IEA Heat Pump Programme

IEA HPP Annex 28

Final Report IEA HPP Annex 28

Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating

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In the frame of the Heat Pump Programme (HPP)
of the International Energy Agency (IEA)

Executive summary

Motivation for IEA HPP Annex 28

Which space heating and domestic hot water (DHW) system is the best for my application?

Even though this question appears fundamental, it is still not easy to answer, since standardised characteristic numbers with regard to the energy consumption - or better the standardised calculation methods to derive these numbers - for the comparison of heating systems are still missing, in particular on an international basis.

On this background IEA HPP Annex 28 entitled "Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating" was launched in January 2003 in the framework of the Heat Pump Programme (HPP) of the International Energy Agency (IEA) with nine participating countries: AT, CA, CH, DE, FR, JP, NO, SE and USA. The Annex 28 was initiated by the Swiss Federal Office of Energy (SFOE). The project management (operating agent) has been accomplished the Institute of Energy in Building (IEB) of the University of Applied Sciences Northwestern Switzerland (up to the end of 2005 Institute of Energy of the University of Applied Sciences Basel) in charge of the SFOE. The Annex 28 was finished by the end of 2005.

The objective of the Annex 28 is to fill this gap of missing standards and develop comprehensive test procedures to calculate the seasonal performance factor (SPF) of combined operating heat pumps as a recommendation to international standardisation committees.

The scope of the Annex is restricted to combined heat pump systems including ventilation compact units with heat pump for low energy houses, but the characteristic number Seasonal Performance Factor is suited to perform comparisons to other heating systems, too.

Actually, the SPF is the basis for a calculation of other characteristic numbers like primary energy consumption or CO_2-emissions, which for instance is used for heating system comparison in the framework of the EU Directive on the Energy Performance of Buildings (EPBD). In the frame of the Directive, a comprehensive set of standards is developed by the European standardisation organisation CEN, which is meant to support and facilitate the implementation of the Directive in the EU member states. Switzerland as EFTA-member has to implement the CEN standards of the EPBD. The EPBD comprises as well the introduction of an building energy certificate, which displays the characteristic numbers in form of a label, so that in case of a change of the building owner of tenant the energetic quality of the building can be assessed by the building energy certificate. Moreover, optimisation potentials are included in the certificate. Switzerland is not obliged to introduce the energy certificate for buildings, but an introduction in Switzerland on a voluntary or compulsory basis is in discussion.

Especially new system developments using combined operation are not covered by existing standard testing or calculation methods. Thus, the application of the test procedures and the calculation methods developed in the framework of IEA HPP Annex 28 is manifold:

- Manufacturers have regulations for providing precise and uniform technical data
- On the other hand, system layouts can be compared in the design process
- Moreover, energy labels or building standards can be based upon the SPF.
- Hence, a uniform testing and calculation is necessary to overcome trade barriers and enhance consumer confidence, e.g. by transparent labelling.
- Last but not least a better notion of the performance can stimulate system improvements.

Task 1: State-of-the-art survey (markets and standardisation)

The work in the IEA HPP Annex 28 started with a characterisation of the markets of combined operating heat pump systems as well as an enquiry of the systems under development in the participating countries. Furthermore, the status-quo in the respective standardisation both on the international level of the European, American and Japanese standardisation and on the national level of the participating countries was analysed.

Results revealed that European markets are dominated by alternate combined operating systems, i.e. switching the heat pump to either the space heating or DHW function. However, simultaneous combined operating heat pumps, i.e. heat production for both functions at the same time, e.g. by desuperheating and/or condensate subcooling, can also be found on the markets. In Sweden, Norway, France and Austria, different system configurations using desuperheating for the domestic

hot water production are on the market. Further simultaneous operating systems are under development.

European standardisation comprises standards for the testing of the space heating-only operation and the DHW-only operation. However, combined operation is not yet treated in the standards. A common calculation approach for the seasonal performance factor on the European level does not exist, either, but is presently under development in the framework of the EPBD.

