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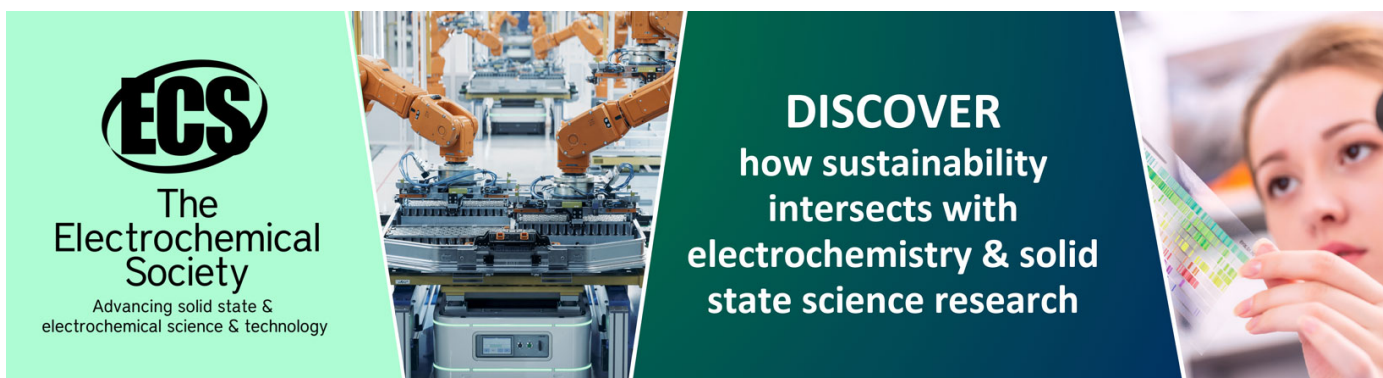
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Daily solar irradiance in Daily useful energy of Domestic solar water heater

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Abstract. Daily useful energy was studied on different daily solar irradiance, which is important to the coefficient of thermal performance(CTP) of domestic solar water heater. The numerical simulation of 8 hours thermal performance experimental was carried out by Fluent ,and the thermal energy equation was obtained by least-squares fitting method , the influence between daily solar irradiance and daily useful energy was analyzed quantitatively ,The feasibility of the equation was verified . The accuracy of the test results could be increased by the application of the equation .

1. Introduction

Energy efficiency grades of domestic solar water heater products is of great significance for transparent market and guide enterprises to improve product quality, Efficiency and accuracy energy efficiency grades of household solar water heater products is a concern of enterprises and testing center. GB / T 26969 gives[1]:

$$CTP = q_{17} / Q_s(m) - 0.9U_{sl}(e) / U_{sl}(M) \quad (1)$$

CTP , the energy efficiency coefficient of home solar water heater,dimensionless; q_{17} , daily useful energy per contour aperture area of domestic solar water heater when daily solar irradiance is 17 MJ / m² (hereinafter referred to as daily useful energy), MJ / m². q_{17} is an important factor to the energy

efficiency grades of domestic solar water heaters, National standard gives: $q_{17} = \frac{17q}{H}$, q , daily useful energy per contour aperture area of domestic solar water heater(hereinafter referred to as daily energy), MJ / m²; H , daily solar irradiance, MJ / m².

Some scholars have studied the heat of water heater products, Quo Chao have conducted thermal performance experimental on one domestic solar water heater for many days, Fitting the thermal energy equation[2].Ma Ying-chang thought there is no difference to the results when relaxing the experimental conditions[3].However, there is little research and analysis on the daily solar irradiance and daily useful energy, and a large number of experimental show that the daily useful energy will change with the amount of solar radiation changes. If the enterprise or testing center only do the thermal performance of water heater products for a single test, resulting in product energy efficiency test results are less accurate.

In this paper, 8 hours thermal performance experimental will be simulated by FLUENT software to explore the mathematical relationship between useful heat and daily solar radiation Under the condition of solar radiation changed.



