Energy Conservation of Air Conditioning Systems in Large Public Buildings

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Abstract: Analyzing the actuality of the large-scale public buildings' energy consumption, we know that most of them run not only in low efficiency, but also in high energy consumption. According to the characteristics of the building, we should proceed with the heating characteristics of the exterior -protected construction, the set value of the temperature of the air-conditioning, the lectotype of the Central air-conditioning system, the regulation and the modification of the transmission and distribution system, the use of the new energy and the daily management or the method of adjustment and control, and so on , so we can make the air-conditioning system run efficiently. Analyzing and comparing the large-scale public buildings' energy consumption with each other, some pointed improvement measures are proposed further. According to the study and analysis, even though large-scale public buildings consume a great of energy, there exists a huge potential for energy conservation.

Keyword: the large-scale public building; air-conditioning system; energy conservation; the analysis of the energy; optimizing run

1. THE STATUS QUO OF THE ENERGY CONSUMPTION IN THE LARGE-SCALE PUBLIC BUILDING

The energy consumption of the large-scale public building takes a large proportion of the energy consumption of the construction, so it should be the most important part in the energy conservation. According to the stat of Beijing recently, we know that every per construction area of all kinds of the large-scale public buildings have consumed 100-350kwh electric energy in a year, which is about as 10-15 times as that of the residences in downtown areas. There are about 20 million square meters large-scale public buildings in total, which is only 5 percents of the whole civil architectures in Beijing , but the total electric consumption is as much as 3.3 billion kWh ,and it is nearly as much as that being used for life by the citizens in halt of the city. However, the energy consumption of the air conditioners in the large-scale public buildings is 30%-60% of the total energy consumption. So the study of the large-scale public buildings' air-conditioning has an important meaning to us.

2. THE ENERGY CONSERATION OF THE EXTERIOR-PROTECTED CONSTRUCTION

In recent year, large glass curtain walls have been used for the exterior -protected constructions in many public buildings. However, a popular design way of elevation have they become, the load of the air-conditioning is increased and the light pollution of the environment become more and more serious. So the proper ratio of windows and walls is a must, and we can not only satisfy the aesthetic need, but neglect the energy consumption.

2.1 Using the Way of Pasting the Lamina Membranaceas to Reduce the Load of the Air-conditioning Causing by Solar Radiation

This method is applied to supermarkets with a high quality of the aesthetic need, It has many merits, such as being convenient to construct, without harming the normal operation, keeping the hyalescence of the former glass curtain walls in vision, without harming the inner and outer of the glass curtain walls' aesthetic effectiveness ,and reducing the load of the air-conditioning causing by solar radiation.

2.2 Using the Double Deck Elevation System

The double deck elevation system includes the inner layer, the outer layer and the air layer between them. To make the best of the solar energy, the low emissivity glass, which can reduce the harmful effect to the surroundings by the reflection, is used in the outer layer of this system, such as low-e glass,

