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# Dynamic characterization for flat-plate solar collectors

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**Abstract:** Due to its restrictive environment requirements of the steady-state testing, a dynamic method for characterizing the thermal performance of flat-plate solar collectors has been developed. The dynamic-state is created by forced transient conditions, which is performed to the incoming solar radiation to increase the thermal capacitance effect. These conditions are achieved by shielding the collector area for a specific time interval and then exposing it to the sun. In view of a simplified model used in the current work, the constituent elements of the collector (*glass, absorber, liquid contained, and insulation*) were lumped together, in which the whole mass can be represented by a single temperature that refers to the mean fluid temperature. Furthermore, Multiple Linear Regression (MLR) was applied to the measured data to identify the collector parameters. The impact on both the different number of test sequences and the different test spans for dynamic characterization was investigated. It is concluded that at least three test sequences (*with different constant inlet temperatures*) are required to yield more realistic results. The characterization results show good agreement with those obtained from the reference values and are found to be independent of the test spans. Therefore, the dynamic method is easily performed and is less time consuming.

**Keywords**: dynamic characterization, solar collectors, forced transient conditions.

## 1. Introduction

Test methods for characterizing the thermal solar collectors are of great importance in the standard testing procedures. These provide objective information that can help designers and manufacturers to optimize the design collector and system performance for a particular application. On the other hand, consumers can also compare the performance and cost-effectiveness of a competing product (S.J Harison et al. 1993).

Several steady-state testings (ISO 9806-1 1994; EN 12975 (*section 6.1-2*) 2006; ANSI/ASHRAE 93 2003) in terms of the rating of solar thermal collectors have been adopted worldwide as a reference method. They are available for testing solar collectors under outdoor test conditions. According to this fact, there is *a difficulty* that may arise for testing outdoors in use with these standards, where the weather is often *not at the clear sky conditions* for many parts of the worlds. If the procedures for testing are performed in such weather conditions, it might take *a very long time* to complete a test. To cope with the difficulty, transient methods have been developed as reported in the literatures (E. H. Amer et al. 1998, J.K Nayak et.al 1999 and EN 12975). However, not much the literatures have been investigated with regard to the dynamic characterization that can be applied to transient weather conditions

Amer et al.(1998) proposed the Quick Dynamic Tests (QDT) by applying forced transient conditions on solar radiation. From a practical point of view, it is a great advantage that the QDT method could be accepted in the simple procedures under dynamic-state testing. The duration time testing is only a few minutes that lead to less time-consuming. As reported by authors, the results from this method are affected to some extent by the choice of time limits that define the span during which calculations are made. In other words, *the method is sensitive* to the selection of the test span used for the calculation and is likely to fluctuate from one test to another associated with the different test span. Therefore, the procedure requires a somewhat *more demanding effort for the determination of the span test of data*. To eliminate with this limitation, Amer et al.(1999) proposed a new dynamic method (NDM) for applying forced transient conditions within a wider range time of data measurements with minimization of residual error between predictions and measurements using unconditional non-linear optimization technique. Again, the NDM method might perform *in several days* where it takes time of an experiment longer than the duration of the QDT method. Moreover, the model requires the *extensive knowledge* of the non-linear optimization techniques using *Levenberg-Marquardt method*.

Beside the steady-state testing, the EN 12975 *(section 6.3)* is also available for dynamic testing of solar thermal collector and valid throughout Europe. According to this standard, the minimum length of a test sequence shall be three hours, and one test sequence shall be conducted under partly cloudy conditions, including broken cloud as well as clear sky conditions. This is mainly to increase the heat capacitance effect of the collectors. The number of the actual days dependent on the actual weather conditions on the tests site. The recommended test sequences consist of 4-5 days. If the sufficient data has been recorded after these periods of days, the data collected shall be then evaluated. If this is not the case, therefore, the extra test day (*it might take several days*) is needed until the proper data has been reached again.

Since several works are concerned with the dynamic method and the results obtained are not sufficiently expected, therefore, the need for improved the method is of interest to be investigated. The aim of the present study is to develop a simple dynamic method for characterizing the thermal collectors. The details of methods are described in the following sections.

## 2. MODEL AND PARAMETER IDENTIFICATION

In the present study a simple model based on the energy balance for the useful heat power per unit area is developed. It extends the Hottel-Whillier-Bliss equation (Dufie et al. 2006) to a dynamic model by adding the heat thermal capacity term as given in Equation (1):

$$q_u = F^{'}(\tau\alpha)_e K_\theta(\theta) R_s - F^{'} U_L (T_m - T_a) - (mc)_e (dT_m / dt) \qquad (1)$$

where $F^{'}(\tau\alpha)_e$ is the zero loss efficiency, $K_\theta(\theta)$ is the incident angle modifier, $F^{'}U_L$ is the overall heat loss coefficient, and $(mc)_e$ is the effective thermal capacity respectively. In view of simplification purpose, the model is then considered as a lumped-thermal capacity model for the tube, absorber plate, cover and insulation of the collectors, in which the whole mass can be represented by a single temperature that refers to the mean temperature of the working-fluid.

