BAM
Bundesanstalt für Materialforschung und -prüfung

2020-09-21

Test guideline for a load-based performance testing

Heat pumps with electrically driven compressors for space heating

BAM, S.4 Ecodesign and energy labelling

Carsten Palkowski

carsten.palkowski@bam.de

Contents

1. Scope 3
1.1 General 3
2. Normative references 3
3. Symbols, abbreviated terms and units 3
4. General requirements 4
4.1 Permissible deviations from set values 4
5. Test setup 5
6. Test conditions 8
7. Test procedure 8
7.1 Test preparation (Pre-Conditioning phase) 8
7.2 Test procedure 9
7.3 Pump Correction 10
8. Evaluation of the RRT 11
8.1 General Information 11
8.2 Evaluation of measurement data 11

1. Scope

This test guideline describes a test method for a load-based performance test of heat pumps with electrically driven compressors to be applied for the round robin test of BAM.

1.1 General

The procedures described in this test guideline apply to water-based heat pumps that are

a. air-source or ground-source;
b. water-sink or brine-sink;
c. single-split systems with matching assemblies;
d. intended for space-heating in buildings;
e. electrically driven, mechanical, vapor-compression-type systems; and
f. rated below 70 kW heating at standard rating conditions (in accordance with EN14511).

2. Normative references

The procedures described in this test guideline refer to the following publications:

a. EN 14825:2018
b. EN 14511:2018

3. Symbols, abbreviated terms and units

Table 1: Symbols, abbreviated terms and units

Symbol and abbreviated terms	Denomination	Units
COP	Coefficient of Performance	-
DB	Dry bulb	-
$\dot{Q}_{design}$	Compensation Load under full load conditions	kW
$\dot{Q}_{comp}$	Compensation Load	kW
$\dot{Q}_h$	Heating capacity	kW
T_{biv}	Bivalent temperature	°C
T_{design}	Reference design temperature conditions	°C
TOL	Operation limit temperature	°C
ϑ_o	Outdoor temperature	°C
ϑ_i	Indoor temperature	°C
ϑ_s	Outlet water temperature	°C
ϑ_w	Inlet water temperature	°C
WB	Wet bulb	-

4. General requirements

During a load-based test the heating circuit of the test stand is subjected to a compensation load simulating a building load. The heat pump responds in accordance with its heating curve as it tries to maintain the required supply temperature, while outdoor room conditions are held constant. These compensation loads, as well as the test conditions on the source side, are provided by the test bench's conditioning apparatus. Single-speed, multiple-speed and variable-speed heat pumps under test shall be operated under control of the equipment and not in a fixed-speed mode. The heat pumps are thus permitted to switch into on/off operation.

The units tested shall be installed in accordance to the installation manual from the manufacturer and the EN14511-3:2018. The heat pumps shall be tested at the settings they are available on the market (factory settings) provided by BAM. Furthermore, the following information shall be provided by the manufacturer:

- the basic control strategy of the heat pump for changing the capacity (e.g. return temperature or supply temperature)
- access to the control elements which allow the adjustment of the heating curve to achieve the required supply temperature according to Table 4

The recording frequency shall be 10 seconds.

4.1 Permissible deviations from set values

For load-based testing, in dependence on the operating condition the following permissible deviations apply:

- During continuous operation / steady state operation of the HP the permissible deviations to be applied are shown in Table 2. Continuous operation / steady state operation starts from 10 minutes after the compressor is switched on.
- During off operation of the HP the permissible deviations to be applied are shown in Table 3.
- In case of defrosting the permissible deviations according to EN14511-3:2018 Table 5 (Interval D and H) shall be applied.

Table 2: Permissible deviations during continuous / steady state operation of the HP

Measurand	Permissible deviations of the arithmetic mean values from the set values	Permissible deviations of the individual measured values from the set values
Source Side		
Inlet air temperature (DB)	± 0,3K	± 1,0K
Inlet air temperature (WB)	± 0,4K	± 1,0K
Inlet water/brine temperature	± 0,2K	± 0,5K
Water/brine flow rate	± 1%	± 2,5%
Sink Side		
Outlet water temperature	± 0,3K	± 0,6K
Water/brine flow rate	± 1%	± 2,5%

Electrical voltage	± 4%	± 4%
Compensation load	± 10%	± 10%

Table 3: Permissible deviations during off operation of the HP

Measurand	Permissible deviations of the arithmetic mean values from the set values	Permissible deviations of the individual measured values from the set values
Source Side		
Inlet air temperature (DB)	± 0,6K	± 2,0K
Inlet air temperature (WB)	± 0,6K	± 2,0K
Inlet water/brine temperature	-	-
Water/brine flow rate	-	-
Sink Side		
Outlet water temperature	-	-
Water/brine flow rate	-	-
Electrical voltage	± 4%	-
Compensation load*	± 10%*	-

*in some cases a measurement within the permissible deviations may not be possible, however, please report in the test report/the data sheet that compensation load exceeded the permissible deviations

5. Test setup

Brine/water and water/water heat pumps are measured on the sink and source side using the enthalpy method in accordance with EN 14511-3:2018. Figure 1 shows two possible options for the test setup.