2. Theory

GB/T 18708 on the domestic solar thermal performance test results that, the heat from the different H value of the input and output equation that[4]:

$$q = a_1 H + a_2 (t_{ad} - t_b) + a_3 \quad (2)$$

t_{ad} is the daily average ambient temperature, °C; t_b is the storage tank temperature at the beginning of the thermal performance experimental, and the coefficients a_1 , a_2 and a_3 are determined by the least squares method according to the test results. substituting $q_{17} = \frac{17q}{H}$, there is:

$$q_{17} = 17a_1 + \frac{17a_2(t_{ad} - t_b) + 17a_3}{H} \quad (3)$$

Deriving the derivative of daily solar irradiance H:

$$\frac{\partial q_{17}}{\partial H} = -\frac{17a_2(t_{ad} - t_b) + 17a_3}{H^2} \quad (4)$$

Due to the uncertainty of t_{ad} , a_2 and a_3 , q_{17} on the H derivative value is not constant to zero, the daily useful energy q_{17} calculated value changes with daily solar irradiance H, when the test conditions vary greatly, The accuracy of the test results will be reduced due to calculation.

according to equation(2), there is:

$$\frac{q_{17} - [a_2(t_{ad} - t_b) + a_3]}{17} = \frac{q - [a_2(t_{ad} - t_b) + a_3]}{H} \quad (5)$$

the equation of daily useful energy is got:

$$q_{17} = \frac{17q}{H} + [a_2(t_{ad} - t_b) + a_3](1 - \frac{17}{H}) \quad (6)$$

q_{17} on the H derivative value is zero by the equation of (6), q_{17} will no longer change with H.

GB/T 18708 has described the linear relationship between the average ambient temperature t_{ad} and the daily useful energy q_{17} , which Yin Zhi-qiang derived the relationship between the two: $\Delta q_{17} = a_2 \Delta t_{ad}$ [5], That is, the average ambient temperature will cause the q_{17} —H equation to increase or decrease on the intercept. If $t_{ad} = t_b$, ignoring the effect of ambient temperature, the equation of daily useful energy is:

$$q_{17} = \frac{17q}{H} + a_3(1 - \frac{17}{H}) \quad (7)$$

3. Numerical simulation

In this paper, the common domestic solar water heater as the object, to simulate by FLUENT, the main parameters shown in Table 1

Table 1. The main parameters of domestic solar water heater

Parameter	Value
Vacuum tube length/mm	1800
Outside glass tube diameter/mm	58
Inside glass tube diameter/mm	47
Glass tube thickness/mm	1.7
storage tank diameter/mm	360
Insulation thickness/mm	50
With the ground angle/°	45
Collector area/m ²	2.24
capacity of Storage tank/L	160

In order to simplify the calculation, it is assumed that the absorption characteristics of the selective absorption coating are assigned to the inner glass vacuum tube, ignoring the heat transfer of the

absorbing coating; the vacuum sandwich, the spring holder and the getter have no heat conduction and thermal convection; neglect the ground reflection and the sky scattered radiation.

Important parameters are set as follows:

1) The model of Radiation is DO radiation model ,The sunny ray tracing model has a clear sky index of 0.85;

2) The density of water with temperature is expressed as: $\rho = 715 + 2.08T - 0.00384T^2$, where T is the absolute temperature, K;

3) inside and outside the glass tube is non-bold, selective absorption coating for the black body;

4) The initial water temperature and ambient temperature of the storage tank are set to 20 °C;

4. Data analysis

The thermal experimental for different solar irradiance has been simulated, the end of the relationship between the storage tank mean temperature t_e and shows in Figure 1.