Since the solar radiation measurements are created by applying the forced transient conditions around the solar noon and the collector is perpendicular to the sun, so that the incident angle modifier effect of the Equation (1) can be excluded:

$$q_u = F^{'}(\tau\alpha)_e R_s - F^{'} U_L (T_m - T_a) - (mc)_e (dT_m / dt) \qquad (2)$$

From the above equation, the $q_u$ as the useful heat power per unit area is determined by the following equation:

$$q_u = \dot{m} c_p (T_m - T_a) / A_{abs} \qquad (3)$$

In equation (3), $\dot{m}$ is the mass flow rate of fluid, $c_p$ is the heat capacity of fluid, $(T_m - T_a)$ is the temperature difference between mean fluid and ambient, and $A_{abs}$ is the area of absorber plate. Furthermore, the dependence of $U_L$ on both wind speed and temperature difference is given below(Dufie et al. 2006):

$$U_L = U_1 + U_2 \Delta T + U_3 v \qquad (4)$$

where $U_1$ and $U_2$ are the first and second-order heat loss coefficients, $\Delta T = (T_m - T_a)$, $v$ is the wind speed, and $U_3$ is the heat loss coefficient due to wind speed.

## 3. EXPERIMENTS

The dynamic test here was performed using an open-loop collector as illustrated in Figure 1. In principle, the experimental test setup has similar configuration to that conducted in the steady-state testing. In view of data collection, measurements were made for inlet and outlet fluid temperatures, ambient temperature, wind speed and solar radiation, respectively. All measurement data were measured every 1 second, and their mean values were recorded every 10 seconds as shown in Figure 2.

The test using a small test PV/T flat-plate solar collector with an area of absorber plate equal to 0.15 $m^2$ was conducted at the Applied Energy Research Centre (CREA) at University of Lleida (Spain). The test site is located in Lleida at latitude 41.36$^o$ N and longitude 0.37$^o$ E.

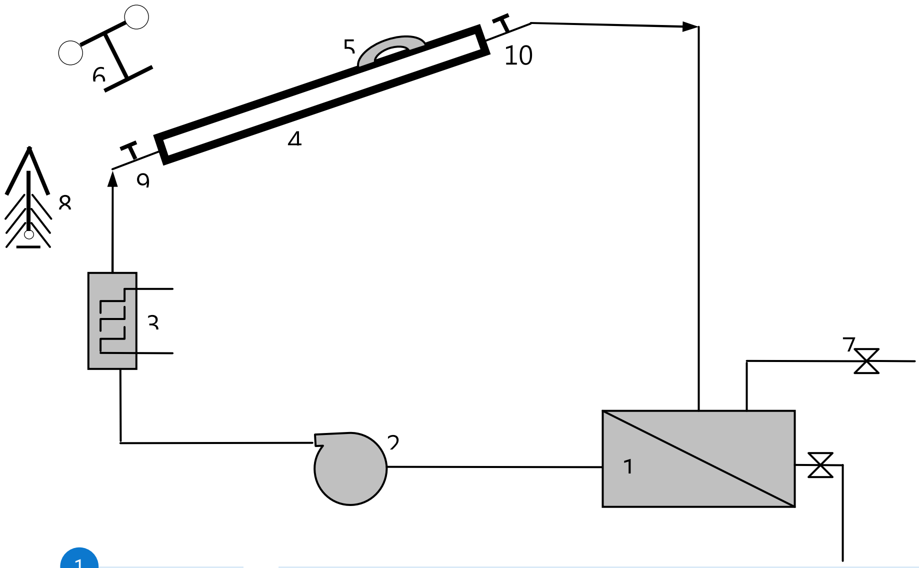

Figure 1 Experimental of set-up: 1.Storage tank 2.Pump 3.Heater 4. Solar collector 5.Pyranometer 6.Anemometer 7. Valve 8. Ambient temperature sensor 9-10. Inlet and outlet temperatures sensor