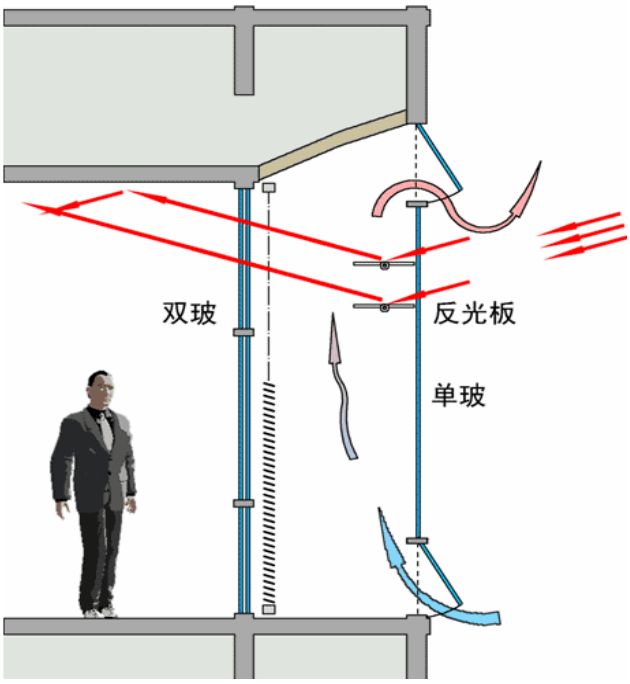


Fig.1 Low-energy consumption building of Tsing Hua University

A specific application is shown in Fig.1 (low-energy consumption building of Tsing Hua University).The toughened glass of the outer layer is 6-mm-thick and hyaline. There are air inlet and air outlet in the outer layer, which are both 600-mm-high, and can be opened by the electric power.

The inner one is closed, and it is double hollow low-e glass.

There is a 600-mm-wide ventilating duct between layers.

The air layer in the middle is very important, because it can improve the capabilities of the the double deck elevation system, such as insulation work, heat insulation, sound insulation and natural ventilation. During cold seasons, the closed middle air layer absorbs the solar energy, and becomes the buffer layer of space between the inside and outside because of the glasshouse effect. In this case, the indoor heat loss can be reduced. While during the hot seasons, the air inlet below and the air outlet above can be opened, so the the air can become upward draft in the reason of the chimney effect, and draw away the heat absorbed continuously。In this case, the surface temperature of the inner layer can be avoided to rise. The comfortableness can be improved without increasing the energy consumption. Meanwhile, the natural ventilation can be achieved.

According to the survey, compared to the traditional curtain wall, the double deck system can save energy by 42 to 52 percent when heating, and 38 to 60 percent when cooling. Also the sound insulation is greatly improved. This system has not only reduced the energy consumption of the building effectively, but also has created an comfortable and natural climatic microenvironment for the people indoor. Considering the energy conservation and the ecological environmental protection, this system not only satisfies the aesthetic need of the architecture, but also is the need of developing the sustainable buildings.

3. CHANGING THE SET POINT OF THE AIR-CONDITIONING'S TEMPERATURE

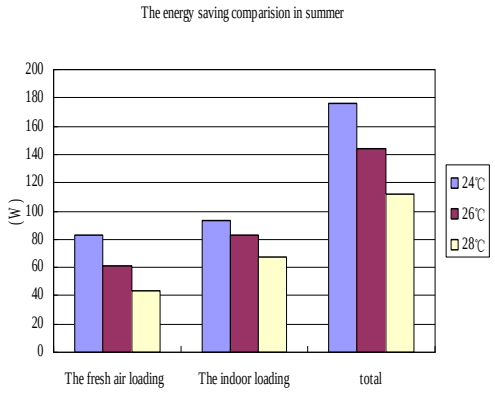
Many people think that the lower indoor temperature it is in summer, more comfortable indoor environment they can enjoy. So it is in winter. So the temperature in summer is raised and in winter is lowed. However, the result is that the indoor temperature in winter is higher than that in summer. In fact, if the temperature is too low(lower than 26℃), there will be a great temperature difference between the surface of the people's body and the indoor temperature when the people come into the house in a short time. In this case, the thermoregulation of the body is effected by the

Tab. 1 The energy saving effectiveness when the indoor parameter is modified

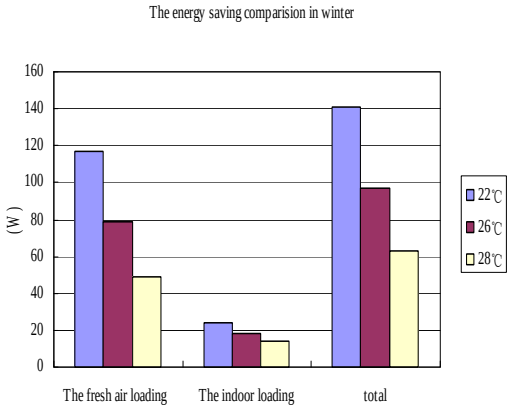
	summer			winter		
Indoor temperature ( )	24	26	28	22	20	18
The fresh air loading (W)	83	61.2	44.0	117.3	78.4	48.6
The indoor loading (W)	93	83.0	67.5	23.9	18.4	14.2
total (W)	176	144.2	111.5	141.2	96.8	62.8
Energy saving (%)	0	18.1	36.6	0	31.5	55.5

