Conference Proceedings

EuroSun 2014
Aix-les-Bains (France), 16 - 19 September 2014

Energy labelling and testing of hot water stores, collectors and solar thermal systems

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Abstract

The standing losses of two typical bivalent hot water stores have been determined according to three different standards (EN 12977-3:2012, EN 12897:2006, EN 15332:2007). The different test procedures of these three standards as well as an additional standard (EN 60379:2004) contain methods to provide the basis for the classification of hot water stores into energy efficiency classes. This classification is used to label the hot water stores according to the European Directive 2010/30/EU with different energy labels from either A to G or A+ to F.

The results of the work performed show that, depending on the chosen standard or test procedure respectively, significantly different standing losses result. Therefore, a certain hot water store would be classified as "C" according to the test results of one standard, whereas the same store would be classified as "D" according to another standard. Consequently, the fractional energy savings and further characteristic values of the tested solar thermal system vary significantly.

Keywords:

Hot water store testing, collector testing, system testing, energy labelling, standing losses, heat loss rate.

1. Introduction

The Commission delegated regulation (EU) No 812/2013, supplementing the Energy Labelling Directive (Directive 2010/30/EU) (European Union, 2010) "with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device" was published in September 2013. Only in combination with solar thermal a system will be able to achieve the labelling class A+++. As soon as solar thermal is part of a system, the so called 'package label' and its requirements apply. A solar thermal system itself cannot achieve a product label since it is classified as an efficiency technology and not as a heat generator. But such a 'product label' is required for certain parts of a solar thermal system, e.g. pumps and stores. Although, only stores with a volume up to 500 L require the product label, manufactures of stores with a higher volume must deliver a technical documentation containing all necessary information for issuing the package label.

Since the store is one of the core components of a heat generator, no matter if it is combined with a solar thermal system or not, a deeper survey of the classification procedure of hot water stores is necessary.

The EU directive No. 812/2013 classifies hot water stores into eight energy efficiency classes. The classification only depends on the standing losses of the hot water store. These standing losses have to be examined according to "[…] reliable, accurate and reproducible measurement and calculation procedures that take into account recognised state-of-the-art measurement and calculation methods including, where available, harmonised standards […]" (European Union, 2013). This means that the following standards are appropriate and approved for the determination of the standing losses:

EN 12977-3:2008 (CEN, 2012), EN 12897:2006 (CEN, 2006), EN 15332:2007 (CEN, 2007) and

Selection and/or peer review under responsibility of EuroSun2014 Scientific Committee
doi:10.18086/eurosun.2014.03.02 Available at http://proceedings.ises.org

EN 60379:2004 (CENELEC, 2004).

Although, even if the applicability of some of these standards is limited with regard to the type, to the size of the store or to the kind of charging, the standing losses of most hot water stores can be determined according to several standards. From this matter of fact the following two questions arise:

- Do all approved test procedures of the mentioned standards lead to the same results for the standing losses and the heat loss rate respectively?
- Which apparatus for performing the tests according to the different procedures is required and can the apparatus be used for tests according to the different test procedures?

2. Test method

In order to assess the test procedures of the different standards, the standing losses of two typical bivalent hot water stores have been determined according to EN 12977-3:2008, EN 12897:2006 and EN 15332:2007. The procedure described in EN 60379:2004 is merely applicable to hot water stores charged only by an immersed electrical heating element. Therefore this kind of stores cannot be combined with conventional solar thermal systems. Since the aim of the work performed was an assessment related to solar thermal hot water stores, this procedure was not further taken into account.

The small hot water store has a nominal volume of 300 L and 50 mm PU-foam insulation, whereas the other hot water store has a nominal volume of 500 L and 100 mm polyester fiber mat insulation.

For the determination of the standing losses according to EN 12897, both hot water stores have been charged via an immersed electrical heating element with a nominal power of 3 kW. The standing losses according to EN 15332 were determined using an electrical heating wire with a nominal power of 290 W, immersed in the lower third of the store. The determination of the heat loss rate according to EN 12977-3 was performed using the internal heat exchanger intended for the connection to the solar thermal collector loop. Here, the 300 L store was charged with 3 kW at a flow rate of 360 L/h, the 500 L store with 5 kW at a flow rate of 600 L/h.