Air/water heat pumps are measured on the sink side using the water enthalpy method according to EN 14511-3:2018. Figure 2 shows two possible options for the test setup.

The volume of the sink side hydraulic system is recommended to be 10 l/kW – 30 l/kW. Furthermore, the pressure drop is recommended to be 0.4 bar.

The compensation load shall be applied as shown in Figure 1 and Figure 2 according to the following two options:

Option 1: If possible, the control of the test stand shall regulate the conditions of the cooling apparatus (without regulating the volume flow at the heat pump condenser) so that the compensation load is applied directly at the heat pump condenser.

Option 2: If the control of the test stand is incapable of realizing this, the compensation load shall be applied as follows:

- For test stands with intermediate circuit, the compensation load shall be applied at the heat exchanger between sink side and cooling apparatus.

- For test stands without intermediate circuit, the compensation load shall be applied at the mixing valve connecting the sink side and the test stand.

For Option 2, please note that the measurement results for both, the compensation load and the load at the heat pump condenser, shall be provided to BAM.

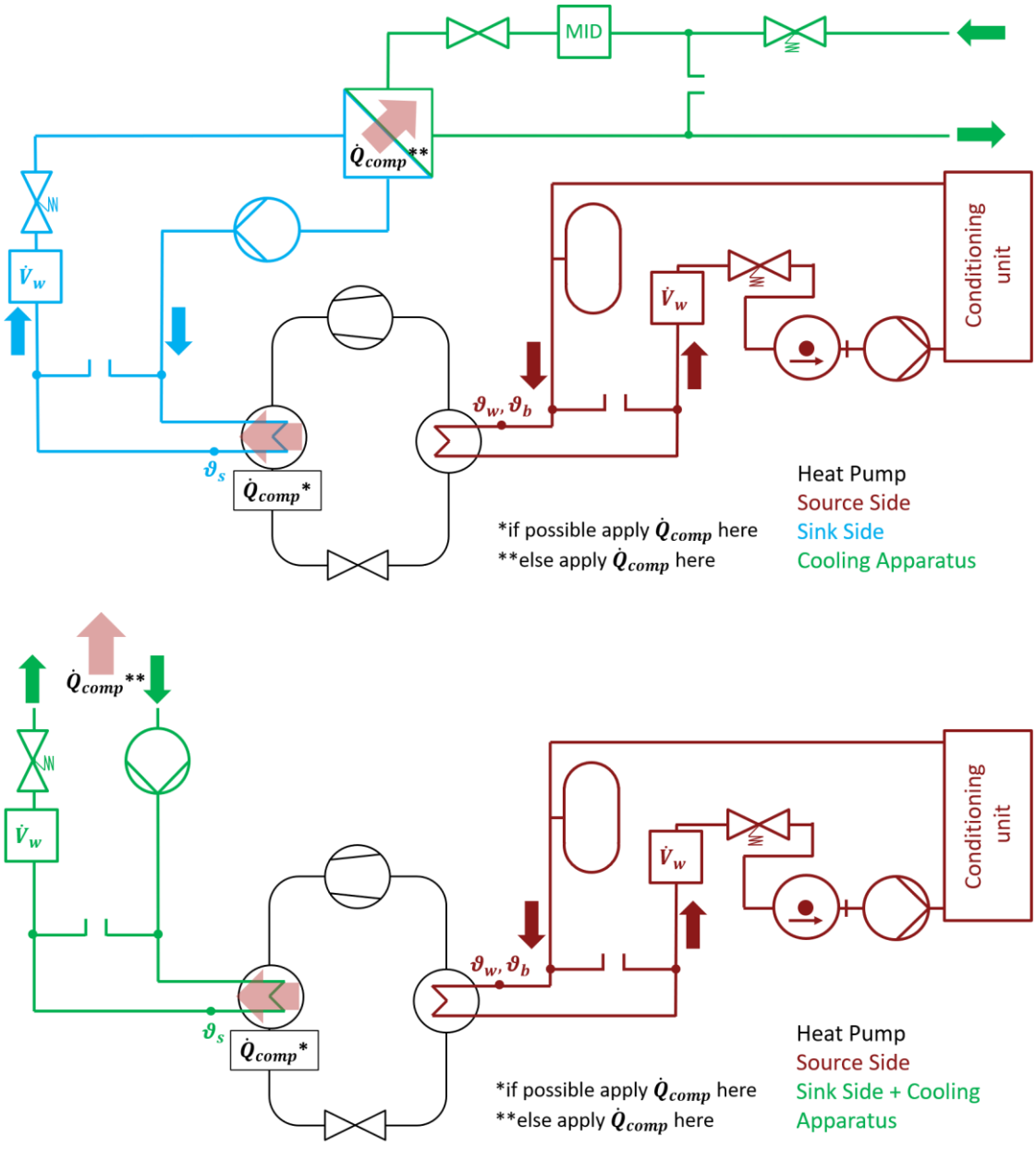


Figure 1: Test setup for testing brine and water/water heat pumps with and without an intermediate circuit.

