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Application and Design of Split Solar Water Heater with Conversion of Solar Energy into Thermal Energy through Chemical Methods

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With a view to effectively using the solar energy as one of the clean energies, this paper mainly explores to produce split water heater with the conversion of solar energy into thermal energy through chemical methods in the application and design so as to achieve a better integration of solar water heater with the building, thereby making the solar water heater one of the major ways to use new energy in the new or existing buildings. Based on the analysis of the functions and characteristics of the split solar water heater, this paper tries to convert the solar energy into thermal energy through the most effective chemical methods in order to find an integrated design concept of the split solar water heater and the architecture, and it also proposes the design principles with practical values, which provides a reliable theoretical basis for the application of the chemical conversion of the one of the clean energies, namely the solar energy, in the design, especially the modification design.

1. Introduction

With the implementation of clean energy such as solar energy, the continuous development of green building, the rapid development of technology, and the steady improvement of the people's material living standard, the energy consumption of buildings is becoming higher and higher, and their burden heavier and heavier. Therefore, the application of solar energy products in buildings sees important economic value, social needs, energy saving and environmental protection, and other practical significance. At present, the solar hot water system is able to meet the hot water use for households 24/7, and there are many ways to combine the solar water heater with houses. As shown in Table 1, the roofs, walls and balconies, etc., are available for reasonably placing the solar water heater which can still make the house full of senses of technology and fashion. If the real estate developer integrates the solar energy and the building in the architectural design from the beginning, then the building can use the function of the house rationally and can better meet the living needs of the residents, so that the quality and sales of commercial residential buildings can be improved. The systematic combination of solar water heater with residential building can not only beautify the appearance of residential buildings to have a decorative effect, but can also save energy and protect environment, reduce carbon emissions and reduce energy consumption, as well as create a healthy environment for physical and mental health.

Table 1: The practical application of solar water heater and residential building integration

the plan roofs	the solpe roofs	balconies	walls
			

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2. Structure Classification and Characteristics of Solar Water Heater

The solar water heater used in the house and on the market is usually composed of heat collector, storage tank, bracket, connecting pipe, auxiliary heat source and other related components (Yang and Zhou, 1999). According to the structure classification, it mainly includes: the integrated solar water heater, the compact solar water heater, the wall-mounted solar water heater and so on.

2.1 Characteristics of the integrated solar water heater

The integrated solar water heater's storage tank and heat collector are combined into one, and its heating process and circulating flow of cold and hot water are carried out inside the tank. The water reaches the desired temperature in the storage tank after one day's sun burn (internal natural circulation). With simple structure and low cost, it is easy to use and promote, which show its advantages (Wang et al., 2016). But with high heat loss, poor insulation, etc., the hot water obtained after a day of heating is only enough for the use of the same night, which shows its disadvantages. The integrated solar water heater can be generally divided into shallow pool solar water heater, plastic bag solar water heater, cylindrical solar water heaters and vacuum tube integrated solar water heater, as shown in Figure 1.

Figure 1: Stuffy dry type solar water heater

Figure 2: Compact type solar water heater

2.2 Compact solar water heater

As shown in Figure 2, the collector of the compact solar water heater mainly consists of the flat plate collector, the all glass vacuum tube collector and heat pipe collector. The solar water heater consisting of the all glass vacuum tube collector is a non-pressure bearing system, where the vacuum tube is directly inserted into the tank. The solar water heater composed of a flat plate collector or a heat pipe collector may be a non-pressure bearing system or a pressure bearing system, where the flat plate collector and the storage tank are connected and fixed with a bracket (Huang, 2013). Regardless of the all glass vacuum tube collector or the flat panel collector, they both receive heat from the sun's radiation. The water or heat-conducting medium in the collector is heated and then sent to the upper storage tank, and the cold water or low-temperature heat-conducting medium in the storage tank flows back to the collector for heating, which cycles back and forth. This natural circulation makes the water temperature inside the storage tank kept at a certain temperature (Song, 2013). In the frozen areas in winter, the pipeline of the compact solar water heater should be treated with anti-freezing measures, such as emptying the pipeline or by the way of electric belt.

With mature and stable technology and the low price, compact solar water heater, currently the most widely used solar water heater, was the major type of solar water heater (system) for the last ten years and will still be even a long time in the future.

