Umwelt Bundesamt

BAM
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Proposal for the revision of the harmonised test standard EN 14825:2016, for the testing and rating of air conditioners and heat pumps at part load conditions and calculation of seasonal performance

Authors

Anne Simo, Carsten Palkowski, André Wachau

Federal Institute for Materials Research and Testing (BAM)

Contact

André Wachau (BAM), andre.wachau@bam.de, Tel. +49 30 8104 4270

Jens Schuberth, jens.schuberth@uba.de, Tel. +49 340 2103 2450,
Federal Environment Agency (UBA)

1. Situation

Test procedures are the foundation of any product regulation. Both, the limits set, and the methods used by regulation define the level of performance. Hence, the referred test procedures influence product design if fair competition can be assured by market surveillance. Therefore, criteria for good standards are:

- **representativeness** of test conditions (close to real life operation)
- **independency** of testing (out of the box)
- **comparability** of appliances
- **repeatability** and **reproducibility**
- **costs** and test **duration**

The latter are important factors which may influence product price and may pose a barrier to effective market surveillance.

On behalf of the German Federal Ministry for Economic Affairs and Energy, the Federal Institute for Materials Research and Testing carried out a research project to support market surveillance activities in Germany. Within this project several tests were performed on both air conditioners (ACs) and heat pumps (HPs) in accredited test laboratories throughout Europe. It was found that the current harmonized test standard EN 14825:2016 for testing heat pumps and air conditioners:

- does not reflect real life operation due to abnormal operation (fixed compressor speed)
- lacks comparability of different appliances, since individual control strategies are not considered (inactive control)
- does not allow for the independent compliance verification by market surveillance authorities as outlined below

In addition, the test is very time-consuming, costly and reproducibility is poor, as recent Round Robin tests indicate (see section 2).

Thus, an alternative ‘dynamic test’ procedure was developed. In a first step a high number of appliances were tested according to the current standard, using both test procedures described in EN 14825: measuring with (1) fixed compressor speed (inactive control, preset by manufacturer) and (2) unfixed compressor speed (compensation procedure, active control, not preset). In section 2 the observations made, using both test procedures are

summarized. The compensation procedure became practicable and test duration could be reduced significantly by relaxing the tolerances only for individual measured temperature values (section 2.2). In a second step the 'dynamic test' was developed. It is based on the compensation procedure using an increased resolution, as inter- and extrapolation is shown to be problematic. The methodology is outlined in section 3 explaining the main differences to the current standard and including the test results. Section 4 gives a side by side comparison of both methodologies. Finally, an outlook on the next steps is presented in section 5.

For the reasons given in this document it is proposed to use the dynamic test for the revised regulations of lot 1, 2 and 10. Modality and timing is suggested to be discussed within a consultation forum.

2. EN 14825

To determine the seasonal performance of variable capacity units, EN 14825:2016 requires fixing the compressor speed to achieve steady-state conditions. The frequencies to be set for the specified test conditions must be supplied by the manufacturers as stated in paragraph 8.5.1 of EN 14825:2016 (see box below).

> ***„8.5 Test procedure for staged and variable capacity units***
> ***8.5.1 Settings for the required capacity ratio***
> *The capacity ratio to be tested shall be set according to the instructions of the manufacturer. The manufacturer shall provide laboratories with the necessary information on the setting of the unit for operating at the required capacity conditions upon request. Contact information to obtain such information shall be provided in both user's manual and website of the manufacturer or importer.*
> *The unit shall operate continuously during the part load test. The only discontinuity allowed is the defrost cycle of a unit.*
> *For inverter type control units, if the manufacturer gives instructions for the setting of the frequency for each rating condition, this setting shall be done. To set up a multi-split system which incorporates an inverter-controlled compressor, skilled personnel with knowledge of control software will be required. The manufacturer or his nominated agent should be in attendance when the system is being installed and prepared for tests.***"**

The unit's control, being an integral part of the appliances, is set inactive and compressor speed is fixed during testing. For the vast majority of appliances with variable capacity (variable compressor speed) this is an abnormal operation mode.

As an alternative, a second test procedure is described in paragraph 8.5.2 "Compensation Method" of EN 14825:2016 which would allow the unit to run in normal operation mode (unfixed compressor, control active). But, this procedure is commonly not used, because the tolerances laid down by EN 14511 can hardly be achieved, and in particular there is no chance to meet the tolerances when ON/OFF operation occurs (see also section 2.2).

Please note that already the review study on air conditioners[1] raised the issue of test results deviating from real life performance due to fixing the compressor speed. Also, a recently published Nordic project report (Nordsyn Study)[2] mentions: "The normal control system of the heat pump is bypassed, and the compressor frequency is fixed, during the test, resulting in different operation in the laboratory compared to in real installations."

2.1. Fixed Compressor Speed

Currently, it is common practice to establish steady state conditions during testing as mentioned before. However, fixing the compressor speed causes several problems as described in the following paragraphs.

A number of different products (11 ACs and 28 HPs) were tested with fixed compressor speed (see Annex for results). It was observed that fixing the compressor speed requires specific test modes, which in some cases could only be achieved using additional equipment provided by the manufacturer, for instance an additional control board or a specific remote control (Figure 1). In the remaining cases tests could only be done with the manufacturer being present for activating the test mode.

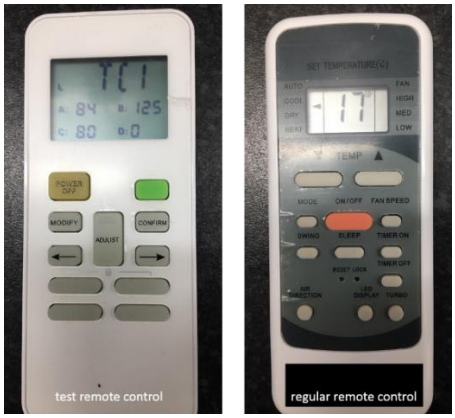


Figure 1. Photograph of the two remote controls for one of the tested units, test remote control (left) and regular remote control (right).

