Impact of the Variable Refrigerant Volume Air Conditioning System on Building Energy Efficiency

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Abstract: The application of the variable refrigerant volume multi-zone air conditioning systems has met with mixed results since the publication of the Design Standard for Energy Efficiency of Public Buildings. This paper analyzes the characteristics of the variable refrigerant volume multi-zone air conditioning system, and discusses the advantages of its application.

Key words: Design standard for energy efficiency of public buildings, variable refrigerant volume air conditioning system, energy efficiency of buildings, application

1. INTRODUCTION

At present, China is in its boom period of housing construction, the scale being unprecedented both in the Chinese history and in the history of the world. The total floor space, not counting industrial buildings, has reached 40,000 million square meters, with the energy consumption accounting for about 30 percent of the country's grand total. It is estimated that by 2020 another 30,000 million square meters of floor space will be added, which will push up the energy consumption of buildings considerably. This will have a strong influence on China's energy consumption for a long time to come. Energy efficiency for buildings has therefore become a hot issue of growing concern.

On April 4, 2005 the Ministry of Construction and the State Bureau of Quality and Technical Supervision jointly promulgated the Design Standard for Energy Efficiency of Public Buildings (GB50189-2005), which came into effect on July 1 of the same year. This is China's first set of national comprehensive design standard for energy efficiency of public buildings, applicable to the energy efficiency design of newly built, extended and converted buildings.

The goal of the Design Standard for Energy Efficiency of Public Buildings is to reduce the yearly total of energy consumption of heating, ventilation, air-condition and lighting by 50 %, without changing the comfort coefficient in the indoor heating environment, in comparison with that of the public buildings designed and put up in the early 1980's. The approach to attaining this goal is to improve the thermal insulation of the skirting structure of buildings, and to increase the efficiency of heating, ventilation, and air-conditioning equipment and systems.

The general consensus of opinion in the industry is that the "Standard", which is considered to have filled up a technical blank in our country, has assimilated the latest research findings of the developed countries, thus reaching an advanced level internationally. Its implementation will play a very important role in changing the backwardness of energy efficiency of public buildings and in guiding our energy efficiency work along the lines of legalization and standardization.

With the publicity and implementation of the Design Standard for Energy Efficiency of Public Buildings, the application of the variable refrigerant volume flow multi-unit air conditioning system has led to extensive criticism.

2. THE CHARACTERISTICS OF THE VARIABLE REFRIGERANT VOLUME AIR CONDITIONING SYSTEM AND ITS PRESENT APPLICATION

2.1 The characteristics of the variable refrigerant volume air conditioning system

The working principle of the variable refrigerant volume air conditioning system is as follows: The indoor temperature sensor, according to the actual load of the indoor unit, controls the electronic expansion valve on the refrigerant medium pipe of the indoor unit. And it controls the compressor of the outdoor unit according to the change in the refrigerant medium pressure, varying the refrigerant volume of the system. In this way, the air conditioning system can adjust itself automatically to meet the needs of the change in the indoor load so as to attain the goal of conserving energy. At present, there are two types of variable refrigerant volume air conditioning system, namely the variable frequency multi-zone and the variable volume multi-zone. The two types look quite similar in appearance, but they are fundamentally different in terms of volume variation.

The variable refrigerant volume air conditioning system has the following characteristics:

Each variable refrigerant volume air conditioning system is made up of an outdoor unit and an indoor unit. The outdoor unit is led through the wall by a trunk duct into the room and connected with the indoor unit by a branch duct.

The style and volume of the indoor unit of the variable refrigerant volume air conditioning system are various, so that users can make their choices according to their needs of temperature and decoration effect.

The refrigerant medium duct of the variable refrigerant volume air conditioning system can be 100 – 150 meters long, and the height difference can be 50 meters. So there is a lot of flexibility to arrange the outdoor unit to avoid the conflict between the positioning of the outdoor unit and the architectural effect.

The variable refrigerant volume air conditioning system has a high degree of intellectual control, with every indoor unit being able to directly start the air-conditioning system, freely setting and regulating the temperature, the volume and direction of the current, and the mode. Every indoor unit can separately control its start and close, and set and regulate its operations, so that it can meet the individual needs of the end-users, which is something the central air-conditioning system cannot do.

