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Air-cooled air conditioners and air-to-air heat pumps — Testing and calculating methods for seasonal performance factors —

Part 2: Heating seasonal performance factor

Climatiseurs à condenseur à air et pompes à chaleur air/air — Essais et méthodes de calcul des coefficients de performance saisonniers —

Partie 2: Coefficient de performance saisonnier de chauffage (COPSC)

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 6, *Testing and rating of air-conditioners and heat pumps*.

The parts of ISO 16358 are given below:

- — *Part 1: Cooling seasonal performance factor*
- — *Part 2: Heating seasonal performance factor*
- — *Part 3: Annual performance factor*

Air-cooled air conditioners and air-to-air heat pumps — Testing and calculating methods for seasonal performance factors —

Part 2:
Heating seasonal performance factor

1 Scope

1.1 This part of ISO 16358 specifies the testing and calculating methods for seasonal performance factor of equipment covered by ISO 5151, ISO 13253 and ISO 15042. For the purposes of this part of ISO 16358, it is assumed that any make-up heating will be provided by electric heaters running concurrently with the heat pump.

1.2 This part of ISO 16358 also specifies the seasonal performance test conditions and the corresponding test procedures for determining the seasonal performance factor of equipment, as specified in 1.1, under mandatory test conditions and is intended for use only in marking, comparison, and certification purposes.

1.3 This part of ISO 16358 does not apply to the testing and rating of:

a) water-source heat pumps or water-cooled air conditioners;

b) portable units having a condenser exhaust duct;

c) individual assemblies not constituting a complete refrigeration system; or

d) equipment using the absorption refrigeration cycle.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5151, *Non-ducted air conditioners and heat pumps — Testing and rating for performance*

ISO 13253, *Ducted air-conditioners and air-to-air heat pumps — Testing and rating for performance*

ISO 15042, *Multiple split-system air-conditioners and air-to-air heat pumps — Testing and rating for performance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5151, ISO 13253, ISO 15042 and the following apply.

3.1
defined heating load, L_h
heat defined as heating demand for a given outdoor temperature

3.2
make-up heating
electric heat required to cover the deficiency of the heating capacity delivered by the heat pump for the heating load

3.3
heating seasonal total load
HSTL
total annual amount of heat, including make-up heat, which is added to the indoor air when the equipment is operated for heating in active mode

3.4
heating seasonal energy consumption
HSEC
total annual amount of energy consumed by the equipment, including make-up heat, when it is operated for heating in active mode

3.5
heating seasonal performance factor
HSPF
ratio of the total annual amount of heat that the equipment, including make-up heat, can add to the indoor air when operated for heating in active mode to the total annual amount of energy consumed by the equipment during the same period

3.6
part load factor
PLF
ratio of the performance when the equipment is cyclically operated to the performance when the equipment is continuously operated, at the same temperature and humidity conditions

3.7
degradation coefficient, C_D
coefficient that indicates efficiency loss caused by cyclic operation

3.8
fixed capacity unit
equipment which does not have possibility to change its capacity

Note 1 to entry: to entry This definition applies to each cooling and heating operation individually.

3.9
two (2)-stage capacity unit
equipment where the capacity is varied by two steps

Note 1 to entry: This definition applies to each cooling and heating operation individually.

3.10
multi-stage capacity unit
equipment where the capacity is varied by 3 or 4 steps

Note 1 to entry: This definition applies to each cooling and heating operation individually.

3.11
variable capacity unit
equipment where the capacity is varied by five or more steps to represent continuously variable capacity

Note 1 to entry: This definition applies to each cooling and heating operation individually.

3.12
heating full-load operation

operation with the equipment and controls configured for maximum continuous refrigeration capacity at H1 condition

Note 1 to entry: Unless otherwise regulated by the automatic controls of the equipment, all indoor units and compressors shall be functioning.

3.13
heating extended-load operation

operation of the equipment at maximum continuous refrigeration capacity at H2 condition

Note 1 to entry: Unless otherwise regulated by the automatic controls of the equipment, all indoor units and compressors shall be functioning.

3.14
minimum-load operation

operation of the equipment and controls at minimum continuous refrigeration capacity

Note 1 to entry: All indoor units shall be functioning

3.15
standard heating full capacity

heating capacity at H1 at full-load operating condition

3.16
standard heating full power input

electric power input at H1 at full-load operating condition

3.17
standard heating half capacity

capacity which is 50 % of heating full capacity at H1 condition with all indoor units functioning

3.18
standard heating half power input

electric power input when operated at 50 % of heating full capacity at H1 condition with all indoor units functioning

3.19
standard heating minimum capacity

capacity which is minimum heating capacity at H1 condition at the minimum-load operation

3.20
standard heating minimum power input

electric power input when operated at minimum heating capacity at H1 condition at the minimum-load operation

3.21
standard heating extended capacity

heating capacity when operated at H2 condition at the extended-load operation

3.22
standard heating extended power input

electric power input when operated at H2 condition at the extended-load operation

3.23
total heating seasonal performance factor
THSPF

ratio of the total annual amount of heat that the equipment, including make-up heat, can add to the indoor air to the total annual amount of energy consumed by the equipment, including the active, inactive and disconnected modes

3.24
active mode
mode corresponding to the hours with a heating demand of the building and whereby the heating function of the unit is switched on

3.25
inactive mode
mode corresponding to the hours when the unit is not operating to meet heating demand

Note 1 to entry: This mode may include the operation of a crankcase heater.

3.26
disconnected mode
mode corresponding to the hours when the unit is electrically disconnected from the main power supply

Note 1 to entry: Power consumption is zero.

4 Symbols

Symbol	Description	Unit
C_{HSE}	heating seasonal energy consumption (HSEC)	Wh
$C_{\mathrm{OP}}\ (t)$	heating coefficient of performance (COP) at continuous outdoor temperature t	W/W
$C_{\mathrm{OP}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ ext}}\ (t_{\mathrm{h}})$	heating coefficient of performance (COP) when heating load is equal to non-frosting range heating extended capacity	W/W
$C_{\mathrm{OP,\ ext,\ f}}\ (t_{\mathrm{f}})$	heating coefficient of performance (COP) when heating load is equal to frosting range heating extended capacity	W/W
$C_{\mathrm{OP,\ fe}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) in non-frosting variable operation between full and extended capacity at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ fe,\ f}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) in frosting variable operation between full and extended capacity at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ ful}}\ (t_{\mathrm{a}})$	heating coefficient of performance (COP) when heating load is equal to non-frosting range heating full capacity	W/W
$C_{\mathrm{OP,\ ful,\ f}}\ (t_{\mathrm{g}})$	heating coefficient of performance (COP) when heating load is equal to frosting range heating full capacity	W/W
$C_{\mathrm{OP,\ haf}}\ (t_{\mathrm{d}})$	heating coefficient of performance (COP) when heating load is equal to non-frosting range heating half capacity	W/W
$C_{\mathrm{OP,\ haf,\ f}}\ (t_{\mathrm{e}})$	heating coefficient of performance (COP) when heating load is equal to frosting range heating half capacity	W/W
$C_{\mathrm{OP,\ hf}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) in non-frosting variable operation between half and full capacity at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ hf,\ f}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) in frosting variable operation between half and full capacity at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ mh}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) in non-frosting variable operation between minimum and half capacity at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ mh,f}}\ (t_{\mathrm{j}})$	heating coefficient of performance (COP) in frosting variable operation between minimum and half capacity at outdoor temperature t_{j}	W/W
$C_{\mathrm{OP,\ min}}\ (t_{\mathrm{q}})$	heating coefficient of performance (COP) when heating load is equal to non-frosting range heating minimum capacity	W/W

Symbol	Description	Unit
$C_{\mathrm{OP,\ min,f}}\ (t_{\mathrm{r}})$	heating coefficient of performance (COP) when heating load is equal to frosting range heating minimum capacity	W/W
F_{HSP}	heating seasonal performance factor (HSPF)	–
$F_{\mathrm{PL}}\ (t_{\mathrm{j}})$	part load factor (PLF) at outdoor temperature t_{j}	–
F_{THSP}	total heating seasonal performance factor (THSPF)	–
L_{HST}	heating seasonal total load (HSTL)	Wh
$L_{\mathrm{h}}(t_{\mathrm{j}})$	defined heating load at outdoor temperature t_{j}	W
n	number of temperature bins	–
n_{j}	bin hours	h
$P(t)$	heating power input calculated by equation of $P(t_{\mathrm{j}})$ at continuous outdoor temperature t	W
$P(t_{\mathrm{j}})$	heating power input applicable to any capacity at outdoor temperature t_{j}	W
$P_{\mathrm{ext}}(t_{\mathrm{j}})$	non-frosting range heating extended power input at outdoor temperature t_{j}	W
$P_{\mathrm{ext}}(-7)$	heating extended power input at outdoor temperature −7 °C	W
$P_{\mathrm{ext}}(2)$	calculated heating extended power input at outdoor temperature 2 °C	W
$P_{\mathrm{ext,\ f}}(t_{\mathrm{j}})$	frosting range heating extended power input at outdoor temperature t_{j}	W
$P_{\mathrm{ext,\ f}}(2)$	heating extended power input at H2 temperature condition	W
$P_{\mathrm{fe}}(t_{\mathrm{j}})$	heating power input in variable operation between full and extended capacity at outdoor temperature t_{j}	W
$P_{\mathrm{ful}}(t_{\mathrm{j}})$	non-frosting range heating full power input at outdoor temperature t_{j}	W
$P_{\mathrm{ful}}(7)$	heating full power input at H1 temperature condition	W
$P_{\mathrm{ful}}(-7)$	heating full power input at outdoor temperature −7 °C	W
$P_{\mathrm{ful}}(2)$	calculated heating full power input at outdoor temperature 2 °C	W
$P_{\mathrm{ful,\ f}}(t_{\mathrm{j}})$	frosting range heating full power input at outdoor temperature t_{j}	W
$P_{\mathrm{ful,\ f}}(2)$	heating full power input at H2 temperature condition	W
$P_{\mathrm{haf}}(t_{\mathrm{j}})$	non-frosting range heating half power input at outdoor temperature t_{j}	W
$P_{\mathrm{haf}}(7)$	heating half power input at H1 temperature condition	W
$P_{\mathrm{haf}}(-7)$	heating half power input at outdoor temperature −7 °C	W
$P_{\mathrm{haf}}(2)$	calculated heating half power input at outdoor temperature 2 °C	W
$P_{\mathrm{haf,\ f}}(t_{\mathrm{j}})$	frosting range heating half power input at outdoor temperature t_{j}	W
$P_{\mathrm{haf,\ f}}(2)$	heating half power input at H2 temperature condition	W
$P_{\mathrm{hf}}(t_{\mathrm{j}})$	heating power input in variable operation between half and full capacity at outdoor temperature t_{j}	W
$P_{\mathrm{mf}}(t_{\mathrm{j}})$	heating power input in second stage cyclic operation between minimum and full capacity at outdoor temperature t_{j}	W
$P_{\mathrm{mh}}(t_{\mathrm{j}})$	heating power input in variable operation between minimum and half capacity at outdoor temperature t_{j}	W
$P_{\mathrm{min}}(t_{\mathrm{j}})$	non-frosting range heating minimum power input at outdoor temperature t_{j}	W
$P_{\mathrm{min}}(7)$	heating minimum power input at H1 temperature condition	W
$P_{\mathrm{min}}(-7)$	heating minimum power input at outdoor temperature −7 °C	W
$P_{\mathrm{min}}(2)$	calculated heating minimum power input at outdoor temperature 2 °C	W

