

Test Procedures and Seasonal Performance Calculation for Residential Heat Pumps with Combined Space and Domestic Hot Water Heating

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In January 2003 the new Annex 28 of the IEA Heat Pump Programme with the above title has started. 10 countries are participating in the Annex 28 and at the kick-off meeting in Muttenz, Switzerland, a first step to coordinate the project work and the contributions of the single participants has taken place. The article describes the objectives and the actual state of the new Annex 28.

Introduction

Combined heating and hot water production is gaining interest, as energy directives, which limit the building energy consumption of new buildings, yielded a considerable decrease of the heating requirement since the beginning of the nineties. Henceforth, the energy for the domestic hot water (DHW) production has a growing impact on the thermal energy demand. This is reflected in an increased number of combined working system configuration on the market and under development. Due to changes to natural working fluids, in particular CO₂, process layout can be favorable for a combined production by decoupling high temperature heat from the process to produce DHW.

However to assess the potential of energy reduction by a combined production of space heating and domestic hot water adequate test procedures for the components and calculations method for the overall seasonal performance factor (SPF) have to be available as a common standard. Actually in European standardization test procedures are restricted to separate space heating (or cooling) and domestic water heating. Thus only alternative operation of combined working systems is covered by existing standards.

Objectives, structure and time schedule

In Annex 28 the testing of the most common integrated heat pump systems using the following mechanisms will be investigated:

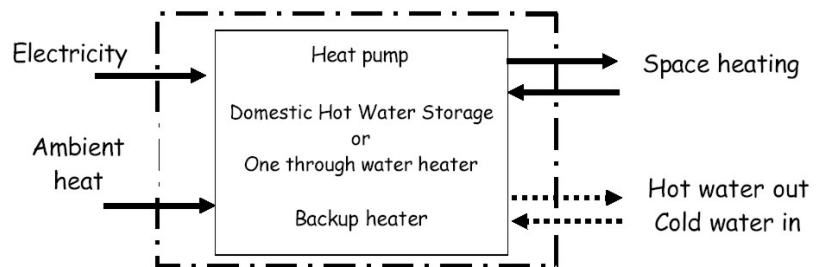


Figure 1: system boundary as black box (taken from [1])

- switching heat pump between space heating and DHW (alternate mode)
- cascade heat pump with condensate subcooling of the lower stage as heat source of the upper stage
- desuperheating for DHW and condensing for space heating

There is no restriction to system configurations using the above methods.

Expected results according to the legal text [1] are to establish a test procedure that yields the necessary data in order to calculate the overall Seasonal Performance Factor of such heat pump systems with a minimum requirement for testing equipment and testing time, and, as the second objective, to work out an easy method to calculate the Seasonal Performance Factor for the heat pump systems. The system boundary is shown in **figure 1**. The system includes the heat pump, the hot water storage (or a one through water heater respectively) and an optional supplemental back-up heater. Concerning heat distribution the annex has been opened for air systems as well.

To avoid doubled effort, the results should be communicated to national and international standardization institutions as soon as possible with the aim to establish the developed test procedure and calculation method in comprehensive and uniform standards.

To achieve these objectives the Annex has been structured in three tasks:

In **Task 1** a thorough analysis of the state of the art in combined heat and hot water production with residential heat pump is to be carried out. This comprises

- a market survey of commercially available systems in the participating countries as well as systems under development
- a definition of system boundaries on the basis of the found systems and a decision, if only values at the system boundary are to be used in the methods (black-box concept, see figure 1) or if information from inside the system boundary should be available as well (grey-box concept)

- a survey of existing standards for component testing and the calculation of SPF for heating and domestic hot water application
- establishment of boundary conditions, that may have an impact on the design and performance of the systems, e.g. hot water temperature, tapping profile, interrupted electricity supply, building load etc.
- definition of the parameters required to calculate the overall seasonal performance factor of the systems

Task 1 has started in January 2003 and is to be finished in June 2003. Country reports will be sent to the operating agent by September 2003 and results will be discussed on the second meeting in October 2003.

Task 2 and **Task 3** are worked out in parallel, as they depend on each other. They start in July 2003 and continue till December 2004, where a workshop to present the results of the Annex 28 is to be held.

