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Project

Calculation method for the seasonal performance of heat pump compact units and validation

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SUMMARY

The focus of the activities in 2003 was to encounter pilot plants for the field measurements and the definition of the measurement concept and the devices for the testing of the compact units. The IfE (FHBB) will carry out field measurements of the LWZ 303 SOL by the manufacturer STIEBEL ELTRON. The measurement concept has been worked out and the measurement devices procurement is in progress. The installation and implementation of the measurements will take place at the beginning of next year.

At the HLKS (HTA Lucerne), which will develop a test procedure as basis for the calculation method, first test rig measurements of the Vitotres 343 by the manufacturer Viessmann have been carried out. A pilot plant for the field measurement of this system could not been found so far.

The calculation method, - entitled FHBB-method -, which was developed in the SFOE-project "calculation method and seasonal performance factor of residential heat pumps for combined space heating and domestic hot water production", was modified to meet the requirements set by the European standardisation in CEN. It is the basis for the extension to compact units in this project. The FHBB-method forms the major part of the final draft for the heat pump calculation in the framework of the draft standard prEN14335. This final draft of the heat pump part of prEN14355, which has basically been written by Switzerland, was presented and accepted in the plenary meeting of the respective CEN working group CEN/TC 228/WG 4 end of october. It will be sent out for public enquiry soon.

The focus for the further work in the next year is the installation and carrying out of measurements in an appropriate pilot plant and the validation and extension of the calculation method. The HLKS test centre of HTA Lucerne provides the new testing method to be verified on the new test rig for compact units at HTA Lucerne.

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Objectives

Objective of the project is the development of an as far as possible easy-to-use hand calculation method for the seasonal performance factor of heat pump compact units and its validation. The calculation is based on the product characteristic of the heat pump compact unit, which has to be delivered by an adequate test procedure that is to be developed at the HLKS test centre at HTA Lucerne. The calculation method is to be validated by field measurements of two systems, the *LWZ 303 SOL* of the manufacturer *Stiebel Eltron* and the *Vitotres 343* of the manufacturer *Viessmann*. As the systems are in the market introduction, neither detailed experience with the real behaviour in the field application nor extensive data of the systems in operation exist, so field measurements for the two systems are to be carried out in this project as input for the validation of the calculation method, too.

The seasonal performance calculation of the systems is needed on the one hand to compare the performance of compact units to other heating systems, which is enhancing the market competitiveness, as actually only limited statements can be given on the annual system performance in the field. On the other hand, the seasonal performance calculation is needed for labelling, which is required e.g. for building standards like the Swiss *MINERGIE* standard.

The calculation method and the test procedure shall be an input to the CEN Standardisation Committees on the European level.

Work carried out and results

Field measurements of the pilot plant

As there was only short time from the start of the project to the beginning of the heating season, the focus of the work carried out in 2003 was the development of the measurement concept and the acquisition of pilot plants for the field measurements.

For the Stiebel Eltron LWZ 303 SOL a pilot plant has been encountered in Gelterkinden BL, see fig. 1. The measurement concept for the first pilot plant was discussed with the project partner at HTA Lucerne and is determined now. The procurement of the measurement devices is in progress. Installation will be completed by the beginning of 2004 and the measurement data acquisition will presumably start by the end of January.

fig. 1: situation of the pilot plant Stiebel Eltron LWZ 303 SOL in Gelterkinden (Kt. BL)

The measurement concept has the aim to calculate the following key values to evaluate the seasonal performance of the compact units. These values are:

- electro-thermal amplification factor of air heat recovery system

$$ETV_{wrg} = \frac{H_{wrg\_ZU} - H_{wrg\_AU}}{E_{wrg\_VE\_EB}}$$

eq. 1

- temperature change coefficient of air heat recovery system

$$\Phi_{AB} = \frac{T_{wrg\_AB} - T_{wrg\_FO}}{T_{wrg\_AB} - T_{wrg\_AU}}$$

eq. 2

- heat recovery efficiency

$$\eta_{wrg\_AB} = \frac{\dot{H}_{wrg\_AB} - \dot{H}_{wrg\_FO}}{\dot{H}_{wrg\_AB} - \dot{H}_{wrg\_AU}}$$

eq. 3

- generator seasonal performance factor

$$WNG = \frac{Q_{h\_HK} + Q_{h\_WW} + Q_{v\_VW}}{E_{s\_EB} + E_{wp\_KP\_EB} + E_{wp\_VE\_EB} + E_{wrg\_VW-VE\_EB} + E_{h-ww\_EH\_EB} + E_{aux}}$$

eq. 4

- system seasonal performance factor

$$SNG = \frac{Q_{h\_HK\_NE} + Q_{ww\_NE} + Q_{wrg\_NE}}{\sum E_{EB}}$$

eq. 5

- heat generation shares
- used heat shares

The measurement points are therefore set in a way that, as far as possible, energy balances for all component groups and operation modes can be carried out.

