BAM
Bundesanstalt für Materialforschung und -prüfung

Test guideline for dynamic performance testing and calculation of the seasonal coefficient of performance

Air conditioners with electrically driven compressors for space heating and cooling

BAM, S.4 Ecodesign and energy labelling

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1. Scope

This test guideline describes a test method for determining the seasonal performance (SEER, SCOP) of air conditioners with electrically driven compressors as an alternative to EN14825:2018.

2. Normative references

The methodology for the dynamic testing of air conditioners described in this test guideline is based on assumptions and correlations which can also be found in the current European standards EN14825 and EN14511. Assumptions that are used in these standards are explicitly mentioned in this test guideline.

3. Basic principle and general conditions of dynamic testing

The dynamic method is based on the requirement that the test specimen has to cover specified building loads and temperatures under various outdoor conditions. The building loads are applied on the test bench to the test specimen by a compensation load. These loads, as well as the test conditions on the source side, are provided by the test bench's conditioning apparatus. The control system of the test specimen is active at all time during the test. By using this test methodology, there is no complete decoupling of compensation load and delivered heat or cooling output. This test guideline describes the necessary general test conditions needed to minimise the interactions and to ensure reproducibility of the results on different test benches.

3.1 Procedure for the dynamic testing

The procedure of dynamic testing is divided into the steps shown in Figure 1 for the heating mode and Figure 2 for the cooling mode.

3.1.1 Heating mode

Pre-test at T_{biv} and creation of the target heating characteristics

The pre-test at T_{biv} to verify P_{biv} should also be used for the creation of the target heating characteristics. The target heating characteristics shall be based on the measured $\dot{Q}_{biv}$ at T_{biv} (PLR=100 %). If $T_{biv} = T_{design}$, the test at T_{design} will not be required and the performance measurement according to the temperature profile will be performed directly after the pre-test at T_{biv}.

Test at T_{design}

According to the heating characteristics determined, a test is carried out at the outdoor temperature T_{design} and the correlating specifications for the sink parameters. The duration of this measurement is two hours.

Temperature profile test

Following the test at T_{design} or $T_{biv} = T_{design}$, the compensation loads are tested for each temperature sequence according to the temperature profile.

Test methods for electric power input during thermostat-off mode, standby mode, crankcase heater mode and off mode

The test methods for electric power input during thermostat-off mode, standby mode, crankcase heater mode and off mode are performed according to the test methods described in EN 14825:2018.

3.1.2 Cooling mode

Pre-test at T_{design} and creation of the target cooling characteristics

The pre-test at T_{design} to verify $\dot{Q}_{design}$ should also be used for the creation of the target cooling characteristics. The duration of this measurement is two hours. If $T_{design} = 35°C$, the two hours of measurement can be added to the temperature profile test. The target cooling characteristics shall be based on the measured $\dot{Q}_{design}$ at T_{design} (PLR=100 %).

Temperature profile test

Following the test at T_{design} the compensation loads are tested for each temperature sequence according to the temperature profile.

Test methods for electric power input during thermostat-off mode, standby mode, crankcase heater mode and off mode

The test methods for electric power input during thermostat-off mode, standby mode, crankcase heater mode and off mode are performed according to the test methods described in EN 14825:2018.