3. Test apparatus

The test procedures of the three considered standards require three different test setups. Usually this ends up with three different sets of sensors, hydraulics, data acquisition systems and further infrastructure due to the requirements of the specific test procedure. But based on the long-term experiences of SWT in combining several test procedures into one test facility, a test concept was developed that allows for testing the standing losses of hot water stores according to all three above mentioned standards with only one single test setup.

One step further represents the integration of this test concept into the world wide well-known and successfully distributed mobile all-in-one test facility for solar thermal systems and collectors. This concept enables testing of solar thermal systems according to two different standards and testing of solar thermal collectors according to another standard. And now also testing of hot water stores according to the energy label requirements is possible. Figures 1 shows the hydraulics of a test facility able to perform tests of four different types of samples acc. to six standards.

Figure 1: Hydraulics of the mobile all-in-one test facility (overview)

Figure 2 reveals a module for testing only the thermal performance of hot water stores acc. to EN 12977-3.

Figure 2: Module for testing the thermal performance of hot water stores acc. to EN 12977-3

The main advantage of this solution is obvious: Nowadays, the cost-effectiveness of such a test facility is of highest importance. Expensive sensors, data acquisition systems and other infrastructure must be purchased, maintained, calibrated, etc. only once. Further the flexibility with respect to both the selection of the test procedure as well as to the installation location of the test facility is impressive. Due to the setup based on a conventional 20 ft container, an installation, disassembly, transport to another test site and new installation is not only easy but also possible within shortest of time. Additionally, the space-saving setup must be mentioned, since test approaches for four different types of samples acc. to six different standards are implemented into only one test facility.

4. Results

Table 1 shows both the results of the survey related to the standing losses of the two bivalent hot water stores and the resulting energy label based on the EU regulation 812/2013.

Tab. 1: Standing losses in kWh/24 h determined acc. to the corresponding standards and the resulting energy label

	300 L store	500 L store
EN 12897 [kWh/24 h] / Label [-]	2.44 / D	2.53 / C
EN 15332 [kWh/24 h] / Label [-]	2.25 / C	2.71 / C
EN 12977-3 [kWh/24 h] / Label [-]	2.60 / D	2.85 / D

The highest values show the determination of the standing losses acc. to EN 12977-3. This is mainly due to the external charging of the hot water store. Since four hydraulic connections are necessary, additional thermal bridges are existent compared to the other two procedures where only an immersed electrical heating element and no hydraulic connection is required. Furthermore, a higher value of the standing losses results from the test procedure acc. to EN 12897 than from the procedure acc. to EN 15332 for the 300 L store; whereas the result is vice versa for the 500 L store. The reason for this is the evaluation procedure acc. to EN 12897: For the determination of the standing losses, time periods with durations of exactly 24 h have to be used. Therefore, the situation can happen that the hot water store has at the end of the test period a lower temperature than at the beginning. This was the case for the 500 L store and a lower value for the standing losses results. Additionally, the relative large switching hysteresis of 4 K tightens this problematic. The procedure acc. to EN 15332 requires a switching hysteresis of only 0.8 K. During the test of the 300 L store, these effects have been balanced more or less, since after the first 24 h sequence the store temperature was higher than at the beginning, but after the second sequence it was lower than at the beginning. Although, the results seem to be plausible in this case, this test and evaluation procedure is not suitable for the determination of reliable results and should be changed since the procedure itself can cause wrong values for the standing losses.

Contrary, the procedure acc. to EN 15332 starts and ends always at the power-on or power-off status of the controller. This ensures that the hot water store has the same temperature at the beginning and at the end of a test sequence. Therefore, the test periods are mostly longer than 24 h, but this is taken into account with a correction factor (24 h/duration of test period).

Table 1 shows that the applied test procedure influences also the classification of the hot water store with regard to the energy label. But this must be avoided, since it can be assumed that in future the energy labels of the hot water stores are mentioned without the applied test procedure.