The measurement points for the Stiebel Eltron pilot plant are shown in fig. 2. A detailed description of the single points is given in the Appendix. Measurements are partly recorded using the internal interface of the compact unit and partly realised with additional measurement devices and a data logging system. The data will be transferred via modem connection to the Institute of Energy in Muttenz and checked and evaluated there in a weekly schedule to avoid greater data losses at system faults.

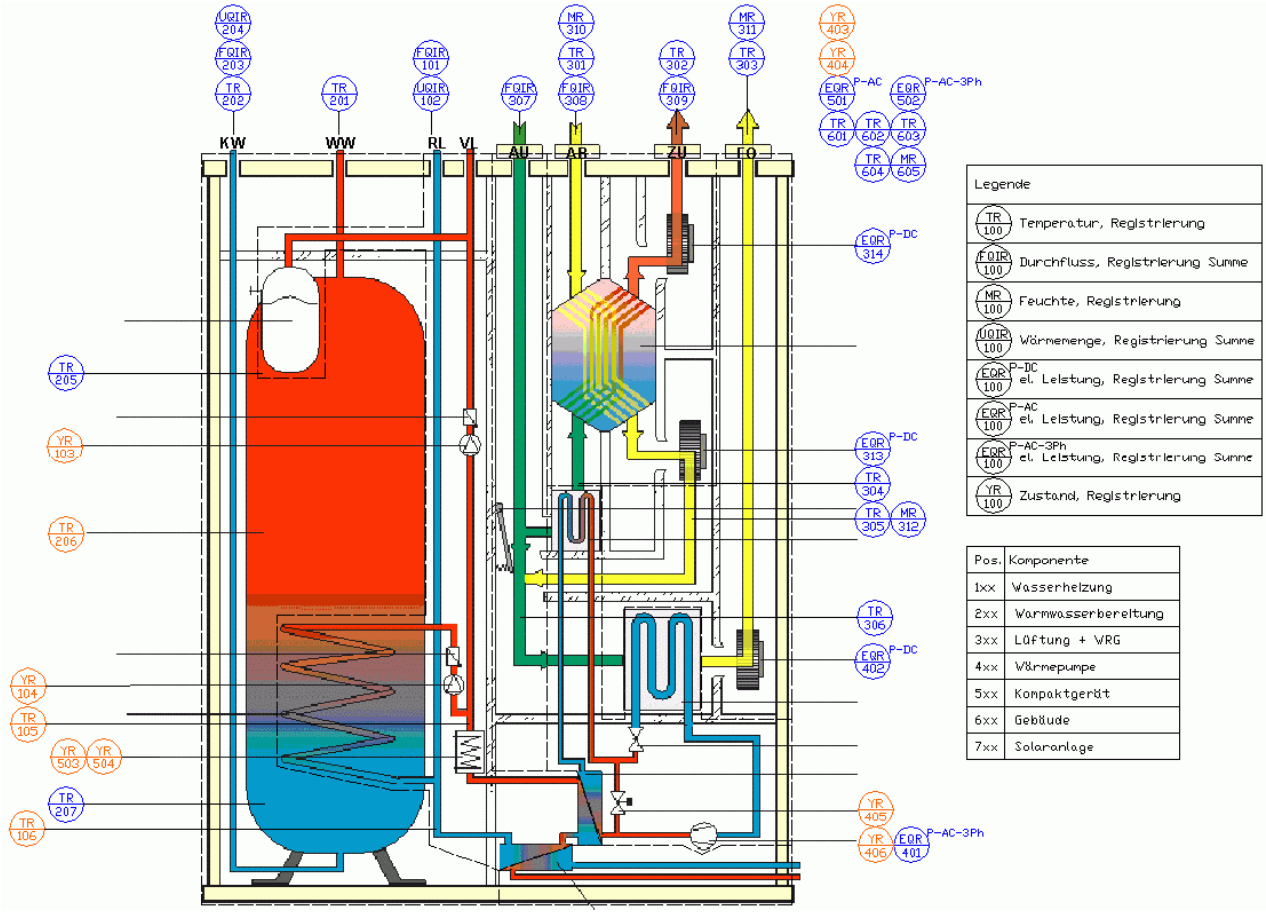

fig. 2: measurement points for the Stiebel Eltron LWZ 303 SOL pilot plant (taken from [1])

Test rig measurements carried out at the HLKS test centre at HTA Lucerne

The heat pump compact unit Viessmann Vitotres 343 has been measured on a provisional test rig of the HLKS test centre at the HTA Lucerne. In the framework of a diploma thesis first preliminary thermodynamic and acoustic measurements were accomplished [2]. The results of these investigations will be considered to extend the existing test procedure [8] to compact units.