➔ **Independency of testing ('out of the box') is not fulfilled**

[1] Task 1 report; Review of Regulation 206/2012 and 626/2011; first draft published mid-2017; p. 40 f.
[2] Nordsyn Study report; p. 11; http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1312951&dswid=3406

To achieve steady-state conditions ON/OFF operation must be prevented during the test. Therefore, EN 14825 allows deviations from the predefined heating/cooling demand without restrictions. The heating/cooling demand is artificially adjusted to the unit´s capacity by changing the sink side conditions. It was observed that heating/cooling capacities may differ from the predefined heating/cooling demand up to 300% (Figure 2). However, (1) those appliances would switch to ON/OFF operation in the field to adjust their heating/cooling capacity to the lower heating/cooling demands. So, (2) the test conditions are adjusted to the appliances' characteristics and do not properly represent conditions in the field (e.g. lower heating/cooling demands).

➔ **Representativeness is not fulfilled satisfactory**

Moreover, (3) the test conditions (heat demand) are not comparable for different appliances. In particular for units with the same rated capacity a fair comparison would require identical heat demand at each outdoor temperature.

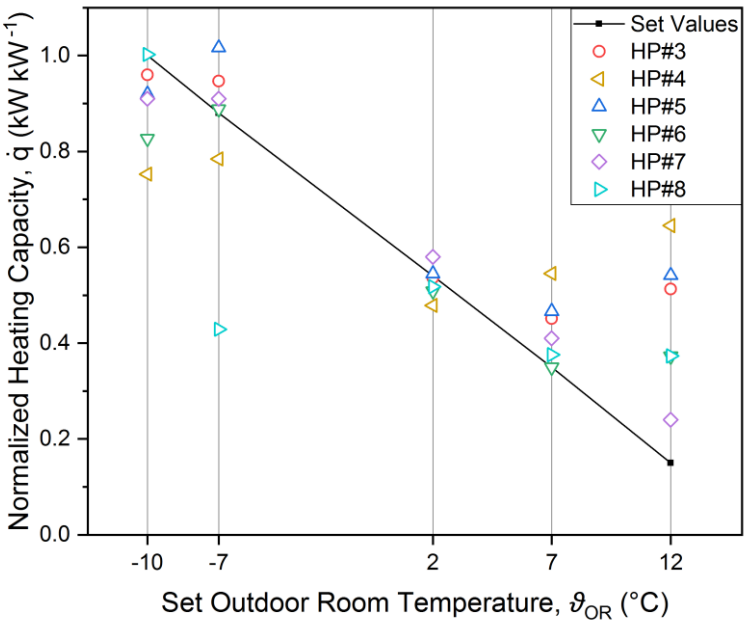


Figure 2: Normalized heating capacities of different HPs tested according to EN 14825. Heating capacities differ from the predefined heat demand (set value). Especially at low part load ratios (PLR = 15 %) deviations of up to 300 % can be observed.

In contrast, using the compensation procedure (see Section 2.2 and 3) ON/OFF operation can be observed for all units tested. [3] However, the efficiency losses due to ON/OFF operation differ between appliances: (1) The point where the transition from continuous modulation to ON/OFF operation occurs depends on the specific appliance. (2) The ON/OFF pattern can be very different due to different control strategies as shown in Figure 3. Those differences cannot be captured when measuring according to EN 14825 with fixed compressor speed and inactive control.[4]

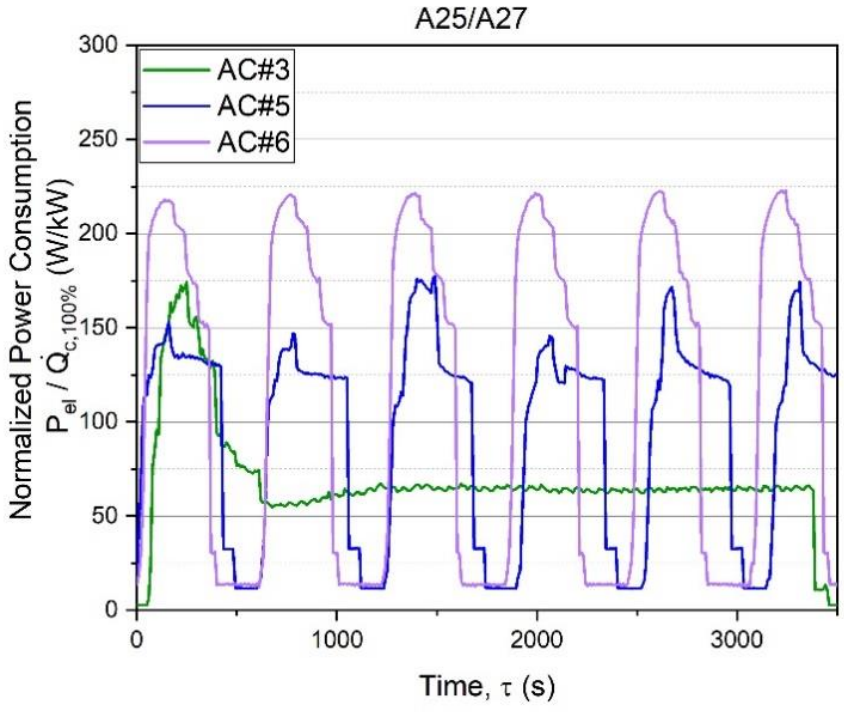


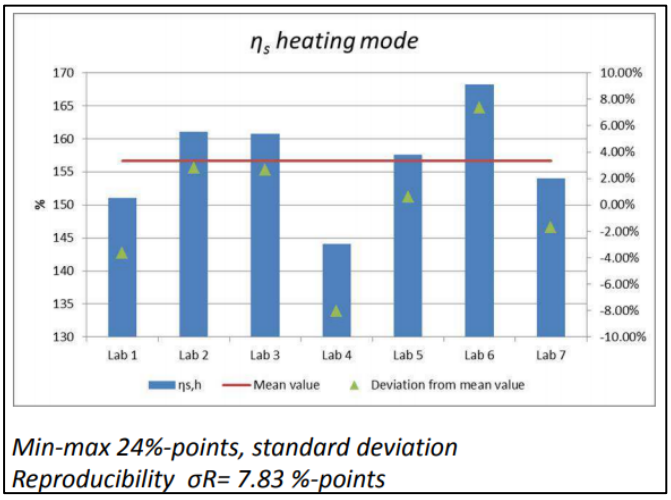
Figure 3: Normalised power consumption over time of three different air conditioners (AC#3, AC#5 and AC#6). Very different cycling pattern are observed for the different units tested.