Task 2 has the focus on the development of the test procedure, which basically will deliver the relevant input data needed for the calculation method of the seasonal performance. Moreover possible output data from the test procedure could be further characteristics of

the component, e.g. the operation limits. Subtasks of Task 2 are thus

- Assessment of existing test procedures for space and domestic water heating using heat pump systems, e.g. EN 255, ASHRAE 124 or ARI 470.
- Determination of missing items for the testing of combined space and water heating.
- Development and detailed documentation of a comprehensive test procedure for heat pump systems with alternative or simultaneous space and domestic water heating and the test parameters needed.

Task 3 is to develop a calculation method for the overall seasonal performance factor based on publicly available data, in particular the component characteristics delivered by the test procedure or manufacturer data. Subtasks of Task 3 are thus

- Assessment of existing calculation methods for the seasonal performance factor
- Determination of missing items for combined space heating and hot water requirements
- Definition of data that have to be delivered by the test procedure

- Development and documentation of the calculation method for alternative and simultaneous working heat pumps

Exchange of intermediate results and coordination of the tasks will be done on two meetings, which will take place in October 2003 and June 2004.

Participants and working fields

The Operating Agent for this Annex is Switzerland, represented by the "Institute of Energy at the University of Applied Sciences Basel (FHBB)".

The other participating countries with the respective institution are (in alphabetical order):

- Austria (Arsenal research)
- Canada (LTE Hydro Quebec)
- France (EdF, CETIAT)
- Germany (TU Dresden, Viessmann Werke GmbH)
- Japan (University of Tokyo)
- Norway (SINTEF)
- Sweden (SP)
- UK (Kensaengineering Ltd.)
- USA (DOE)

The activities of the participating countries are different, which increases the opportunity to create a comprehensive standard, which is applicable for a large number of systems.

In the following the activities of the countries and the focus concerning Task 2 (test procedure) and Task 3 (calculation method) are shortly described. **Table 1** gives an overview of the projects and their focus.

Austria

Direct expansion systems with desuperheating in the storage – testing, field measurements and calculation.



Figure 2: participants of the kick-off meeting in Muttenz, Switzerland

Tab. 1: Overview of the contributions to the Annex

	Task 2: Test procedure		Task 3: Calculation	Heat source	Refrigerant	System
	Test rig	field				
AU	X	X	X	ground		Direct expansion, Desuperheating
CA	X	X		B/W		Desuperheater, Heating/cooling/DHW
FR						
CE	X	X		A/W, B/W	CO ₂	Alternative and combined
EdF			X	A/A		Heating and cooling
DE						
TU D	X			A/W, B/W		Desuperheating/Condensate subcooling
Viess.			X	exhaust air		passive house systems
JP	X			A/W	CO ₂	Alternative and combined Event inverter drive
NO	X	X		ground	CO ₂ /R407C /HC	Heating and DHW, desuperheating, condensate subcooling, internal HX
SE	X		X	exhaust air A/W,B/W		Heating and DHW
CH	X		X	A/W, B/W		Heating/DHW, condensate subcooling
UK	X		X	W/W,B/W		DHW/cooling/desuperheating
USA						Project development

Canada

Field test for monofluid heat pumps with desuperheater for domestic hot water (DHW) as well as test rig measurements for ground source heat pumps with space heating, DHW and cooling.

France

CETIAT:

Test rig measurements of alternative operating A/W heat pump with CO₂ as working fluid and field measurements of A/W and B/W heat pumps.

EdF:

SPF calculation method for A/A heat pumps for heating and cooling (combined with test procedure)

Germany

TU Dresden:

Test rig measurements of A/W heat pumps and field measurements with B/W heat pump equipped with desuperheating and condensate subcooling.

Viessmann Werke GmbH:

Calculation method for unitary systems for passive houses using exhaust air.

Japan

Test rig measurements for alternative and combined systems with CO₂ as working fluid, eventually inverter driven heat pumps.

Norway

Test rig measurements of heat pump with hydrocarbons as working fluid at combined operation, field test for CO₂ / R 407 C systems, development of an adequate test procedure.

Switzerland

WPZ:

Test procedure for small scale systems for alternative and combined operating systems with condensate subcooling

FHBB:

Calculation method for the systems above.