The results specified in the following are extracts of the diploma thesis and are therefore preliminarily to be scrutinized in upcoming measurements.

The results of the thermodynamic examination are on the one hand difficulties with the measurements and on the other hand first thermodynamic measurements [2]. The main difficulties concerning the measurements were the adjustment of the different mass flows and the balance of mass flow rates. The reasons are:

⇒ Leakages

⇒ Difficulties in adjusting the internal fans which show divergent fan characteristics

⇒ Undefined pressure conditions caused by the heat pump ventilator

⇒ Additional pressure build-up by external fans

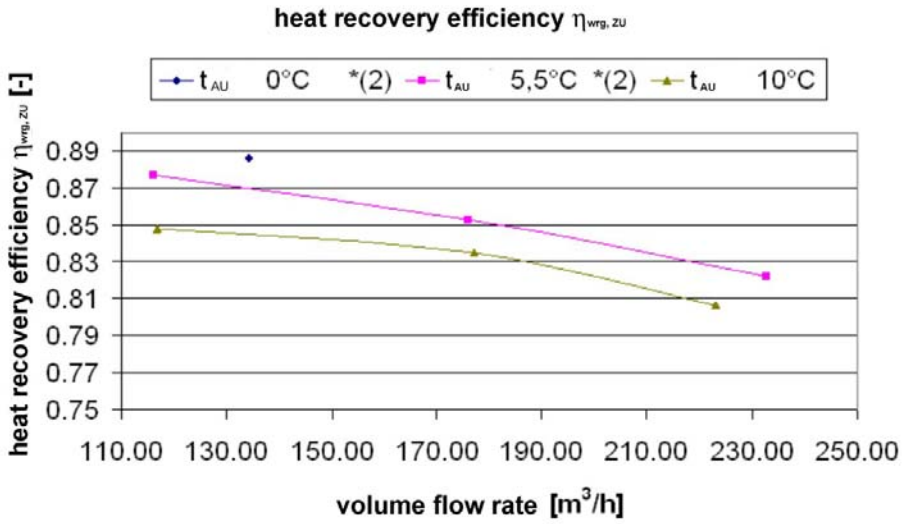

fig. 3: measured values for the heat recovery efficiency of Viessmann Vitotres 343 (taken from [2])

Adaption of the FHBB calculation method in the framework of the CEN standardisation

The FHBB calculation method developed in the SFOE project "calculation method for the seasonal performance factor of residential heat pumps with combined space heating and domestic hot water production" [5] has been introduced in the work going on in the European standardisation process in the working group CEN/TC 228/WG 4 "heating systems in buildings – methods for the calculation of system requirements and systems efficiencies". The participants of the heat pump subgroup of this CEN working group are the countries FR, CH, NL, DE and UK. FR and CH have each worked out a standard draft, which had to be harmonised for the public enquiry of the document on the European level.

Therefore some modifications of the FHBB-method (e.g. concerning system boundary, recoverable heat losses, domestic hot water calculation etc.) had to be made to the FHBB-method to match the requirements of the general calculation scheme of the prEN 14335 [4].

The Swiss and French draft have been harmonised in two working meetings in Muttenz, Switzerland, and Paris, France. A harmonisation with the boiler calculation approach, which is described in another part of the standard prEN 14335, could be achieved as far as possible. The editing of the final draft [7] was completed by Switzerland. It incorporates most of the FHBB calculation method worked out in the SFOE project [5] and has been presented at the plenary meeting of the working group CEN/TC 228/WG 4. Members of the working group agreed broadly on the draft, so that the document is now in preparation of the public enquiry.

National co-operation

The national co-operation takes place with the HLKS test centre at HTA Lucerne, which is in the process of establishing a test rig for ventilation systems with the capability to measure heat pump compact units, as well. The objective of the HTA is the development a test procedure that can deliver the product characteristic for the calculation method.

The test procedure shall be based on the test procedure developed by WPZ Töss [8], which has to be extended for the ventilation operation mode. Moreover the HTA Lucerne takes care of the projected field measurements of the second pilot plant, the Vitotres 343 of the manufacturer Viess-

mann, which is especially designed for extremely low energy houses according to the Swiss MINERGIE-P standard.

