Heat pump standard EN 15316-4-2 – From compliance to real consumption

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Europe target carbon neutrality for 2050. Electrically driven heat pumps are considered as key in energy transition. This article describes the development of the energy performance calculation in heat pump standards from simplified versions, destinated to fulfil compliance with building regulations, towards more detailed hourly methods to get closer to the real consumption. The principles and main influencing parameters are explained.

Keywords: energy efficiency calculation, heat pumps, European Standards

In the past, the assessment of the building energy performance in building regulations was destinated to distinguish between energy efficient and less efficient buildings. To be close to the "real" energy consumption was not a main target. The regulations focused first on the building envelope. The technical systems where simply characterised by seasonal efficiencies. The evaluation methods were simplified, adapted to check the compliance to building regulation. The heat pump standard EN 15316-4-2 from 2007 was in line with this approach.

➢ **EN 15316-4-2: 2007 Method for calculation of system energy requirements and system efficiencies** — Part 4.2: Space heating generation systems, heat pump systems

In EN 15316-4-2 from 2007, two performance calculation methods are described:

- Simplified seasonal performance method based on system typology (tabulated values, not case specific);
- Detailed case specific calculation based on component efficiency data (Bin-method).

In the simplified seasonal performance method, the considered calculation period is the heating season. The performance is calculated with tabulated values for fixed performance classes of heat pumps. The operating conditions of the heating system related to climate, heat source and heat sink type are fixed by typology. The method is not case (building) specific.

Note: The methodology related to the Ecodesign Directive is also a simplified seasonal performance method based on system typology.

To be more case specific a more detailed method was provided. Supplementary data are needed in order to take into account the specific operating conditions of each individual installation. The calculation period is split-up in bins dependent on the outdoor air temperature. The annual frequency of the outdoor air temperature is cumulated and divided into temperature intervals (bins). The operating conditions of the bins are characterised by an operating point in the centre of each bin. The area under the cumulative frequency, the cumulative heating degree hours, is correlated with the energy requirement for space heating.

The cumulative frequency is only dependent on the outdoor air temperature, and therefore does not consider solar and internal gains. For existing buildings, the approximation of the energy demand by the outdoor air temperature maybe enough, while for nearly zero energy buildings it may not. The relation between the sink temperature of water-based heat pump systems (heat distribution temperatures) and the source outdoor temperature is not always directly related to the outdoor air temperature. It depends on the control system.

Part load conditions, as continuous modulation or on-off operating are neglected in the frame of this standard if not quantified by available test data. If no test data on part load operating are available, only the auxiliary stand-by consumption was taken into account to evaluate the degradation of the COP in part load operating.

➢ **EN 15316-4-2: 2017 Method for calculation of system energy requirements and system efficiencies** — Part 4-2: Space heating generation systems, heat pump systems, Module M3-8-2, M8-8-2

The trend towards nearly zero energy buildings and the availability of additional product data (EN 14825) related to part load operation leaded ten years later to the revision of EN 15316-4-2 with two major improvements:

- Calculation of COP and thermal capacity at full load based on EN 14511 series (Path A);
- Calculation of COP and thermal capacity including part load based on EN 14825 (Path B).

For both methods a major improvement was the introduction of a matrix presenting performance coefficients for the COP and thermal capacity. These coefficients are determined at the beginning of the calculation. Both methods are hourly methods.

The coefficients may be taken by default or interpolated from test results. They are adapted to the operating conditions based on the exergetic approach presented in Annex D of EN 15316-4-2:2017.

The hypothesis of the exergetic approach is that the thermodynamic quality of the process stays constant over the whole operating range. The thermodynamic quality of a process is expressed by the exergetic efficiency which is the ratio between the real COP of the process and an ideal Carnot COP. However, in real processes, the exergetic efficiency does not stay constant over the entire operating range (e.g. compressor efficiency). Therefore, the extrapolation of test values provides best results only near the test points. If more test points are available, closer is the performance map to the real results of the heat pump.