2.2 The present application of the variable refrigerant volume air conditioning system

It is generally recognized that the variable refrigerant volume air conditioning system, because it is energy-efficient and easy to use, can be installed in residential buildings as well as medium and small-sized public buildings. As a matter of fact, this system has been installed in medium and small-sized office blocks, stores, restaurants and residential buildings, showing a growing trend. The problems is that the variable refrigerant volume air conditioning system is increasingly used in extra large office projects, and in the Jiangsu, Shanghai and Zhejiang region this system is in the likelihood of replacing the traditional central air-conditioning system.

3. The Design Standard for Energy Efficiency of Public Buildings and the analysis of the application of the variable refrigerant volume air conditioning system

3.1 Recommendation of the “Standard” on the application of the variable refrigerant volume air conditioning system.

The publicity material of the Design Standard for Energy Efficiency of Public Buildings points out that the energy consumption ratio of the variable refrigerant volume air conditioning system is smaller than that of the water-cooling central-conditioning system: the same amount of refrigeration requires more electricity consumption. For those large institutional and governmental office buildings, the yearly energy consumption will increase considerably. The volume capacity of the air-conditioning system will increase substantially. And the efficiency of the transformer and distribution equipment will decrease. When the full load of the variable refrigerant volume multi zone is under 2.4, it is even lower than an indoor air-conditioner. Its high

efficiency takes place between 30 – 70 % loads. If the machine is used in homes and hotels on a round-the-clock basis, the energy-efficiency effect will be great, especially at night. However, if it is used in office buildings, when the operating hours are in the high-load periods during the day, rather than conserving energy, it will add to the peak workload. Especially in the morning when the system gets started, which is in the 8 – 11 peak period of power consumption, the variable refrigerant volume multi zone of the compressor will start with extra frequency, which means its COP value is even lower than that of 100% workload.

In large buildings the refrigerant pipe to the multi zone machines will have to be extended. As a result, the efficiency will be further reduced. Supposing the set workload of the variant refrigerant volume is 2.4, then the length of the pipe will reach 150m and the COP will be 1.63.

The opinion of the “Standard” is as follows: In large public buildings, the use of the variable refrigerant volume air conditioning system should be restricted. It is not suitable for the variable refrigerant volume air conditioning system. It is recommended that COP above 4.0 water cooling system be use as the heating and cooling resources of air-conditioning in public buildings of fairly large sizes (20,000 M2). It is strongly recommended that the variable refrigerant volume air conditioning system should be prohibited in large buildings.

3.2 The analysis of the application of the variable refrigerant volume air conditioning system

The implementation of the Design Standard for Energy Efficiency of Public Buildings involves two aspects: one is to reduce the construction costs; the other is to increase energy efficiency. In order to reduce energy consumption, it is necessary to adopt energy monitoring and recording systems. To increase energy efficiency it is necessary to use highly efficient systems and equipment of energy supply, enabling the equipment to operate in the high efficiency zone. At the same time, the energy consumption system must be optimized by means of energy saving measures in part of the spaces and workloads.

The variable refrigerant volume air conditioning system can computerize the precise energy consumption of each indoor unit by calculating its refrigerant volume, operating time and the temperature of reversing current. This will solve the problem of the central air-conditioning system being unable to separate energy consumption costs by units and households. This function is especially good for rental office buildings.

The variable refrigerant volume air conditioning system adopts the refrigerant medium direct cooling and heating approach. Heat exchanges take place only once during the process of heat transmission. The loss of energy is little and the time of response is short. But in a central air-conditioning system, heat exchange occurs twice, so there is more loss of energy during the transmission. Figure 1 shows the full load COP value of a variable refrigerant volume air conditioning system supplied by a certain manufacturer. Green color shows refrigeration (outdoor temperature 35 DB, indoor temperature 35 DB); red shows heating (outdoor temperature 7 DB, indoor temperature 20 DB). The COP value should be considered to be quite good. However, it must be pointed out that the COP value of a multi-zone machine is of the system. On the other hand, the COP value of the traditional air-conditioning system is of the mainframe itself, not including the loss of power on the frozen pump, the cooling pump, the cooling tower, and the lower end of the air-conditioner. The loss of power in these parts can account for 30-40% of the total energy consumption. It affects the COP value of the system so much that it cannot be overlooked.