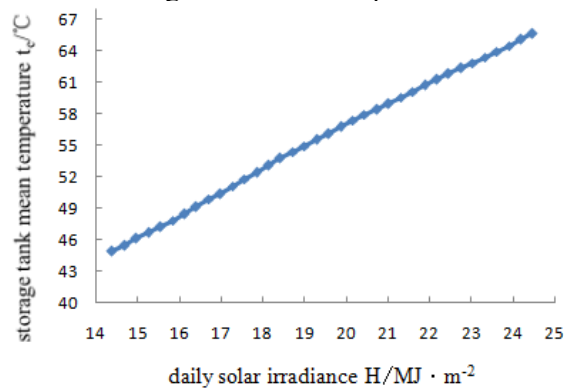


Figure.1: t_e —H Trends

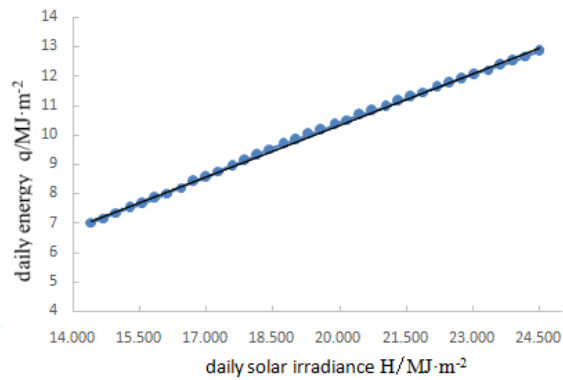


Figure. 2: q—H Trends

At the end of the test, the average temperature t_e of the storage tank increases with the amount of. According to the use of t_e and equation in GB/T 19141-2011[6], calculating.

The trend of daily energy q and daily solar irradiance shows in Figure 2.

In Fig. 2, the daily energy q increases linearly with the daily solar irradiance H. The coefficient a_1 is 0.583 and a_3 is -1.34 by the least squares method. The relationship between the daily useful energy q_{17} and the daily energy q and the daily solar irradiance H is:

$$q_{17} = \frac{17q}{H} - 1.34(1 - \frac{17}{H}) \quad (8)$$

The simulation data were taken into the original equation and equation (8) to calculate the daily useful energy q_{17} , daily solar irradiance H to the amount of change in the trend shown in Figure 3.

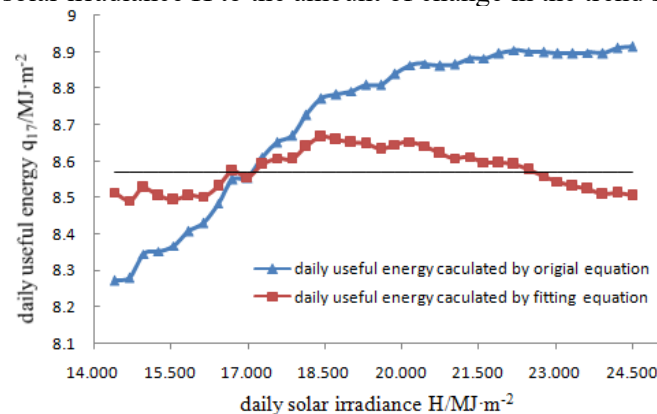


Figure.3: q_{17} —H Trends

When the solar irradiance increased from 14.4 MJ · m⁻² to 24.5 MJ · m⁻², the daily useful energy

calculated by the original equation was increased, the daily useful heat value calculated in equation (8) fluctuates around $8.57 \text{ MJ} \cdot \text{m}^{-2}$, which does not exceed $0.1 \text{ MJ} \cdot \text{m}^{-2}$.

In the case of a compact water heater, for example, when the daily solar irradiance varies between $16 \text{ MJ} \cdot \text{m}^{-2}$ and $24.5 \text{ MJ} \cdot \text{m}^{-2}$, the maximum value calculated in the original equation is $0.7 \text{ MJ} \cdot \text{m}^{-2}$, $\Delta CTP = \Delta q_{17} / 7.7 = 0.091$, the maximum value is $0.15 \text{ MJ} \cdot \text{m}^{-2}$ in the equation (8), $\Delta CTP = \Delta q_{17} / 7.7 = 0.019$.

GB/T 19141-2011 in the test given the minimum daily solar radiation for the $16 \text{ MJ} \cdot \text{m}^{-2}$, usually sunny day can reach $24.5 \text{ MJ} \cdot \text{m}^{-2}$ and above, when the solar irradiance changes For $8.5 \text{ MJ} \cdot \text{m}^{-2}$, the application of the equation, resulting in energy efficiency coefficient of domestic water heater up to 0.091, easy to cause energy efficiency grade migration, the difference between the energy efficiency coefficient is only 0.019 by the application of equation(8), improving the accuracy of the test results.