International co-operation

The international co-operation is based on the co-operation within the framework of the IEA HPP Annex 28 [3]. The objective of the Annex 28 is the development of comprehensive test procedures and calculation methods for the seasonal performance of different types of combined operating heat pump systems. Thus this project is a Swiss national contribution to the IEA HPP Annex 28. Nine other countries (AT, CA, DE, FR, JP, NO, SE, UK, USA) are participating in the IEA HPP Annex 28.

On the other hand the results should be an input to standardisation committees, and so, a co-operation in the respective working groups of the CEN standardisation on the European level is undergoing. The developed FHBB calculation method is brought in the respective working group by an expert of the IfE. The HTA Lucerne has nominated an expert for the working group CEN/TC 113/WG 10 dealing with the domestic hot water system testing, that is currently under constitution.

Evaluation of 2003 and Perspectives for 2004

The focus of the three month in 2003 was to encounter and to install the measurement devices for the pilot plants. This was the priority since the heating season has already begun and measurements of the pilot plants are to be recorded as early as possible. At the end of October a pilot plant for the LWZ 303 SOL has been encountered and the measurement concept is worked out. The installation of the measurement devices and the commissioning will be carried out beginning of next year.

The FHBB-calculation method [5] as basis for the method to be developed in this project has been modified and successfully introduced in the respective European standardisation carried out in the CEN working CEN/TC 228/WG 4 in the framework of the draft standard prEN 14335 [4]. The final draft of the heat pump calculation was accepted by the working group and will be sent out to public enquiry at the beginning of next year. Due to the deadlines of the CEN/TC 228/WG 4 the validation of the developed FHBB-method with existing measurement data was postponed and will be carried out beginning of 2004.

For the second compact unit under investigation, the Vitotres 343, first test rig measurements have been accomplished at the HLKS test centre at the project partner HTA Lucerne. However, a pilot plant has not been encountered so far, as currently no system of this type is in operation in Switzerland. The contact to the manufacturer, SATAG, is established to be up to date for the acquisition of the second pilot plant.

References

[1] ***Manufacturer description LWZ 303 SOL,*** *Stiebel Eltron, Holzminden*, 2002

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[3] M. Zogg et al**:** ***IEA HPP Annex 28, legal text,*** *IEA HPP Annex 28 N1****,*** March 2003

[4] ***prEN 14335, Heating systems in buildings – calculation of the system requirements and system efficiencies, general part,*** 2001

[5] C. Wemhöner, T. Afjei: ***Calculation method for the seasonal performance factor of residential heat pumps for combined space heating and domestic hot water production,*** *final report in English, SFOE research programme heat pumping technologies, cogeneration, refrigeration,* October 2003
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http://www.waermepumpe.ch/fe, category “Berichte”

[6] J. Zirngibl, B. Young, L. Socal: ***Heating systems in buildings – method for calculation of the system requirements and system efficiencies – Part 2: Heat generation - combustion systems,*** *internal working document N292 of CEN/TC 228/WG 4 for the draft standard prEN14335****,*** October 2003

[7] C. Wemhöner, T. Afjei, C. Feldmann: ***Heating systems in buildings – Method for calculation of the system requirements and system efficiencies – Part 4: Heat pump systems****, internal working document N295 of CEN/TC 228/WG 4 for the draft standard prEN 14335****,*** September 2003

[8] A. Montani: ***Wärmepumpentest für die kombinierte Raumheizung und Warmwasserbereitung***, *final report in German*, *SFOE research programme heat pumping technologies, cogeneration, refrigeration,* November 2003.
Download available on the website of the SFOE research program
http://www.waermepumpe.ch/fe, category “Berichte”