➔ **Comparability between appliances is not fulfilled**

[3] The units should regulate their capacities continuously with their speed-controlled drive of the inverter, but beyond a specific temperature the units switch into ON/OFF operation which is most likely due to the fact that lubrication imposes a minimum speed of the compressor.
[4] This holds even though EN 14825 prescribes to use of correction factors if the heating/cooling capacities exceed the heating/cooling demand by more than 10 %, since this simplifying approach does not take individual control patterns, as shown in Figure 3, into account.

Further, reproducibility of test results is found to be low in Round Robin tests (see Figure 4a) due to a considerable degree of uncertainty regarding the test procedure and data evaluation.[5] For instance, default correction factors were assumed erroneously.

a)



b)

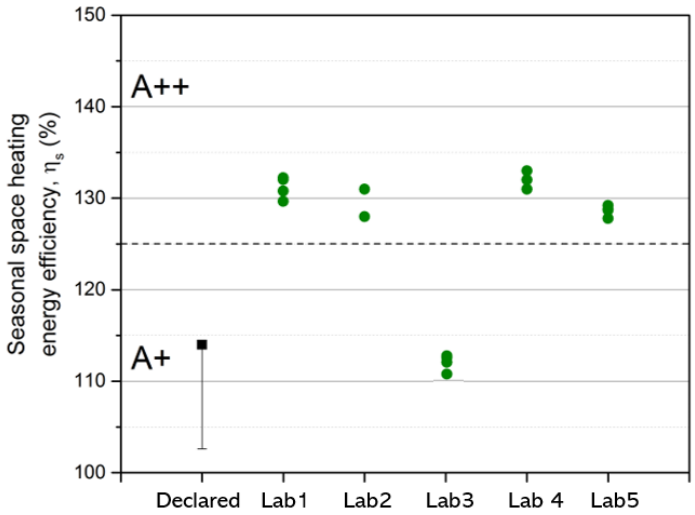


Figure 4: Round Robin tests results a) conducted by ECOtest in seven different laboratories [picture source: VHK presentation, 2nd stakeholder meeting for the review of lot 1 and 2, 26.04.2019] and b) organized by BAM in five different accredited laboratories.

[5] Presentation by VHK; 2nd stakeholder meeting of lot 1 and 2; 26th of April 2019

Similar observations were made in a Round Robin tests organized by BAM. The measurements took from 2016 to 2017 to be completed. The Round Robin test involved five independent and accredited laboratories. Each laboratory carried out four repetitive measurements according to the standard EN 14825 on two selected heat pumps. Four laboratories obtained the correction factor by measurement but laboratory 3 used the default correction factor[6], resulting in a significant different efficiency (see Figure 4b). The results revealed a repeatability standard deviation of 0.9 % and a reproducibility standard deviation of 6.7 %.

➔ **Reproducibility is not fulfilled satisfactory**

Dependent on the experience of the laboratory and the mode of operation being tested, testing duration is approximately six days and rather expensive, impeding market surveillance activities.

➔ **Costs and test duration should be improved**

In summary, fixing the compressor speed raises several issues. Since ON/OFF cycling is to be prevented, deviations from the predefined heating/cooling demand are allowed. These deviations lead to (1) test conditions that do not represent conditions in the field (where ON/OFF cycling and/or variable frequencies occur), and – in combination with the fact that different units have different control strategies – to (2) that units cannot be compared in a fair way. Moreover, these deviations require (3) correction factors to be applied which in turn leads to a poor reproducibility.

[6] According to the standard determination by measurement or using the default value are both permissible.

2.2. Unfixed Compressor Speed (Compensation Procedure)

Compensation measurements were performed according to section 8.5.2 in EN 14825. The same experimental setup can be used when measuring with fixed or unfixed compressor speed. In contrast to the requirement stated in paragraph 8.5.1 of EN 14825:2016 (fixed speed), the frequency of the compressor is not set according to the instructions of the manufacturer and the units are not fixed into a test mode but achieve the required test conditions by using their variable speed controller (unfixed compressor speed, active control).

➔ **Independency of testing ('out of the box') is fulfilled**

However, the compensation procedure is not used in practice since the narrow tolerances laid down by EN 14511 are not relaxed for single measured values. This is questionable, especially, as all appliances change to ON/OFF operation below a certain part load ratio. It is evident that ON/OFF operation requires higher tolerances on short time scale to be permitted. Instead of applying the narrow temperature tolerances on single measurement points they should only be applied to the mean value of a sequence of measurement points.

This approach was followed in our tests and the procedure became practicable. In general, the test conditions and tolerances were kept according to EN 14511. The tolerances on humidity were kept for both, individual measured values and the arithmetic mean values. However, relaxed tolerances were used for individual measured temperature values but were kept on average values (compare Figure 9).

The measurement conditions are achieved via the given compensation load. For cooling mode measurements, a certain heating capacity is given by the electrical heater of the test bench; for heating mode measurements a certain cooling capacity is given by a cooling apparatus of the test bench (Figure 5). According to the requirements given by the test bench, the unit running in a non-fixed mode, responds with an equivalent heating/cooling capacity.