However, the exposure of the storage tank of the compact solar water heaters outside of the room, not only causes great heat loss, but also affects the facade of the building, undermining the appearance of the building and the cityscape (Wang et al., 2015). The compact solar water heater usually requires the building to be its carrier, but it is not suitable to be installed on the roof of the building, firstly, because the visual effect will not be good and it influences the appearance of the building; secondly, because it is difficult for this way of installation to integrate with the building perfectly; thirdly, because this way of installation is not safe, combined with its own shortcomings, such as that its vacuum tube is easy to explode and can not bear pressure, limiting its use and popularization.

2.3 Wall-mounted solar water heater

The wall-mounted solar water heater is also known as the split type solar water heater, whose most notable feature lies in that its storage tank and the collector are separate, and they are connected by pipes, as shown in Figure 3. It is composed of a collector, a storage tank, the auxiliary heat source, an intelligent control system, the pipe used for connection, fixed supporting bracket, and the corresponding component and accessories. Among them, the collector can be an all glass vacuum tube type or a flat plate type. The split solar water heater emancipates the storage tank, which greatly increases the capacity of the tank, so that its installation can be more flexible.

Figure 3: A wall-mounted solar water heater

The integration of wall-mounted solar water heater with the building mainly lies in the integration of its collector with the building. There are several ways to install it, including that it can be installed on a flat roof, a slope roof, a wall, or a balcony, such as the wall-mounted mode or the balcony-mounted mode. If it is installed on the roof, then the collector can be installed on the roof, and the storage tank can be concealed under the roof, or placed inside each house of each floor or outside the wall of each house. The installation of the collector is similar to that of the flat roof, in that the special mounting bracket is used, which is fixed to the wall surface with the expansion bolts.

To integrate the wall-mounted solar water heater with the building requires the architectural design unit and the developer to take into account the solar water heater before the architectural design, incorporate the solar water heater into the architectural design, structural design, water supply and drainage design, and electrical design, and communicate with the solar energy manufacturers to select an appropriate solar system in order to reserve the installation space for the collector, storage tank, pipe, etc. In this way, not only the collector and the building can be combined perfectly, but also waterproof, pipe layout and other issues can be better tackled with, thus more conducive to the realization of an integrated design.

3. Integrated Design Concept of Split Solar Water Heater and the Multi-storey Building

3.1 Applicable building types for the split type solar water heater

The most prominent characteristic of the split solar water heater is that the collector is separated from the storage tank and other auxiliary components; hence it is widely applicable (Yang, 2000). In addition to being installed on residential buildings, such as the roof, wall or balcony of the villa, multi-storey and high-rise building, as well as on the flat roof, slope roof, wall and balcony, providing living hot water for households, it can also be installed on the roof or wall of the factory, office building, hotel, hospital, school and so on, as shown in Table 2. Only a special bracket is needed to install a solar collector on a flat roof in a residential building. A base shall be built with concrete and the embedded parts determined aside for fixing the bracket of the collector on the flat roof. The embedded parts exposed out of the top surface of the base shall be processed with anticorrosive measures. After the base construction is completed, waterproofing shall be done (Wang et al., 2016).

Similarly, in the office buildings, hotels, school buildings, dormitories and other public buildings, the installation location for solar collectors shall be reserved according to the corresponding forms of buildings, adding to that the collector of the split solar water heater can be arranged flexibly (He and Jiang, 1993), hence the design and installation of the solar heater can effectively integrate with various parts of the building, which will improve the overall quality of the building while fully improving the thermal efficiency of the collector, so as to provide more applicable types of constructions for the integration of solar energy and architecture, and open up a wider range of applications and markets.

Table 2: Solar energy water heater in the construction of practical application

Beijing China	Shandong China	Jilin China
		

From the examples of Table 2, it can be seen that the split solar water heater can be widely used, which is not only limited to be installed to residential buildings, but also to the large public construction projects, such as

museums, urban complexes, stadiums and other buildings in accordance with their unique shape, function or structure, as shown in Table 2. If the owner, design unit, construction unit, and solar water heater manufacturers can communicate with each other frankly and sincerely in the early stage of architectural design, or at the scheme phase to reach a good design scheme and a design concept, then it will not only achieve the perfect integration of the solar water heater and the building, but also greatly improves work efficiency and effectively solves the various problems that arise in the construction process.

