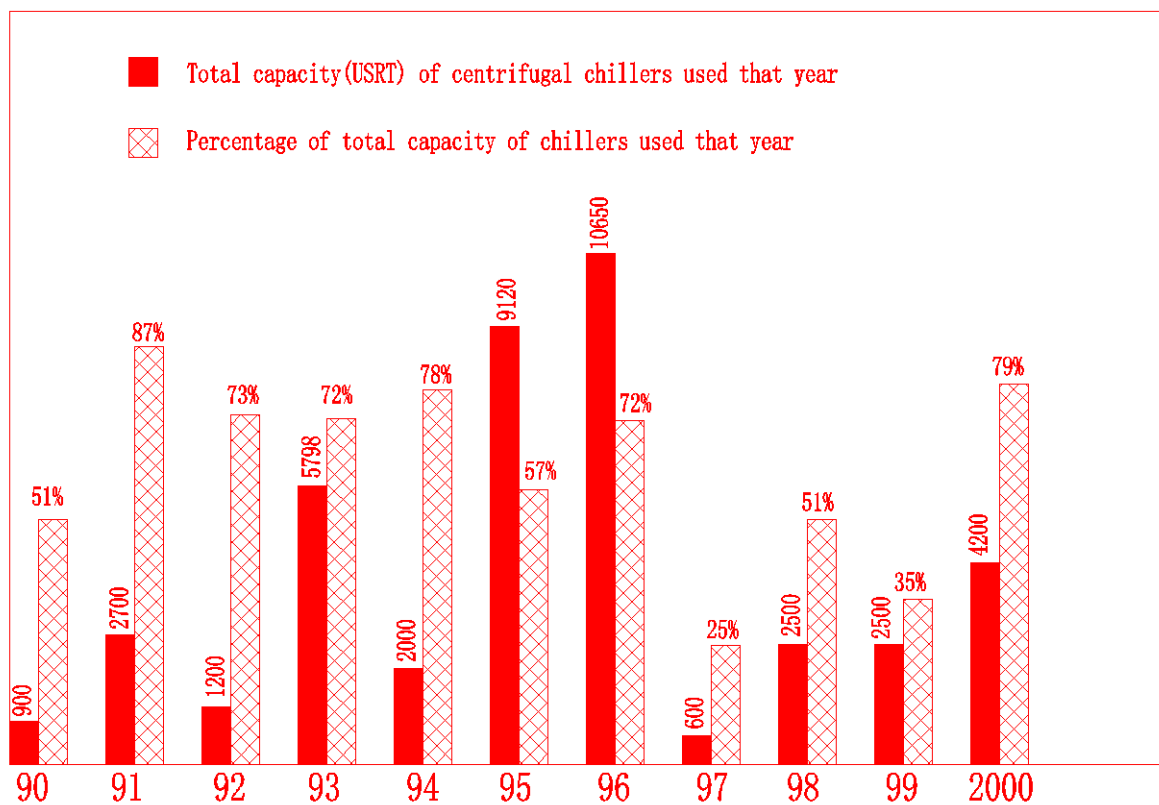


Fig.1. The use of centrifugal chillers in a design institute

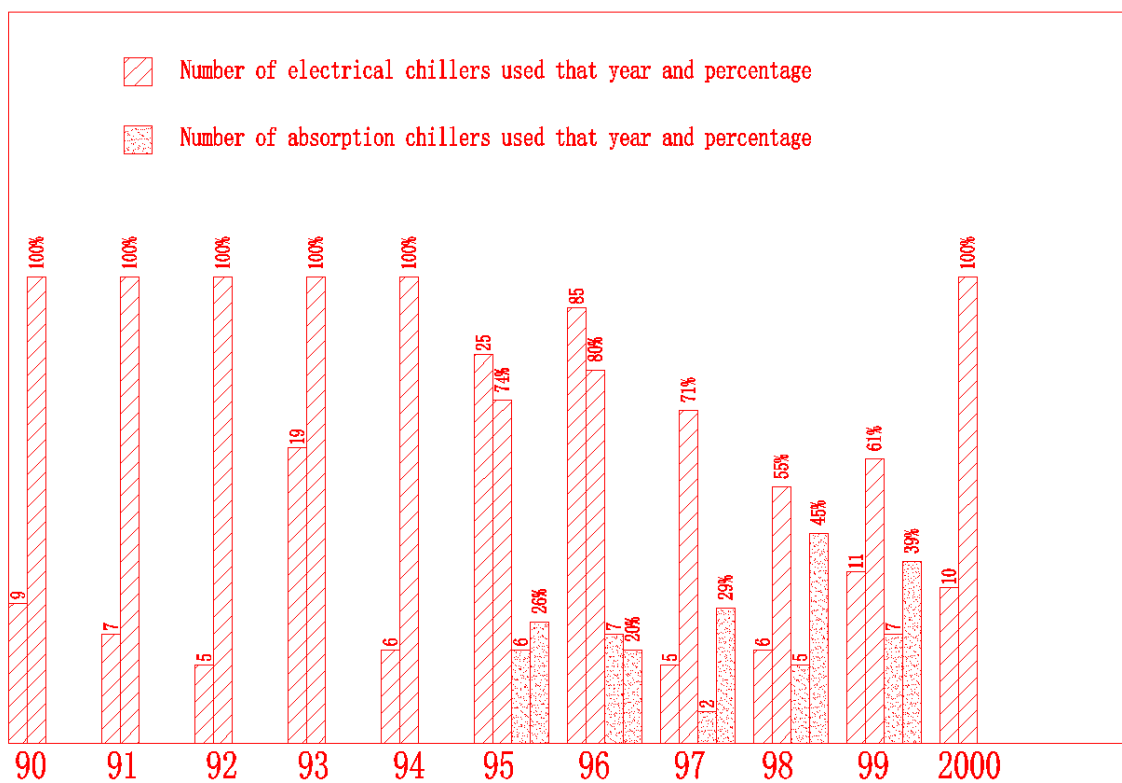


Fig.2. The number of electrical chillers and absorption chillers used

in certain design institute

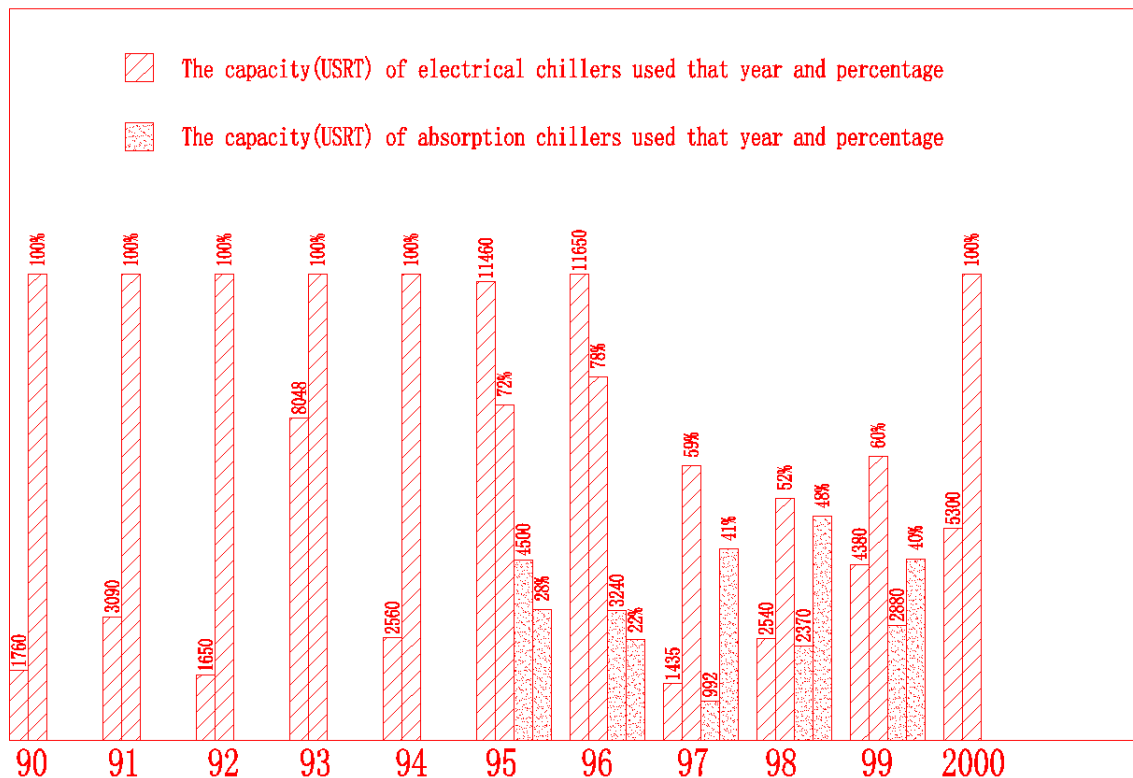


Fig.3. The capacity of electrical chillers and absorption chillers used in a design institute

2.4 Direct evaporation air conditioning system

Direct evaporation air conditioning system has been developed from direct evaporation air conditioner. When the latter was used early in commercial buildings, it was used mostly in large space rooms, such as restaurants, shops and meeting rooms, etc. with structural forms of separated air-cooled condenser (water-cooled monolithic cabinet units were seldom used). Indoor units are directly placed in air-conditioned rooms to supply cooling and heating. There are two types of outdoor units: one type has only condenser. The units are cheaper, but the indoor units have bigger noise; another type is to combine the compressor with the condenser. The unitary direct evaporation units are simple in operation and management, less in investment and better in refrigerating effect, as well as flexible and convenient in use, therefore, they have been still used in many projects.