As an example, the test conditions for each part load ratio of a cooling mode measurement were achieved with a given heating capacity for the indoor unit:

- 20°C inlet-temperature 21% of the capacity of P_{design}
- 25°C inlet-temperature 47% of the capacity of P_{design}
- 30°C inlet-temperature 74% of the capacity of P_{design}
- 35°C inlet-temperature 100% of the capacity of P_{design}

The set temperature of the unit is adjusted for example via the unit´s regular remote control until the desired capacity and the room temperature of 27 °C are achieved.

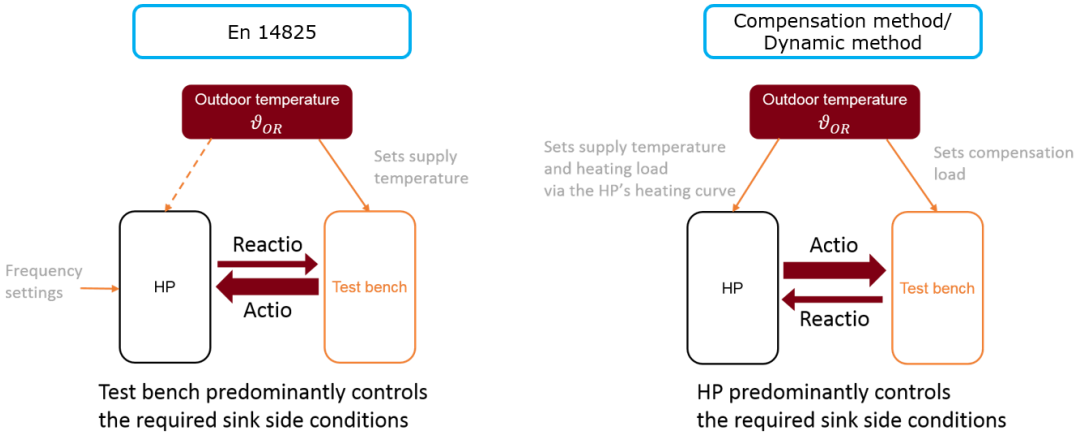


Figure 5: Methodology of: (**a**) the steady-state test according to EN 14825; and (**b**) the compensation/dynamic test.

Fifteen single-split units (with nominal capacity P_{design} between 2.0 - 5.3 kW) from different manufacturers were measured so far. The seasonal performance was then calculated according to the formulas given in the standard EN 14825:2016. The compensation method can equally be performed on HPs. Two ASHP and three GSHP were measured according to the compensation method so far (test results are not included).

Figure 6 shows the seasonal efficiency results for air conditioners determined with the compensation procedure. For the majority of tested units a lower energy efficiency rating is observed compared to the declared values and compared to the standard test according to EN 14825. The units behave differently under part load conditions below a certain outdoor temperature (25 °C < $\vartheta_{1or,cr}$ < 30 °C) when tested without fixing the compressor speed. ON/OFF cycling was observed for all units, but the cycling pattern differ for the different units tested due to different control

strategies. Four units (AC#4, AC#5, AC#8 and AC#15) were found matching the declared values despite ON/OFF operation. It appears that the compensation method allows to better compare between units with well-designed control systems and such with less well-designed ones.

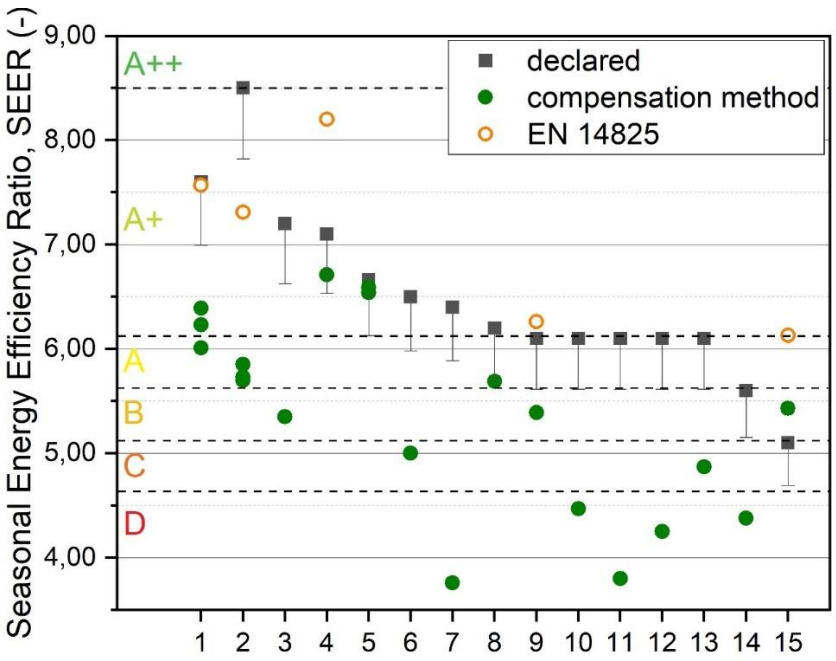


Figure 6: Seasonal energy efficiency ratios SEER measured with the compensation method (green circles), EN 14825 (orange circles) and declared values (black squares) for 15 different ACs. The tolerance bar indicates the allowed tolerance according to regulation (EU) 626/2011.

➔ **Comparability and representativeness are increased by considering ON/OFF operation (active control)**

3. Dynamic Method

Differences

The dynamic method is based on the compensation procedure applying relaxed tolerances (as described above) with measurements at the different outdoor temperatures of a typical heating/cooling season.

As outlined in section 2.2, the compressor runs unfixed and the control is active during the whole measurement. Therefore, the two criteria independency and comparability are also met for the dynamic method.

- ➔ **Independency of testing ('out of the box') is fulfilled**
- ➔ **Comparability is increased by considering ON/OFF operation (active control)**

According to EN 14825 the seasonal performance is calculated from the climate BIN method[7], in which a typical heating and cooling season are defined by 1K intervals (bins) of the outdoor temperature and hours of occurrence. However, only few outdoor temperature conditions are tested according to EN 14825 and linear interpolation of the heating/cooling demand and energy consumption for all outdoor temperature bins is necessary to consider a whole season.