3.2 Design principles for installing the split solar water heater in multi-storey residential buildings

3.2.1 Design principles for installing the split solar water heater on the balcony

It is also a very common design technique to install the split solar water heater on the fence of the balcony of the multi-storey residential building. In the solar water heater market, this kind of heater is referred to as the wall- mounted solar water heater. The solar collector, water tank, pipeline, auxiliary heat source and other devices can be arranged uniformly according to the balcony space (Fan, 2009). There are three modes to install heat collector on the balcony, namely the embedded, external-mounting or tilted modes. The following design principles shall be observed when installing the solar water heater on the balcony:

(1) In Changchun in northern China, for example, the multi-storey residential buildings mainly adopt the enclosed balcony. The collector is installed on the fence of the lower part of the balcony frame, while the upper part is reserved for windows. Water storage tank shall be placed within the reasonable space of the balcony, and the space for pipeline shall be determined aside on the fence to connect the collector and the storage tank. To install the heat collector on the balcony fence shall deal with its influence on the balcony shape and its proportion to the facade of the house.

(2) Sunshine analysis is required to install solar collector on the balcony fence at the beginning of the design, so that the balcony will not be blocked, ensuring that the solar collector have 4h of sunshine.

(3) The solar collectors shall be installed on the balcony fence with appropriate inclination so that the collectors can effectively receive solar radiation.

(4) Solar collector bracket installed on the balcony fence shall be firmly connected with the embedded parts in the fence, and the embedded parts shall be accurately located in the construction drawings so as to provide convenience for future maintenance and repair, as shown in Figure 4.

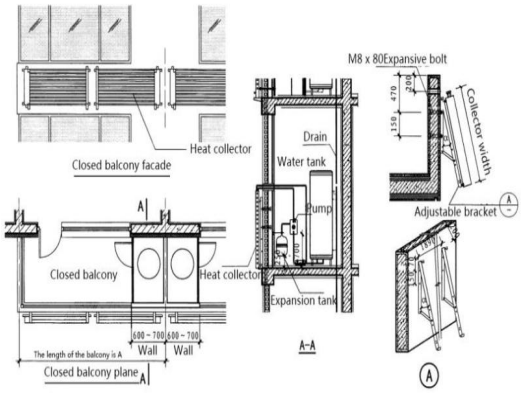

Figure 4: The balcony system installation drawing Figure 5: The project of solar collectors installed on metope

(5) If the collector constitutes part of the balcony fence, it shall meet the requirements for strength, stiffness, and protection function of the architectural design, and protective railings shall be determined up behind the solar collector. The load of the collector installed on the balcony fence shall be considered in the architectural design, and the load of the balcony itself shall be calculated and verified so as to meet the requirements for the collector's installation.

(6) The balcony fence for installing collector shall adopt the solid boards. The metal parts of the fence shall be painted with antirust paint 2 times and with enamel for 2~4 times. Their color can be determined by the designer.

3.2.2 Design principles for installing the split solar water heater on the wall

The installation of the split solar water heater on the exterior wall of the house, will enrich the building facade and can make up for the defect that there is not enough room for installing solar water heaters on the roof (Yuan and Su, 2005). Therefore, the installation of the collector on the exterior wall of the house is also a good

choice, in addition, with flexible layout; the split solar water heater can meet the needs of all users within the house for living hot water, as shown in Figure 5.

In multi-storey residential buildings, the installation of solar collectors on the exterior wall of the house shows the advantages of shortening the pipeline, convenient installation and maintenance. As the number of dwellings continues to increase, it has also become a common design practice. To install solar heat collector on the outer wall shall observe the following design principles:

(1) The area of the south wall of the house is limited, thus when installing the collector onto the outer wall, it is necessary to well handle its relations with the balcony, windows, air conditioning and other residential facade elements. At the initial design stage, the installation location of the solar collector shall be reserved and its proportion to the residential facade shall be properly handled.

(2) Sunshine analysis is required to install solar collector on the exterior wall of the house at the beginning of the design, so that the wall will not be blocked, ensuring that the solar collector have 4h of sunshine.

(3) The solar collectors shall be installed onto the exterior wall with appropriate inclination so that the collectors can effectively receive solar radiation. To install solar collectors on the top of the window shall carry out the shade analysis. Split solar water heater installation mode is divided into two kinds, namely, vertical mode and tilted mode. The vertical mode is divided into two types, the embedded and external-mounting. For the vertical mode, the heat collector, which is closely combined with the wall body, is parallel to the wall body. The advantage is that it does not destroy the facade of the building, but rather beautifies the appearance of the building. Generally, the installation location of the collector is usually reserved at the early stage of the architectural design. For the tilted mode, the solar collector and the wall form a certain angle, and they are connected and fixed by the stainless steel bracket. Its heat collecting efficiency is higher, but its decorative effect is not as good as that of the vertical mode.