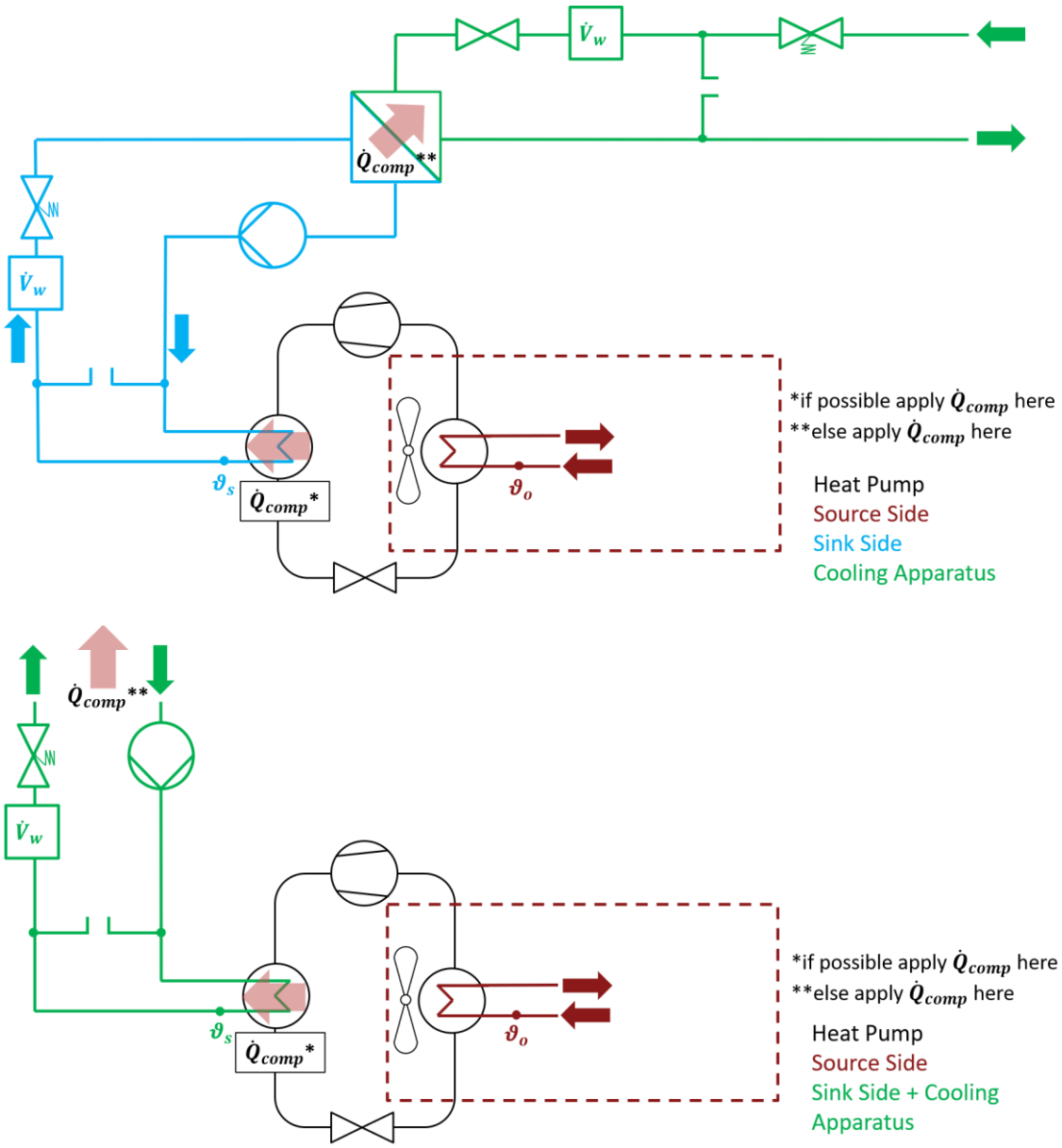


Figure 2: Test setup for testing air/water heat pumps with and without an intermediate circuit.

6. Test conditions

Table 4: Part load conditions for the heating capacity tests according to EN 14825:2018 for average European climate and low temperature application.

Test interval	DB outdoor temperature $\vartheta_{o,DB}$ (°C)	WB outdoor temperature $\vartheta_{o,WB}$ (°C)	Water inlet temperature (source side) ϑ_w (°C)	Water outlet temperature (sink side) ϑ_s (°C)	Compensation load $\dot{Q}_{comp}$ (kW)
A	-7	-8	10	34	$\frac{-7-16}{(T_{design}-16)}\dot{Q}_{design}$
B	2	1	10	30	$\frac{+2-16}{(T_{design}-16)}\cdot\dot{Q}_{design}$
C	7	6	10	27	$\frac{+7-16}{(T_{design}-16)}\cdot\dot{Q}_{design}$
D	12	11	10	24	$\frac{+12-16}{(T_{design}-16)}\cdot\dot{Q}_{design}$
E	TOL	-	10	a	$\frac{TOL-16}{(T_{design}-16)}\cdot\dot{Q}_{design}$

a: The supply temperature shall be calculated by interpolation from T_{design} and the temperature which is the closest to the TOL value.

7. Test procedure

During the compensation test, the sink side water system is used to maintain the supply temperature and the heating load, which are updated based on the building load model (Table 4) that includes interaction with the unit performance in real-time. The outdoor room is used to maintain constant outdoor conditions over a temperature range associated with different climate zones for testing air-water heat pumps; for ground sourced heat pumps the source side inlet temperature is to maintain constant according to Table 4. In Figure 3 the test preparation and test procedure are shown.

7.1 Test preparation (Pre-Conditioning phase)

Prior to each test interval, the deviations between the arithmetic mean supply temperature values and the set values are checked. If the occurring deviations are within the permissible deviations of the arithmetic mean values from the set values (Table 2 or Table 3) for at least 10 minutes, the next period of the test procedure can be started.