Figure 7 shows the coefficient of performance (COP) results of an AC in heating mode measured for the different outdoor temperatures conditions of the average climate. No linear correlation is found above 2 °C and linear inter- and extrapolation according to EN 14825 would lead to wrong estimates. Therefore, a higher number of test points compared to EN 14825 is required. For this reason, for the dynamic method the different outdoor temperatures are combined to form a temperature profile that represents the climate.

7 For each climate zone the standard EN 14825:2016 defines an annual outdoor temperature distribution representing a typical heating and cooling season.

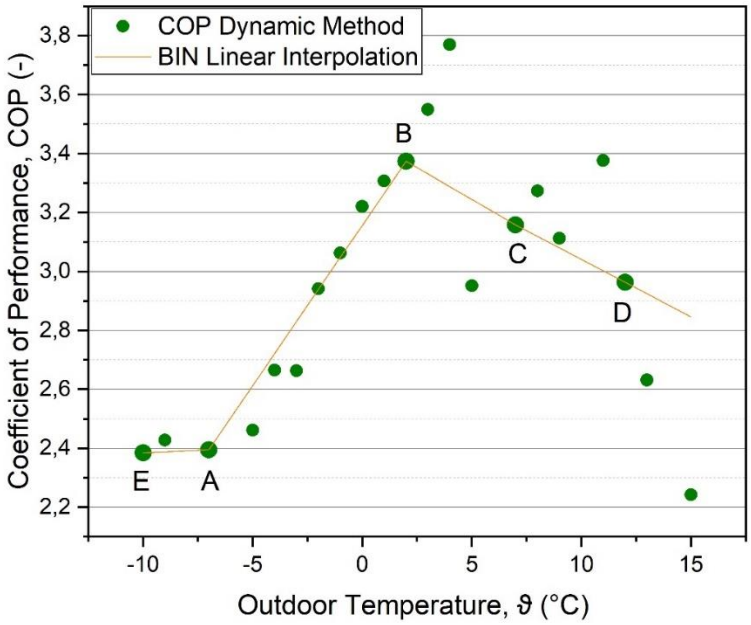


Figure 7: COP results measured with the dynamic test for an AC in heating mode. The part load ratios A-E measured according to EN 14825 are indicated. Linear interpolation of these points would lead to an underestimation of COP values for outdoor temperatures above 2 °C (B) and to an overestimation of COP values for outdoor temperatures above 12 °C (D). The results were confirmed three times by repeating measurements.

Please note that amongst possible reasons for deviations between field and test results the Nordsyn Study report mentioned earlier also says that "standard tests are performed…at too few test points." (p. 11).

➔ **Representativeness is further increased due to higher resolution**

In contrast to measurements according to EN 14825 with fixed compressor speed the heating/cooling capacity closely follows the predefined heat demand with the control being active (unfixed compressor speed) (Figure 8). The HP reacts to the conditions set by the test bench and corrections become obsolete. Therefore, comparability, in particular for units with the same rated capacity, is increased since all appliances are subjected to the same heat demand at each outdoor temperature (identical test conditions).

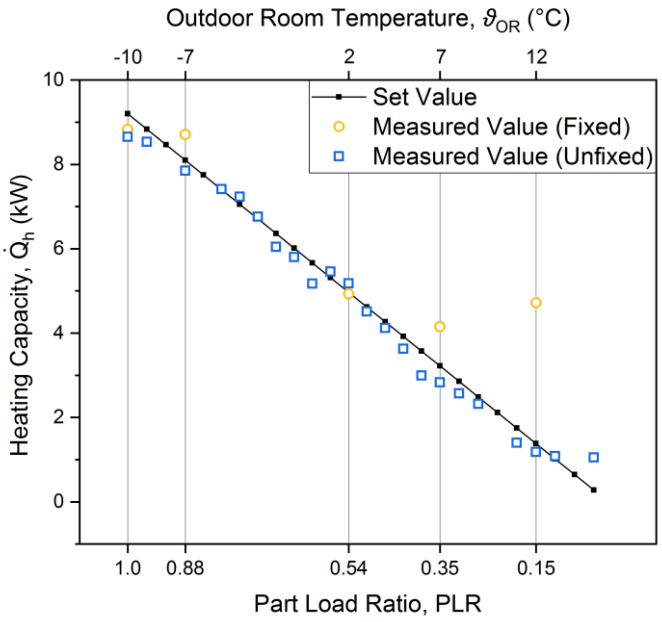


Figure 8: Heating capacity of one HP tested according to EN 14825 (fixed) and according to the dynamic method (unfixed). During dynamic testing the measured heating capacity matches the heating demand.

Setup and calculation

The alternative dynamic method can be used with the same experimental setup as applied in the current test standard EN 14825:2016. The units are subjected to a temperature profile. The profile consists of the different outdoor temperatures of a typical heating/cooling season. The duration of each individual outdoor temperature corresponds to BINs given in EN 14825. Thus, the seasonal performance can be calculated from the ratio of heating/cooling energy measured to the amount of electricity consumed over the entire measurement period.

Please note: An in-depth analysis can be found in our publication in the Energies Journal[8]. The published temperature profile can be shortened at certain temperature ranges. However, a significantly higher resolution will be kept.

[8] https://www.mdpi.com/1996-1073/12/6/1045

Test Duration

Exemplarily, the temperature sequence at outdoor temperature ϑ_0 = 20 °C is shown in Figure 9. The cooling/heating capacities obtained with the dynamic method are the average values of the entire temperature sequence, including the periods of OFF operation and the stabilization phase (highlighted in blue in Figure 9) at the beginning of each sequence. The small fluctuations during the stabilization phase were considered but have only a negligibly small influence on the final result. The subsequent cyclic intervals due to ON/OFF operation of the air conditioner continuously repeat and thus the test duration can be shortened without losing precision.