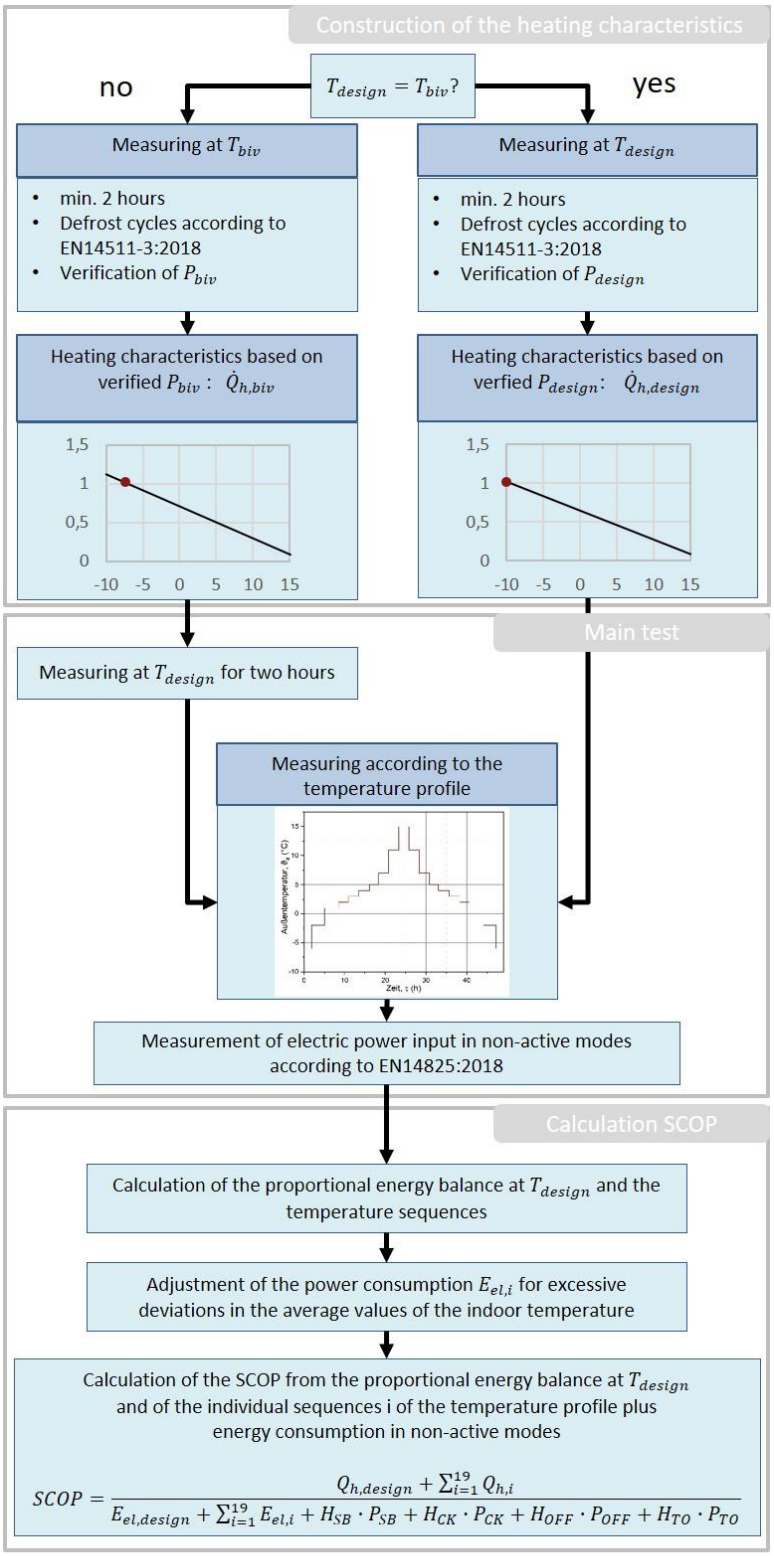


Figure 1: Procedure for the dynamic testing of air conditioners in heating mode.