Sweden

Test rig measurement and calculation method for exhaust air systems.

UK

Test rig measurement for combined DHW and cooling heat pumps with desuperheating, twin condenser, calculation method for W/W and B/W heat pumps with combined DHW and cooling.

USA

The USA has not attended the kick-off meeting. According to information of Mr Ryan, the USA is in the state of project development to join the Annex.

Results of the Kick-off meeting

Besides getting to know the other participants and organizational issues, preliminary discussion led to the following results.

Motivation of the participants to join the annex is:

- characterization of system behavior by evaluation of standardised test conditions.
- studies of the system behaviour.
- a common standard for different countries (to facilitate trading).
- calculation of a key value needed to evaluate seasonal performance (SPF).
- sensitivity analysis for different boundary conditions (meteo data, DHW ratio, building standard, temperature requirements, etc..).
- comparison of different heat pump systems (with regard to application).
- comparison of different heating systems (background: market penetration).

The following preliminary criteria for the definition of systems to be investigated were worked out:

- used energy
focus on heating and DHW (cooling: add-on modules for cooling and inverter-driven systems)
- heat sources
ground (DX, brine), water, ambient air, exhaust air
- system boundary
all before distribution system

The following requirements for the test procedure and the calculation method were defined

test procedure:

- standardised testing points for all countries as defined in EN 255 or prEN 14511, respectively

A possible concept is to split the test procedure in a

- basic testing procedure which is required in every case
- and a
- comprehensive test procedure with extensions for different systems as add-on modules of special test procedures required for the respective system or boundary condition, e.g. an obligatory testing point at -15°C ambient air temperature only for cold climates

The basic part of the test procedure should at least contain the

- testing points
- measurement of the operation limits
- consider boundary conditions e.g. with regard to legionella prevention.

calculation method:

- hand calculation method.
- transparent method, i.e. clear source of parameters and/or factors.
- applicable for:
 - different consumption of DHW (characteristic number for fixed tapping pattern, but sensitivity analysis for other tapping patterns or ratio DHW possible)
 - different building standards
 - bivalent systems
 - different boundary conditions (meteo data, temperature requirements)
- method backed-up and validated by computer simulations and field measurements.

A definite decision on the above points for the test procedure and calculation method is to be made on the next meeting in October 2003. Focus for this meeting is the system definition derived as a result of Task 1 and the discussion of intermediate results of Task 2 and Task 3.

Contact to European standardisation institutions

In order to coordinate the standardization activities in the field of testing and calculation of heat pumps and domestic hot water systems, close cooperation is planned with the respective working groups. CEN/TC 228/WG 4 is working in the framework of prEN 14335 [2] on calculation methods for heat pump heating systems. CEN/TC 113 will form a new working group for the revision of EN 255-3 [3], i.e. the actual standard for testing of heat pump water heaters. Moreover, a mandate of the EU to CEN/CENELEC [4] in connection with EU Directive 92/75/EEC [5] is to elaborate, adapt and adopt European measurements standards of water heaters, hot water storage appliances and water heating systems with view to the requirements of the Council Directive 92/75/EEC. This mandate will be treated in the above or new formed working groups of CEN.

Summary

The IEA HPP Annex 28 has started in January 2003 with Task 1, a system assessment and survey of existing standards for the combined production of space and water heating with heat pumps. Task 2 and Task 3, which start in July 2003 are to deliver concise test procedures and hand calculation method for the introduction in international standards. Final results are to be presented in a workshop in December 2004 and the final report is scheduled for May 2005.

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References

[1] Zogg, M. et al (2003), 'test procedure and seasonal performance calculation of residential heat pump with combined space and hot water heating', legal text Annex 28, IEA HPP, Paris

[2] prEN 14335:2002, 'Heating systems in buildings, methods for calculation of system energy requirements and system efficiencies'

[3] EN 255-3:1997, 'Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors – Heating mode – Part 3: Testing and requirements for marking for sanitary hot water units

[4], 'Mandate to CEN and CENELEC (2002) for the elaboration and adoption of measurement standards for household appliances: Water heaters, hot water storage appliances and water heating systems', TREN D1 D(2002), Brussels

[5] 'Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances', Official Journal L 297, 13/10/1992 p. 0016 - 0019)