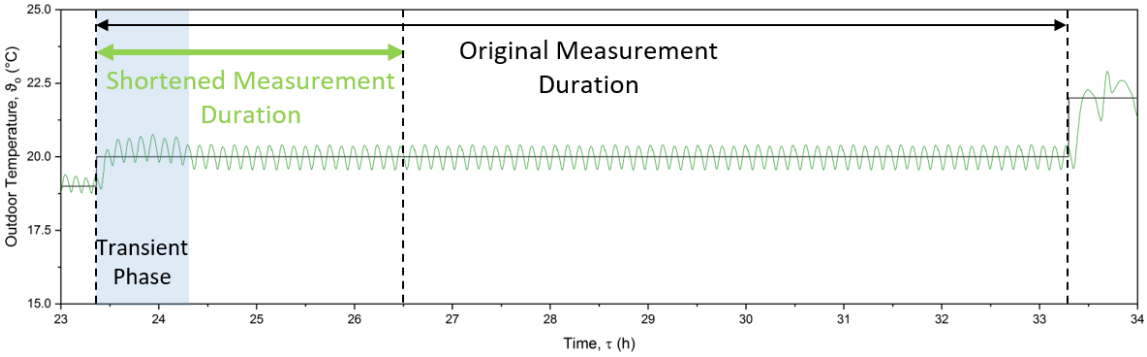


Figure 9: Results of the dynamic test for an AC in cooling mode (at part load ratio PLR = 21 %). During the test, the outdoor temperature (green), the supply temperature, the cooling capacity and the electrical power consumption were recorded with measurement intervals of ten seconds. ON/OFF-operation was observed, but the measured temperatures and cooling capacity show a continuous cyclic behavior following the set value (black line). The average values of temperatures, cooling capacity and electrical power consumption approach the set value rather quickly (+/- 5 % after 30 minutes and +/- 2 % after 60 minutes for the sequence shown above).

The same applies for other temperature sequences. However, for certain operating conditions, such as defrost cycles, it is necessary to keep a longer duration to maintain high reproducibility. Hence, we have shortened the duration of testing depending on the type of unit and the operation mode tested. The results in Table 1 give an overview of the testing duration for the different types of units and the different operation modes being tested.

Table 1. Testing duration of the dynamic method for different types of units and different modes of operation

	air source heat pumps (ASHP)	ground source heat pumps (GSHP)	air conditioners (AC)
Cooling mode			2 days
Heating mode	3 days	2 days	3 days

➔ **Costs and test duration will be improved**

Results

The feasibility of the proposed dynamic method has been shown for several single-split air conditioners for the cooling and heating mode, two brine/water heat pumps (HP#1 and HP#2) and three air/water heat pumps (HP#3, HP#4 and HP#5) for the heating mode. The tests were repeated in different laboratories.

The results of the tested HPs are shown in Figure 10. The repeatability of the results using the dynamic testing (~2 %) is found to be comparable with the current standard. For most tested units, the dynamic testing results in a lower energy efficiency rating as compared to the declared values.

The results of the tested air conditioners are shown in Figure 11. Two ACs were measured in cooling mode and two different samples were measured in heating mode. The repeatability was tested for AC#4 in heating mode (<1 %).

➔ **Repeatability and reproducibility of present results are good**

Dependent on the control behavior of the tested air conditioner, ON/OFF-operation of the compressor was also observed during dynamic testing. However, one sample AC#2 still reaches higher efficiency results using the dynamic method.

In case of the air/water heat pumps ON/OFF-operation of the compressor was also observed, but the occurrence of ON/OFF-operation differs between the tested models: For HP#3 ON/OFF-operation occurs at all temperatures, whereas for HP#4 only at outdoor room temperatures higher than 2 °C.

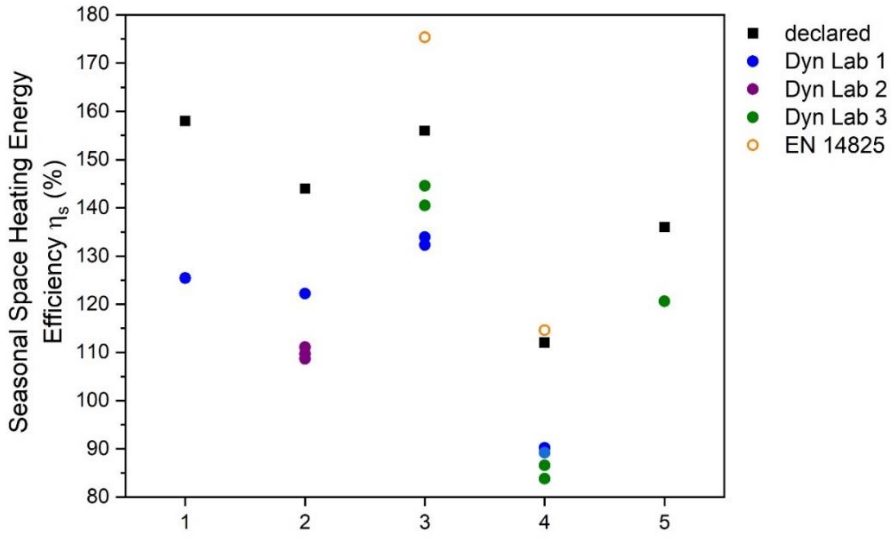


Figure 10: Seasonal space heating energy efficiency measured with the dynamic method, EN 14825 (orange circles) and declared values (black squares) for 5 different HPs (GSHP: HP#1 and HP#2, ASHP: HP#3-HP#5). The tests were repeated in different laboratories. Different colored circles were used to indicate for the different laboratories which carried out the tests. Results were found repeatable and reproducible.

First results of the ECOtest-Project have shown min-max deviations of up to 24 %-points (standard deviation Reproducibility σR= 7.83 %-points) between labs, when measuring according to the current standard EN 14825.[9] It turned out that some labs misinterpreted the standard in doing false corrections. In our view, there is less freedom of interpretation for the dynamic test, which might improve reproducibility compared to EN 14825 (e.g. no corrections, interpolations).