Because of drawbacks of unitary air conditioner, such as distance between indoor and outdoor units is limited and outdoor units have influence on building elevation when there are many rooms in building, a new system of multi-indoor units combined with less outdoor units has begun to adopt in some medium and small office buildings and hotel buildings since 1993. The reason why it is called as a system is that viewing from the point of structure, it is similar to central air conditioning systems: there is main unit--outdoor unit; there is terminal--indoor unit and there is also connection pipe--coolant pipes. Actually, it is still one form of direct evaporation units. The only difference from unitary unit is that the unitary unit is generally of the form of one matching one, while the new system is one outdoor unit matching with multi- indoor units (viewing from the product at present, the maximum can be 16~32 indoor

units). In order to meet the demand of adjustment of load of multi-indoor units respectively, adjustable electronic expansion valve is installed on each indoor unit to adjust coolant volume, at the same time frequency control technique is adopted for outdoor units, therefore, this system is also called as variable refrigerant volume (VRV) air conditioning system. In VRV system, the distance between indoor and outdoor units can reach to 100m Compared with unitary unit. The number of outdoor units is greatly reduced. It makes locating of outdoor units more flexible and reduces the influence on building appearance. Compared with the central air conditioning system, it basically does not occupy the area of machine room and only occupy less space of pipes, therefore it has been welcome by users who require higher rate of usable area. It has larger flexibility to satisfy the need of various rooms at different use period by consuming lower energy.

2.5 Application of heat pump

The heat pump currently used can be divided into two kinds from the point of energy source, namely air source heat pump and water source heat pump. From the characteristics of devices, it can be divided into heat pump air conditioner and heat pump central cold and hot water machine.

Both heat pump unit and variable refrigerant volume system use air-cooling mode. The former is mainly adopted in residential, but the latter is more widely in application. With a view of current products, it is generally required that the lowest outdoor temperature should not be less than -10°C for heating supply (it is said that for individual product, the outdoor temperature can be as low as -15°C). The heating capacity at -10°C outdoor temperature of the most products only accounts for approximately 50~60% of the rated cooling capacity. Therefore, when air-cooling heat pump is used for whole-year air conditioning of buildings, there is a limit to loading performance of buildings and location of buildings. Generally speaking, it is demanded that the ratio of heating loads in winter to cooling loads in summer should not exceed 70%, otherwise it would not be economic to choose units only according to working condition in winter. At the same time, the lowest outdoor temperature of the location of buildings in winter should satisfy the demand of the product itself. Generally, it is mostly proper to use in the areas in the southern part beyond Huabei.

The water-cooling heat pump air conditioner constitutes water-loop heat pump system, which was introduced to China at the end of 80s and began to be used in projects in 1994. The characteristic is that units which supply air directly into the air conditioned spaces are connected by closed circuit water pipe, which at the same time connects with outdoor closed circuit cooling tower. When the whole building is at the state of cooling supply, the cooling tower becomes heat exhaust facility (this is similar to central air conditioning system at cooling supply); when the whole buildings is at the state of heating supply, low-temperature hot water can be supplied by supplementary central heat source. The advantages of this system are: The first, due to the application of water-cooling means, the value of COP for heating supply is higher than air cooling and low potential heat source can be used; The second, the requirement for simultaneous cooling supply and heating supply exists in different zones within many buildings during transient season, even in winter. This system can carry out cooling and heating transfer inside and there is no need or less need for cooling and heating source provided by outside. Therefore the energy conservation effect is rather obvious; The third, due to the fact that there is constant temperature ($15\sim 35^{\circ}\text{C}$) water in the pipes, the pipes have no need of insulation, thus reducing spaces occupied by pipes and

providing convenience to operation and maintenance. Because there are still some aspects that are not satisfying, such as noise of terminal units, range of units specifications and investment in the system, this system has not been widely used at present.

The heat pump central cold and hot water units mainly have three types: air-source, water-source and ground-source. Due to its limit of outdoor temperature and difficult anti-frozen treatment of water, the air-source type is mostly used in southern area where the outdoor temperature is not lower than 0 °C. The water-source heat pump have been developed in recent two years in China. It uses cooling and heating transfer of natural water source and underground water to supply cold and hot water used by air conditioning sytem. During refrigerating, due to using lower temperature water, its water-cooling condenser has higher efficiency than ordinary units with cooling water supplied by cooling tower. During heating supply, except the electricity used for running of heat pump, there is no need to consume other heat source. It uses completely natural heat source, with results of obvious energy saving, no construction of boilers and heat exchange stations and no atmospheric pollution. It is a cooling and heating source unit with great future for development. Of cause, when underground water is taken as cooling and heating source, there is a need to give proper treatment to the quality of underground water. At the same time, pollution of underground water should be prevented from and the problems of return filling and balancing of underground water should be solved. The basic principle for ground source heat pump cold and hot water units is the same as water source type. The only difference lies in that it does not directly use natural water or underground water, it carries out heat exchange between soil and embedded pipes in soil. It uses cold and hot source in soil to supply cooling and heating. Therefore, it is a closed circulating water system. It solved the problem of water pollution and underground water balance existed in water source type. At present, the main factor impedes wide use of the system is that initial investment on the system is comparatively high`, therefore it influences on economic effect to some extent.

In general, heat pump is a comparatively clean energy device with higher efficiency. The final energy for water source and ground source is solar energy, which is of great importance for China, a developing country who is in great demand of energy and bears the responsibility of atmospheric protection. Positive research and proper application of heat pump should be our common duty for every colleague engaged in the cause of HVAC.