American markets are dominated by simultaneous combined operating systems using desuperheating basically by air-to-air heat pump systems. Standards on the testing and calculation of the space heating-only and the DHW-only operation exist as well as a standard for testing and calculation of the simultaneous combined operation restricted to the system configuration of air-to-air heat pumps with desuperheater.

In Japan, an alternate combined operating heat pump system for DHW and a floor heating system has recently been introduced in the market. However, standards for the combined operation do not exist, yet, only standards for the space heating-only and the DHW-only operation modes are in use.

Results of the survey (Task 1) were presented in detail in an Interim report delivered to the Executive Committee of the IEA Heat Pump Program in March 2004.

Conclusions of the results

Based on these results it was decided to cover the combined operating systems by an extension of the existing standards.

- Concerning the system boundary the heat generator as well as attached storages and back-up heaters are included, since many integrated systems contain these components in one casing. Concerning the calculation scheme according to the EPBD, this corresponds to the system boundary “generator” and “storage”, see Fig. 1.

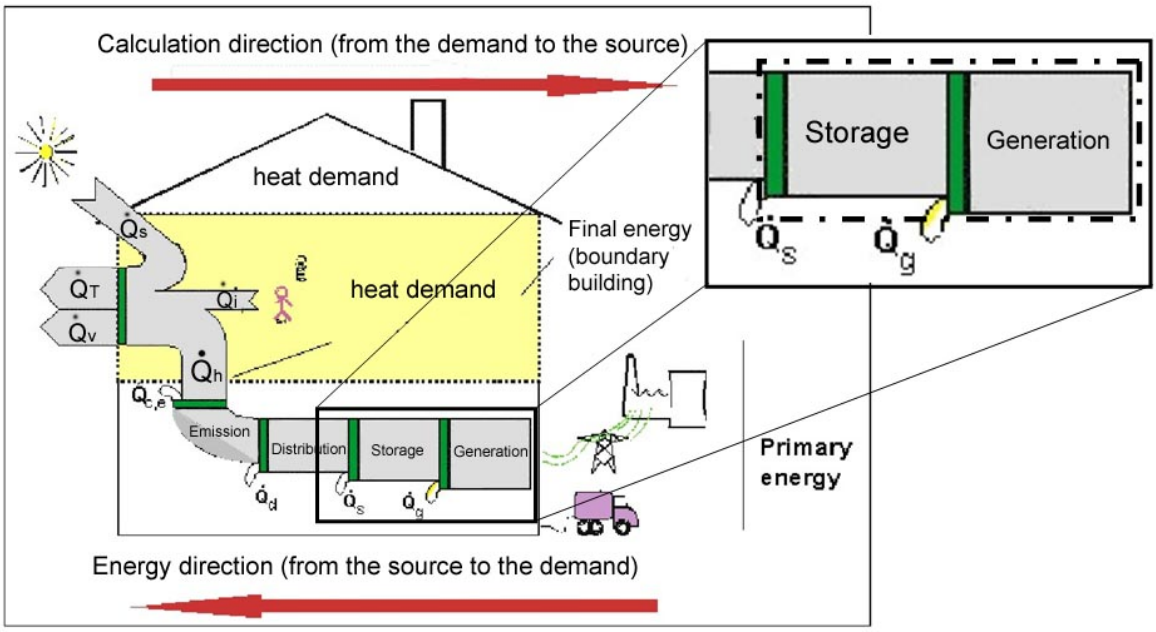

Fig. 1: Calculation scheme in the framework of the EU "Directive on the Energy Performance of Buildings" (EPBD)

- For the testing, a black box approach according to Fig. 2 was chosen, i.e. only values on the system boundary are measured in order to facilitate and unify the handling of different system layouts. Highly integrated systems are to be tested in system testing, while for other systems a component based testing can be applied.