5. Verification

In the study of useful daily energy, Wei Feng and Li Ren-fei, who have carried out experimental of single water heater products under different solar irradiance, the use of its test results for verification, the comparison chart shown in Figure 4 and Figure 5.

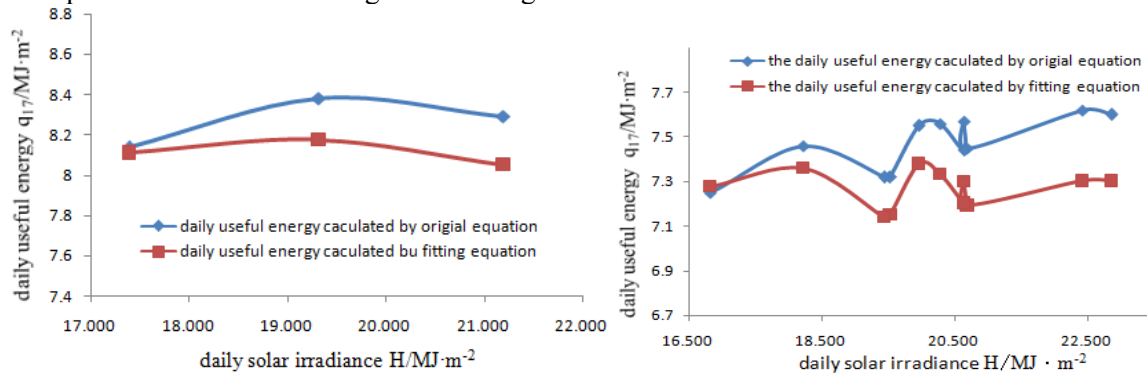


Figure. 4: Test comparison 1#Figure. 5: Test comparison 2#

The basic trend of daily useful energy calculated by fitting equation (8) is consistent with that of the original equation, but the magnitude of the available energy change in equation (8) is obviously reduced and significantly decreased. In test comparison 2, Δq_{17} decreased from 0.37 to 0.24, ΔCTP decreased from 0.048 to 0.031, the daily useful energy calculation error is reduced to increase the accuracy of the test results.

In the original equation, the daily useful energy increases with the amount of daily solar irradiance, which shows a slight decrease in the situation, Wei Feng and others thought that is the test when the ambient temperature and environmental impact caused by wind speed [7]. Li Ren-fei, whose test also exist the phenomenon with useful energy not rising strictly [8].

6. Conclusion

The usefulness of the heat equation $q_{17} = \frac{17q}{H} - 1.34(1 - \frac{17}{H})$ proposed in this paper can reflect the thermal performance of the water heater more accurately, and the test result is more reliable. Numerical simulations only take into account the effects of solar irradiance, other factors can be considered in the future.

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References

- [1] GB/T 26969-2011, Minimum allowable values of energy efficiency and energy efficiency grades for domestic solar water heating systems[S]
- [2] Guo Chao, Qin Chao-kui, Ma Fei, Yang Xian-chao. Experimental study of heat gained of evacuated tube solar water heater[J]. Journal of Thermal Science and Technology, 2011, 10(02): 142~145.
- [3] Ma Ying-chang, Zhou Ling, Ma Guang-bai. The Study on the Test Conditions of daily solar energy[J]. Solar Energy, 2011, (14): 46~48, 51.
- [4] GB/T 18708-2002, Test methods for thermal performance of domestic solar water heating systems[s].
- [5] Yin Zhi-qiang, Ma Guang-bai, Lin Yu-wu, Zhou Xiao-wen, Zhou Ling. Influence of environment and measurement uncertainty on energy efficiency level migration of solar water heater[J]. Solar Energy, 2012, (15): 18~22.
- [6] GB/T 19141-2011, Specification of domestic solar water heating systems[s].
- [7] WEI Feng, ZHANG Xiao- Li, XIN Li. Influence of environment on heating performance of solar heating water system[J]. Energy Technology, 2006, 27(2): 63~65.
- [8] Li Ren-fei, Gao Wen-Feng, Liu Tao, Lin Wen-Xian. The influence of an evacuated tube solar water heater[J]. 2014, 34(1): 31~35.