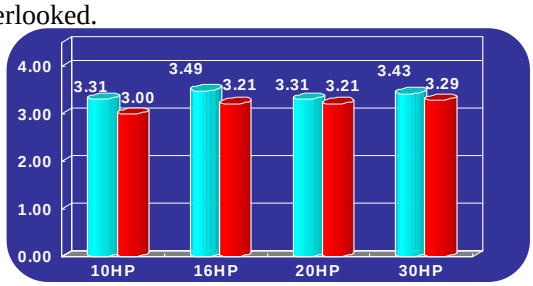

Fig. 1 The full load COP value of VRV

When an air-conditioning system is in operation, full load operation is only short-lived. Partial load operation occupies most of the time. Therefore, the COP value of partial load is an important factor to

evaluate the energy saving feature of an air-conditioning product. Figure 2 shows the COP curve of a 10 Hp variable refrigerant volume air conditioning system supplied by a certain manufacturer. The COP value of partial load can reach as high as 3.8, which can satisfy the actual needs much better than the traditional central air-conditioning system.

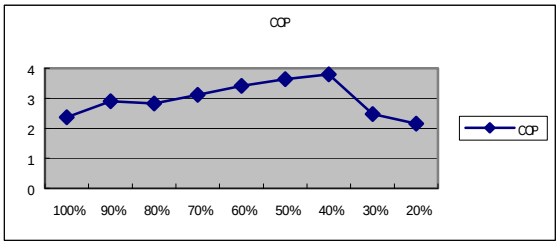

Fig. 2 The curve of COP value of VRV

Compared with the traditional central air-conditioning system, the most striking features of the variable refrigerant volume air conditioning system is easy to install, and flexible to operate. It can be installed, according to the availability of investment and the needs of decoration, by block, by section, by floor, by household, by phase and by batch.

Operation of traditional central air-conditioning system is totally pre-designed by management side in accordance with time. It demands considerable high-energy consumption in low-loading operation, thus it cannot meet special needs of users. The variable refrigerant volume air conditioning system can make it true that each room is independently controlled. The output of outdoor machine can be automatically adjusted with the change of indoor working load, so the system can run with low cost round the hour as per user's actual needs. It is fit for use in holidays and in extra work shift.

The variable refrigerant volume air conditioning system is designed with high intelligence. The air conditioning system contains strong controlling system of itself while supply BAS for owners. As the general power system, traditional central A/C system consists of cold-water units, cooling water pump, chilled water pump, cooling tower and the terminal, which are closely related with each other. People should select suitable equipment to ensure high operation efficiency in even partial working load and then to cut down annual energy consumption. To this end, it needs to be supported by BAS whose cost is very much high.

No doubt, among all the A/C systems of large scaled buildings in full loading work, the traditional A/C system is the most efficient one. However, only when A/C system matches with actual function needs of target buildings, can we ensure the lowest energy consumption. For this purpose, we should take full consideration when selecting A/C program.

4. THE ENGINEERING APPLICATION OF THE VARIABLE REFRIGERANT VOLUME AIR CONDITIONING SYSTEM

Qianjiangxincheng will be the new center of Hangzhou city in future while the right project is located in the core block of it. The main building is 150 meters high with building area of 76300 square meters of which 1st to 4th floor of attached building is for the use of business and banking purpose, and 5th to 40th floor is the 5A degree high standard office building. As per the demands of property owner, from 5th to 12th floor, each floor needs to be divided into 4 basic units for sale, from 13th to 20th floor, each floor needs to be divided into 2 basic units for sale, and up from 21st floor, each complete floor is to be sold. Each unit has separate toilet.

The air conditioning system may adopt the following programs in accordance with the function demand of the whole building:

Program A: collective set-up of air conditioning system. Cold source of A/C adopts water-cooled refrigerating machine, powered by the city electricity while the warm source taking gas heating boiler. The refrigerating machine and hot water boilers will be set up underground, and the cooling tower is laid out on the roof of the attached buildings.

Program B: collective set-up of air conditioning system. Both the warm and cold source adopt direct-fired lithium-bromide absorption-type refrigerating machine powered by city natural gas. The direct-fired lithium-bromide absorption-type refrigerating machine will be set up underground and the cooling tower is laid out on the roof of the attached buildings.

Program C: air conditioning system is separately

set up both in mail building and attached building. Cold/ warm sources of attached building A/C system use heat pump units powered city electricity system, and the units will be set up in the hidden and ventilating places on the roof of the attached building. A/C system of the main building takes the variable refrigerant volume air conditioning system, one powered by city electricity. The main units of A/C system will be separately set up in the surface of attached building, the 15th asylum, the 30ty asylum and roof place of main building.