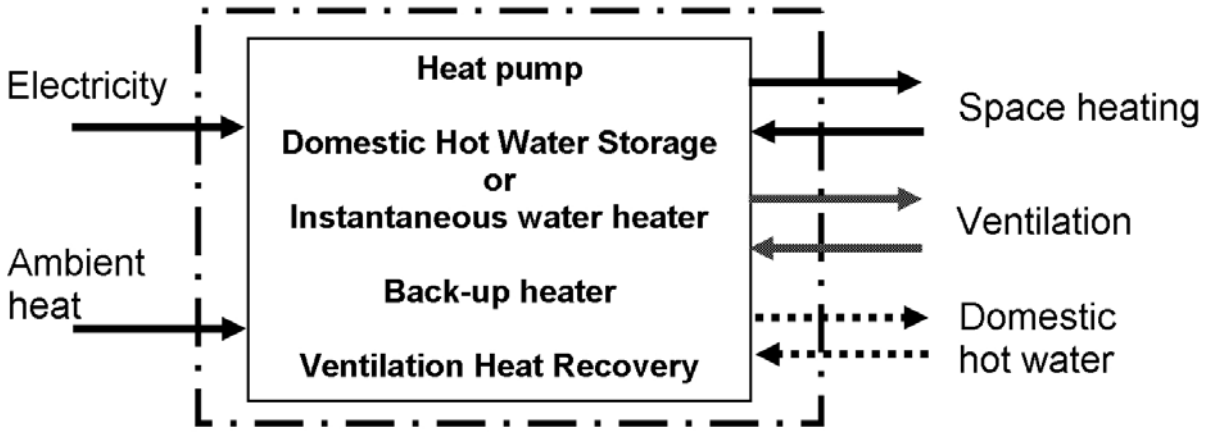

Fig. 2: Black box testing

- For the calculation a temperature class approach (bin method) was chosen, since it is the best compromise between exactness of the results and computational expense and is already introduced in the American standardisation for the calculation of the space heating-only operation and in national guidelines in some European countries.

Task 2: Test procedure

Testing of different combined operating heat pump systems in both alternate configuration and simultaneous configuration according to existing standards and standard proposals have been performed. Feedback of the evaluation of these actual standards in operation and the proposed ones will be transferred to the respective working groups of the standardisation organisations.

Evaluation of the test procedure confirmed, that alternate combined operation can be covered by testing of SH-only and DHW-only operation according to existing standards, since the heat pump is either in the one or the other of the two operation modes. Therefore, the heat pump characteristic does not change for alternate combined operation with regard to the single operation modes and no additional testing is required for alternate combined operating systems.

Based on these experiences with the standards the extension for combined operation has been accomplished by introducing a third test for the combined operation mode by performing the cycle of the DHW-only testing during operation of the heating system. Evaluation of the combined testing, however, is not that simple as in space heating-only mode and DHW-only mode, since allocation of electrical energy input to the different operation modes is not obvious. On the other hand, calculation shall yield an overall seasonal performance factor of the heat pump system. Thus, combined operation can also be treated as an additional operation mode with an own characteristic, which significantly simplifies the evaluation of the combined testing.

Task 3: Calculation method

As stated before, the calculation shall be performed on the basis of a bin method. The principle of a bin method is depicted in Fig. 3.

The cumulative annual frequency of the ambient dry bulb temperature is divided into temperature classes (temperature bins). In the centre of each bin, an operating point is evaluated with regard to the heat pump operation at these specific ambient conditions, which are determined by the standard component testing according to the respective standard for the space heating-only operation. Therefore, the operating points should be chosen at known test points of the heat pump. 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, and consequently characterises the energy consumption in the bin. Thus, a weighting of the operating conditions with this energy fraction of the bin and a subsequent summation of all bins delivers the seasonal performance.

Electrical back-up heaters are also considered by an evaluation of the respective area in the cumulative frequency diagram, in Fig. 3 the area BU. The straight limit is thereby an approximation,

