IEA HPP Annex 28 – standard testing and performance calculation for integrated heat pump systems

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Overall energy rating of buildings including installed HVAC systems as in the frame of building energy certificates to be introduced in the EU gets more important on the background of climate protection. Innovative multifunctional system layouts for combined space heating, domestic hot water production and ventilation, however, are often not covered by current product test standards and calculation methods. Therefore, IEA HPP Annex 28 has delivered recommendations for comprehensive testing and subsequent performance calculation of residential heat pump systems with combined space and domestic hot water heating for standardisation organisations. First comparisons with systems in field monitoring of different types of combined operating heat pumps, including a ventilation compact unit with air-source heat pump, show deviations between calculated and monitored overall seasonal performance in the range of ±6%, approving the feasibility of the method. The recommendations are currently implemented in the frame of the revision of the European heat pump test standards for the domestic hot water testing and calculation standards in the frame of the EU Directive on the Energy Performance of Buildings (EPBD).

1. Background

1.1 Motivation

Due to reduced energy needs of low energy buildings, new multifunctional system layouts were introduced in the market, which cover the different building needs for space heating (SH), domestic hot water (DHW) and ventilation with one unit. However, standard calculation methods for the seasonal performance factor (SPF) as basis for the assessment of primary energy consumption or CO_2 emissions, and the required component characteristics from product testing are missing or do not cover innovative system layouts. Therefore, the different stakeholders require uniform standard test procedures and subsequent calculation method:

- *Manufacturers* need regulations for providing precise and uniform technical data of their components derived from standard testing.
- *Designers* need methods to enable a comparison of different heating systems or system layouts in the design process.
- *Consumers* need a clear indication of environmental impact and energy costs as a guideline for their purchase decision, e.g. by transparent labelling.
- *Consultants and policy makers* need uniform values to set targets in regulations and directives on the background of climate protection policies.

1.2 Standardisation work

This is addressed by two mandates of the EU to the European standardisation organisation CEN:

- In Mandate 343 a set of calculation standards for the building and the different building technologies is elaborated to support the implementation of the EU Directive on the Energy Performance of Buildings (EPBD) (EU 2002).
- In Mandate 324 test procedures of different domestic hot water household appliances are to be harmonised in the frame of the EU Energy Labelling Directive. The mandate contains EU reference tapping cycles for the testing.

In the frame of these two mandates a revision of existing testing and calculation standards is presently in progress.

2. Co-normative research in IEA HPP Annex 28

IEA HPP Annex 28 was accomplished as 3-year research project in the heat pump program (HPP) of the International Energy Agency (IEA) in the years 2003-2005 with the nine participating countries and AT, CA, CH, DE, FR, JP, NO, SE and USA. The scope and objective of the IEA HPP Annex 28 was to deliver

- *comprehensive test procedures* for combined operating heat pumps for SH and DHW with minimum testing requirements
- *subsequent transparent and easy-to-use calculation methods* for the SPF of combined operating heat pumps

as recommendations to standardisation organisations. Thereby, two types of marketable combined operating heat pump systems have to be differentiated

- *alternate combined operation*, where the heat pump is switched between SH- and DHW-operation, and
- *simultaneous systems*, where SH and DHW energy is produced at the same time.

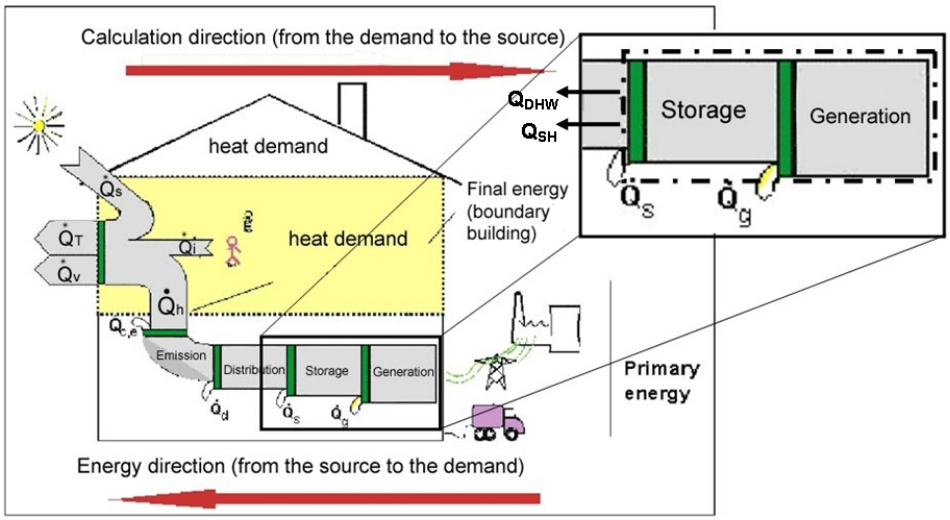

Figure 1: System boundary of Annex 28 in the calculation scheme of the EPBD (CEN 2006a)

Common simultaneous system layouts use refrigerant desuperheating and condensate subcooling as well as cascade system configurations.
The system boundary for the testing and calculation has been defined to include the heat pump, attached SH and DHW storages and eventually installed back-up heaters in order to cover the most common system configurations on the market. Figure 1 shows the system boundary in the calculation scheme of the EPBD (CEN 2006a).