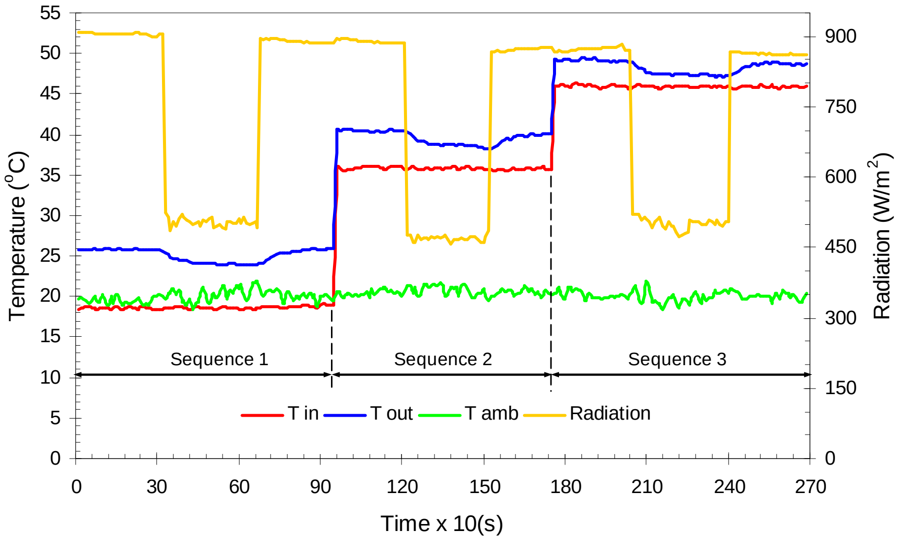

Figure 2 Experimental measured data of the three test sequences under forced transient conditions.

## 4. RESULTS AND DISCUSSION

In order to validate the proposed method, the tests for determining the reference values were conducted. The results obtained from the standard test method (*the steady-state testing*) are $F'(\tau\alpha)_e$ = 0.541 ± 0.009 and $F'U_L$ =14.42 ± 0.48 $W/(m^2K)$ with a coefficient determinant of 0.997. Then, the effective heat capacity $(mc)_e$ values are found to be 12.610 $W/(m^2K)$.

### 4.1 Dynamic Characterization for a Number of Test Sequences

In terms of the simplified procedures in the present study, several test sequences have been conducted with regard to the dynamic testing procedures for different level of inlet temperatures. The measurements were performed around the solar noon in which each of the test sequences takes time only in a few minutes. Therefore, the measurements could be repeated several times to ensure the reproducibility of results. To further identify the collector parameters, computations have been applied using for both the data of individual test sequence and data sets formed by combining several test sequences together. The standard errors in the estimation of the respective parameters are included in the table, and the deviations compared to the reference values of each parameter are presented within brackets as well.

Table 1 shows the results of the dynamic collector characterization with a 95 % level of confidence. The first three results presented in this table [(**1**);(**2**);(**3**)] are the values for each test sequence itself as shown in Figure 2, the others are the values obtained from a combination between the three test sequences. From Table 1, it can be observed that the values of $F^{'}(\tau\alpha)_e, F^{'}U_L$ and $(mc)_e$ of the test sequence [(**1,2,3**)] are found to be much closer to those obtained from the reference values than the others. It is clear that by addition of test sequence numbers for dynamic characterization here gives the satisfactory results, and the percentage deviations are shown less than 2 % as a good indicator of acceptability of the proposed method. It can be noted that at least three different constant inlet temperatures are required to yield the realistic results. One test sequence of them should be conducted with the inlet fluid temperature as closely as possible to the ambient temperature in order to get the accurate value of zero loss efficiency parameter. The other two sets should be performed close to the middle and the highest of the temperature operation, respectively.

Table 1 Collector parameters obtained from various test sequences.

| **Test Sequences** | $F^{'}(\tau\alpha)_e$ [-] | $F^{'}U_L$ $[W/(m^2K)]$ | $(mc)_e$ $[kJ/(m^2K)]$ |
|---|---|---|---|
| ( **1** ) | 0.538±0.001<br>(0.005 ) | 26.026±1.520<br>(0.805 ) | 13.749±0.371<br>(0.091 ) |
| ( **2** ) | 0.520±0.012<br>(0.039 ) | 13.179±0.581<br>( 0.086) | 12.902±0.509<br>(0.024 ) |
| ( **3** ) | 0.416±0.008<br>(0.231 ) | 10.749±0.248<br>(0.255 ) | 8.914±0.438<br>(0.293 ) |
| ( **1,2** ) | 0.539±0.002<br>(0.004 ) | 14.063±0.128<br>(0.025 ) | 13.319±0.316<br>(0.057 ) |
| ( **1,3** ) | 0.534±0.003<br>(0.013) | 14.222±0.106<br>(0.013) | 11.789±0.451<br>(0.064) |
| ( **2,3** ) | 0.511±0.007<br>(0.055 ) | 13.352±0.234<br>( 0.074) | 11.654±0.451<br>(0.075 ) |
| ( **1,2,3** ) | 0.536±0.002<br>(0.009) | 14.181±0.097<br>(0.016) | 12.410±0.364<br>( 0.015) |