The performance coefficient of the Carnot cycle depends on the outlet temperature of the condenser fluid and the inlet temperature of the evaporator fluid. Assumption are made for the temperature spread between the source / sink temperatures and the evaporator / condenser fluid temperatures. For water-based components the temperature difference between the heat transfer medium and the refrigerant fluid can be approximated by $\Delta Tsk = \Delta Tsc = 4$ K. For air-based components $\Delta Tsk = \Delta Tsc = 15$ K may be set. The minimum temperature difference between the heat transfer medium and the refrigerant shall be kept.

Attention is also paid to auxiliary consumption. Auxiliary consumption only comprises the fractions not included in the COP according to EN 14511 standard testing. The auxiliary consumption is a function of the part load ratio.

Calculation of COP at full load based on EN 14511 series (Path A)

In Path A, matrix presenting default coefficients for calculation of the COP and thermal capacity at full load are provided. If only one test value is available, they are built from this unique reference value corresponding to nominal conditions of the sink and source temperatures of heat pump types (see **Figure 1**).

Note: The test values of EN 14511 have not to be and are not at 100% capacity of inverter-controlled heat pumps. The values at −7°C or −15°C are at 100% capacity, but the values at 2°C, 7°C or higher may be given at a lower capacity (e.g. 60%).

The whole matrix of the performance coefficients is obtained using the weighting factors which account:

- in the last row only for temperature changes at the source;
- in the last column only for temperature changes at the sink.

The values for the COP at full load for other operating conditions are calculated by multiplying the default performance coefficients starting at the unique reference (see **Figure 2**).

If additional test data are available, the default coefficients can be replaced by heat pump specific coefficients.

The example in **Figure 1** indicate that if:

- only the source temperature varies from -15°C to +20 °C the COP is multiplied by 3,9 (1,25/0,32);
- only the sink temperature varies from 65°C to 25°C the COP is multiplied by 2,1 (1,1/0,51);

In total, if the operating conditions change from the less favourable operating conditions (sc: –7°C,sk:65°C) to the most favourable operating conditions (sc: 20°C, sk: 25°C) the COP is multiplied by more than 8 at full load conditions.

This example underlines the sensibility of a heat pump on the operating conditions. It shows that with a seasonal or bin method it is not possible to take this sensibility on operating conditions into account in a precise manner.

Air-Water heat pumps - Weighting factors for calculation of the COP										
										Air
Water		0 °C	0 °C	0 °C	0 °C	0 °C	0 °C	0 °C	0 °C	$\Delta\theta_{in;ref}$
		−15 °C	−15 °C	−7 °C	2 °C	7 °C	20 °C	20 °C	20 °C	ϑ_{in}
$\Delta\theta_{out;ref}$	ϑ_{out}									Weighting factor ϑ_{out}
3	25									1
3	25									1.1
5	35					$COP_{gen.Pn.ref}$				1
5	45									0.8
8	55									0.8
10	65									0.8
	Weighting factor ϑ_{in}	1	0.8	0.5	0.8	1	1.25	1	1.0	

Figure 1. Performance matrix with default values EN 15316-4-2: 2017.