3. Results

3.1 Markets

Europe has mostly alternate combined operating systems on the market while North America mainly uses simultaneous systems with desuperheating for domestic hot water production, sometimes in combination with combined cooling/air conditioning and domestic hot water production. In Japan, heat pump water heaters with CO_2 refrigerant, so-called Eco-cute systems, became very popular, and combination of such systems with both floor and radiator heating has been introduced in the market.

3.2 Test procedure

In the participating countries test procedures for the SH-only and DHW-only operation are in use, while combined operation is only treated for the specific case of an air-to-air heat pump with desuperheater.
Thus, the testing is extended based on the existing standards for the single operation modes. In order to cover the variety of different system configurations testing is performed as black box testing where only the values at the system boundary are evaluated. It has to be secured that the basic operation modes are covered by the testing.
Testing performed in Annex 28 approved that alternate combined operating systems can be covered by the existing standards for the SH-only and DHW-only operation mode. For ventilation compact units with heat pump the additional impact of the ventilation system has to be considered. Since most compact units on the market are of alternate type, the basic operation modes for the testing are ventilation-only, combined ventilation and heat pump SH-mode, and combined ventilation and DHW-mode.
For simultaneous combined operating systems, additional testing is required, since the heat pump characteristic may change significantly. Therefore, based on the testing for the SH-only and DHW-only the simultaneous combined operation is tested by performing the DHW tapping cycle during the SH operation. Due to the black box testing, however, only the total electrical energy input to the heat pump can be monitored, so the allocation of the electrical energy to the operation modes is not possible. Thus, the combined operation is evaluated as own operation mode, since in the end, the overall seasonal performance is the relevant characteristic number.

3.4 Calculation method

Input data of the calculation method are the energy needs of the SH and DHW distribution system (cf. Figure 1), test points of the unit as well as meteo data of the site, the system configuration and control details (e.g. heating curve, balance point).
The cumulative annual frequency of the outside air temperature is divided into temperature classes (bins). In the centre of each bin, an operating point is evaluated with

regard to the heat pump operation at these specific ambient conditions based on the product testing, i.e. the operating points shall be chosen at known test points of the unit. The operating point is considered to characterise the heat pump operation of the whole bin. The areas of each bin correspond to heating degree hours, which are proportional to the energy need in the bin. Thus, a weighting of COP-values at the operating conditions with the energy fraction of the bin and a subsequent summation of all bins delivers the seasonal performance.
Electrical back-up heaters and recovered heat by a ventilation heat recovery – only, if not already taken into account in the building energy calculation - can also be considered by an evaluation of the respective area in the cumulative frequency diagram.

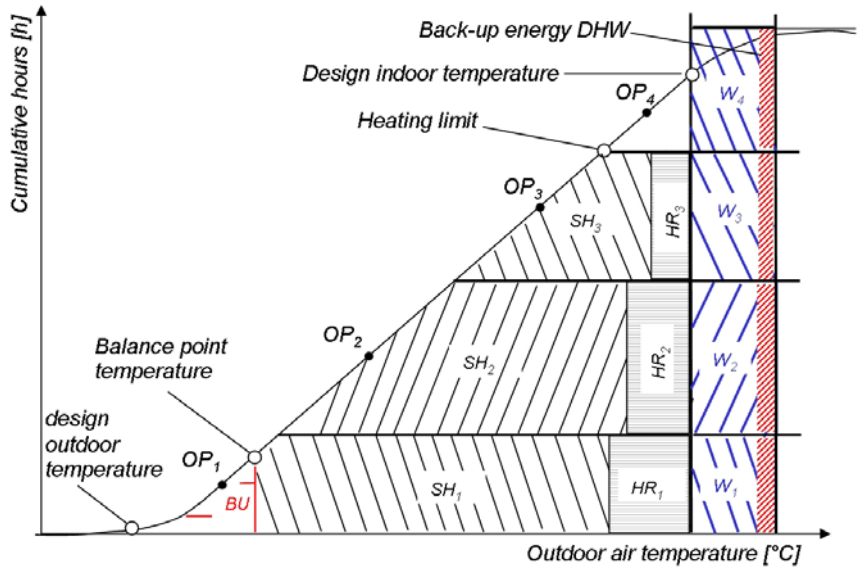

Figure 2: Principle of the bin method for multifunctional system for SH, DHW and ventilation with heat recovery unit (alternate mode) (OP - operating point, BU – back-up, SH – heat pump SH mode, heat pump DHW mode, HR – heat recovery unit)