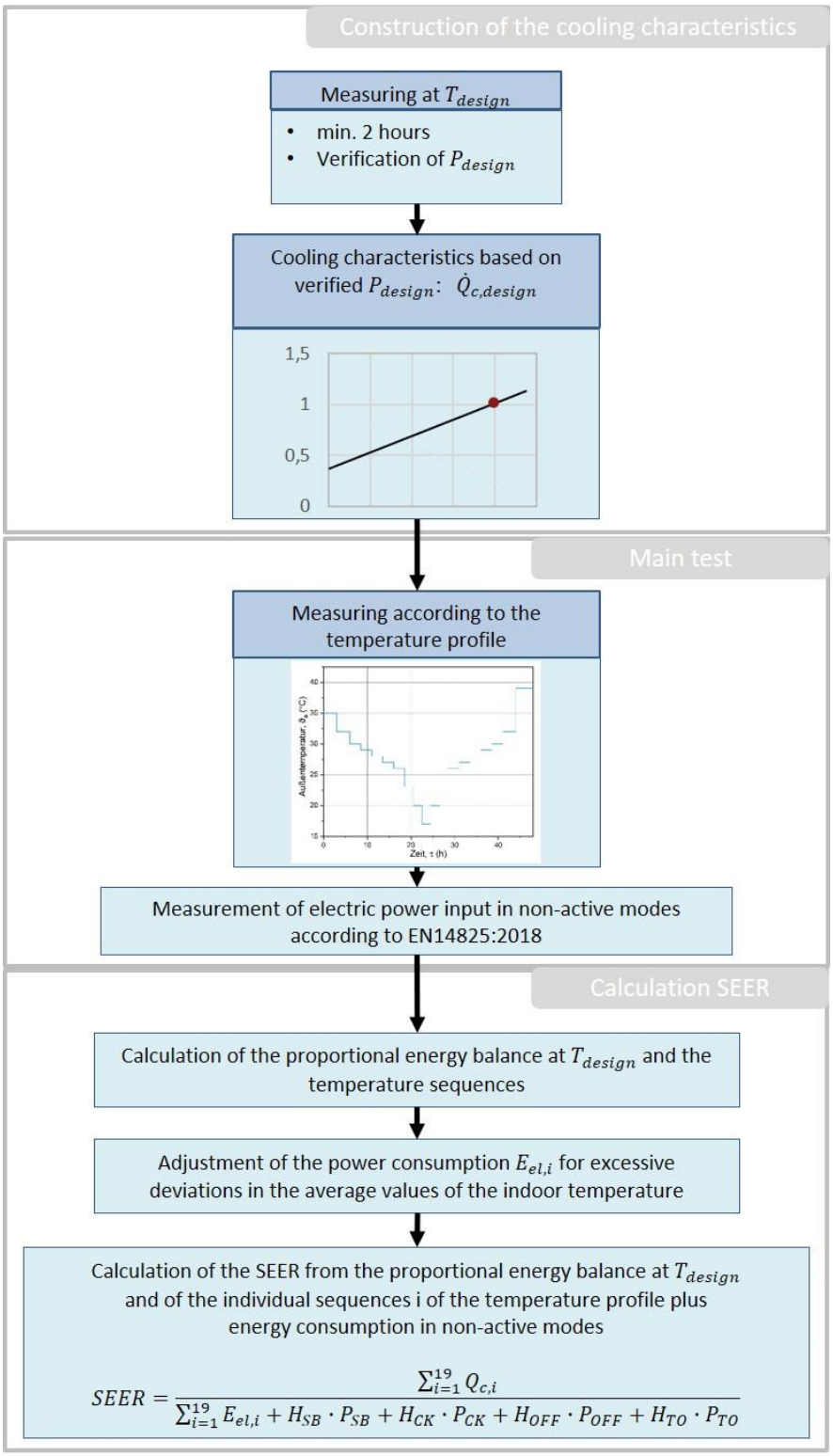


Figure 2: Procedure for the dynamic testing of air conditioners in cooling mode.

3.2 Target outdoor temperature profile and correlation between source and sink side

The temperature range and the temperatures used in the dynamic test are based on the temperature distribution of the average reference heating period from Annex B of EN 14825:2018. The shares of the seasonal heating demand of individual temperatures were grouped into bins, represented by the outdoor temperature profile. The dynamic test, based on the reference building model according to Chapter 6 of EN 14825:2018, also includes the building loads correlating with the outdoor temperature and the requirements for sink temperatures. Figure 3 shows the outdoor temperature profile to be taken during the test in heating mode. Figure 4 shows the outdoor temperature profile to be applied during the test in cooling mode. During the test, consecutive compensation measurements are performed by applying various compensation loads at different outdoor temperatures. At each outdoor temperature, the target values for the compensation load and the sink temperature change according to the reference building model specified in Chapter 6 of EN 14825:2018. Table 1 summarizes the outdoor temperature with correlating heating load (part load ratio) for the heating mode. Table 2 summarizes the outdoor temperature with correlating cooling load (part load ratio) for the cooling mode.