Program D: air conditioning system is separately set up both in mail building and attached building. Cold/ warm sources of attached building A/C system use outdoor package direct-fired lithium-bromide absorption-type refrigerating machine, which will be set up on the roof of, attached building and powered by city gas. A/C system of the main building takes the variable refrigerant volume air conditioning system, one powered by city electricity. The main units of A/C system will be separately set up in the surface of attached building, the 15th asylum, the 30th asylum and roof place of main building.

Program E: air conditioning system is separately set up both in mail building and attached building. Cold/ warm sources of attached building A/C system use outdoor package direct-fired lithium-bromide absorption-type refrigerating machine, which will be set up on the roof of, attached building and powered by city gas. A/C system of the 5th to 12th floor of main building uses the variable refrigerant volume air conditioning system (GHP), one powered by city gas, and the main units of A/C system will be separately set up in the surface of attached building. A/C system of the 13th to 40th floor of main building adopts the variable refrigerant volume air conditioning system, one powered by city electricity. The main units of A/C system will be separately set up in the 15th asylum, the 30th asylum and roof place of main building.

To analyze the A/C system of the project from technological and economic perspective, each program has its main features as follows:

Program A: The technology is matured and application is reliable with the least initial investment, the best function coefficient when fully loaded and the lowest operation cost. However, it needs more underground space for the machinery and to certain extent it has the fire safety problem when the gas powered warm water boilers are laid out in the underground basement. The biggest problem is that each unit in the main building cannot use A/C system separately and flexibly.

Program B: The program adopts the natural refrigerant, which is the most environment-protected refrigerating technology. It is powered by city natural gas, which brings down electricity investment tremendously. Under the current energy shortage circumstance in Zhejiang province, this program enjoys comprehensive economic advantages in cutting down the usage of electricity at summer peak and filling in gas at summer valley. In this program, one unit serves two purposes therefore to save the investment on boiler and boiler's room. The program needs the underground room for machinery, and it has the fire danger when the gas enters the underground basement. The disadvantages are the same as the program A.

Program C: In this program, in accordance with the different function needs of main and attached buildings, the different A/C systems are set up separately. The working units are separately controlled as per particular rooms and floors, which will increase the efficiency of A/C operation economically and conveniently. The program needs no underground space and has no fire worries but it demands more initial investment.

Program D: This program not only carries all the features of program C but also enjoys all the advantages of program B. Cold/ warm sources of attached building A/C system use outdoor package direct-fired lithium-bromide absorption-type refrigerating machine. It meets the needs of environment protection for it operates with lower noise and smaller vibration. The working units serve three purposes that are to supply hot water for employee's canteen and gymnasium while operating.

Program E: This program has all the features of program D. A/C system of the 5th to 12th floor of main building uses the variable refrigerant volume air conditioning system (GHP). In winter, there is no need to do de-frost job. Compared with normal heat pump, it

has better environment adaptation. At the same time, it has the higher primary energy efficiency. Therefore GHP system enjoys apparent operation cost advantage when considering the present gas and electricity prices in Hangzhou. Nevertheless, the initial investment for GHP is comparatively high.

Through comprehensive analysis from the perspective of technology, economy and energy saving, program C, D and E are all fit for the project. They technically guarantee the flexible function, convenient management and energy-saving operation for the project.

5. CONCLUSION

The amount of public building construction is so much and concerns so widely that the percentage of energy-consuming construction is very high; therefore the energy-saving potentials are tremendous. The energy-saving work performance directly affect, to a big extent, to achieve the final goal of construction energy saving of our country.

The design standard of public construction energy saving study materials point out, the right usage of the variable refrigerant volume air conditioning system affect so much on whether it saves energy or not and the effectiveness of the energy-saving, thus we must analyze and apply them scientifically and logically. It's undoubtedly correct and necessary. But its special advice----no application of the variable refrigerant volume air conditioning system in large scaled public constructions—is really confusing and worth discussing. I, the author, think the advice is too much one sided at least. To analyze scientifically and logically, what counts for the adaptation of the variable refrigerant volume air conditioning system is the function usage of the construction itself and has nothing to do with the construction scale directly. In large-scaled public constructions, especially the commercial office buildings, the variable refrigerant volume air conditioning system could absolutely save energies and its actual operation cost is much better than the traditionally applied central-controlled A/C system as long as we set up the A/C systems in accordance with the different demand of both the constructions function for use and the customers actual needs and earnestly analyze, reasonably select and correctly design them in the light of its technical features.