Symbol	Description	Unit
$P_{\text{min, f}}(t_{\text{j}})$	frosting range heating minimum power input at outdoor temperature t_{j}	W
$P_{\text{min, f}}(2)$	heating minimum power input at H2 temperature condition	W
$P_{\text{RH}}(t_{\text{j}})$	make-up heating energy at outdoor temperature t_{j}	Wh
t	general continuous outdoor temperature	°C
t_{j}	outdoor temperature corresponding to each temperature bin	°C
t_{a}	outdoor temperature when heating load is equal to non-frosting range heating full capacity	°C
t_{d}	outdoor temperature when heating load is equal to non-frosting range heating half capacity	°C
t_{e}	outdoor temperature when heating load is equal to frosting range heating half capacity	°C
t_{f}	outdoor temperature when heating load is equal to frosting range heating extended capacity	°C
t_{g}	outdoor temperature when heating load is equal to frosting range heating full capacity	°C
t_{h}	outdoor temperature when heating load is equal to non-frosting range heating extended capacity	°C
t_{q}	outdoor temperature when heating load is equal to non-frosting range heating minimum capacity	°C
t_{r}	outdoor temperature when heating load is equal to frosting range heating minimum capacity	°C
$X(t_{\text{j}})$	ratio of load to capacity at outdoor temperature t_{j}	–
$X_{\text{fe}}(t_{\text{j}})$	ratio of excess capacity over load to capacity difference between full and extended capacity at outdoor temperature t_{j}	–
$X_{\text{hf}}(t_{\text{j}})$	ratio of excess capacity over load to capacity difference between half and full capacity at outdoor temperature t_{j}	–
$X_{\text{mf}}(t_{\text{j}})$	ratio of excess capacity over load to capacity difference between minimum and full capacity at outdoor temperature t_{j}	–
$X_{\text{mh}}(t_{\text{j}})$	ratio of excess capacity over load to capacity difference between minimum and half capacity at outdoor temperature t_{j}	–
$\phi(t)$	heating capacity calculated by equation of $\phi(t_{\text{j}})$ at continuous outdoor temperature t	W
$\phi(t_{\text{j}})$	heating capacity applicable to any capacity at outdoor temperature t_{j}	W
$\phi_{\text{ext}}(t_{\text{j}})$	non-frosting range heating extended capacity at outdoor temperature t_{j}	W
$\phi_{\text{ext}}(-7)$	heating extended capacity at outdoor temperature −7 °C	W
$\phi_{\text{ext}}(2)$	calculated heating extended capacity at outdoor temperature 2 °C	W
$\phi_{\text{ext, f}}(t_{\text{j}})$	frosting range heating extended capacity at outdoor temperature t_{j}	W
$\phi_{\text{ext, f}}(2)$	frosting range heating extended capacity at H2 temperature condition	W
$\phi_{\text{ful}}(t_{\text{j}})$	non-frosting range heating full capacity at outdoor temperature t_{j}	W
$\phi_{\text{ful}}(7)$	heating full capacity at H1 temperature condition	W
$\phi_{\text{ful}}(-7)$	heating full capacity at outdoor temperature −7 °C	W
$\phi_{\text{ful}}(2)$	calculated heating full capacity at outdoor temperature 2 °C	W
$\phi_{\text{ful, f}}(t_{\text{j}})$	frosting range heating full capacity at outdoor temperature t_{j}	W
$\phi_{\text{ful, f}}(2)$	frosting range heating full capacity at H2 temperature condition	W

Symbol	Description	Unit
$\phi_{\mathrm{haf}}(t_{\mathrm{j}})$	non-frosting range heating half capacity at outdoor temperature t_{j}	W
$\phi_{\mathrm{haf}}(7)$	heating half capacity at H1 temperature condition	W
$\phi_{\mathrm{haf}}(-7)$	heating half capacity at outdoor temperature −7 °C	W
$\phi_{\mathrm{haf}}(2)$	calculated heating half capacity at outdoor temperature 2 °C	W
$\phi_{\mathrm{haf,\,f}}(t_{\mathrm{j}})$	frosting range heating half capacity at outdoor temperature t_{j}	W
$\phi_{\mathrm{haf,\,f}}(2)$	frosting range heating half capacity at H2 temperature condition	W
$\phi_{\mathrm{min}}(t_{\mathrm{j}})$	non-frosting range heating minimum capacity at outdoor temperature t_{j}	W
$\phi_{\mathrm{min}}(7)$	heating minimum capacity at H1 temperature condition	W
$\phi_{\mathrm{min}}(-7)$	heating minimum capacity at outdoor temperature −7 °C	W
$\phi_{\mathrm{min}}(2)$	calculated heating minimum capacity at outdoor temperature 2 °C	W
$\phi_{\mathrm{min,\,f}}(t_{\mathrm{j}})$	frosting range heating minimum capacity at outdoor temperature t_{j}	W
$\phi_{\mathrm{min,\,f}}(2)$	frosting range heating minimum capacity at H2 temperature condition	W

5 Tests

5.1 General

These tests are additional to those in ISO 5151, ISO 13253 and ISO 15042.

The accuracy of the instruments used for tests shall conform to the test methods and uncertainties of measurements specified in ISO 5151, ISO 13253 and ISO 15042.

5.2 Test conditions

Temperature and humidity conditions as well as default values for calculation shall be as specified in Table 1.

Table 1 — Temperature and humidity conditions and default values for heating

Test	Characteristics		Fixed	Two-stage	Multi-stage	Variable	Default value
Standard heating capacity Indoor DB 20°C WB 15 °C Max. Outdoor DB 7°C WB 6°C	Full capacity $\phi_{ful}(7)$ (W)		■	■	■	■	
	Full power input $P_{ful}(7)$ (W)						
	Half capacity $\phi_{haf}(7)$ (W)		—	—	■	■	
	Half power input $P_{haf}(7)$ (W)						
	Minimum capacity $\phi_{min}(7)$ (W)		—	■	○	○	
	Minimum power input $P_{min}(7)$ (W)						
Low temperature heating capacity Indoor DB 20°C WB 15°C Max. Outdoor DB 2°C WB 1°C	Extended capacity $\phi_{ext,f}(2)$ (W)		—	—	■[a]	■[a]	
	Extended power input $P_{ext,f}(2)$ (W)						
	Calculated extended capacity $\phi_{ext}(2)$ (W)		—	—	b	b	1,12$\phi_{ext,f}(2)$
	Calcul'd extended power input $P_{ext}(2)$ (W)						1,06$P_{ext,f}(2)$
	Full capacity $\phi_{ful,f}(2)$ (W)		■[c]	■[c]	□[ac]	□[ac]	$\phi_{ful}(2)/1,12$[d]
	Full power input $P_{ful,f}(2)$ (W)						$P_{ful}(2)/1,06$[d]
	Half capacity $\phi_{haf,f}(2)$ (W)		—	—	○[c]	○[c]	$\phi_{haf}(2)/1,12$[d]
	Half power input $P_{haf,f}(2)$ (W)						$P_{haf}(2)/1,06$[d]
	Minimum capacity $\phi_{min,f}(2)$ (W)		—	○[c]	—	—	$\phi_{min}(2)/1,12$[d]
	Minimum power input $P_{min,f}(2)$ (W)						$P_{min}(2)/1,06$[d]
Extra-low temperature heating capacity Indoor DB 20°C WB 15°C Max. Outdoor DB −7°C WB −8°C	Extended capacity $\phi_{ext}(-7)$ (W)		—	—	○	○	0,734$\phi_{ext}(2)$
	Extended power input $P_{ext}(-7)$ (W)						0,877$P_{ext}(2)$
	Full capacity $\phi_{ful}(-7)$ (W)		○	○	○	○	0,64$\phi_{ful}(7)$
	Full power input $P_{ful}(-7)$ (W)						0,82$P_{ful}(7)$
	Half capacity $\phi_{haf}(-7)$ (W)		—	—	○	○	0,64$\phi_{haf}(7)$
	Half power input $P_{haf}(-7)$ (W)						0,82$P_{haf}(7)$
	Minimum capacity $\phi_{min}(-7)$ (W)		—	—	—	—	0,64$\phi_{min}(7)$
	Minimum power input $P_{min}(-7)$ (W)						0,82$P_{min}(7)$
Cyclic heating Indoor DB 20°C WB 15°C Max. Outdoor DB 7°C WB 6°C	Degradation coefficient C_D	Full capacity	○	—	—	—	0,25
		Half capacity	—	—	○	—	0,25
		Minimum capacity	—	○	○	—	0,25

■ required test.

○ optional test.

□ test required when there is not an extended mode.

[a] When the equipment has an extended mode, low temperature extended capacity measurement is mandatory and low temperature full capacity measurement is optional. When the equipment has not an extended mode, low temperature full capacity measurement is mandatory.