5. Consequences for the fractional energy savings

To determine the consequences for the fractional energy savings based on the different test results related to the standing losses of hot water stores, a simulation was performed with the transient system simulation software TRNSYS in version 17. Two different solar thermal systems have been simulated:

- A typical solar thermal system for hot water preparation: store volume of 300 L, flat plate collectors with an aperture area of 4.66 m^2, inclination angle 45° facing directly the south
- A typical solar thermal combi system: store volume of 1,000 L, flat plate collectors with an aperture area of 14.26 m^2, inclination angle 45° facing directly the south

Both solar thermal systems supply a single family house with 128 m² living area at the location Würzburg with heat. The hot water demand amounts to 200 L/day at 45 °C and results in 2,945 kWh/a. The combi system supplies the heat for hot water preparation via an external fresh water station. The space heating is connected as a return flow increase. The heating demand of the building amounts to 71 kWh/($m^2 \cdot$a) or 9,090 kWh/a. The space heating operates in 50/30 °C modus. The overall heating demand amounts to 12,679 kWh/a including thermal losses of the store of 644 kWh/a.

For both stores the standing losses have been chosen in such a way that the stores achieve just the corresponding class of the particular energy label. For the maximum values of the standing losses at a temperature difference of 45 K between mean store and ambient temperature for the corresponding energy label see table 2. Since the energy label D is the energy class, which most market available hot water stores achieve, the lower labels have been not considered.

Table 2: Standing losses for the 300 L and the 1,000 L store

Energy label	Standing losses [kWh/24 h] 300 L store	Standing losses [kWh/24 h] 1,000 L store
A+	0.89	1.31
A	1.22	1.78
B	1.71	2.48
C	2.40	3.49
D	2.98	4.33

The requirements for the labels B, A and A+ are quite high. Presumably, up to now there are no hot water stores available on the market with one of these labels.

Table 3 and 4 show for both solar thermal systems the fractional energy savings f_{sav} and the absolute energy savings in relation to a store with the energy label D. Both values do not take into account the efficiency of the boiler. Additionally, the difference between the actual energy label and the next lower one is given.

For both systems, the biggest difference of the energy savings is at the step from label C to B. Therefore label B could be an economical optimum, especially since the requirements of the thermal losses of the stores are achievable with conventional insulation materials and acceptable insulation thicknesses. With a further increase of the insulation (and a further increase of the energy label, respectively) the additional achievable energy savings decrease. The lowest increase is at the step from label A to A+. This matter of fact surprises, since the effort to achieve the next better label becomes more and more with the increase of the label.

Table 3: Fractional and absolute energy savings for the solar thermal system for hot water preparation

Energy label	Fractional energy savings [%]	Absolute energy savings [kWh]	Difference to the next lower label [kWh]
A+	62.5	287	47
A	61.2	240	66
B	59.3	174	92
C	56.8	82	82
D	54.5	0	-

Table 4: Fractional and absolute energy savings for the solar thermal combi system

Energy label	Fractional energy savings [%]	Absolute energy savings [kWh]	Difference to the next lower label [kWh]
A+	31.8	326	49
A	31.4	277	80
B	30.8	197	106
C	29.9	91	91
D	29.2	0	-

6. Conclusions

The Commission delegated regulation 812/2013 supplementing the EU Energy Labelling Directive (Directive 2010/30/EU) allows four different test procedures for determination the standing losses of hot water stores. An implementation of these test procedures into one single test facility enables a cost-effective solution for manufactures and test labs to perform the tests acc. to the corresponding standards. For a further increase of the effectiveness with regard to costs, space and flexibility, the test procedures have been implemented into the mobile, all-in-one test facility of SWT.

The comparison of the test procedures for the determination of the standing losses of hot water stores showed that the different procedures can lead to different results. The reasons for this are the different types of hydraulic connections of the stores (amount of thermal bridges due to external or internal charge of the stores) but also the deficiencies of the test procedures itself: The test procedure acc. to EN 12897 does not ensure that the store has the same temperature at the end of the test period as at the beginning. Here a careful revision of the standard seems to be mandatory. But basically, the energy labels are a good way to compare stores with the same volume on the basis of their insulation characteristics.

Furthermore, the additional achievable energy savings are important. Up to the label B, for both systems (hot water preparation and combi system) the additional achievable energy savings increase, but for the higher labels A and A+ the additional energy savings decrease. This actual situation should be recognized by the manufacturers and the end consumers for a correct rating of the energy labels. For the manufacturers it is evident to check if it is reasonable to achieve the higher levels A and A+. Probably a further increase of the energy label of a store becomes more difficult the higher the store is already classified. Therefore, from an economic point of view, it may be more reasonable to realize further energy savings with other measures, e.g. a larger collector area, than with a better energy labeled store (A or even A+).

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