[9] presentation given by VHK during the second stakeholder meeting for lot 1 and 2

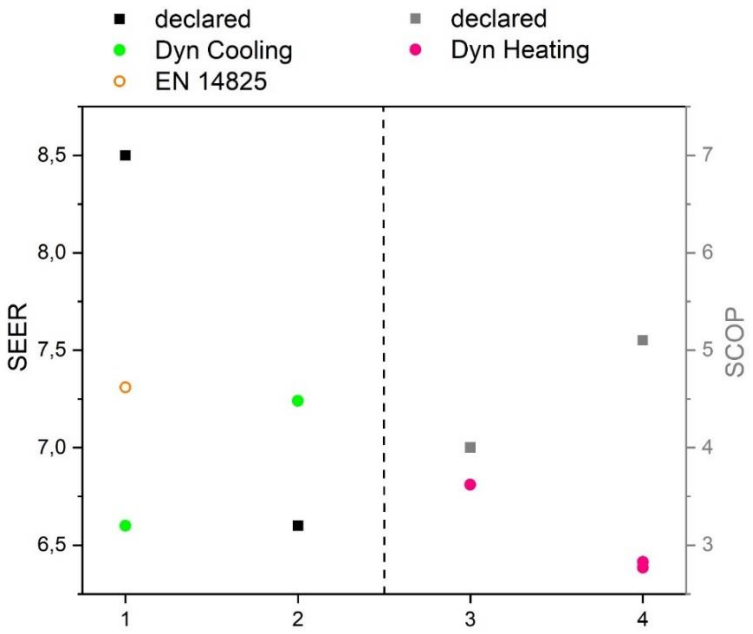


Figure 11: Seasonal energy efficiency ratios SEER measured with the dynamic method (green and pink points), EN 14825 (orange circles) and declared values (black squares) for four different ACs; in cooling mode (left) and heating mode (right). For AC#4 the tests were repeated in the same laboratory and results are found highly repeatable (circles are superimposed). Please note that due to necessary manufacturer support measurements according to EN 14825 were only possible for a small number of units.

4. Comparison of EN 14825 and the 'dynamic test method'

Figure 12 illustrates the main differences of the dynamic method compared to the standard method EN 14825. For the dynamic testing, the units are operated in normal mode (active control, unfixed compressor) including both capacity modulation via variable frequency drive and ON/OFF operation. In contrast to EN 14825, the dynamic test allows for out of the box testing, including the units' controls. Therefore, individual control strategies, especially under part load conditions, can be captured, which impact the energy efficiency in the field. Further, dynamic testing requires no inter- or extrapolation, nor corrections for deviations of the heating capacity from the heating/cooling demand.

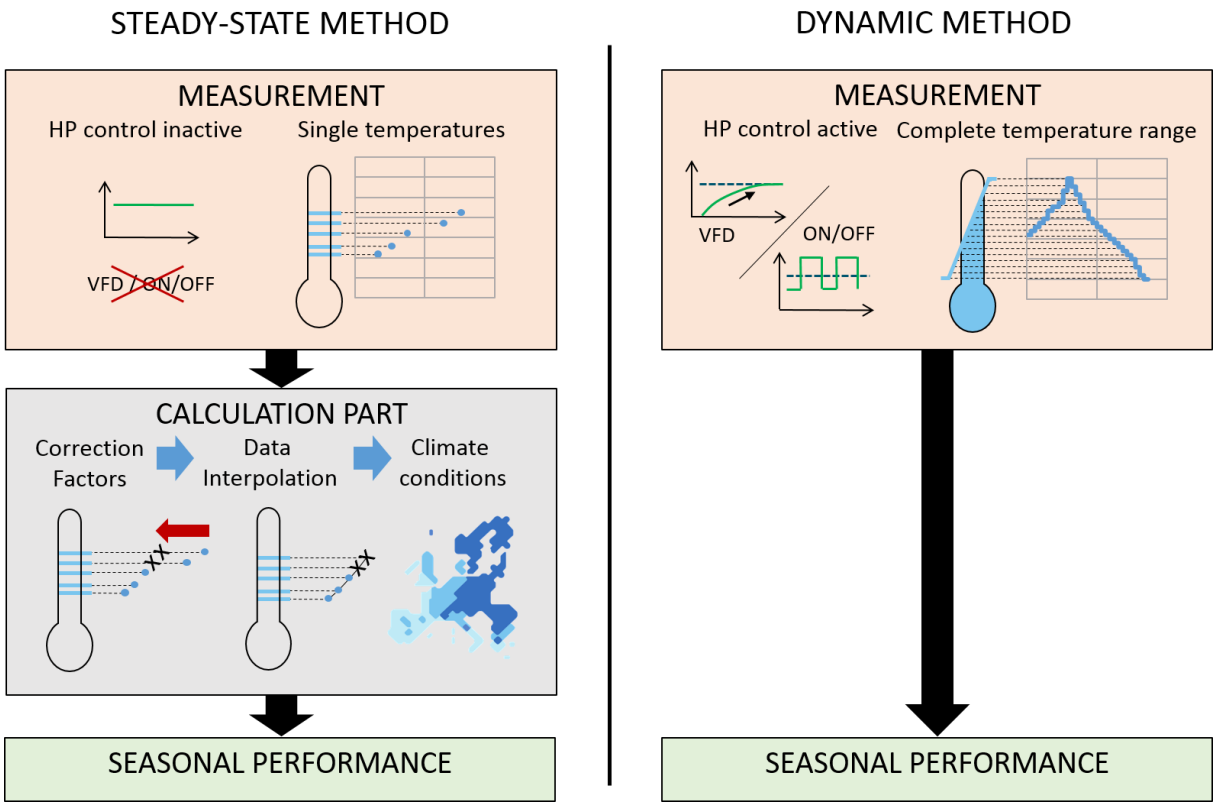


Figure 12: Test procedures for the steady-state method according to EN 14825 and the dynamic method.