[b] This value shall be calculated using default value.

[c] When this value is measured, $\phi_x(2)$ and/or $P_x(2)$ shall not be calculated from this value, but the equations in footnote d shall be used instead.

[d] The following two equations apply to the full capacity, half capacity and minimum capacity data when $\phi_{x,f}(2)$ and $P_{x,f}(2)$ are calculated:

$$\phi_x(2) = \phi_x(-7) + \frac{\phi_x(7) - \phi_x(-7)}{7 - (-7)} \times \left(2 - (-7)\right), \quad P_x(2) = P_x(-7) + \frac{P_x(7) - P_x(-7)}{7 - (-7)} \times \left(2 - (-7)\right)$$

NOTE Voltage(s) and frequency(ies) shall be as given in the three referenced standards.

5.3 Test methods

5.3.1 Standard heating capacity tests

The standard heating capacity tests shall be conducted in accordance with Annex A of ISO 5151 and Annex B of ISO 13253 and ISO 15042. The heating capacity and effective power input shall be measured during the standard heating capacity tests.

The half capacity test shall be conducted at 50 % of full load operation. The test tolerance shall be ± 5 % of full load capacity for continuously variable equipment. For multi-stage equipment, if 50 % capacity is not achievable, then the test shall be conducted at the next step above 50 %.

The minimum capacity test shall be conducted at the lowest capacity control setting which allows steady-state operation of the equipment at the given test conditions.

If the minimum capacity tests are conducted, but if the required uncertainty of measurement specified in ISO 5151, ISO 13253 and ISO 15042 cannot be achieved, the alternative method of calculation shall be used. (Refer to 6.6.4 and 6.7.4.)

The manufacturer shall provide information on how to set the capacity if requested by the testing laboratories.

5.3.2 Low temperature heating capacity test

The low temperature heating capacity test shall be conducted at H2 condition in accordance with Annex A of ISO 5151 and Annex B of ISO 13253 and ISO 15042. The heating capacity and effective power input shall be measured during the low temperature heating capacity test.

The half capacity test shall be conducted at 50 % of full load operation. The test tolerance shall be ± 5 % of full load capacity for continuously variable equipment. For multi-stage equipment, if 50 % capacity is not achievable, then the test shall be conducted at the next step above 50 %.

The minimum capacity test shall be conducted at the lowest capacity control setting which allows steady-state operation of the equipment at the given test conditions.

If the minimum capacity tests are conducted, but if the required uncertainty of measurement specified in ISO 5151, ISO 13253 and ISO 15042 cannot be achieved, the alternative method of calculation shall be used. (Refer to 6.6.4 and 6.7.4.)

The manufacturer shall provide information on how to set the capacity if requested by the testing laboratories.

5.3.3 Extra-low temperature heating capacity test

The extra-low temperature heating capacity test shall be conducted at H3 condition in accordance with Annex A of ISO 5151 and Annex B of ISO 13253 and ISO 15042. The heating capacity and effective power input shall be measured during the extra-low temperature heating capacity test. If the test is not conducted, default values as given in Table 1 shall be used.

The half capacity test shall be conducted at 50 % of full load operation. The test tolerance shall be ± 5 % of full load capacity for continuously variable equipment. For multi-stage equipment, if 50 % capacity is not achievable, then the test shall be conducted at the next step above 50 %.

The manufacturer shall provide information on how to set the capacity if requested by the testing laboratories.

5.3.4 Cyclic heating test

The cyclic heating test shall be conducted in accordance with Annex C. If the test is not conducted, default values as given in Table 1 shall be used.

6 Calculations

6.1 Heating seasonal performance factor (HSPF) and total heating seasonal performance factor (THSPF)

Heating seasonal performance factor (HSPF), F_{HSP}, of the equipment shall be calculated by Formula (1).

$$F_{\mathrm{HSP}}=\frac{L_{\mathrm{HST}}}{C_{\mathrm{HSE}}} \tag{1}$$

In case of calculating the total heating seasonal performance factor (THSPF), refer to Annex B.

6.2 Defined heating load

The defined heating load shall be represented by a value and the assumption that it is linearly changing depending on the change in outdoor temperature.

Defined heating load which shall be used is shown in Table 2.

Table 2 — Defined heating load

Parameter	Load zero (0)	Load 100 %
Heating load (W)	0	0,82 × ϕ_{ful}(H1)
Temperature(°C)	t_0	t_{100}

where t_{100} is the outdoor temperature at 100 % load and t_0 is the outdoor temperature at 0 % load.

Reference values of defined heating load to be used shall be as follows:

t_0 = 17 °C and t_{100} = 0 °C

In case of setting other heating load, refer to the setting method as described in Annex D.

Defined heating load $L_{\mathrm{h}}(t_{\mathrm{j}})$ at outdoor temperature t_{j}, which is necessary to calculate heating seasonal performance factor, shall be determined by Formula (2).

$$L_{\mathrm{h}}(t_{\mathrm{j}})=\frac{\phi_{\mathrm{ful}}(t_{100})\times(t_0-t_{\mathrm{j}})}{(t_0-t_{100})} \tag{2}$$

where $\phi_{\mathrm{ful}}(t_{100})$ is the heating capacity at t_{100} at full-load operating conditions.

Ratio of the heating operational capacity at 0 °C in non-frosting condition to the standard heating capacity at 7 °C is assumed to be 0,82.

6.3 Outdoor temperature bin distribution for heating

Value of outdoor temperature and bin hours differ from region to region. If bin hours is set to a certain value for a certain region, the integrated value of heating load and electric energy consumption can be determined.

Table 3 shows the reference outdoor temperature bin distribution.

Table 3 — Reference outdoor temperature bin distribution for heating

Bin number j	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Outdoor temperature t_j °C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3
Fractional bin hours	0	0	0	0	0	0	0	0	0	0,001	0,005	0,012	0,024	0,042
Bin hours n_j	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}
Reference bin hours (n_j) h	0	0	0	0	0	0	0	0	0	4	15	33	68	119
Bin number j	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
Outdoor temperature t_j °C	4	5	6	7	8	9	10	11	12	13	14	15	16	
Fractional bin hours	0,059	0,070	0,082	0,087	0,091	0,092	0,091	0,085	0,075	0,067	0,053	0,038	0,027	
Bin hours n_j	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}	n_{25}	n_{26}	n_{27}	
Reference bin hours (n_j) h	169	200	234	250	260	265	260	245	215	192	151	110	76	2 866

Bin hours of each outdoor temperature may be calculated by multiplying the fractional bin hours by the total annual heating hours if the fractional bin hours are applicable.

In case of setting other outdoor temperature bin distribution, refer to the setting method as described in Annex D.

6.4 Heating seasonal characteristics of fixed capacity units

Operational performance at each test, which is necessary to calculate the heating seasonal performance factor, shall be in accordance with Table 1.

6.4.1 Capacity characteristics against outdoor temperature

Frosting occurs in a range of outdoor temperature from 5,5 °C to −7 °C. It is assumed that decrease rates in heating capacity and electric power input due to defrost operation are the biggest when operated at 5,5 °C, then become smaller as outdoor temperature goes down, and reach zero (0) at −7 °C.

a) In case that outdoor temperature is in non-frosting temperature range ($t_j \leq -7$°C or 5,5°C $\leq t_j$):

Capacity $\phi_{\text{ful}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall linearly change depending on outdoor temperatures in the non-frosting temperature range, as shown in Figure A.1 in Annex A, and be determined by Formula (3).

$$\phi_{\text{ful}}(t_j) = \phi_{\text{ful}}(-7) + \frac{\phi_{\text{ful}}(7) - \phi_{\text{ful}}(-7)}{7-(-7)} \times \left(t_j - (-7)\right) \tag{3}$$

b) In case that outdoor temperature is in frosting temperature range (−7°C < t_j < 5,5°C):

Capacity $\phi_{\text{ful,f}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall linearly change depending on outdoor temperatures in the frosting temperature range, as shown in Figure A.1 in Annex A, and be determined by Formula (4).

$$\phi_{\text{ful,f}}(t_j) = \phi_{\text{ful}}(-7) + \frac{\phi_{\text{ful,f}}(2) - \phi_{\text{ful}}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{4}$$

6.4.2 Power input characteristics against outdoor temperature

a) Electric power input $P_{\text{ful}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall linearly change depending on outdoor temperatures in the non-frosting temperature range, as shown in Figure A.1 in Annex A, and be determined by Formula (5).

$$P_{\text{ful}}(t_j)=P_{\text{ful}}(-7)+\frac{P_{\text{ful}}(7)-P_{\text{ful}}(-7)}{7-(-7)}\times\left(t_j-(-7)\right) \tag{5}$$

b) Electric power input $P_{\text{ful, f}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall linearly change depending on outdoor temperatures in the frosting temperature range, as shown in Figure A.1 in Annex A, and be determined by Formula (6).

$$P_{\text{ful,f}}(t_j)=P_{\text{ful}}(-7)+\frac{P_{\text{ful,f}}(2)-P_{\text{ful}}(-7)}{2-(-7)}\times\left(t_j-(-7)\right) \tag{6}$$

6.4.3 Calculation of heating seasonal total load (HSTL)

Heating seasonal total load (HSTL), L_{HST}, shall be calculated by Formula (7).

$$L_{\text{HST}}=\sum_{j=1}^{n}L_{\text{h}}(t_j)\times n_j \tag{7}$$

6.4.4 Calculation of heating seasonal energy consumption (HSEC)

Heating seasonal energy consumption (HSEC), C_{HSE}, shall be determined using Formula (8) from the total sum of heating energy consumption at each outdoor temperature t_j.

$$C_{\text{HSE}}=\sum_{j=1}^{n}\frac{X(t_j)\times P(t_j)\times n_j}{F_{\text{PL}}(t_j)}+\sum_{j=1}^{n}P_{\text{RH}}(t_j)\times n_j \tag{8}$$

When load is rather large as compared to heating capacity, make-up heating by the electric heater shall be added.