obvious temperature difference and the evaporation of the sweat, so people will feel cooler than it is (the principle in winter is the same as it is in summer). This method not only consumes extra energy, but also makes people feel supercooling or superheating. If the indoor temperature is set reasonably with the change of the seasons, the supercooling in summer and superheating in winter will be avoided. The heat loading of the exterior-protected construction and the fresh air loading can be reduced, so the energy consumption of the air-conditioning can be reduced.

《The design specifications of the heating, ventilating and air-conditioning》(G B J 19—87) has specified the standards: the temperature of the air-conditioning in civilian constructions is 24℃~28℃ in summer, and 18℃~22℃ in winter. In this extent, when the exterior -protected constructions and outdoor parameters are invariant, the energy consumption will be reduced by 10%-15%, if the indoor temperature falls by 1℃ when heating; And 10% when cooling. The Japanese modified the indoor temperature of the comfortable air-conditioning which has been used. And the results are shown in table 1.



(a)



(b)

Fig.2 (a)The load in different indoor temperature in summer ;
(b)The load in different indoor temperature in winter

Most of the public buildings are for

entertainment, which is another specific of them. Because people visit these places in their spare time, there will be more people than that on usual. So the temperature of the air conditioning should be adjusted according to the number of the people. In this way, we can not only improve the comfort of the buildings, but also save energy. Such as the cinema, we can make the best of the great changes of the number of the people to adjust the indoor temperature. The temperature can be reduced when there are more people in winter; and can be raised when there are less people in summer, because the radiation of the body will be intensified at this time.

4. THE ENERGY SAVING OF THE CENTRAL AIR CONDITIONING SYSTEM

The complicate functions are the trend of the large-scale public buildings, and a building usually includes offices, flats, supermarkets, restaurants, and the places of entertainment. Some energy saving ways of the central air conditioning system are analyzed according to the specific above.

4.1 Proper Division

For same buildings with large areas and large depth, the load of their outskirt is impacted by both the exterior -protected constructions and the indoor thermal disturbance. However, the outdoor disturbance is changing with the time, and the indoor disturbance is constant all the year around. So the alternating between heat and coldness may generate in the outskirt, while the load of the inner regions is cold loading all year around. The heat between outer and inner regions is equal, which will make the customers in different regions feel different. If we can divide the regions properly, we can not only solve the unequal distribution of the heat, but can also avoid the counteraction of the heat and coldness. So the purpose of energy saving can be achieved.

4.2 Selecting Air-conditioning Unit Properly

For the multi-use architectures, they usually operate at part load, because the function, the operating characteristic and the service time among the different sections are different. If we can consider the part load reasonably, and choose the scheme of the water chilling units' collocation feasibly, the water chilling units will run at a higher COP most of the time. And the energy consumption will be reduced greatly. Then a specific project will be used to show the energy saving of the water chilling units' proper collocation. This office building lies in Beijing, and it covers about 20000 m^2. The total refrigerating output is 6857kW.

Scheme 1: choose 2 water chilling units of 2823kw + 1 of 1231kw

Scheme 2: choose 3 water chilling units of 2283kw

Choose appropriate capability of the heat or cold resource and the other collocations for each of the two scheme, shown in table 2.