3.2.1 Heating mode

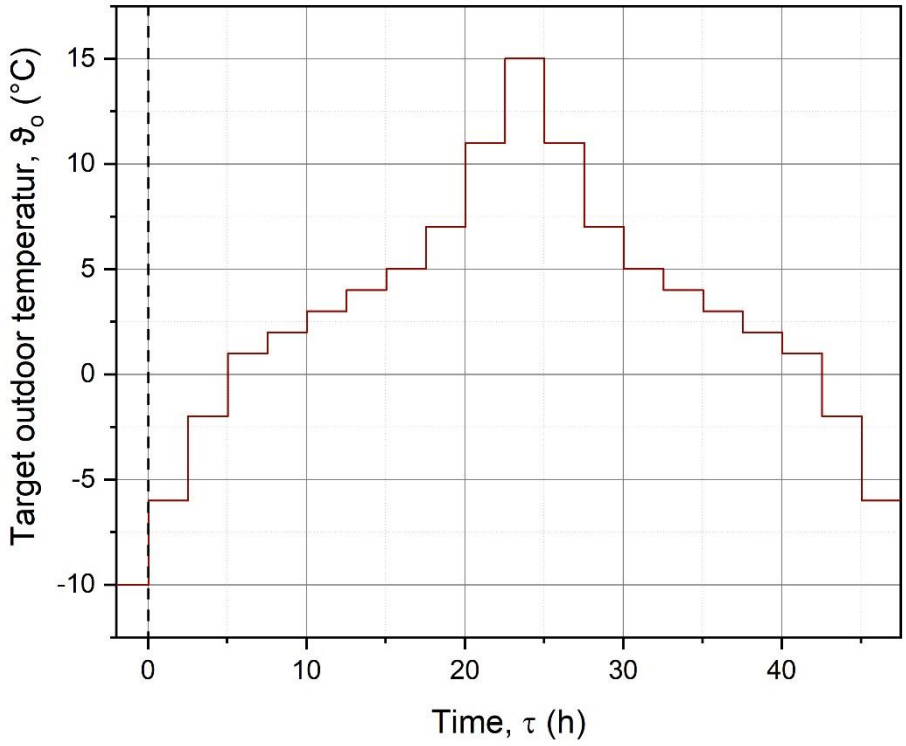


Figure 3: Outdoor temperature profile during the dynamic test for the heating mode.

Table 1: Length of the individual temperature sequences and correlation between outdoor temperature and heat output in heating mode. The indoor temperature is constant at 20 °C, according to EN 14825:2018.

Number i of sequence (-)	Length of sequence (min)	Cumulative test time (h)	Outdoor temperature ϑ_a (°C)	Part load ratio PLR with regard to nominal power (%)	Indoor temperature ϑ_i (°C)
0	150,00	-	-10	$\frac{-10-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
1	150,00	2,50	-7	$\frac{-7-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
2	150,00	5,00	-3	$\frac{-3-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
3	150,00	7,50	1	$\frac{1-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
4	150,00	10,00	2	$\frac{2-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
5	150,00	12,50	3	$\frac{3-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
6	150,00	15,00	4	$\frac{4-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
7	150,00	17,50	5	$\frac{5-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
8	150,00	20,00	7	$\frac{7-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
9	150,00	22,50	12	$\frac{12-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
10	150,00	25,00	15	$\frac{15-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
11	150,00	27,50	12	$\frac{12-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
12	150,00	30,00	7	$\frac{7-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
13	150,00	32,50	5	$\frac{5-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
14	150,00	35,00	4	$\frac{4-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20

15	150,00	37,50	3	$\frac{3-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
16	150,00	40,00	2	$\frac{2-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
17	150,00	42,50	1	$\frac{1-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
18	150,00	45,00	-3	$\frac{-3-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20
19	150,00	47,50	-6	$\frac{-7-16}{(T_{biv}-16)} \cdot \frac{\dot{Q}_{h,biv}}{\dot{Q}_{design}}$	20