Table 2 provides a side by side comparison of EN 14825 and the 'dynamic test' developed by BAM in cooperation with accredited test institutes. Please note that the comparison shows the main differences and is not meant to be fully complete.

Table 2: Side by side comparison of EN 14825 and the dynamic test method

EN 14825	Dynamic method
Setup	
	- The same experimental setup is used as for calorimetric testing according to EN 14825 - Full automation is an option
Test Design	
- Fixed compressor speed (control inactive)	- Unfixed compressor speed (control active) - compensation measurement (load based)
- Low resolution (5-7 temperatures)	- High resolution (18 temperatures; 28 temperature steps (up/down)) - **Please note:** Dependent on current tests the temperature profile might be shortened slightly in certain temperature ranges to save further test time. However, a significantly higher resolution will be kept.
Measurement Conditions	
- Tolerances are defined by EN 14511 (very narrow tolerances on temperature fluctuations)	- Relaxed tolerances on short time scale but kept on average (Figure 9) - **Please note**: Tolerances on humidity are kept according to EN 14511
- No tolerances for heating capacity; deviations from predefined heating/cooling demand are allowed without restrictions to prevent ON/OFF operation by adapting the sink side conditions (if deviation from heating/cooling demand exceeds 10%, correction factors are applied, see later) - **Observation**: Deviations from predefined heating/cooling demand up to 300% (Figure 2)	- Deviation from predefined heating/cooling demand are allowed by +/-10% only - **Observation**: Units follow load (Figure 8)
- Test conditions need to be adapted to the unit's characteristics (Figure 5)	- Test conditions are fixed, units need to cope with the set conditions (Figure 5)
Calculations and Corrections	
- Linear Interpolation/extrapolation of COP/EER, however, COP/EER is not linear to outdoor temperature (Figure 7)	- No interpolation/extrapolation needed
- Correction factors (e.g. to correct for deviations from heating/cooling demand); individual control (on/off) behavior is not considered	- No correction factors needed (fair comparison of different units) - Only weighting of temperature steps according to bin distribution
- First results of the Eco Test project have shown that min/max deviations are up to 24 %-points due to misunderstanding of the standard (e.g. wrong corrections) (source: presentation by VHK, 2nd stakeholder meeting for lot 1 and 2)	- Simple evaluation of test results; less room for interpretation likely increases reproducibility
Duration	
- 4-6 days depending on experience of lab - Full test for each climate needed	- 2-3 days - Full test for each climate needed - **Please note**: Our paper in energies does not reflect the current status of the development regarding test duration

5. Outlook

Test Guide – Improvement of Methodology by BAM

A test guide will be developed until July 2019. The temperature profile shown in our paper in the Energies Journal was designed for investigation purposes. However, the final profile will be published with the test guide. Thus, the following investigations will be done until July and are part of the current tests:

- To further improve reproducibility, we investigate potential degrees of freedom, which are
  - the parameterization of the heating curve and its influence on the performance of the test specimen
  - the inertia of the test bench side and its influence on the test results
  - the return flow temperature and its influence on the ON/OFF behavior of the test specimen
  - the integrated circulation pump and its influence on the test procedure
  - Influence of increasing and decreasing outdoor temperature slopes on the behavior of the test specimen

As a result, tolerances for parameters of the test stand should be defined that will be published with the test guide.

Technical Meeting

BAM presented the proposed dynamic test method at the stakeholder meeting for the review of lot 1 and 2 on the 26th of April. Due to limited time no discussion was possible during the meeting. Therefore, Germany, Belgium, Sweden and the Netherlands asked the EU-Commission to call for a separate technical meeting, aiming to create a common understanding of the proposed test among stakeholders. Germany offered to assist in finding a conference room in Brussels if availability of rooms is limited.

Round Robin Test

The developed test guide will be spread among the CEN technical committee for feedback. Subsequently a Round Robin test will be organized by BAM to investigate requirements on the test stand and to confirm reproducibility. The public announcement is planned for summer 2019.

Depending on the results, Germany will propose to use the new test method for the revised regulations of lot 1, 2 and 10. Modality and timing is suggested to be discussed within a consultation forum.

6. Annex

Test results according to EN 14825 are shown in Figure 13 for 11 air conditioners. Except for two units, the measured seasonal energy efficiency ratio (SEER) matches the declared values (within the tolerances). Similar results (not included) were obtained for the 28 HPs (air source (ASHP) and ground source (GSHP) heat pumps). Only for one HP results were out of tolerance.

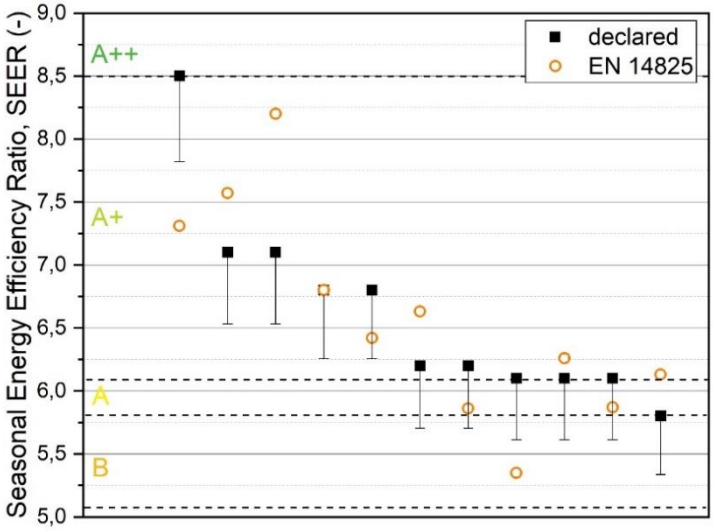


Figure 13: Seasonal energy efficiency ratios SEER measured with EN 14825 (orange circles) and declared values (black squares) for 11 ACs. The tolerance bar indicates the allowed tolerance according to regulation (EU) 626/2011.