Tab.2 The total power consumption of the heat and cold resource of the different schemes

The total power consumption (GJ)	Scheme 1	Scheme 2
The water chilling units	2260 . 20	2603 . 89
The fans of the cooling towers	152 . 15	217 . 40
The cooling pumps	728 . 65	1006 . 35

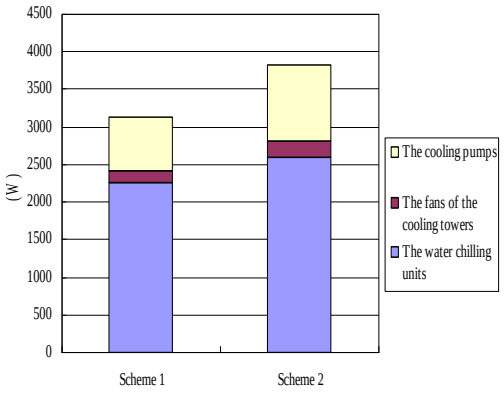


Fig.3 The total power consumption of the heat and cold resource of the different schemes

For scheme 1, if we use the host machines with high-capacity at high load, and use the one with small –capacity at low load, the host machines running at low load when the load is small can be avoided. From which is shown in table 2 and the

chart 2, we can know that the total power consumption in a year, which is reduced by 18 percent in scheme 1, is obvious lower than that in scheme 2.

4.3 The Regulation and Reform of the Water System

As the equipment of the centre air-conditionings' water system, the power consumption of the pumps is about 15-30 percent of the air-conditioning system, so the potential of the energy saving is tremendous. Above all, the optimum design of the water pipe network system, the proper choice and matching of the water circulating pumps are the key to the normal running and the energy saving of the water system.

Combining with the multi-use architectures' traits, which are the different time of their use and the large difference of the time-varied load, and the problem of the design of the water system, we should control the energy consumption according to the ways below:

(1) Choose the model and specs of the pumps properly according to the flux-pressure performance chart and the pipeline performance chart. Don't choose the oversize flux and the oversize delivery lift pumps.

If the oversize model of the pumps is chosen, most of the valves in the outlet conduit will be semi-open, which can increase the restriction loss of the valves.And in the actual operation, there will be many problems because of the water shortage. For example, each of the refrigerating machines can't supply enough coolness, and the multi-machines run at part load most of the time. Even more the electric energy is wasted heavily.

(2) Increase the temperature difference between the water supply and the backwater as possible as you can, while the craft and comfortable should be satisfied first.

The large temperature differences can reduce not only the delivery energy consumption, but also the cross dimensions of the pipes, so that the first cost can be reduced. However, the large temperature differences can also influence the performance of the air-conditionings. For example, the large temperature differences of the chilled water can lead the cooling capacity and the dehumidification capacity of the fan coils and the surface chillers to reduce.

(3) Change the designs choosing the pumps with the same model

The balance method can also be used to choose pumps (the same as the choice of the units above). If three pumps are needed, one should be different from the other two. Whether the model of single one should be chosen bigger or not , we should decided according to the specific condition, and both the load and the performance chart of the pump should be considered at the same time.

(4) Balance the hydraulic resistance of each loop to avoid the hydraulic disturbance mismatch.

The hydraulic system should be well –designed, and its resistance should be calculated accurately, so that the hydraulic balance of each loop can be satisfied.

The secondary circulating pumps should be set in the high-drag loop with large differential pressure, and the equilibrators should be set in every loop. The filters should be periodic cleaning in the process of the air-conditioning system running. If the filters are blocked by the sediment, the resistance when the water passes though the filters will be increased a lot.

(5) Divide the water system of the air-conditioning

The water system should be divided according to the difference of the usage mode and the usage time in the building, For example, the guest rooms and the public areas of the hotels, the offices and the public areas of the official buildings, and so on. The public areas, such as the dining-rooms, supermarkets and the recreation areas, are also used in different times. So if the areas are divided appropriately, the water system can be managed independently. Also the energy can be saved furthest when it is unused.

4.4 The Energy Saving of the Wind System

4.4.1 The energy saving analysis of the fans

The electric consumption of the fans is a large percent of that of the air-conditioning, so the energy

saving potential is very large. Now we introduce the ways to reduce the energy consumption of the fans:

Routine clearing the filters;

Routine examining and repairing;

Examine whether the strap being loose, the operating point being excursion, and whether the air supply state being appropriate.