Appendix

LIST OF MEASUREMENT POINTS FOR THE STIEBEL ELTRON LWZ 303 SOL PILOT PLANT

Pos.	Symbol	Unit	Measured value	Measurement principle
101	$\dot{V}_{h\_HK}$	l/Pulse	volume flow heating (>550 l/h)=1420 l/h	Mass flow rate meter
102	$\dot{Q}_{h\_HK}$	Wh/ Pulse	heat amount to heating circuit	Heat meter
103	Z_{h_UWP-HK}	1/0	status circulation pump heating circuit	LWZ 303 SOL
104	Z_{h_UWP-WW}	1/0	status circulation pump domestic hot water	LWZ 303 SOL
105	$\theta_{h\_VL\_EH}$	°C	temperature supply HP + natural gas heating	LWZ 303 SOL
106	θ_{h_RL}	°C	temperature return	LWZ 303 SOL
107	$\theta_{h\_VL\_WP}$	°C	temperature supply HP (optional)	Pt100
201	θ_{ww_WW}	°C	temperature domestic hot water	PT100
202	θ_{ww_KW}	°C	temperature cold water	PT100
203	$\dot{V}_{ww}$	l/min	volume flow rate domestic hot water	Volume flow rate meter
204	$\dot{Q}_{ww}$	Wh/ Pulse	heat amount delivered to domestic hot water	Heat meter
205	θ_{ww_SP-o}	°C	temperature storage top position	PT100
206	θ_{ww_SP-m}	°C	temperature storage middle position	LWZ 303 SOL
207	θ_{ww_SP-u}	°C	temperature storage bottom position	PT100
301	θ_{v_AB}	°C	temperature inlet air entering compact unit from building	PT100
302	θ_{v_ZU}	°C	temperature outlet air from compact unit to building	PT100
303	θ_{v_FO}	°C	temperature outlet exhaust air leaving compact unit to ambience	PT100
304	θ_{wrg_EIN}	°C	temperature inlet air entering heat recovery within compact unit	PT100
305	θ_{wrg_AUS}	°C	temperature outlet air exiting heat recovery within compact unit	PT100
306	θ_{wp_ML}	°C	temperature mixed air entering HP	PT100
307	$\dot{V}_{v\_AU}$	m^3/h	volume flow rate outside air	anemometer

Pos.	Symbol	Unit	Measured value	Measurement principle
308	$\dot{V}_{v\_AB}$	m^3/h	volume flow rate inlet air entering compact unit from building	anemometer
309	$\dot{V}_{v\_ZU}$	m^3/h	volume flow rate outlet air from compact unit to building	anemometer
310	φ_{v_AB}	%r.F.	rel. humidity inlet air entering compact unit from building	cap. sensor
311	φ_{v_FO}	%r.F.	rel. humidity outlet exhaust air leaving compact unit to ambience	cap. sensor
312	φ_{wrg_AUS}	%r.F.	rel. humidity outlet air exiting heat recovery within compact unit	cap. sensor
313	$P_{v\_VE-AB\_EB}$	Wh	el. energy input fan inlet air from building	U&I DC
314	$P_{v\_VE-ZU\_EB}$	Wh	el. energy input fan outlet air to building	U&I DC
401	$P_{wp\_KP\_EB}$	kWh	energy input compressor	rotating current counter
402	$P_{wp\_VE\_EB}$	Wh	el. energy input fan HP	U&I DC.
403	Z_{kpg_ERR-HD}	0/1	high pressure fault	LWZ 303 SOL
404	Z_{kpg_ERR-ND}	0/1	low pressure fault	LWZ 303 SOL
405	Z_{wp_MV}	0/1	status defrosting valve	LWZ 303 SOL
406	Z_{wp_KP}	0/1	status compressor	LWZ 303 SOL
501	$P_{kpg\_VE+CON\_EB}$	Wh	el. energy input fans and control	energy meter
502	P_{kpg_EB}	kWh	el. energy input compact unit	Counter Utility
503	$Z_{h\_EH\_St1}$	0/1	status el. back-up heating step 1 (BE1)	LWZ 303 SOL
504	$Z_{h\_EH\_St2}$	0/1	status el. back-up heating step 2 (BE3)	LWZ 303 SOL
601	θ_{geb_EG}	°C	room temperature ground floor	PT100
602	θ_{geb_UG}	°C	room temperature cellar	PT100
603	θ_{geb_TR}	°C	temperature plant room	PT100
604	θ_{geb_AU}	°C	temperature outside air building	PT100
605	φ_{geb_AU}	%r.F.	rel. humidity outside air building	cap. sensor

NOMENCLATURE

Variables

Variable	Description	Unit
$\dot{H}$	Enthalpy flow rate	W
η	Heat recovery efficiency	-
Φ	Temperature change coefficient of air heat recovery system	-
E	Electrical energy	J
ETV	Electro-thermal amplification factor of air heat recovery system	-
H	Enthalpy	J
Q	Heat energy	J
SNG	System seasonal performance factor	-
WNG	Generation seasonal performance factor	-

Indices

Index	Description
AB	Outlet air from building to heat recovery
AU	Outside air from ambience to heat recovery
aux	Supplementary components
EB	Energy demand
EH	Back-up heating
FO	Exhaust air from heat recovery to ambience
h	Space heating by means of hydronic distribution system
HK	Hydronic heating circuit
KP	compressor
NE	Used energy
s	Solar system
v	ventilation
VE	fan
VW	preheating
wp	Heat pump
wrg	Heat recovery
WW	Domestic hot water
ww	Domestic hot water system
ZU	Inlet air from heat recovery to building