3.2.2 Cooling mode

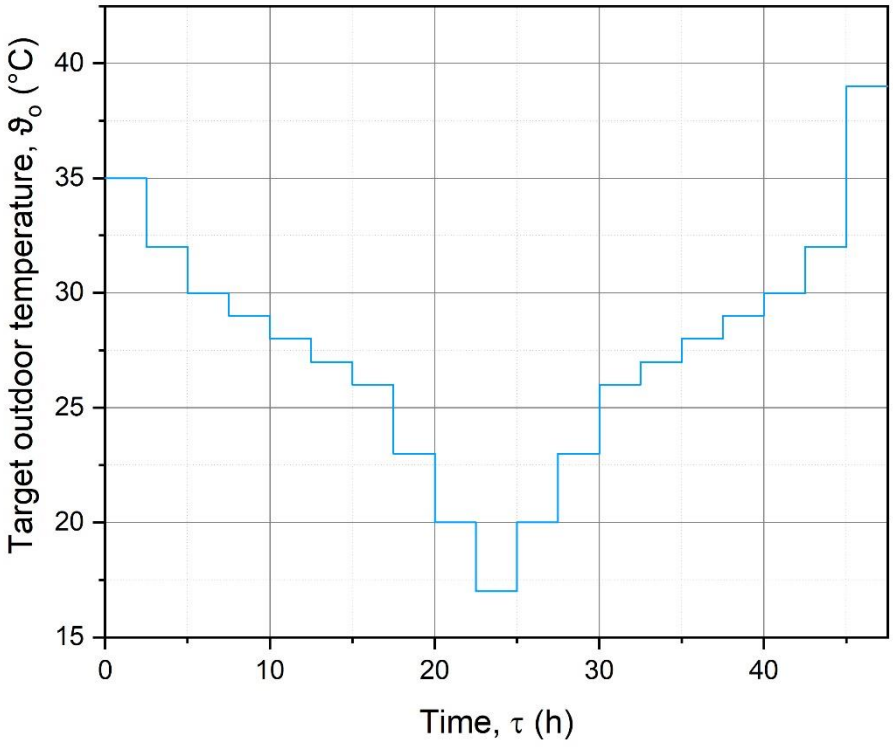


Figure 4: Outdoor temperature profile during the dynamic test for the cooling mode.

Table 2: Length of the individual temperature sequences and correlation between outdoor temperature and cooling output in cooling mode. The indoor temperature is constant at 27 °C, according to EN 14825:2018.

Number i of sequence (-)	Length of sequence (min)	Cumulative test time (h)	Outdoor temperature ϑ_a (°C)	Part load ratio PLR with regard to nominal power (%)	Indoor temperature ϑ_i (°C)
1	150,00	2,50	35	$\frac{35-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
2	150,00	5,00	32	$\frac{32-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
3	150,00	7,50	30	$\frac{30-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
4	150,00	10,00	29	$\frac{29-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
5	150,00	12,50	28	$\frac{28-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
6	150,00	15,00	27	$\frac{27-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
7	150,00	17,50	26	$\frac{26-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
8	150,00	20,00	23	$\frac{23-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
9	150,00	22,50	20	$\frac{20-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
10	150,00	25,00	17	$\frac{17-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
11	150,00	27,50	20	$\frac{20-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
12	150,00	30,00	23	$\frac{23-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
13	150,00	32,50	26	$\frac{26-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
14	150,00	35,00	27	$\frac{27-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
15	150,00	37,50	28	$\frac{28-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
16	150,00	40,00	29	$\frac{29-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27
17	150,00	42,50	30	$\frac{30-16}{(T_{design}-16)} \cdot \dot{Q}_{design}$	27

18	150,00	45,00	32	$\frac{32 - 16}{(T_{design} - 16)} \cdot \dot{Q}_{design}$	27
19	150,00	47,50	39	$\frac{39 - 16}{(T_{design} - 16)} \cdot \dot{Q}_{design}$	27

3.3 Permissible deviations from target values

If no defrost cycles occur or the heat pump is not in standby mode, the permissible deviations listed in Table 3 apply to the test bench side. Defrost cycles are defined according to the criteria defined in EN14511. In any case, the test bench must ensure that the deviations listed in Table 3 for the parameters at the air conditioner inlet (outdoor temperature, indoor temperature, compensation load) are not exceeded. The measurement data should be recorded at least every 10 seconds.

Table 3: Permissible deviations from the test bench-dependent target values

Measurand	Permissible deviation of the arithmetic mean values from target values of sequence i	Permissible deviations of the individual measured values from the target values of sequence i
Indoor/outdoor temperature	± 1K	± 3K
heating/cooling capacity	± 2,5%	± 5%

3.3.1 Maximum acceptable deviation of indoor temperature

The indoor temperature and the heating/cooling output primarily depend on the normal quality of the test specimen, provided that the permissible deviations from the target value in Table 4 are adhered to. Table 3 shows the maximum acceptable deviation of the indoor temperature. If this is exceeded or undercut, the heating/cooling load in the energy balance of sequence i is adjusted in accordance with Section 7.3.

Table 4: Maximum acceptable deviation of the indoor temperature

Measurand	Maximum acceptable deviation of the arithmetic mean from target value
Indoor temperature	± 0,5K

4.Test setup

Air conditioners can be tested with the calorimeter method according to EN 14511-3:2018. Figure 5 shows the setup for two options: (a) single calorimeter-and (b) double calorimeter.