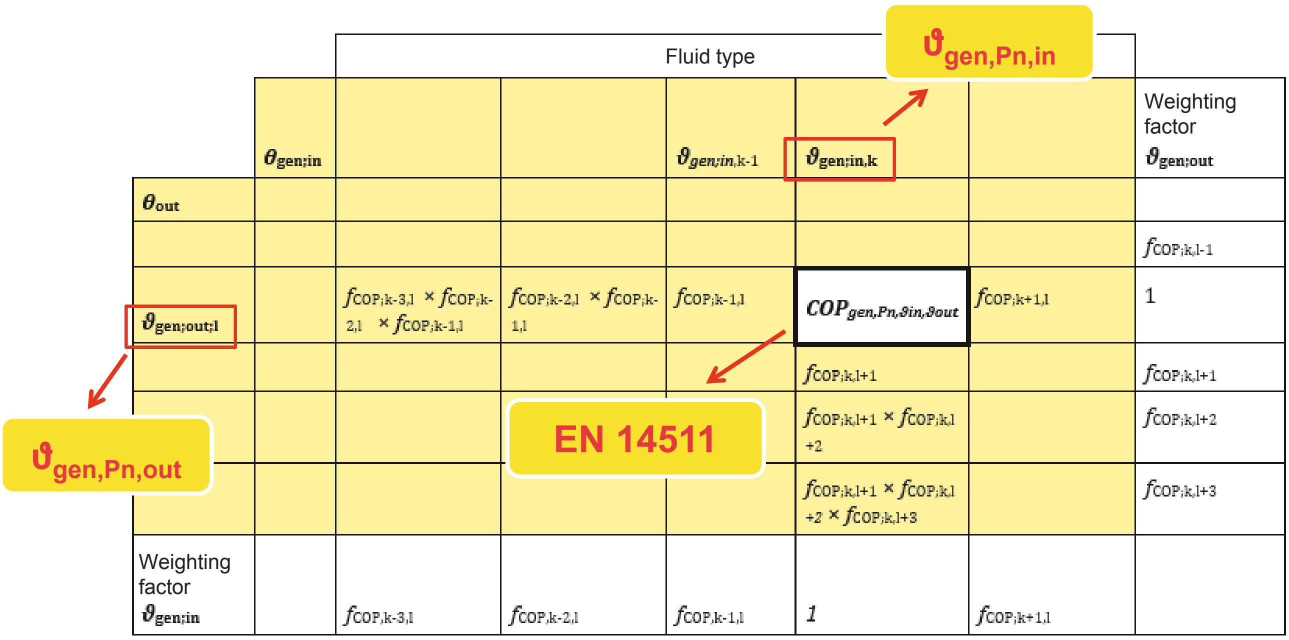

Figure 2. Principle for establishing the whole matrix (source: CEN-CE project).

In Path A, the influence of the part load can only be considered by typologies as no test data are available (no product specific test data on part load in EN 14511).

Therefore, the following conventions have been made:

- when the compressor operates continuous modulating, the variation of the COP from the minimum value for continuous operation to full load is a linear function of the load factor;
- when the compressor operates in ON/OFF mode, the compressor power is increased due to non-reversibility of the heat pump (inertia). Dynamic effects related to transient thermal conditions are transformed into a time delay depending on the type of emitters and heat pump characteristics. The time delay is calculated as a ratio of both time constant and as a function of the load ratio. Default values are provided in the standard.

Compared to the previous version of 15316-4-2 from 2007, the introduction of the performance map facilitates the usability of available product performance data a full load (Path A). Especially if there are more test results available, the influence of the operating conditions on the heat pump performance at full load is well defined, because the influencing parameters vary one by one.

To take into account part load operating, the full load performance is corrected. As there are no test results available for part load, the conventions to consider part load operating has been completed compared to the previous versions of the standard. But they remain conventions which are not product specific.

Calculation of COP including part load based on EN 14825 (Path B)

EN 14825 was worked out to deliver the data required by the ECODESIGN directive. Heat pumps are tested at part load conditions.

Figure 3 shows the conventional operating conditions (e.g. average, warm, cold climate, the load ratio) published in the product fiche. According to EN 14825 the manufacturer is obligated to test the unit for various temperature applications (low temperature 35°C, intermediate temperature 45°C, medium temperature 55°C, high temperature 65°C) in the three typical climates (average, warm and cold).

In Path B the COP at operating conditions are derived from the test results according to EN 14825. The values are interpolated from the results and adapted to the operating conditions by using the exergetic approach already describe before.

Input data based on EN 14825 test results									
	Load Ratio for different climates			Output temperature $COP_{\vartheta_{in};\vartheta_{out;ref}}$			Thermal capacity $\Phi_{\vartheta_{in};\vartheta_{out;ref}}$		
Point	Average %	Warm %	Cold %						
A	0,88		0,61						
B	0,54	1,00	0,37						
C	0,35	0,64	0,24						
D	0,15	0,29	0,11						
E	TOL		TOL						
F	ϑbiv	ϑbiv	ϑbiv						
G			0,82						

Term	Unit	Symbol	Value
Thermostat off	kW	P_hto	
Standby	kW	P_stby	
Off mode	kW	P_off	
Pdegration	kW	P_cd	
Degradation factor	–	f_cd	

Figure 3. Product fiche related to EN 14825.