Operation factor $X(t_j)$ shall be calculated by Formula (9).

$$X(t_j)=\frac{L_{\text{h}}(t_j)}{\phi(t_j)} \tag{9}$$

Part load factor (PLF), $F_{\text{PL}}(t_j)$, shall be calculated by Formula (10) using degradation coefficient C_{D}.

$$F_{\text{PL}}\left(t_j\right)=1-C_{\text{D}}\left(1-X\left(t_j\right)\right) \tag{10}$$

When $L_{\text{h}}(t_j) > \phi(t_j)$, $X(t_j) = F_{\text{PL}}(t_j) = 1$.

Make-up heat $P_{\text{RH}}(t_j)$ shall be calculated by Formula (11).

$$P_{\text{RH}}(t_j)=L_{\text{h}}(t_j)-\phi(t_j) \tag{11}$$

a) Non-frosting temperature range ($t_j \leq -7$ °C or 5,5 °C $\leq t_j$)

  1) Cyclic operation ($L_{\text{h}}(t_j) \leq \phi_{\text{ful}}(t_j)$)

  $P_{\text{RH}}(t_j) = 0$

  $\phi(t_j) = \phi_{\text{ful}}(t_j)$ in Formula (9)

  $P(t_j) = P_{\text{ful}}(t_j)$.

  2) Full capacity operation ($L_{\text{h}}(t_j) > \phi_{\text{ful}}(t_j)$)

$X(t_j) = F_{PL}(t_j) = 1$

$\phi\,(t_j) = \phi_{ful}(t_j)$ in Formula (11)

$P(t_j) = P_{ful}(t_j)$.

b) Frosting temperature range (–7 °C < t_j < 5,5 °C)

1) Cyclic operation ($L_h(t_j) \le \phi_{ful,\,f}(t_j)$)

$P_{RH}(t_j) = 0$

$\phi\,(t_j) = \phi_{ful,\,f}(t_j)$ in Formula (9).

$P(t_j) = P_{ful,\,f}(t_j)$.

2) Full capacity operation ($L_h(t_j) > \phi_{ful,\,f}(t_j)$)

$X(t_j) = F_{PL}(t_j) = 1$

$\phi\,(t_j) = \phi_{ful}(t_j)$ in Formula (11).

$P(t_j) = P_{ful}(t_j)$.

6.5 Heating seasonal characteristics of two-stage capacity units

Coefficients shown in Table 1 may be used for each characteristic.

6.5.1 Capacity characteristics against outdoor temperature

Capacities $\phi_{ful}(t_j)$ and $\phi_{min}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined by Formulae (3) and (12), respectively.

$$\phi_{min}(t_j) = \phi_{min}(-7) + \frac{\phi_{min}(7) - \phi_{min}(-7)}{7 - (-7)} \times \left(t_j - (-7)\right) \tag{12}$$

Capacities $\phi_{ful,f}(t_j)$ and $\phi_{min,f}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined by Formulae (4) and (13), respectively.

$$\phi_{min,f}(t_j) = \phi_{min}(-7) + \frac{\phi_{min,f}(2) - \phi_{min}(-7)}{2 - (-7)} \times \left(t_j - (-7)\right) \tag{13}$$

6.5.2 Power input characteristics against outdoor temperature

Electric power input $P_{ful}(t_j)$ and $P_{min}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined from Formulae (5) and (14), respectively.

$$P_{min}(t_j) = P_{min}(-7) + \frac{P_{min}(7) - P_{min}(-7)}{7 - (-7)} \times \left(t_j - (-7)\right) \tag{14}$$

Electric power input $P_{ful,f}(t_j)$ and $P_{min,f}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined from Formulae (6) and (15), respectively.

$$P_{min,f}(t_j) = P_{min}(-7) + \frac{P_{min,f}(2) - P_{min}(-7)}{2 - (-7)} \times \left(t_j - (-7)\right) \tag{15}$$

6.5.3 Calculation of heating seasonal total load (HSTL)

Heating seasonal total load (HSTL), L_{HST}, shall be calculated by Formula (7).

6.5.4 Calculation of heating seasonal energy consumption (HSEC)

Heating seasonal energy consumption (HSEC), C_{HSE}, shall be calculated by Formula (16).

$$C_{\mathrm{HSE}} = \sum_{\mathrm{j=1}}^{n} \frac{X(t_{\mathrm{j}}) \times P(t_{\mathrm{j}}) \times n_{\mathrm{j}}}{F_{\mathrm{PL}}(t_{\mathrm{j}})} + \sum_{\mathrm{j=1}}^{n} P_{\mathrm{mf}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j=1}}^{n} P_{\mathrm{ful}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j=1}}^{n} P_{\mathrm{RH}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} \tag{16}$$

The relation of heating capacity characteristics and energy consumption characteristics to heating load at outdoor temperature t_{j} is shown in Figure A.2 in Annex A.

a) Non-frosting temperature range ($t_{\mathrm{j}} \leq -7$ °C or $5{,}5$ °C $\leq t_{\mathrm{j}}$)

1) First stage cyclic operation ($L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{min}}(t_{\mathrm{j}})$)

$P_{\mathrm{mf}}(t_{\mathrm{j}}) = P_{\mathrm{ful}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$ in Formula (16).

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{min}}(t_{\mathrm{j}})$ in Formula (9).

$P(t_{\mathrm{j}}) = P_{\mathrm{min}}(t_{\mathrm{j}})$.

2) Second stage cyclic operation ($\phi_{\mathrm{min}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{ful}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{ful}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$ in Formula (16).

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$$P_{\mathrm{mf}}(t_{\mathrm{j}}) = X_{\mathrm{mf}}(t_{\mathrm{j}}) \times P_{\mathrm{min}}(t_{\mathrm{j}}) + \left(1 - X_{\mathrm{mf}}(t_{\mathrm{j}})\right) \times P_{\mathrm{ful}}(t_{\mathrm{j}}) \tag{17}$$

$$X_{\mathrm{mf}}(t_{\mathrm{j}}) = \frac{\phi_{\mathrm{ful}}(t_{\mathrm{j}}) - L_{\mathrm{h}}(t_{\mathrm{j}})}{\phi_{\mathrm{ful}}(t_{\mathrm{j}}) - \phi_{\mathrm{min}}(t_{\mathrm{j}})} \tag{18}$$

3) Full capacity operation ($L_{\mathrm{h}}(t_{\mathrm{j}}) > \phi_{\mathrm{ful}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{mf}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{ful}}(t_{\mathrm{j}})$ in Formula (11).

$P(t_{\mathrm{j}}) = P_{\mathrm{ful}}(t_{\mathrm{j}})$.

b) Frosting temperature range (-7 °C $< t_{\mathrm{j}} < 5{,}5$ °C)

1) First stage cyclic operation ($L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{min,\,f}}(t_{\mathrm{j}})$)

$P_{\mathrm{mf}}(t_{\mathrm{j}}) = P_{\mathrm{ful}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$ in Formula (16).

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{min,\,f}}(t_{\mathrm{j}})$ in Formula (9).

$P(t_{\mathrm{j}}) = P_{\mathrm{min,\,f}}(t_{\mathrm{j}})$.

2) Second stage cyclic operation ($\phi_{\mathrm{min,\,f}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{ful,f}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{ful}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$ in Formula (16).

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$$P_{\mathrm{mf}}(t_{\mathrm{j}}) = X_{\mathrm{mf}}(t_{\mathrm{j}}) \times P_{\mathrm{min,f}}(t_{\mathrm{j}}) + \left(1 - X_{\mathrm{mf}}(t_{\mathrm{j}})\right) \times P_{\mathrm{ful,\,f}}(t_{\mathrm{j}}) \tag{19}$$

$$X_{\mathrm{mf}}(t_{\mathrm{j}}) = \frac{\phi_{\mathrm{ful,f}}(t_{\mathrm{j}}) - L_{\mathrm{h}}(t_{\mathrm{j}})}{\phi_{\mathrm{ful,f}}(t_{\mathrm{j}}) - \phi_{\mathrm{min,f}}(t_{\mathrm{j}})} \tag{20}$$

3) Full capacity operation ($L_h(t_j) > \phi_{ful,\,f}(t_j)$)

$P(t_j) = P_{mf}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ful,\,f}(t_j)$ in Formula (11).

$P_{ful}\,(t_j) = P_{ful,\,f}(t_j)$

6.6 Heating seasonal characteristics of multi-stage capacity units

6.6.1 Capacity characteristics against outdoor temperature

Capacities $\phi_{ful}(t_j)$, $\phi_{min}(t_j)$, $\phi_{ext}(t_j)$ and $\phi_{haf}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined by Formulae (3), (12), (21) and (22), respectively.

$$\phi_{ext}(t_j) = \phi_{ext}(-7) + \frac{\phi_{ext}(2) - \phi_{ext}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{21}$$

$$\phi_{haf}(t_j) = \phi_{haf}(-7) + \frac{\phi_{haf}(7) - \phi_{haf}(-7)}{7-(-7)} \times \left(t_j - (-7)\right) \tag{22}$$

Capacities $\phi_{ful,f}(t_j)$, $\phi_{min,f}(t_j)$, $\phi_{ext,f}(t_j)$ and $\phi_{haf,f}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined by Formulae (4), (13), (23) and (24), respectively.

$$\phi_{ext,f}(t_j) = \phi_{ext}(-7) + \frac{\phi_{ext,f}(2) - \phi_{ext}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{23}$$

$$\phi_{haf,f}(t_j) = \phi_{haf}(-7) + \frac{\phi_{haf,f}(2) - \phi_{haf}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{24}$$

6.6.2 Power input characteristics against outdoor temperature

Electric power input $P_{ful}(t_j)$, $P_{min}(t_j)$, $P_{ext}(t_j)$ and $P_{haf}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined from Formulae (5), (14), (25) and (26), respectively.

$$P_{ext}(t_j) = P_{ext}(-7) + \frac{P_{ext}(2) - P_{ext}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{25}$$

$$P_{haf}(t_j) = P_{haf}(-7) + \frac{P_{haf}(7) - P_{haf}(-7)}{7-(-7)} \times \left(t_j - (-7)\right) \tag{26}$$

Electric power input $P_{ful,f}(t_j)$, $P_{min,f}(t_j)$, $P_{ext,f}(t_j)$ and $P_{haf,f}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined from Formulae (6), (15), (27) and (28), respectively.

$$P_{ext,f}(t_j) = P_{ext}(-7) + \frac{P_{ext,f}(2) - P_{ext}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{27}$$

$$P_{haf,f}(t_j) = P_{haf}(-7) + \frac{P_{haf,f}(2) - P_{haf}(-7)}{2-(-7)} \times \left(t_j - (-7)\right) \tag{28}$$

6.6.3 Calculation of heating seasonal total load (HSTL)

Heating seasonal total load (HSTL), L_{HST}, shall be calculated by Formula (7).