Another effective way to reduce the energy consumption of the fans is on the bases of that the variable air volume system can change the air supply volume according to the building load. Further more, the VAV system is convenient to be partition control and can satisfy different need of the air-conditioning. So the VAV system is appropriate for the large-scale public buildings.

4.4.2 The fresh air system

The energy consumption of the fresh air in the center air-conditioning is 25-35 percent of the total energy consumption of the air-conditioning, so the appropriate management of the fresh air is one of the most effective ways of energy saving.

(1) The volume of the fresh air should be determined properly. If we increase it blindly, the fresh air load will be increased. Additional, in the transitional seasons, the air-conditionings should be at whole fresh air run when the outdoor enthalpy value is larger than the indoor one. If the wind system runs single, the cold resource and the water system can be closed. In this situation, we can not only reduce the energy consumption of the equipments, but also improve the indoor air quality.

(2) The mismatching of the blow bellows and the return bellows is another important reason to increase the fresh air load. At present, the air-conditionings which is used in many high-demanding places is double-bellows system, one blow bellow and one return bellow. In such system, the matching of the blow bellows and the circulating bellows is needed, especially that the total pressure of the return bellows can be oversize. Although it is convenient, we can not choose the model of the return bellows the same as that of the blow bellows. Because the delivery conduits of the fresh air can easily become exhaust ducts, the blow volume will less than the return volume in the whole areas. Additional, the indoor suction pressure becomes larger, so the large number of fresh air will come in through the ducts connecting to the outdoor environment, and the result is that the fresh air load is increased.

Besides, the proper blow air-flow organization and return air-flow organization are the kegs to save energy for the wind system. The below ways can be used: avoiding separating the users irrationally; avoiding distributing the volume of the fresh air in each door unequally; cleaning the filters frequently.

5. APPLICATIONS OF THE OTHER ENERGY SAVING WAYS

5.1 Natural Ventilation

Making the best of the natural ventilation without the disturbance of the environment noise is an effective way to save energy. The natural ventilation can supply enough fresh air and cool the indoor temperature in the transitional seasons. Also in refrigerating seasons, it can reduce the thermal storage volume of the exterior-protected construction and the furniture by night ventilating, so the starting load of the next day will be reduced. According to the experiments, we know that the indoor temperature will be reduced by 2-4℃, if we can make the best of the night ventilating. If it is possible, the dooryard or the solar energy duct should be constructed to supply the nice natural ventilating. This is a way to save energy by using the funnel effect.

5.2 The Choice of the Air-conditioning Mode

Making the best of the natural cold and heat source is another important way to reduce the energy consumption. As a perfect way, the heat pump can not only greatly reduce the consumption of the primary energy source, but also make the best of the renewable natural resources. The large number of the low-grade resources can be from ground water, geothermal water, soil, river, lake or industrial wastewater. A small amount of power energy can make these resources change into high-grade resources. The conversion rate can reach 4:1, so the effect of energy saving is significant.

Additional, the heat pump can be used both in summer and in winter. In winter, the heat from the ground is warmed up, and then it can supply heat to the buildings. At the same time, the ground is cooled and storage coldness, which can be used in summer. In summer, the heat of the buildings is transmitted to ground. In this process, the buildings are cooled, and the storage heat under the ground can be used in winter. The ground acts as accumulator, so the utilization efficiency of the energy, which is used by the air-conditioning in a whole year, can be improved greatly.

Besides, the ice storage air-conditioning is a new energy saving mode. Especially the energy and the electric power is in short supply, while the ice storage air-conditioning can balance the peak-to-trough difference between the daytime and night of the electric line. And the cold storage equipments reserve coldness in the platykurtic power period of night, which can be supplied in the peak power period of the daytime. This is a most way for the power departments to reduce the power consumption of the refrigerating equipments in the peak power period, which is called the peak clipping and vale filling. According to the states, we know that the ice-cold storage mode can reduce the operating cost by 30-50 percent. Besides, it can greatly reduce the volume of host machines and some relative control panels.