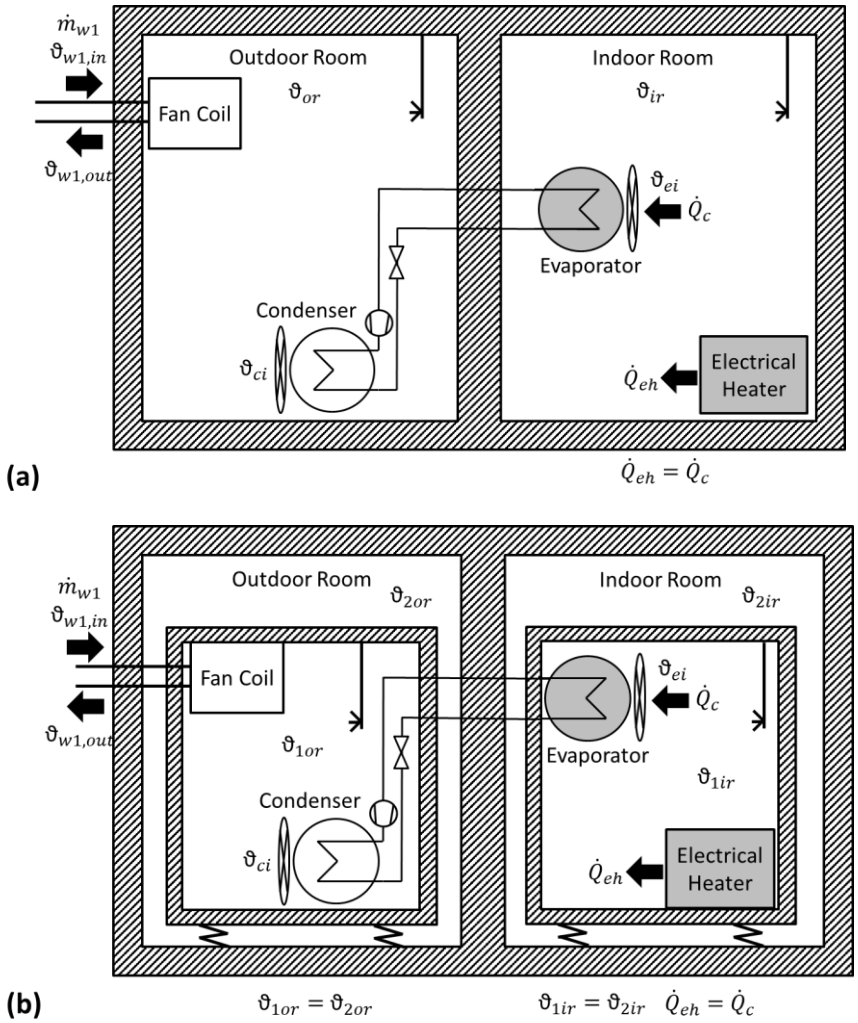


Figure 5: Test setup for testing air conditioners in a) a single calorimeter and b) a doubled calorimeter room.

3 Test preparation

Specific preparations must be made prior to the measurement on a test specimen, depending on the design of the test specimen.

In order to ensure a comparable test, the correct setting of the controller must be checked in advance. This can be done while verifying the manufacturer's data at T_{biv} or T_{design}.
The devices must be tested at the settings that are supplied by the manufacturer or are available on the market (factory settings). Exceptions and settings requiring modification are specified in this section.
Some devices require the application temperature to be set in the control panel. If possible, these settings should be set on the device.

The electric heater (if fitted) is not deactivated, allowing the heater to be switched on at temperatures below the bivalence temperature.

4 Performing the test

4.2 Setting the compensation load and outdoor temperature

On the remote control of the test specimen, the target indoor temperature is set (once) for the entire test. The optimum setting on the remote control may deviate from the specified target indoor temperature of the test bench (20°C for heating, 27°C for cooling). The optimum setting for the remote control should already be evaluated during the test at T_{design}/T_{biv}.

4.2.1 Calorimeter test

The test bench provides the temperatures and relative humidity for both test rooms as well as a compensation load for the indoor room to ensure that the energy balance is kept within a range of +/- 4%. When measuring in the calorimeter, a continuous energetic balancing of the test room is necessary. If the balancing is not in equilibrium, the compensation load must be adjusted accordingly until it is balanced within a range of again +/- 4%.

5 Evaluation and calculation of the seasonal coefficient of performance (SCOP)

5.2 Heating mode

The energy amounts determined for the heating energy measured at the condenser $Q_{h,i,exp}$ and the measured power consumption $E_{el,i,exp}$ of each individual temperature sequence i are the basis for the calculation of the SCOP.