6.6.4 Calculation of heating seasonal energy consumption (HSEC)

When the minimum capacity data are available, then the heating seasonal energy consumption (HSEC), C_{HSE}, shall be calculated by Formula (29).

$$C_{\mathrm{HSE}} = \sum_{\mathrm{j}=1}^{n} \frac{X(t_{\mathrm{j}}) \times P(t_{\mathrm{j}}) \times n_{\mathrm{j}}}{F_{\mathrm{PL}}(t_{\mathrm{j}})} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{mh}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{hf}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{fe}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{ext}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{RH}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} \quad (29)$$

When the minimum capacity data are not available, then the heating seasonal energy consumption (HSEC), C_{HSE}, shall be calculated alternatively by Formula (30).

$$C_{\mathrm{HSE}} = \sum_{\mathrm{j}=1}^{n} \frac{X(t_{\mathrm{j}}) \times P(t_{\mathrm{j}}) \times n_{\mathrm{j}}}{F_{\mathrm{PL}}(t_{\mathrm{j}})} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{hf}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{fe}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{ext}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} + \sum_{\mathrm{j}=1}^{n} P_{\mathrm{RH}}(t_{\mathrm{j}}) \times n_{\mathrm{j}} \quad (30)$$

The relation of heating capacity characteristics and energy consumption characteristics to heating load at outdoor temperature t_{j} is shown in Figure A.3 in Annex A.

6.6.4.1 In case of calculation using Formula (29)

a) Non-frosting temperature range ($t_{\mathrm{j}} \leq -7$ °C or $5{,}5$ °C $\leq t_{\mathrm{j}}$)

1) First stage cyclic operation ($L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{min}}(t_{\mathrm{j}})$)

$P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{fe}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{min}}(t_{\mathrm{j}})$ in Formula (9).

$P(t_{\mathrm{j}}) = P_{\mathrm{min}}(t_{\mathrm{j}})$.

2) Second stage cyclic operation ($\phi_{\mathrm{min}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{haf}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{fe}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$$P_{\mathrm{mh}}(t_{\mathrm{j}}) = X_{\mathrm{mh}}(t_{\mathrm{j}}) \times P_{\mathrm{min}}(t_{\mathrm{j}}) + \left(1 - X_{\mathrm{mh}}(t_{\mathrm{j}})\right) \times P_{\mathrm{haf}}(t_{\mathrm{j}}) \quad (31)$$

$$X_{\mathrm{mh}}(t_{\mathrm{j}}) = \frac{\phi_{\mathrm{haf}}(t_{\mathrm{j}}) - L_{\mathrm{h}}(t_{\mathrm{j}})}{\phi_{\mathrm{haf}}(t_{\mathrm{j}}) - \phi_{\mathrm{min}}(t_{\mathrm{j}})} \quad (32)$$

3) Third stage cyclic operation ($\phi_{\mathrm{haf}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{ful}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{fe}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$$P_{\mathrm{hf}}(t_{\mathrm{j}}) = X_{\mathrm{hf}}(t_{\mathrm{j}}) \times P_{\mathrm{haf}}(t_{\mathrm{j}}) + \left(1 - X_{\mathrm{hf}}(t_{\mathrm{j}})\right) \times P_{\mathrm{ful}}(t_{\mathrm{j}}) \quad (33)$$

$$X_{\mathrm{hf}}(t_{\mathrm{j}}) = \frac{\phi_{\mathrm{ful}}(t_{\mathrm{j}}) - L_{\mathrm{h}}(t_{\mathrm{j}})}{\phi_{\mathrm{ful}}(t_{\mathrm{j}}) - \phi_{\mathrm{haf}}(t_{\mathrm{j}})} \quad (34)$$

4) Fourth stage cyclic operation ($\phi_{\mathrm{ful}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{ext}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$ in Formula (29).

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$$P_{\mathrm{fe}}(t_{\mathrm{j}}) = X_{\mathrm{fe}}(t_{\mathrm{j}}) \times P_{\mathrm{ful}}(t_{\mathrm{j}}) + \left(1 - X_{\mathrm{fe}}(t_{\mathrm{j}})\right) \times P_{\mathrm{ext}}(t_{\mathrm{j}}) \quad (35)$$

$$X_{\text{fe}}(t_{\text{j}})=\frac{\phi_{\text{ext}}(t_{\text{j}})-L_{\text{h}}(t_{\text{j}})}{\phi_{\text{ext}}(t_{\text{j}})-\phi_{\text{ful}}(t_{\text{j}})} \quad (36)$$

For units not having the extended capacity operation,

$P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ful}(t_j)$ in Formula (11).

$P_{fe}(t_j) = P_{ful}(t_j)$.

5) Extended capacity operation ($L_h(t_j) > \phi_{ext}(t_j)$)

$P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ext}(t_j)$ in Formula (11)

For units not having the extended capacity operation, the calculation is not necessary.

b) Frosting temperature range (–7 °C < t_j < 5,5 °C)

1) First stage cyclic operation ($L_h(t_j) \le \phi_{min,\, f}(t_j)$)

$P_{mh}(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$\phi(t_j) = \phi_{min,\, f}(t_j)$ in Formula (9).

$P(t_j) = P_{min,\, f}(t_j)$.

2) Second stage cyclic operation ($\phi_{min,\, f}(t_j) < L_h(t_j) \le \phi_{haf,\, f}(t_j)$)

$P(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$$P_{\text{mh}}(t_{\text{j}})=X_{\text{mh}}(t_{\text{j}})\times P_{\text{min,f}}(t_{\text{j}})+\left(1-X_{\text{mh}}(t_{\text{j}})\right)\times P_{\text{haf,f}}(t_{\text{j}}) \quad (37)$$

$$X_{\text{mh}}(t_{\text{j}})=\frac{\phi_{\text{haf,f}}(t_{\text{j}})-L_{\text{h}}(t_{\text{j}})}{\phi_{\text{haf,f}}(t_{\text{j}})-\phi_{\text{min,f}}(t_{\text{j}})} \quad (38)$$

3) Third stage cyclic operation ($\phi_{haf,\, f}(t_j) < L_h(t_j) \le \phi_{ful,\, f}(t_j)$)

$P(t_j) = P_{mh}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$$P_{\text{hf}}(t_{\text{j}})=X_{\text{hf}}(t_{\text{j}})\times P_{\text{haf,f}}(t_{\text{j}})+\left(1-X_{\text{hf}}(t_{\text{j}})\right)\times P_{\text{ful,f}}(t_{\text{j}}) \quad (39)$$

$$X_{\text{hf}}(t_{\text{j}})=\frac{\phi_{\text{ful,f}}(t_{\text{j}})-L_{\text{h}}(t_{\text{j}})}{\phi_{\text{ful,f}}(t_{\text{j}})-\phi_{\text{haf,f}}(t_{\text{j}})} \quad (40)$$

4) Fourth stage cyclic operation ($\phi_{ful,\, f}(t_j) < L_h(t_j) \le \phi_{ext,\, f}(t_j)$)

$P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$$P_{\mathrm{fe}}(t_{\mathrm{j}}) = X_{\mathrm{fe}}(t_{\mathrm{j}}) \times P_{\mathrm{ful,f}}(t_{\mathrm{j}}) + \left(1 - X_{\mathrm{fe}}(t_{\mathrm{j}})\right) \times P_{\mathrm{ext,f}}(t_{\mathrm{j}}) \tag{41}$$

$$X_{\mathrm{fe}}(t_{\mathrm{j}}) = \frac{\phi_{\mathrm{ext,f}}(t_{\mathrm{j}}) - L_{\mathrm{h}}(t_{\mathrm{j}})}{\phi_{\mathrm{ext,f}}(t_{\mathrm{j}}) - \phi_{\mathrm{ful,f}}(t_{\mathrm{j}})} \tag{42}$$

For units not having the extended capacity operation,

$P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ful,\,f}(t_j)$ in Formula (11).

$P_{fe}(t_j) = P_{ful,\,f}(t_j)$.

5) Extended capacity operation ($L_h(t_j) > \phi_{ext,\,f}(t_j)$)

$P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ext,\,f}(t_j)$ in Formula (11).

$P_{ful}(t_j) = P_{ful,\,f}(t_j)$

For units not having the extended capacity operation, the calculation is not necessary.

6.6.4.2 In case of calculation using Formula (30)

a) Non-frosting temperature range ($t_j \leq -7$ °C or 5,5 °C $\leq t_j$)

1) First stage cyclic operation ($L_h(t_j) \leq \phi_{haf}(t_j)$)

$P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$\phi(t_j) = \phi_{haf}(t_j)$ in Formula (9).

$P(t_j) = P_{haf}(t_j)$.

2) Second stage cyclic operation ($\phi_{haf}(t_j) < L_h(t_j) \leq \phi_{ful}(t_j)$)

$P(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$P_{hf}(t_j)$ shall be calculated using Formula (33).

$X_{hf}(t_j)$ shall be calculated using Formula (34).

3) Third stage cyclic operation ($\phi_{ful}(t_j) < L_h(t_j) \leq \phi_{ext}(t_j)$)

$P(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$ in Formula (30).

$X(t_j) = F_{PL}(t_j) = 1$

$P_{fe}(t_j)$ shall be calculated using Formula (35).

$X_{fe}(t_j)$ shall be calculated using Formula (36).

For units not having the extended capacity operation,

$P(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ful}(t_j)$ in Formula (11).

$P_{fe}(t_j) = P_{ful}(t_j)$.

4) Extended capacity operation ($L_h(t_j) > \phi_{ext}(t_j)$)

$P(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ext}(t_j)$ in Formula (11).