(4) The collector bracket installed on the outer wall shall be anchored firmly with the embedded parts on the wall, and the embedded parts shall be accurately located in the construction drawings so as to provide convenience for future maintenance and repair.

(5) When the pipeline installed on the outer wall is to pass through the wall, the corresponding casing shall be embedded. The embedded casing shall be dealt with waterproof and thermal insulation treatment. The location of the storage tank can be arranged according to the function of the plane, and it is generally placed in the interior in northern China.

(6) The load of the collector installed on the wall shall be considered in the architectural design. Embedded components shall be buried in the wall, and their number and size shall be calculated in advance.

(7) The metal parts shall be painted with antirust paint 2 times and with enamel for 2~4 times. Their color can be determined by the designer.

3.2.3 Design principles for installing the split solar water heater on the roof

The installation of the split solar water heater on the slope roof is more flexible than that of the integrated type, and it looks better. There is little difference between the design principles of installation on the flat roof and those of installation on the slope roof. It is the most common design technique to place the collector on the roof of the house. The advantages lie in that the layout is more flexible, the area for placing the collector is relatively larger, the combination of the collector and the roof molding is more diversified, and the integrated design of the split solar water heater and the house is easier to be realized. The design principles include the following points.

The roof is the fifth facade of the building, which needs to be designed as well. The design for the integration of the collector and the roof, especially the roof design, shall focus on the scale relation of the roof top, the wall and other building parts and the coordination of the overall appearance of the building, so as to ensure the feasibility of the integrated design.

The time that the collector receives sunlight on the roof of the house shall be guaranteed for not less than 4h. The heat collectors shall not block each other, with an orderly arrangement.

(1) There are two ways to install the split solar water heater on the roof, namely the overhead and embedded modes. The overhead mode is the commonly used methods for combining the solar collector and the roof. The collector is installed on the predetermined metal support or support on the original roof structure and it is fixed to the roof through the support. The drainage plate is needed on both sides of the support and the lower part. For the embedded mode, the collector is fully embedded in the roof insulation waterproof layer. With this mode, the integration degree with the roof is higher, but the requirements for the construction technology are also higher. During construction, we shall pay attention not to destroy the roof's thermal insulation and waterproof structure. However, the embedded mode is only applicable to the slope roof, while the overhead mode can be applicable to both the flat roof and the slope roof.

(2) The heat collector is fixed by a bracket or base to the roof. In the design process, the embedded parts suitable for the roof shall be selected in case they are needed for installing and fixing the heat collector, so

that the collector can be anchored firmly on the roof, avoid being damaged in storms, snow or other natural factors. The embedded parts (base or metal components) for fixing collector shall be connected with the structural layer of the building, the upper part of the support shall be wrapped in the waterproof layer, and the sealing around the anchor bolts shall be strengthened.

(3) When the pipeline connecting the collector and the tank is to pass through the roof, the corresponding waterproof casing shall be embedded. And the casting shall be buried before the construction of the roof waterproof layer after its structure is processed with waterproof measures so as to avoid perforating holes in roofs that have been waterproofed and insulated.

(4) If the heat collector is placed on the roof, the roof shall be equipped with a manhole to be used as the entrance and exit for repair and maintenance. The surrounding area and the overhaul passageway of the collector, as well as the pedestrian passageway between the manhole and the collector on the roof shall be laid with rigid protective layer, and cement bricks can be laid to protect the roof waterproof layer.

(5) The load of the collector installed on the roof (including base and bracket) shall be fully considered in the architectural design.

(6) The metal parts shall be painted with antirust paint 2 times and with enamel for 2~4 times. Their color can be determined by the designer.

The above is the design principles for placing the split solar water heater in different locations of the house. If we can follow these principles in the actual design to realize the integration of the solar water heater with residential buildings, especially with existing residential buildings, then it will lay a solid foundation for the popularization and application of the solar water heater in buildings.

4. Conclusions

The multi-storey buildings can choose the decentralized solar water heating system. The storage tank and the heat collector of the split solar water heater are separated from each other, thus it can be better combined with the multi-storey building, and can be flexibly installed on the roof, the wall, and other retaining structures, so as to better achieve the integrated design of the existing multi-storey house and the solar water heater in greenhouse projects.

This paper offers an in-depth understanding of the integrated design of solar energy in multi-storey buildings, and provides reliable theoretical premise and basis for the practical application researches in the greenhouse renovation projects, hoping that the solar water heater can be popularized in the multi-storey residential buildings or in the greenhouse renovation projects, so as to promote the development of clean energy in China.

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