5.2.1 Calculation of the proportional energy balance at T_{design}

In order to adjust the length of the sequence at T_{design} to the share of the heating energy at T_{design} to the total seasonal heating demand as given in Annex B of EN14825:2018, the proportional energies at T_{design} are calculated from the energies determined.

$$Q_{h,design} = Q_{h,design,exp} \cdot \frac{35{,}19s}{7200{,}00s}$$

$$E_{el,design} = E_{el,design,exp} \cdot \frac{35{,}19s}{7200{,}00s}$$

5.2.2 Calculation of the proportional energy balance of the temperature sequence i

The length of each individual temperature sequence must be adjusted for the heating energy weighting of the temperature distribution given in Annex B of EN14825:2018. The amounts of energy measured are therefore corrected for some sequences i as follows. Table 5 displays the values to be used for the weighting factor K_i.

$$Q_{h,i} = Q_{h,i,exp} \cdot K_i$$

$$E_{el,i} = E_{el,i,exp} \cdot K_i$$

Example:

Sequence: $i = 10$

Target outdoor temperature: $\vartheta_{o,target} = 15°C$

Target indoor temperature: $\vartheta_{indoor,target} = 20°C$

Weighting factor: $K_{10} = 0{,}3952$

Measured heat amount: $Q_{h,i,exp} = 10\ kWh$

Measured power consumption: $E_{el,i,exp} = 4\ kWh$

$$Q_{h,i} = Q_{h,i,exp} \cdot K_i = 10\ kWh \cdot 0{,}3952 = 3{,}952\ kWh$$

$$E_{el,i} = E_{el,i,exp} \cdot K_i = 4\ kWh \cdot 0{,}3952 = 1{,}5808\ kWh$$

Table 5: Length of the temperature sequences for the heating mode test based on the temperature distribution given in Annex B of EN14825:2018

Number of Sequence i	Weighting Factor K_i
1	1,4937
2	2,0383
3	2,1557
4	1,2012
5	1,2444
6	1,1454
7	0,8947
8	2,4180
9	1,6050
10	0,3952
11	1,6050
12	2,4180
13	0,8947
14	1,1454
15	1,2444
16	1,2012
17	2,1557
18	2,0383
19	1,4937

5.2.3 Adjustment of the power consumption $E_{el,i}$ for excessive deviations in the average values of the indoor temperature as well as the heat output

If in a sequence i the average values of the indoor temperature exceed the maximum acceptable deviations for the target values specified in Section 3.3.1, the affected sequence is subjected to an additional power input.

$$E_{el,i,kor} = E_{el,i} \cdot F_{indoor,i}$$

The following apply:

If $\vartheta_{indoor,exp} < \vartheta_{indoor,target}$: $F_{indoor,i} = \frac{\vartheta_{indoor,i,target} - 0{,}5K}{\vartheta_{indoor,i,exp}}$

If $\vartheta_{indoor,exp} > \vartheta_{indoor,target}$: $F_{indoor,i} = \frac{\vartheta_{indoor,i,exp}}{\vartheta_{indoor,i,target} + 0{,}5K}$

Example:

Sequence: $i = 4$

Target outdoor temperature: $\vartheta_{a,target} = 2°C$

Target indoor temperature: $\vartheta_{indoor,target} = 20°C$

Arithmetic mean of measured indoor temperature: $\vartheta_{indoor,exp} = 19°C$

$\vartheta_{indoor,exp} < \vartheta_{indoor,target}$

Measured power consumption: $E_{el,4} = 1\ kWh$

$$E_{el,4,kor} = E_{el,4} \cdot \frac{\vartheta_{indoor,4,target} - 0{,}5K}{\vartheta_{indoor,4,exp}} = 1\ kWh \cdot \frac{20 - 0{,}5}{19} = 1{,}03\ kWh$$

6.2.4 SCOP und η_s calculation

If for a sequence i the electrical energy $E_{el,i}$ has been adjusted in accordance with section 6.2.3, the adjusted value $E_{el,i,kor}$ must be used instead of the measured electrical energy $E_{h,i}$ for this sequence in the SCOP calculation.

$$SCOP = \frac{Q_{h,design} + \sum_{i=1}^{19} Q_{h,i}}{E_{el,design} + \sum_{i=1}^{19} E_{el,i} + H_{SB} \cdot P_{SB} + H_{CK} \cdot P_{CK} + H_{off} \cdot P_{off} + H_{TO} \cdot P_{TO}}$$

$$\eta_s = \frac{SCOP}{CC} - \sum F(i)$$

6.3 Cooling

The energy amounts determined for the cooling energy measured at the condenser $Q_{c,i,exp}$ and the measured power consumption $E_{el,i,exp}$ of each individual temperature sequence i are the basis for the calculation of the seasonal energy efficiency ratio (SEER).