$P(t_j) = P_{ext}(t_j)$.

For units not having the extended capacity operation, the calculation is not necessary.

b) Frosting temperature range (−7 °C < t_j < 5,5 °C)

1) First stage cyclic operation ($L_h(t_j) \leq \phi_{haf,\,f}(t_j)$)

$P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$\phi(t_j) = \phi_{haf,\,f}(t_j)$ in Formula (9).

$P(t_j) = P_{haf,f}(t_j)$.

2) Second stage cyclic operation ($\phi_{haf,\,f}(t_j) < L_h(t_j) \leq \phi_{ful,\,f}(t_j)$)

$P(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$P_{hf}(t_j)$ shall be calculated using Formula (39).

$X_{hf}(t_j)$ shall be calculated using Formula (40).

3) Third stage cyclic operation ($\phi_{ful,\,f}(t_j) < L_h(t_j) \leq \phi_{ext,\,f}(t_j)$)

$P(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$P_{fe}(t_j)$ shall be calculated using Formula (41).

$X_{fe}(t_j)$ shall be calculated using Formula (42).

For units not having the extended capacity operation,

$P(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ful,\,f}(t_j)$ in Formula (11).

$P_{fe}(t_j) = P_{ful,\,f}(t_j)$.

4) Extended capacity operation ($L_h(t_j) > \phi_{ext,\,f}(t_j)$)

$P(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ext,\,f}(t_j)$ in Formula (11).

$P_{\text{ful}}(t_j) = P_{\text{ful, f}}(t_j)$

For units not having the extended capacity operation, the calculation is not necessary.

6.7 Heating seasonal characteristics of variable capacity units

Coefficients shown in Table 1 may be used for each characteristic.

6.7.1 Capacity characteristics against outdoor temperature

Capacities $\phi_{\text{ful}}(t_j)$, $\phi_{\text{min}}(t_j)$, $\phi_{\text{ext}}(t_j)$ and $\phi_{\text{haf}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined by Formulae (3), (12), (21) and (22), respectively.

Capacities $\phi_{\text{ful,f}}(t_j)$, $\phi_{\text{min,f}}(t_j)$, $\phi_{\text{ext,f}}(t_j)$ and $\phi_{\text{haf,f}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined by Formulae (4), (13), (23) and (24), respectively.

6.7.2 Power input characteristics against outdoor temperature

Electric power input $P_{\text{ful}}(t_j)$, $P_{\text{min}}(t_j)$, $P_{\text{ext}}(t_j)$ and $P_{\text{haf}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined from Formulae (5), (14), (25) and (26), respectively.

Electric power input $P_{\text{ful,f}}(t_j)$, $P_{\text{min,f}}(t_j)$, $P_{\text{ext,f}}(t_j)$ and $P_{\text{haf,f}}(t_j)$ (W) of the equipment when it is operated for heating at outdoor temperature t_j shall be determined from Formulae (6), (15), (27) and (28), respectively.

6.7.3 Calculation of heating seasonal total load (HSTL)

Heating seasonal total load (HSTL), L_{HST}, shall be calculated by Formula (7).

6.7.4 Calculation of heating seasonal energy consumption (HSEC)

The relation of heating capacity characteristics and energy consumption characteristics to heating load at outdoor temperature t_j is shown in Figure A.4 in Annex A.

When the minimum capacity data are available, then the heating seasonal energy consumption (HSEC), C_{HSE}, shall be calculated by Formula (29).

When the minimum capacity data are not available, then the heating seasonal energy consumption (HSEC), C_{HSE}, shall be calculated alternatively by Formula (30).

6.7.4.1 In case of calculation using Formula (29)

a) Non-frosting temperature range ($t_j \leq -7$ °C or $5{,}5$ °C $\leq t_j$)

   1) Cyclic operation ($L_h(t_j) \leq \phi_{\text{min}}(t_j)$)

      $P_{\text{mh}}(t_j) = P_{\text{hf}}(t_j) = P_{\text{fe}}(t_j) = P_{\text{ext}}(t_j) = P_{\text{RH}}(t_j) = 0$

      $\phi(t_j) = \phi_{\text{min}}(t_j)$ in Formula (9).

      $P(t_j) = P_{\text{min}}(t_j)$.

   2) Variable capacity operation between minimum and half capacity ($\phi_{\text{min}}(t_j) < L_h(t_j) \leq \phi_{\text{haf}}(t_j)$)

      $P(t_j) = P_{\text{hf}}(t_j) = P_{\text{fe}}(t_j) = P_{\text{ext}}(t_j) = P_{\text{RH}}(t_j) = 0$

      $X(t_j) = F_{\text{PL}}(t_j) = 1$

      $C_{\text{OP}}(t)$, Coefficient of Performance (COP) at outdoor temperature t, shall be determined by the following:

$$C_{\mathrm{OP}}(t)=\frac{\phi(t)}{P(t)} \tag{43}$$

It is assumed that COP linearly changes depending on outdoor temperature when the capacity of equipment changes continuously.

$$C_{\mathrm{OP,mh}}(t_{\mathrm{j}})=C_{\mathrm{OP,haf}}(t_{\mathrm{d}})+\frac{C_{\mathrm{OP,\,min}}(t_{\mathrm{q}})-C_{\mathrm{OP,\,haf}}(t_{\mathrm{d}})}{t_{\mathrm{q}}-t_{\mathrm{d}}}\times(t_{\mathrm{j}}-t_{\mathrm{d}}) \tag{44}$$

t_{d} is outdoor temperature when heating load is equal to heating half capacity (refer to Annex E).

$C_{\mathrm{OP,haf}}(t_{\mathrm{d}})$ shall be calculated from Formula (43), where, $\phi(t) = \phi_{\mathrm{haf}}(t_{\mathrm{d}})$ and $P(t) = P_{\mathrm{haf}}(t_{\mathrm{d}})$.

t_{q} is outdoor temperature when heating load is equal to heating minimum capacity (refer to Annex E).

$C_{\mathrm{OP,min}}(t_{\mathrm{q}})$ shall be calculated from Formula (43), where, $\phi(t) = \phi_{\mathrm{min}}(t_{\mathrm{q}})$ and $P(t) = P_{\mathrm{min}}(t_{\mathrm{q}})$.

$P_{\mathrm{mh}}(t_{\mathrm{j}})$ shall be calculated from Formula (45).

$$P\left(t_{\mathrm{j}}\right)=\frac{L_{\mathrm{h}}\left(t_{\mathrm{j}}\right)}{C_{\mathrm{OP}}\left(t_{\mathrm{j}}\right)} \tag{45}$$

where $C_{\mathrm{OP}}(t_{\mathrm{j}}) = C_{\mathrm{OP,mh}}(t_{\mathrm{j}})$.

3) Variable capacity operation between half and full capacity ($\phi_{\mathrm{haf}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \le \phi_{\mathrm{ful}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{fe}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$C_{\mathrm{OP}}(t)$, Coefficient of Performance (COP) at outdoor temperature t, shall be determined by Formula (43).

It is assumed that COP linearly changes depending on outdoor temperature when the capacity of equipment changes continuously.

$$C_{\mathrm{OP,\,hf}}(t_{\mathrm{j}})=C_{\mathrm{OP,\,ful}}(t_{\mathrm{a}})+\frac{C_{\mathrm{OP,\,haf}}(t_{\mathrm{d}})-C_{\mathrm{OP,ful}}(t_{\mathrm{a}})}{t_{\mathrm{d}}-t_{\mathrm{a}}}\times(t_{\mathrm{j}}-t_{\mathrm{a}}) \tag{46}$$

t_{a} is outdoor temperature when heating load is equal to heating full capacity (refer to Annex E).

$C_{\mathrm{OP,\,ful}}(t_{\mathrm{a}})$ shall be calculated from Formula (43), where, $\phi(t) = \phi_{\mathrm{ful}}(t_{\mathrm{a}})$ and $P(t) = P_{\mathrm{ful}}(t_{\mathrm{a}})$.

t_{d} is outdoor temperature when heating load is equal to heating half capacity (refer to Annex E).

$C_{\mathrm{OP,\,haf}}(t_{\mathrm{d}})$ shall be calculated from Formula (43), where $\phi(t) = \phi_{\mathrm{haf}}(t_{\mathrm{d}})$ and $P(t) = P_{\mathrm{haf}}(t_{\mathrm{d}})$.

$P_{\mathrm{hf}}(t_{\mathrm{j}})$ shall be calculated from Formula (45), where $C_{\mathrm{OP}}(t_{\mathrm{j}}) = C_{\mathrm{OP,\,hf}}(t_{\mathrm{j}})$.

4) Full capacity or variable capacity operation between full and extended capacity ($\phi_{\mathrm{ful}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \le \phi_{\mathrm{ext}}(t_{\mathrm{j}})$)

For units not having the extended capacity operation,

$P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{ful}}(t_{\mathrm{j}})$ in Formula (11).

$P_{\mathrm{fe}}(t_{\mathrm{j}}) = P_{\mathrm{ful}}(t_{\mathrm{j}})$.

If there is an extended mode, $P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$.

$X(t_j) = F_{PL}(t_j) = 1$

$$C_{OP,\,fe}(t_j) = C_{OP,\,ext}(t_h) + \frac{C_{OP,\,ful}(t_a) - C_{OP,\,ext}(t_h)}{t_a - t_h} \times (t_j - t_h) \qquad (47)$$

t_h is outdoor temperature when heating load is equal to heating extended capacity (refer to Annex E).

$C_{OP,\,ext}(t_h)$ shall be calculated from Formula (43), where $\phi(t) = \phi_{ext}(t_h)$ and $P(t) = P_{ext}(t_h)$.

t_a is outdoor temperature when heating load is equal to heating full capacity (refer to Annex E).

$C_{OP,ful}(t_a)$ shall be calculated from Formula (43), where $\phi(t) = \phi_{ful}(t_a)$ and $P(t) = P_{ful}(t_a)$.

$P_{fe}(t_j)$ shall be calculated from Formula (45), where $C_{OP}(t_j) = C_{OP,\,fe}(t_j)$.

5) Extended capacity operation ($L_h(t_j) > \phi_{ext}(t_j)$)

$P(t_j) = P_{mh}(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$\phi(t_j) = \phi_{ext}(t_j)$ in Formula (11).