If it is not possible to stay within the permissible deviations of the arithmetic mean values from the set values (Table 2 or Table 3), the heating curve of the heat pump shall be adjusted properly to utmost achieve the required supply temperature.

If a defrost process occurs during this phase the next period of the test procedure shall not be started before the end of the defrost cycle and a recovery period of 10 min.

7.2 Test procedure

A/W heat pump

Each test interval includes three major parts following the EN14511-3:

1) Pre-conditioning phase

2) Equilibrium phase of

a) at least 60 min if no defrost occurs or

b) at least one complete defrost cycle. The data collection period starts immediately after the defrost process is finished.

3) Data collection period of

a) at least 35 min, if steady state operation,

b) at least 180 min - if the heat pump operates in defrost operation after 180 min the data collection period shall not be finished before the complete defrost cycle is detected-,

c) at least 2 cycles, if continuous cycling operation[1]

d) or at least 4 on/off cycles, if discontinuous cycling operation[2].

The test intervals shall be carried out in the following order:

Test run 1	Test run 2
1. Test interval E	1. Test interval D
2. Test interval A	2. Test interval C
3. Test interval B	3. Test interval B
4. Test interval C	4. Test interval A
5. Test interval D	5. Test interval E

W/W heat pump

Each test interval includes two major parts following the EN14511-3:

1) Pre-conditioning phase

2) Data collection period of

a) at least 35 min, if steady state operation,

b) at least 2 cycles, if continuous cycling operation[1]

c) or at least 4 on/off cycles, if discontinuous cycling operation[2].