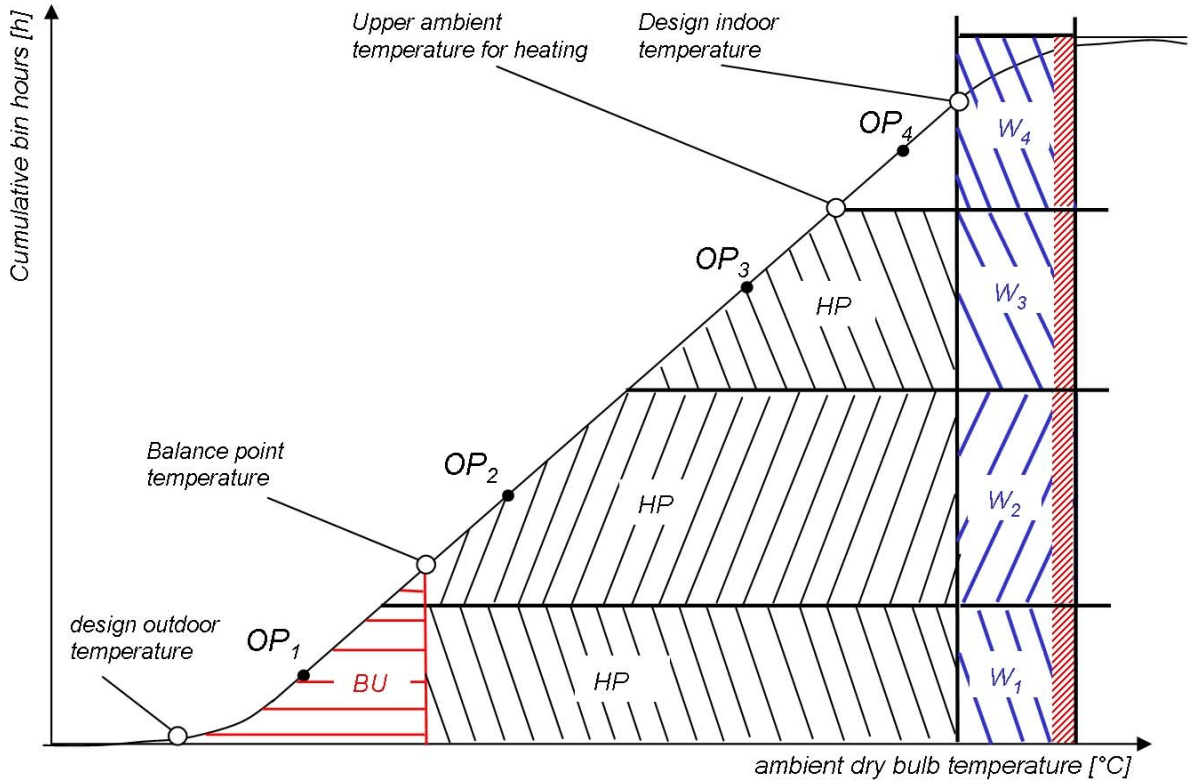

Fig. 3: Principle of the bin-method for alternate SH and DHW operation with parallel back-up operation

which is corrected by an evaluation of the running time: The running time of the heat pump in the bin is limited by the bin time, so if the back-up fraction is too low, the running time of the heat pump is longer than the bin time. In this case, more back-up energy is calculated due to the limit of the running time to the bin time.

For the domestic hot water operation, a similar calculation can be performed based on standardised test results of DHW-testing, e.g. for Europe according to EN 255-3. The overall seasonal performance can be calculated by weighting the single seasonal performance factors with the annual energy consumption in space heating and domestic hot water operation, respectively. Thus, the alternate combined operation can be covered in this way, since these systems are either in space heating mode or in domestic hot water mode and consequently, heat pump characteristic is defined by the respective operation.

In simultaneous combined operation, however, the heat pump characteristic may change significantly between the single and the combined operation mode. Thus, a third operation mode, the combined operation has been introduced based on the test procedure already described. The estimation, how much combined operation takes place in the bin is done by an evaluation of the running time of each mode, which is determined by the respective heating capacity of the heat pump and the energy requirement in the bin.

The overall seasonal performance can be calculated by energy weighting of three operation modes, i.e. SH-only, DHW-only and combined operation.