For units not having the extended capacity operation, the calculation is not necessary.

b) Frosting temperature range ($-7\ °C < t_j < 5{,}5\ °C$)

1) Cyclic operation ($L_h(t_j) \le \phi_{min,\,f}(t_j)$)

$P_{mh}(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$\phi(t_j) = \phi_{min,\,f}(t_j)$ in Formula (9).

$P(t_j) = P_{min,\,f}(t_j)$.

2) Variable capacity operation between minimum and half capacity ($\phi_{min,\,f}(t_j) < L_h(t_j) \le \phi_{haf,\,f}(t_j)$)

$P(t_j) = P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$$C_{OP,\,mh,f}(t_j) = C_{OP,\,haf,f}(t_e) + \frac{C_{OP,\,min,f}(t_r) - C_{OP,\,haf,f}(t_e)}{t_r - t_e} \times (t_j - t_e) \qquad (48)$$

t_r is outdoor temperature when heating load is equal to heating minimum capacity with frosting operation (refer to Annex E).

$C_{OP,\,min,\,f}(t_r)$ shall be calculated from Formula (43), where $\phi(t) = \phi_{min,\,f}(t_r)$ and $P(t) = P_{min,\,f}(t_r)$.

t_e is outdoor temperature when heating load is equal to heating half capacity with frosting operation (refer to Annex E).

$C_{OP,\,haf,\,f}(t_e)$ shall be calculated from Formula (43), where $\phi(t) = \phi_{haf,\,f}(t_e)$ and $P(t) = P_{haf,\,f}(t_e)$.

$P_{mh}(t_j)$ shall be calculated from Formula (45), where $C_{OP}(t_j) = C_{OP,\,mh,\,f}(t_j)$.

3) Variable capacity operation between half and full capacity ($\phi_{haf,\,f}(t_j) < L_h(t_j) \le \phi_{ful,\,f}(t_j)$)

$P(t_j) = P_{mh}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$X(t_j) = F_{PL}(t_j) = 1$

$C_{\mathrm{OP}}(t)$, Coefficient of Performance (COP) at outdoor temperature t, shall be determined by Formula (43).

It is assumed that COP linearly changes depending on outdoor temperature when the capacity of equipment changes continuously.

$$C_{\mathrm{OP,\,hf,\,f}}(t_{\mathrm{j}})=C_{\mathrm{OP,\,ful,\,f}}(t_{\mathrm{g}})+\frac{C_{\mathrm{OP,\,haf,\,f}}(t_{\mathrm{e}})-C_{\mathrm{OP,\,ful,\,f}}(t_{\mathrm{g}})}{t_{\mathrm{e}}-t_{\mathrm{g}}}\times(t_{\mathrm{j}}-t_{\mathrm{g}}) \tag{49}$$

t_{g} is outdoor temperature when heating load is equal to heating full capacity with frosting operation (refer to Annex E).

$C_{\mathrm{OP,\,ful,\,f}}(t_{\mathrm{g}})$ shall be calculated from Formula (43), where $\phi(t) = \phi_{\mathrm{ful,\,f}}(t_{\mathrm{g}})$ and $P(t) = P_{\mathrm{ful,\,f}}(t_{\mathrm{g}})$.

t_{e} is outdoor temperature when heating load is equal to heating half capacity with frosting operation (refer to Annex E).

$C_{\mathrm{OP,\,haf,\,f}}(t_{\mathrm{e}})$ shall be calculated from Formula (43), where $\phi(t) = \phi_{\mathrm{haf,\,f}}(t_{\mathrm{e}})$ and $P(t) = P_{\mathrm{haf,\,f}}(t_{\mathrm{e}})$.

$P_{\mathrm{hf}}(t_{\mathrm{j}})$ shall be calculated from Formula (45), where $C_{\mathrm{OP}}(t_{\mathrm{j}}) = C_{\mathrm{OP,\,hf,\,f}}(t_{\mathrm{j}})$.

4) Full capacity or variable capacity operation between full and extended capacity ($\phi_{\mathrm{ful,f}}(t_{\mathrm{j}}) < L_{\mathrm{h}}(t_{\mathrm{j}}) \leq \phi_{\mathrm{ext,f}}(t_{\mathrm{j}})$)

For units not having the extended capacity operation,

$P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{ful,f}}(t_{\mathrm{j}})$ in Formula (11).

$P_{\mathrm{fe}}(t_{\mathrm{j}}) = P_{\mathrm{ful,f}}(t_{\mathrm{j}})$.

If there is an extended mode, $P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{ext}}(t_{\mathrm{j}}) = P_{\mathrm{RH}}(t_{\mathrm{j}}) = 0$.

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$$C_{\mathrm{OP,\,fe,f}}(t_{\mathrm{j}})=C_{\mathrm{OP,\,ext,f}}(t_{\mathrm{f}})+\frac{C_{\mathrm{OP,\,ful,f}}(t_{\mathrm{g}})-C_{\mathrm{OP,\,ext,f}}(t_{\mathrm{f}})}{t_{\mathrm{g}}-t_{\mathrm{f}}}\times(t_{\mathrm{j}}-t_{\mathrm{f}}) \tag{50}$$

t_{f} is outdoor temperature when heating load is equal to heating extended capacity with frosting operation (refer to Annex E).

$C_{\mathrm{OP,\,ext,\,f}}(t_{\mathrm{f}})$ shall be calculated from Formula (43), where $\phi(t) = \phi_{\mathrm{ext,\,f}}(t_{\mathrm{f}})$ and $P(t) = P_{\mathrm{ext,\,f}}(t_{\mathrm{f}})$.

t_{g} is outdoor temperature when heating load is equal to heating full capacity with frosting operation (refer to Annex E).

$C_{\mathrm{OP,\,ful,\,f}}(t_{\mathrm{g}})$ shall be calculated from Formula (43), where $\phi(t) = \phi_{\mathrm{ful,\,f}}(t_{\mathrm{g}})$ and $P(t) = P_{\mathrm{ful,\,f}}(t_{\mathrm{g}})$.

$P_{\mathrm{fe}}(t_{\mathrm{j}})$ shall be calculated from Formula (45), where $C_{\mathrm{OP}}(t_{\mathrm{j}}) = C_{\mathrm{OP,\,fe,\,f}}(t_{\mathrm{j}})$.

5) Extended capacity operation ($L_{\mathrm{h}}(t_{\mathrm{j}}) > \phi_{\mathrm{ext,\,f}}(t_{\mathrm{j}})$)

$P(t_{\mathrm{j}}) = P_{\mathrm{mh}}(t_{\mathrm{j}}) = P_{\mathrm{hf}}(t_{\mathrm{j}}) = P_{\mathrm{fe}}(t_{\mathrm{j}}) = 0$

$X(t_{\mathrm{j}}) = F_{\mathrm{PL}}(t_{\mathrm{j}}) = 1$

$\phi(t_{\mathrm{j}}) = \phi_{\mathrm{ext,\,f}}(t_{\mathrm{j}})$ in Formula (11).

$P_{\mathrm{ful}}(t_{\mathrm{j}}) = P_{\mathrm{ful,\,f}}(t_{\mathrm{j}})$

For units not having the extended capacity operation, the calculation is not necessary.

6.7.4.2 In case of calculation using Formula (30)

a) Non-frosting temperature range ($t_j \leq -7$ °C or 5,5 °C $\leq t_j$)

1) Cyclic operation ($L_h(t_j) \leq \phi_{haf}(t_j)$)

$P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$\phi(t_j) = \phi_{haf}(t_j)$ in Formula (9).

$P(t_j) = P_{haf}(t_j)$.

2) Variable capacity operation between half and full capacity ($\phi_{haf}(t_j) < L_h(t_j) \leq \phi_{ful}(t_j)$)

6.7.4.1 a) 3) shall apply.

3) Full capacity or variable capacity operation between full and extended capacity ($\phi_{ful}(t_j) < L_h(t_j) \leq \phi_{ext}(t_j)$)

6.7.4.1 a) 4) shall apply.

4) Extended capacity operation ($L_h(t_j) > \phi_{ext}(t_j)$)

6.7.4.1 a) 5) shall apply.

b) Frosting temperature range (–7°C < t_j < 5,5°C)

1) Cyclic operation ($L_h(t_j) \leq \phi_{haf,\,f}(t_j)$)

$P_{hf}(t_j) = P_{fe}(t_j) = P_{ext}(t_j) = P_{RH}(t_j) = 0$

$\phi(t_j) = \phi_{haf,\,f}(t_j)$ in Formula (9).

$P(t_j) = P_{haf,\,f}(t_j)$.

2) Variable capacity operation between half and full capacity ($\phi_{haf,\,f}(t_j) < L_h(t_j) \leq \phi_{ful,\,f}(t_j)$)

6.7.4.1 b) 3) shall apply.

3) Full capacity or variable capacity operation between full and extended capacity ($\phi_{ful,f}(t_j) < L_h(t_j) \leq \phi_{ext,f}(t_j)$)

6.7.4.1 b) 4) shall apply.

4) Extended capacity operation ($L_h(t_j) > \phi_{ext,\,f}(t_j)$)

6.7.4.1 b) 5) shall apply.