6.3.1 Calculation of the proportional energy balance of the temperature sequence i

The length of each individual temperature sequence must be adjusted for the heating energy weighting of the temperature distribution given in Annex B of EN14825:2018. The amounts of energy measured are therefore corrected for some sequences i as follows. Table 5 displays the values to be used for the weighting factor K_i.

$$Q_{c,i} = Q_{c,i,exp} \cdot K_i$$

$$E_{el,i} = E_{el,i,exp} \cdot K_i$$

Example:

Sequence: $i = 4$

Target outdoor temperature: $\vartheta_{o,target} = 30°C$

Target indoor temperature: $\vartheta_{indoor,target} = 27°C$

Weighting factor: K_4= 0,9089

Measured cooling amount: $Q_{c,3,exp} = 10\ kWh$

Measured power consumption: $E_{el,3,exp} = 4\ kWh$

$$Q_{c,i} = Q_{c,3,exp} \cdot K_3 = 10\ kWh \cdot 0{,}9089 = 9{,}089\ kWh$$

$$E_{el,i} = E_{el,3,exp} \cdot K_3 = 4\ kWh \cdot 0{,}9089 = 3{,}6356\ kWh$$

Table 6: Length of the temperature sequences for the cooling mode test based on the temperature distribution given in Annex B of EN14825:2018

Number of Sequence i	Weighting Factor K_i
1	0,3925
2	1,4262
3	0,7008
4	0,9089
5	1,0392
6	1,1974
7	1,2554
8	3,7375
9	2,5981
10	2,1198
11	2,5981
12	3,7375
13	1,2554
14	1,1974
15	1,0392
16	0,9089
17	0,7008
18	1,4262
19	0,5609

6.3.2 Adjustment of the power consumption $E_{el,i}$ for excessive deviations in the average values of the indoor temperature as well as the cooling output

If in a sequence i the average values of the indoor temperature exceed the maximum acceptable deviations for the target values specified in Section 3.3.1, the affected sequence is subjected to an additional power input.

$$E_{el,i,kor} = E_{el,i} \cdot F_{indoor,i}$$

The following apply:

If $\vartheta_{indoor,exp} < \vartheta_{indoor,target}$: $F_{indoor,i} = \frac{\vartheta_{indoor,i,target} - 0{,}5K}{\vartheta_{indoor,i,exp}}$

If $\vartheta_{indoor,exp} > \vartheta_{indoor,target}$: $F_{indoor,i} = \frac{\vartheta_{indoor,i,exp}}{\vartheta_{indoor,i,target} + 0{,}5K}$

Example:

Sequence: $i = 1$

Target outdoor temperature: $\vartheta_{a,target} = 35°C$

Target indoor temperature: $\vartheta_{indoor,target} = 27°C$

Arithmetic mean of measured indoor temperature: $\vartheta_{indoor,1,exp} = 28°C$

$\vartheta_{indoor,exp} > \vartheta_{indoor,target}$ und $\dot{Q}_{c,1,exp} < \dot{Q}_{c,1,target}$

Measured power consumption: $E_{el,4} = 1\ kWh$

$$E_{el,4,kor} = E_{el,4} \cdot \frac{\vartheta_{indoor,1,exp}}{\vartheta_{indoor,1,target} + 0{,}5} = 1\ kWh \cdot \frac{28}{27 + 0{,}5} = 1{,}02\ kWh$$

6.3.3 SEER calculation

If for a sequence i the electrical energy $E_{el,i}$ has been adjusted in accordance with section 6.3.2, the adjusted value $E_{el,i,kor}$ must be used instead of the measured electrical energy $E_{h,i}$ for this sequence in the SEER calculation.

$$SEER = \frac{\sum_{i=1}^{19} Q_{c,i}}{\sum_{i=1}^{19} E_{el,i} + H_{SB} \cdot P_{SB} + H_{CK} \cdot P_{CK} + H_{off} \cdot P_{off} + H_{TO} \cdot P_{TO}}$$