[1] Continuous cycling operation: cycling between two compressor frequencies
[2] Discontinuous cycling operation: cycling between lowest possible frequency/capacity and off operation

The test intervals shall be carried out in the following order:

Test run 1	Test run 2
1. Test interval E	1. Test interval D
2. Test interval A	2. Test interval C
3. Test interval B	3. Test interval B
4. Test interval C	4. Test interval A
5. Test interval D	5. Test interval E

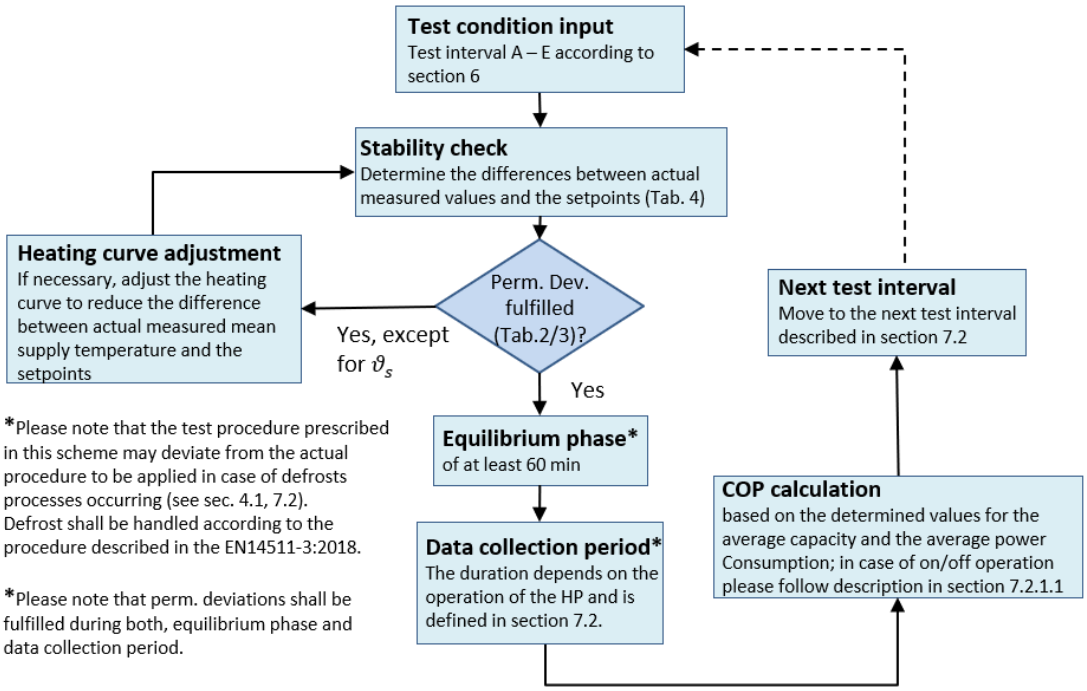


Figure 3: Test procedure for the capacity tests.

The capacity tests at E, A, B, C and D shall be carried out according to the prescribed procedure in Figure 3 and the test conditions according to Table 4. The values for the compensation loads to be applied for the test intervals E, A, B, C and D will be provided by BAM. After the properly setting of the heating curve, a defrost process shall be initiated and the measurement shall be started with the beginning of the defrost cycle (definitions according to EN14511-3:2018).

7.2.1.1 On/Off behavior

If the heat pump switches to cyclic operation during the test, the average capacity and average power consumption considering the entire test interval time (incl. off cycles of the HP) and at least 4 on/off cycles shall be used for the COP calculation, beginning at the start of an on-cycle and ending at the end of an off-cycle.

7.3 Pump Correction

The measured heating capacity shall be corrected for the heat from the circulating pump, in accordance with EN 14511-3:2018. The effective power input shall be obtained from the measured power input and the corrections from the heat from the circulating pump and/or fan, if any.

8. Evaluation of the RRT

8.1 General Information

- Photo documentation of wooden box, photo documentation of damage due to transport
- Photos of installation and instrumentation location
- Information on heating curve adjustment
- RI-Scheme of test stand
- Volume size of test stands (calorimeter room and/or hydraulic systems)
- Measurement uncertainties incl. method of determination
- expansion factor k
- level of confidence
- Information of HP behavior for each test interval (On/off or continuous? Defrost?)

8.2 Evaluation of measurement data

- Raw data for each test interval
- Development of the Outdoor Temperature (DB, WB) or Brine Temperature, Supply Temperature, Return Temperature, Rel. Humidity (Outdoor), Heating Capacity, Compensation Load, Electric Power Consumption and COP for each test interval
- Average Values for each test interval at least for the Outdoor Temperature (DB, WB) or Brine Temperature, Supply Temperature, Return Temperature, Rel. Humidity (Outdoor), Heating Capacity, Compensation Load, Electric Power Consumption and COP