### 4.2 Dynamic Characterization for Different Test Spans

The simplified procedures for characterization the performances of collectors were explored to determine whether it is independent of the different test spans. Figure 3 shows the test span of samples in which the sample B is the test span between two bounding limit where the outlet temperature starts decreasing after the collector is shielded, and the outlet temperature achieves the steady-state value upon removing the shielding. This sample B refers to the span as performed in QDT method (Amer et al. 1998). Meanwhile, the two other samples are taken with adjustable test spans to the data points as illustrated by the samples A and C, respectively. In this context the characterization processes were applied to the measured data of these samples in order to identify the collector parameters, and the results of parameter identification are given in Table 2. Here, the parameter values appear together with their standard error and then the deviation values of respective parameters are presented within brackets as well.

Table 2 Results obtained from different test spans

| **Test span of samples** | $F^{'}(\tau\alpha)_e$ [-] | $F^{'}U_L$ $[W/(m^2K)]$ | $(mc)_e$ $[kJ/(m^2K)]$ |
|---|---|---|---|
| **A** | 0.537±0.002<br>( 0.007) | 14.295±0.094<br>(0.009 ) | 12.956±0.338<br>(0.028 ) |
| **B** | 0.543±0.003<br>(0.004 ) | 14.069±0.107<br>(0.024 ) | 12.563±0.332<br>(0.003 ) |
| **C** | 0.551±0.003<br>(0.019 ) | 14.087±0.118<br>( 0.023) | 12.370±0.327<br>(0.018 ) |

From Table 2, it can be observed that the variations of the parameter values obtained from all the samples are relatively small. This is indicated by the percentage of deviations from the reference values for each of test spans is less than 3%. The proper values given by dynamic characterization performed on these spans lead to substantially easier the procedures, which do not require a somewhat more demanding effort for the determination of a fixed bounding limit. In other words, the different test spans applied here were quite acceptable and were found to be a free selection. Although there were no time limits that define the span during which calculations were made, care should be taken in determining the pairs of data, if not, the results seem to deviate from the reference values. The data points of the spans should be symmetric pairs to solar noon (*line D-D'*) as shown in Figures 3. The symmetric pairs mean that measurements for the same collector outlet temperature are taken at time symmetric to solar noon in which ones characterization values are obtained from with and ones without shielding process.

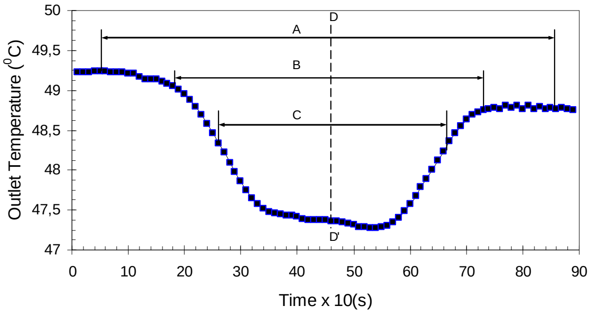

Figure 3 the three different test span of samples.

## 5. CONCLUSIONS

At least three different constant inlet temperatures were required to yield more realistic results in the current work. One test sequence of them should be conducted with the inlet fluid temperature as closely as possible to the ambient temperature in order to get the accurate value of zero loss efficiency parameter. The other two sets should be performed close to the middle and the highest of the temperature operation, respectively. The proposed method allows for a free selection of test spans and does not require a somewhat more demanding effort for the determination of a fixed bounding limit. Therefore, the procedures were easily performed and was less-time consuming. The results exhibited a good degree of agreement with those obtained from the reference values.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1]S.J Horison, B.A. Rogers, H Soltau and B.D Wood. The Characterization and Testing of Solar Collector Thermal Performance, A Report of Task III. *International Energy Agency* – 1993 Solar Heating and Cooling Programme
[2]ISO Standard 9806-1.Thermal performance of glazed liquid heating collectors 1994
[3]European Standard EN 12975-2:2006. CEN (European Committee for Standardisation).
[4]ANSI/ASHRAE Standard 93-2003: Methods of Testing to Determine Thermal Performance of Solar Collectors.
[5]E.H. Amer, J.K.Nayak and G.K.Sharma..Transient Method for Testing Flat-Plate Solar Collectors. *Energy Conversion & Management* (39): 1998 pp549-558.
[6]E.H. Amer, J.K.Nayak and G.K.Sharma. A New Dynamic Method For Testing Solar Flate-Plate Collectors Under Variable Weather. *Energy Conversion & Management* (40): 1999 pp.803-823.
[7]Duffie, J.A., Beckman, W.A. Solar Engineering of Thermal Processes. 2006 Third ed.Wiley

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