For DHW operation, a similar calculation is performed based on standardised testing results of DHW-testing, e.g. for Europe according to EN 255-3.
In simultaneous combined operating systems, a third operation mode, the combined operation, has to be introduced based on the extended test procedure due to the change in the heat pump characteristic. The estimation, how much combined operation takes place in the bin is evaluated by the running time of each mode, which is determined by the respective capacity of the heat pump and the energy need in the bin.
The overall seasonal performance can be calculated by weighting of respective operation modes, i.e. SH-only, DHW-only and combined operation.

3.4 Comparison of the calculation to field monitoring

Results of the calculation have been compared to field monitoring results for two direct expansion ground source heat pumps (only SH mode), one ground source brine-to-water

heat pump (SH, DHW mode) and one air-source heat pump compact unit (SH, DHW and ventilation). Deviations between calculated SPF values and field monitoring results are in the range of ±6%.
Figure 3 presents the system boundaries used for the evaluation of the ventilation compact unit with air-source heat pump, which is installed in a single family low energy house according to the Swiss MINERGIE® standard (Afjei 2007).

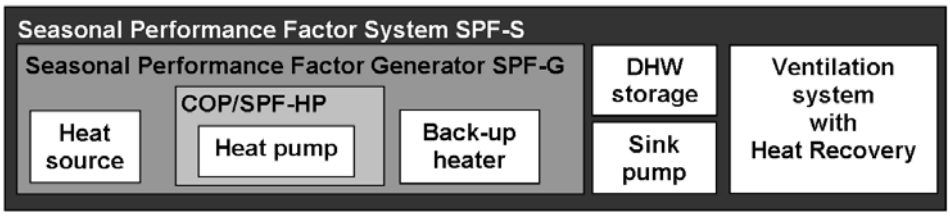

Figure 3: System boundaries for the assessment of the monitored compact unit

The SPF-HP comprises the system boundary according to the European heat pump testing. The Generator SPF (SPF-G) is the ratio of the produced energy of all generators (heat pump, back-up) to the respective electrical energy input and is well suited for the comparison to other heat generators like boilers. The System SPF (SPF-S) is related to the energy need and is calculated as ratio between the used energy (incl. the recovered ventilation energy) and the total electrical energy input to the entire system (incl. auxiliaries and electrical input of the ventilation).
Results of the overall SPF for the respective system boundaries are depicted in Tab.1.

Tab. 1: Monitoring and calculation overall SPF results for a ventilation compact unit with air-source heat pump installed in a low-energy house acc. to MINERGIE®

	Monitoring (Reference)	**Calculation**	**Difference**
SPF-HP	3.66	3.54	-3.3%
SPF-G	3.42	3.42	0.0 %
SPF-S	3.06	2.96	-3.2%

4. Conclusions

IEA HPP Annex 28 has elaborated consistent test procedures and SPF calculation methods for multifunctional heat pump system layouts based on the existing standards for SH-only and DHW-only operation mode. Comparison to monitoring results approves the principle feasibility of the testing and calculation, even though only some of the marketable system types could be field-monitored in IEA HPP Annex 28.

4.1 Approximations of the calculation

The calculation method implies some simplifications. One assumption is the redistribution of the energy according to heating degree hours which are only dependent on the outside air temperature. In low and ultra-low energy houses used solar and internal gains may have a significant impact on the energy redistribution, too. This can be approximated by an adjustment of the upper temperature limit for heating based on the quantity of solar and internal gains as depicted in Figure 2.

Moreover, controller impact can not be considered in detail, since often, details are not known. Therefore, controller impact is simplified to standard settings dependent on the system layout, e.g. for the running time of auxiliaries.

4.2 Implementation of results

The results are currently implemented in the respective CEN standards. The calculation method has been implemented in the CEN draft standard prEN 15316-4.2 (CEN 2006b) in the frame of the EPBD and in DIN V 18599 (DIN 2007) as national German implementation of the EPBD. Recommendation on testing is treated in CEN/TC 113/WG 10 for the revision of the heat pump DHW testing.

4.3 Information on IEA HPP Annex 28

Further information on IEA HPP Annex 28, workshop publications and related documents can be found on the Annex 28 website at http://www.annex28.net.
The final report of IEA HPP Annex 28 (Wemhoener 2006) is available at the IEA Heat Pump Centre and can be ordered via Internet on http://www.heatpumpcentre.org, category Publications/Reports.

5. Acknowledgements

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6. References

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