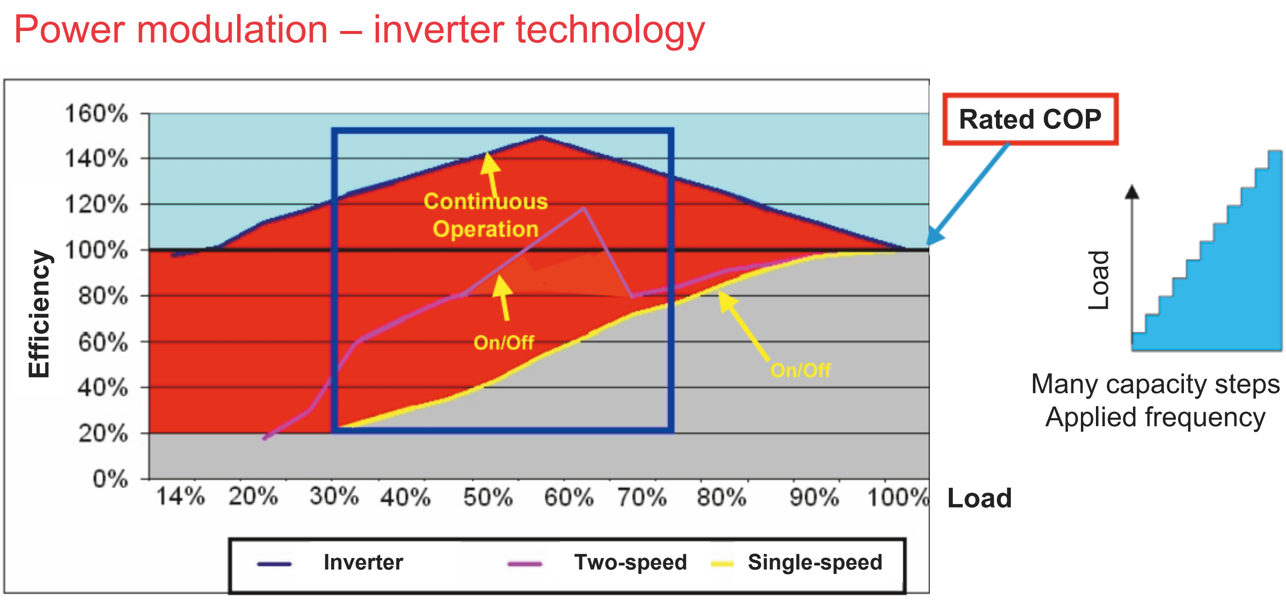

Figure 4. Influence of part load operating on heat pump efficiency (source: CEN-CE project).

The added value of Path B is the more detailed calculation of part load operating based on test results. **Figure** 4 show the influence of part load on the efficiency related to different power control (inverter continuous operating, single speed on-off control etc). At 50% load the efficiency may vary from 40% to 150% of efficiency.

Path B distinguish between on-off operating and continuous modulating operating at part load.

In on-off operating the declared COP is lowered by the degradation factor (up to 25%) and the load ratio. The degradation factor is indicated in the product fiche. This approach is similar to Path A.

In continuous modulating operating, e.g. reduced compressor speed, the difference between the condenser and evaporator fluid temperature is reducing. For example, for an Air/Air unit in point D - EN 14825 (source temperature 2°C, sink temperature 20°C) the difference between the evaporator and condenser fluid temperature may vary from 36 K at 100% load, to 25 K at 15% load. These temperature changes influence the COP. These temperature changes are used in Path B to construct the performance map for part load operating. The performance coefficients at different points of the performance map are then obtained by interpolation between the different test points of EN 14825.

These effects are not taken into account explicitly in Path A.

Conclusion

The heat pump standards changed from simple seasonal methods related to building regulation compliance check to more detailed hourly methods closer to real energy consumption.

These changes were needed by the increasing quality of buildings towards nearly zero energy buildings, which request more precise calculation methods, but also by the claim of building owner and occupants that the promised energy savings are verified by energy savings in reality. To be closer to the real consumption is a general tendency also seen in other sectors. The most well know example is the car industry.

The progress of the calculation methods has been made possible and reliable by additional product test results and the accessibility of product data.

EN 15316-4-2:2017 allows to consider the high variability of the heat pump performance on operating conditions in a more precise way. The counterpart of this evolution is that the new standards are not always easy to apply. The standards are more detailed, not always explicit.

Training is needed to apply them, support is needed to transpose them at national level, product test data has still to be improved and made easily accessible at European level. ■