Obviously, the calculation method implies some simplifications in order to keep the calculation simple. One shortcoming with regard to low and ultra-low energy house may be the redistribution of the energy requirement to the bins, that is only dependent on the heating degree hours and thereby on the outside temperature, while in low-energy dwellings the solar gains may have a higher impact on the energy distribution. This can be considered by an adjustment of the upper ambient temperature for heating, see Fig. 3. A further shortcoming is that controller layout and controller setting can only be partly taken into account. In particular the energy production in combined operation may also depend

on the controller settings. The effects can be taking into account by correction factors for typical control situations depending on the system configuration. Moreover, controller settings for auxiliary components like pumps are often not known in detail and standard situation have to be evaluated.

Validation of the calculation method and the test procedure

To validate the test procedure for simultaneous operation it has been applied to a simultaneous combined operating exhaust-air heat pump. The test delivered representative and reliable values. However, some test points require long testing time, which seems inevitable to enable a fair comparison. Moreover, it could also occur that the test procedure has to be adapted to special configurations of heat pumps in order to make a fair comparison between different system configurations.

To validate the calculation method with real data, field monitoring of pilot plants with combined operating heat pump systems were launched in the framework of the IEA HPP Annex 28. The contained results give a first impression of the exactness of the method and the impact of different approaches.

Three direct expansion ground source heat pumps were evaluated for space heating operation. An air-to-water compact unit and a ground-source brine-to-water heat pump have been evaluated for space heating and DHW-operation. Differences between the calculation and the measured values are in the range of ± 6% for the overall seasonal performance factor. Considering the simplifications in the approach these values are satisfactory and show the applicability of the method.

Not all types of system configuration were tested in the Annex 28 nor were monitored in field measure-ments. Actually, no field measurements with simultaneous combined systems could have been evaluated, which is a task for further project work.

Implementation of results

The implementation of the results of the IEA HPP Annex 28 has already begun in the framework of the revision of standards in connection with the European Performance of Buildings Directive (EPBD). The calculation approach of IEA HPP Annex 28 has been implemented in the heat pump draft of prEN 15316-4.2 (formerly prEN 14335). After the public enquiry, which ended in March 2006 the draft is currently in the final enquiry call formal vote. It will probably become a European standard by the end of 2007.

Germany has already integrated a slightly modified calculation method of the IEA HPP Annex 28 on a monthly basis in the national standard DIN V 18599 as implementation of the EPBD on the national level.

Concerning the test procedure, results are treated in the CEN working group CEN/TC 113/WG 10 for the revision of the EN 255-3 for the DHW testing under the auspices of the Swiss heat pump test centre WPZ Buchs.

Implementation of proposed testing and calculation for ventilation compact units with heat pump is not yet clear, since presently there are no CEN working groups committed to these systems. However, a joint working group with members of the ventilation and heat pump testing technical committee is planned, which gives the perspective of coherent testing of ventilation compact units with regard to ventilation testing and heat pump testing.

Conclusions

IEA HPP Annex 28 has delivered a calculation method for the Seasonal Performance Factor for combined operating heat pump systems including proposals for heat pump compact units. An adapted test procedure has been developed in parallel in order to deliver the necessary input data for the calculation.

First validation of the calculation method shows satisfactory results. Five systems comprising direct expansion, brine-to-water and an air-source compact unit have been compared to field results within the Annex 28.

Results of the Annex 28 for the calculation have already been implemented in upcoming standards in the framework of the EPBD and revision of the heat pump DHW testing. Thereby, a uniform calculation method backed-up by the adequate testing seems realistic. In this respect, the objective of the IEA HPP Annex 28 has been achieved on the European level.

Concerning the international standardisation, the calculation approaches are quite similar, since all methods are based on the bin approach. However, testing is still different due to the different systems on the market. Hence, to introduce internationally uniform standards, mainly the test standards have to be unified, e.g. on ISO level. IEA HPP Annex 28 has delivered an evaluation of the relevant test standards in Europe, North-America and Japan and can thus accelerate this process.

Further information on the project, the participants, publications and further documents in connection with IEA HPP Annex 28 are available on the Annex 28 website at http://www.annex28.net.

The final report is available at the IEA Heat Pump Centre and can be ordered in the category Publications/Reports at http://www.heatpumpcentre.org.