5.3 Application of the Heat Recovery Technique

According to the states, the heat recovery technology can save the consumption of the fresh air by 60-70 percent. For example, in summer or winter, to assure the indoor air fresh enough, and satisfy the comfortable need of people, the air-conditioning system need deliver some fresh air into the room, and release the polluted air to the outdoor. The temperature and the humidity of the discharge air are the same as the indoor design parameter of the air-conditioning. So it is higher than outdoor air in winter, while it is lower in summer. The discharge air can exchange heat or coldness with the fresh air through the total-heat-exchange equipments. The 70-80 percent energy of the discharge air can be recovered, so it has visible energy saving effect.

5.4 Application of the Converter Technique

(1) Apply the frequency control technique to the pumps

The mean yearly cold load and heat load is only 50% of the max load. If the frequency control pumps are used to change the water with the load, the average volume of water in a year is only 50 percent of the max volume of water. Basing on that the power is three times as the flux, the energy consumption of the converter pumps is reduced by 87.5 percent. So the converter pumps can improve the power save ratio by designing the residue and dynamic energy conservation.

(2) Applying the variable fresh air ratio system

Variable fresh air ratio system is an important way to save energy, which is consumed by the air-conditioning every year. Apply the variable fresh air ratio system properly. That is to say that we can make the most of the direct air system in the transition seasons, and can use the minimum fresh air ratio in the summer and winter. So of course the energy can be saved. The research findings and statistical information aboard show that the annual energy consumption of the whole system can be reduced by 10%～15% by controlling the fresh air ratio and applying the fresh air to cool or to precool.

6. EMPHASIS THE DAILY MANAGEMENT OF THE SYSTEM, AND ENHANCE THE EENERGY-SAVING BENEFIT BY PROPER REGULATTION

The daily management determines whether the energy saving of the buildings is efficient. No matter how excellent the energy saving system is, if the management is unsatisfied, the goal of energy saving can not be realized. Now the daily management is introduced as following:

Improve the daily and routine maintenance safeguard of the equipments and system, so as to avoid the cool or heat water emitting and the cool or heat air dripping and leaking;

Bring in advanced automatic system, so that

the building can be intelligent zed. And the automatic equipments and instruments should be often checked, so they can work regularly;

The precooling time should be cut down as soon as possible for the air-conditioning of discontinuous work. And the system should use the loop air, but not the fresh air in precooling time;

When the amount of people changes greatly in the hottest and coldest months, the volume of the fresh air should be variable according to the CO_2 concentration detectors, which can control the entrance valves of the fresh air. For example, when the supermarket is opened just now, or the short time before it closed, and even on holidays, the amount of people will be very small. In this time, the volume of the fresh air can be reduced, so the energy can be saved.

When the buildings have cold load in the transition seasons, the natural refrigerating capacity of the outdoor fresh air should be fully used, so that the cold quantity of the artificial cold resource can be saved.

7. CONCLUSION

There are great diversities of the energy consumption among the large-scale buildings. This phenomenon shows that these buildings have great energy-saving potential. Besides the main energy-saving ways of the large-scale buildings that have been introduced, there are still many other ways—the choice of the cold and heat resource, the selection of the high-activity and energy-saving air conditioning units, the recovery of the waste heat, the improvement of utilization efficiency of the energy, and the development and use of the regenerative energy and new energy resource, and so on. So when the energy-saving measures are selected, some aspects—the physical situation, the rounded cost-effectiveness analysis and the coordinated uses of variety ways--should be considered. Then the optimal energy-saving effects and economic effects can be realized. At the same time, we should do treatment in accordance with local condition, and bring in some advanced technique of heating, ventilating and air-conditioning audaciously. Then we can promote the new energy-saving technique to popularize and apply in the actual projects.

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