ENERGY CONSERVATION AND ENVIRONMENTAL PROTECTION OF A SOLAR DOMESTIC WATER HEATER

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ABSTRACT
Hot water is an essential requirement in most residences. Gas, electricity and furnace oil are being used for obtaining hot water. These sources are not readily available and are scarce in a part of Japan at present. Fortunately, solar thermal energy is plentiful which can be successfully harnessed for getting hot water. In this paper, performance of the copper coil heat exchanger type solar water heater has been described, which provides domestic hot water for a four-person family. And energy-saving quantity per annum is about 6609 MJ and the average of yearly conversion efficiency in 2005 was 62%. It is capable of reducing CO₂ emission by 9.6 ton-C. And can save $209 carbon tax per year by using SDWH. The results show that the use of a solar water heater will conserve a lot of conventional fuels which are being wasted for merely obtaining hot water and achieve good effect of environment.

KEYWORDS
Solar thermal energy, Solar water heater, Energy conservation, Environmental protection

INTRODUCTION
Along with the people living standard unceasing enhancement, the solar water heater is widely applied by the people. The most of solar water heaters are mainly used by the domestic sector for hot water production. Nevertheless, the former solar water heater has the lower thermal performance and convenience. Therefore, adopting the new technology and new material to improve the efficiency is completely necessary.

Globally, reserves of non-renewable sources of energy such as coal, oil and natural gas are declining drastically. Calculated by the proven reserves and the speed of consumption, petroleum, the main source of energy in the world, will be exhausted in 40 to 50 years. By that time, the energy crisis will become a major threat to the world. Meanwhile, the sustainable development of human society demands coordination between energy development, environmental protection and ecological balance. Therefore, many countries are actively developing clean and renewable source of energy, and solar energy is a typical one. Wherein, most of the SWH are mainly used in the domestic sector for hot water production.

In this paper, we focused on SDWH that will be able to be introduced in a four-person family. By regression analysis to the experience data that can get the energy saving by using SDWH. Based on that, significant impacts on energy saving, CO₂ emission reduction and its tax are analyzed.

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THE RESEARCH METHOD
Firstly, the amounts of SDHW hot water generation and heat performance efficiency have been
amounted by using the experiment data during 2005. On the basis of this, the influences on the amount
of heat collection, heat insulation and heat exchange from irradiance, city water temperature, and air
temperature have been studied by using the single regression and multiple regression analysis
method[1].

EXPERIMENT RESULT AND ANALYSIS
1 EXPERIMENT RESULT
1.1 Heat Collection performance result
In this system, field data was recorded by all kinds of meters every 10 minute. The data from 7:00 to
18:00 of someday in the recorded data was considered as reasonable data and analyzed in this
paper[2]. The hourly temperature raise and irradiance amount of SDHW were shown in Figure 1. The
temperature raise was greatly influenced by irradiance. As Figure 1 shown, because Apr. 8 had
the largest irradiance, correspondingly, it generated largest temperature raise with 40℃. The smallest
temperature raise occurred in Mar. 29 with about 38℃.

![Figure 1. Hourly temperature raise and irradiance of SDHW](image)

In this paper, single regression method was used to analyze the relation between irradiance amount
and thermal energy collection. The results are shown in Figure 2. From the results, it can be concluded that the relation between irradiance and thermal energy collection
was linearity with the efficiency value of single-crystal 62%.

![Figure 2. The relation between irradiance amount and thermal energy collection](image)
1.2 Heat insulation performance result

The heat preservation data was recorded by all kinds of meters every 10 minutes. The data from 19:00 to 7:00 of someday in the temperature variety of storage tank was recorded. The results are shown in Figure 3. Seen from Figure 3, the smallest temperature variety is appeared in Summer with temperature depression about 6.7℃. And the largest temperature depression is about 12℃ occurred in Autumn⑨.

![Temperature variety of storage tank](image)

Figure 3. Temperature variety of storage tank

1.3 Heat exchange efficiency result

Based on the principle of thermal transmission and integration variable, the heat exchange efficiency can be expressed as a function of the temperature difference between the heat exchanger and storage tank:

\[
\eta = \frac{\sum m \cdot C_p \cdot (t_{in} - t_{out})}{M \cdot C_p \cdot (t_f - t_i)} \cdot 100\%
\]

The SDHW uses a copper coil as heat exchanger which gains the heat quantity from the storage tank. The following overall heat exchange efficiencies were shown in Figure 4. And the average efficiency was about 78%.

![Heat exchange efficiencies results](image)

Figure 4. Heat exchange efficiencies results

2 REGRESSION ANALYSIS OF PERFORMANCE

In this paper, the heat collection, heat insulation and heat exchange performance were selected as the representative factors to analyze the characteristics of timely Alteration of temperature, irradiance,
air temperature, and city water temperature. And the regression analysis was shown as follows:

1) Multiple regression analysis of heat collection performance

The multiple regressions \[4\] were selected to analyze the relation between irradiance, the temperature variation between the temperature of storage tank and air with temperature raise. Therefore, the temperature raise is defined as the following formula:

\[
\Delta T = 0.386 \cdot H + 0.0688 \cdot (t - t_a) + 2.33
\]  

(2)

The standard determination coefficient is larger than 0.69. Therefore, the equation is considered as the performance equation to calculate the temperature raise. The regression value of theoretical and Correlation were shown in Figure 5.

\[
y = -0.0094x + 0.0171 \\
R^2 = 0.8901
\]  

(3)

Figure 5. The regression value of theoretical and correlation results

2) Multiple regression analysis of heat insulation performance

The multiple regressions were selected to analyze the relation between the temperature variation between the temperature of storage tank and air with temperature depression. And it is shown in Figure 6. From this figure, the temperature variation between storage tank and air with temperature depression were the relation of direct proportion. The temperature depression should be described as the following formula:

\[
\Delta t = -0.00832 \cdot (t - t_a) + 0.0324
\]  

(3)

Figure 6. Relation between the temperature variation between the temperature of storage tank and air with temperature depression
3) Regression analysis of heat exchange efficiency

① Multiple regression analysis of storage tank temperature, city water temperature with heat exchanger outlet temperature

According to simultaneity\(^5\) analyze temperature variation between storage tank temperature, city water temperature and outlet temperature of heat exchanger. Figure 7 displays the regression value of theoretical and Correlation with determination coefficient is larger than 0.98. The variation of outlet temperature can be described as the following expression:

\[ T_{out} = 0.869 \cdot t + 0.131 \cdot t - 2.14 \]  \hspace{1cm} (4)

Figure 7. Regression value of theoretical and correlation

② Single regression analysis of outlet temperature with flushing period

Single regression method was used to analyze the relation between outlet temperature and flushing period. The results are shown in Figure 8. And the temperature variation can be calculated by the following formula:

\[ T^{ext} = -19.6 \cdot Ln(t) + 138 \]  \hspace{1cm} (5)

Figure 8. Relation between outlet temperature and flushing period

4) Calculation of energy saving and environmental protection

By using above expression (1) ~ (5), this paper calculated the energy saving for a family with four persons in 2005 year. As Figure 9 shown, the SDHW has obvious effect of saving energy and average temperature of storage tank is almost higher than 40°C.

Yearly conversion efficiency is defined as the following formula:
\[ \eta^* = \frac{Q_s}{Q_d} \times 100\% \]  

(6)

Where,

\( \eta^* \): conversion efficiency, (%);
\( Q_s \): quantity of heat supply, (MJ);
\( Q_d \): quantity of heat demand, (MJ);

According to the above formula, yearly conversion efficiency can be calculated. The energy-saving quantity per annum is about 6609 MJ and the average of yearly conversion efficiency in 2005 was 62% and reducing CO2 emission by 9.6 ton-C. And can save $209 carbon tax per year[6].

**CONCLUSIONS**

Estimation of hot water supply by using SDWH in a four-person family has been analyzed in this paper. According to use the single regression and multiple regression analysis method[7] and use experience equation to calculate the energy-saving quantity per annum is about 6609 MJ and the average of yearly conversion efficiency in 2005 was 62%. It is capable of reducing CO2 emission by 9.6 ton-C. And can save $209 carbon tax per year by using SDWH.
REFERENCES