7 Test report

The test report shall include:

a) the type of unit;

b) the list of mandatory test points performed, and the resulting capacity and COP values;

c) the list of optional test points performed, and the resulting capacity and COP values;

d) the default values used;

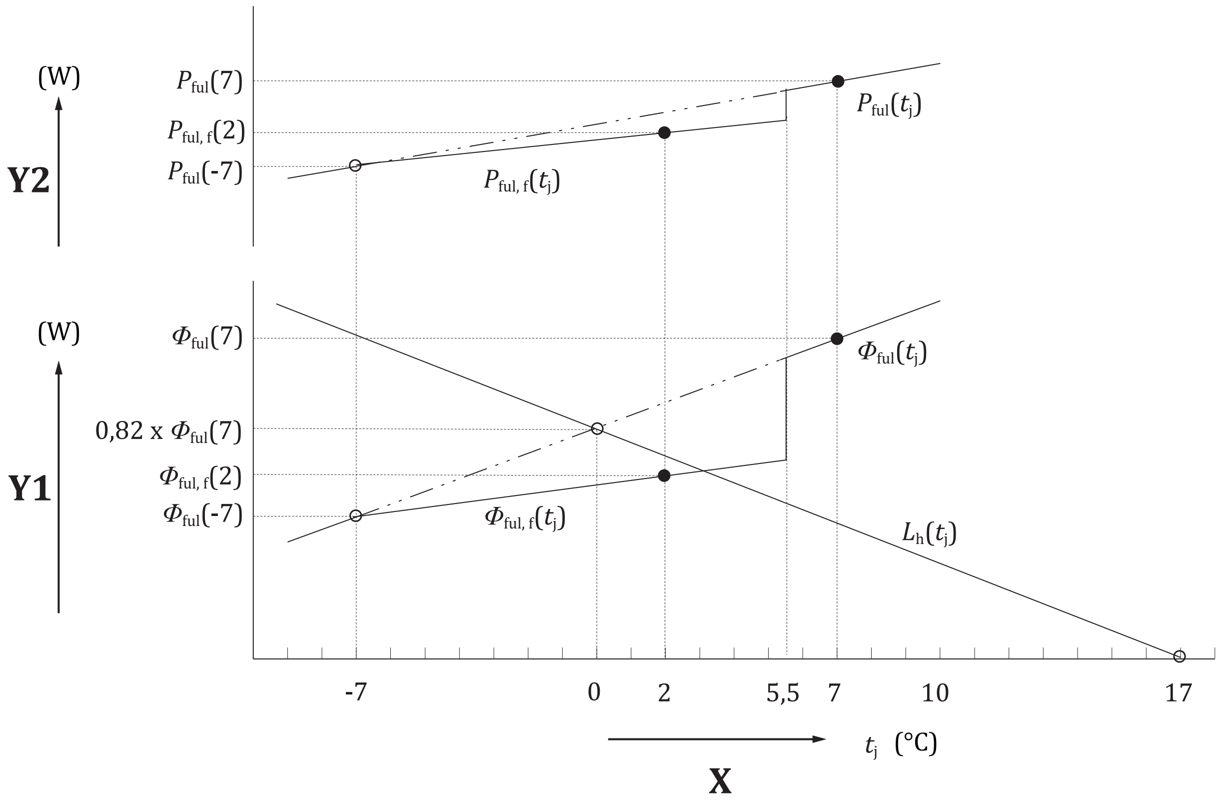
e) for multi-split systems, a combination of indoor units and an outdoor unit.

For variable capacity units, frequency settings for each performed test shall also be indicated.

The heating seasonal performance factor (HSPF) shall be declared with three significant digits, with reference to the reference defined heating load and to the reference outdoor temperature bin distribution used.

Annex A
(informative)

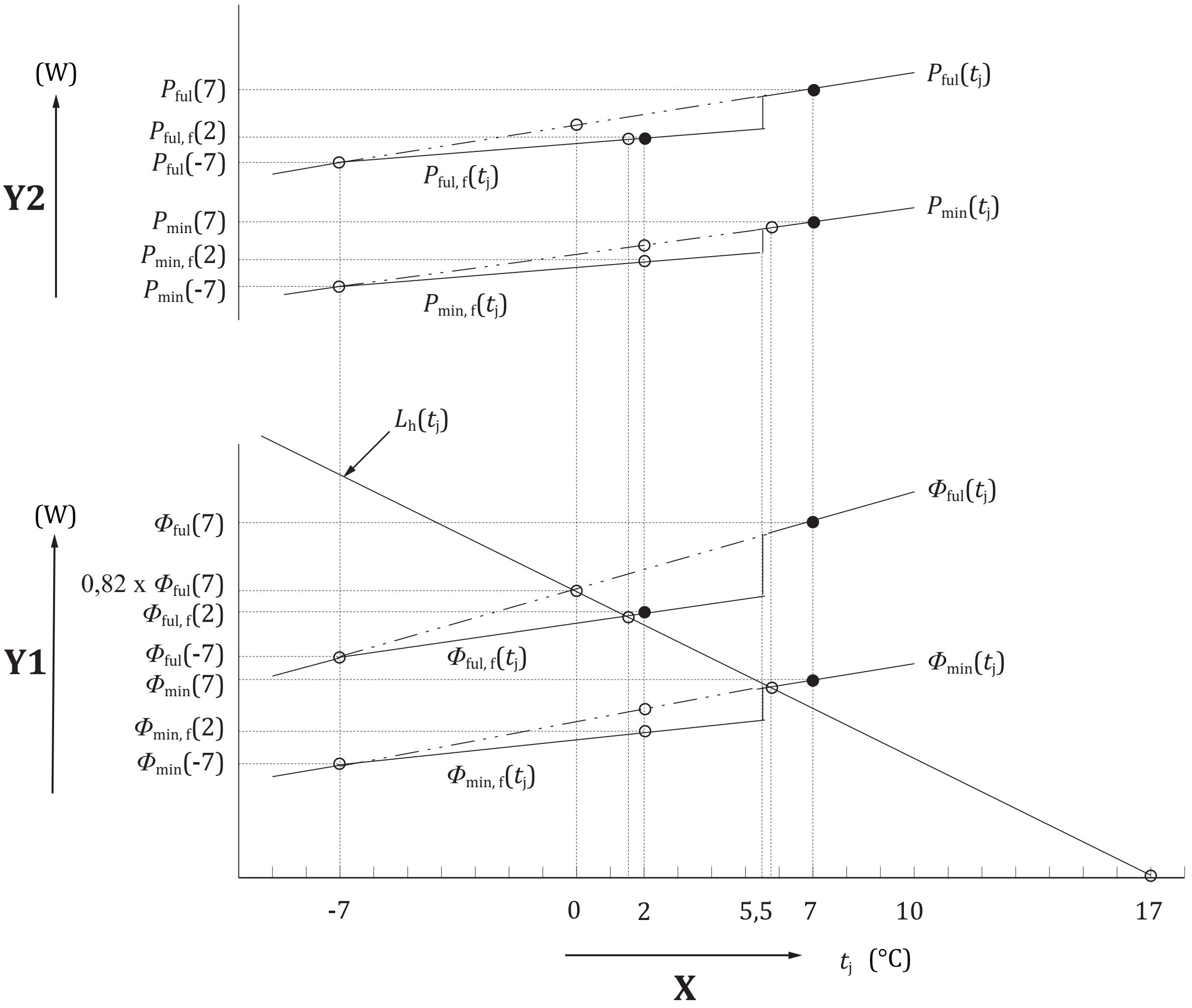
Figures



Key

X	outdoor temperature
Y1	capacity or load
Y2	power input

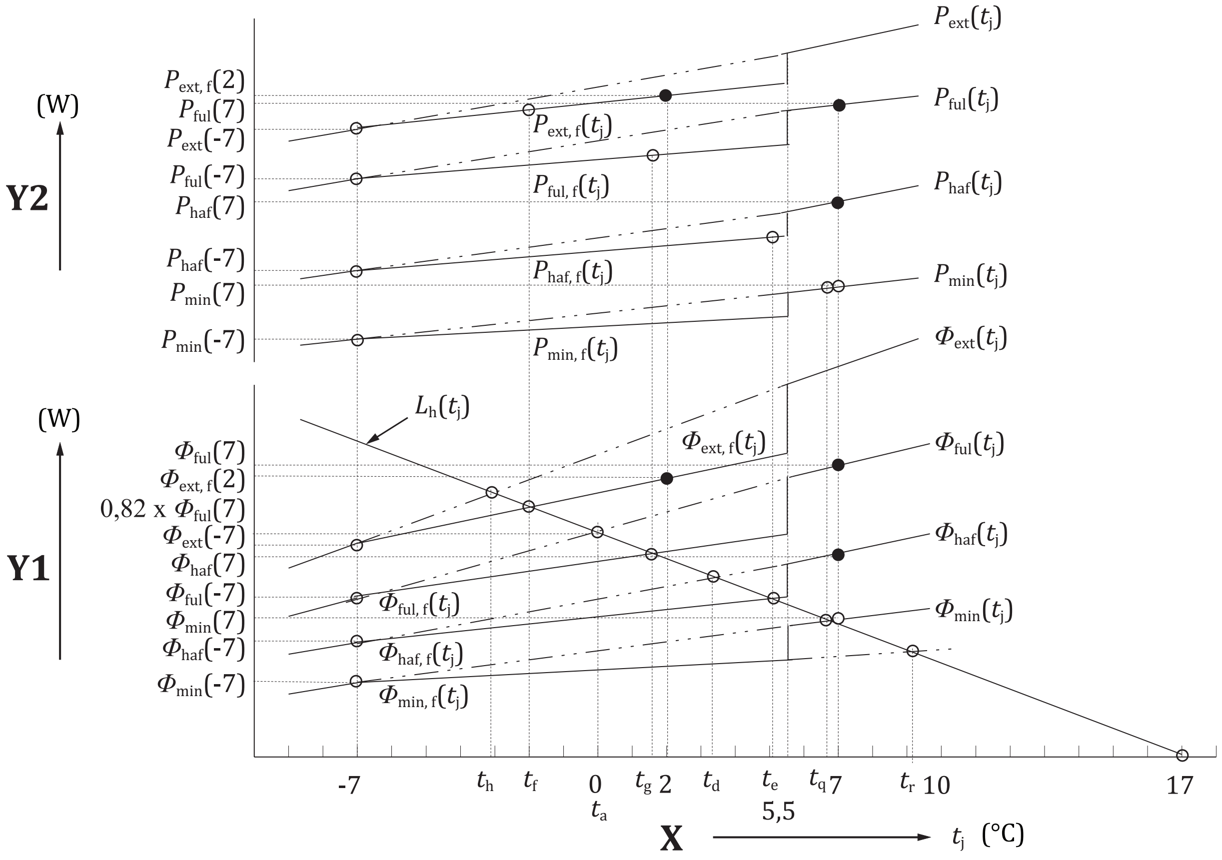
Figure A.1 — Heating capacity, power input and load for fixed capacity units



Key

X	outdoor temperature
Y1	capacity or load
Y2	power input

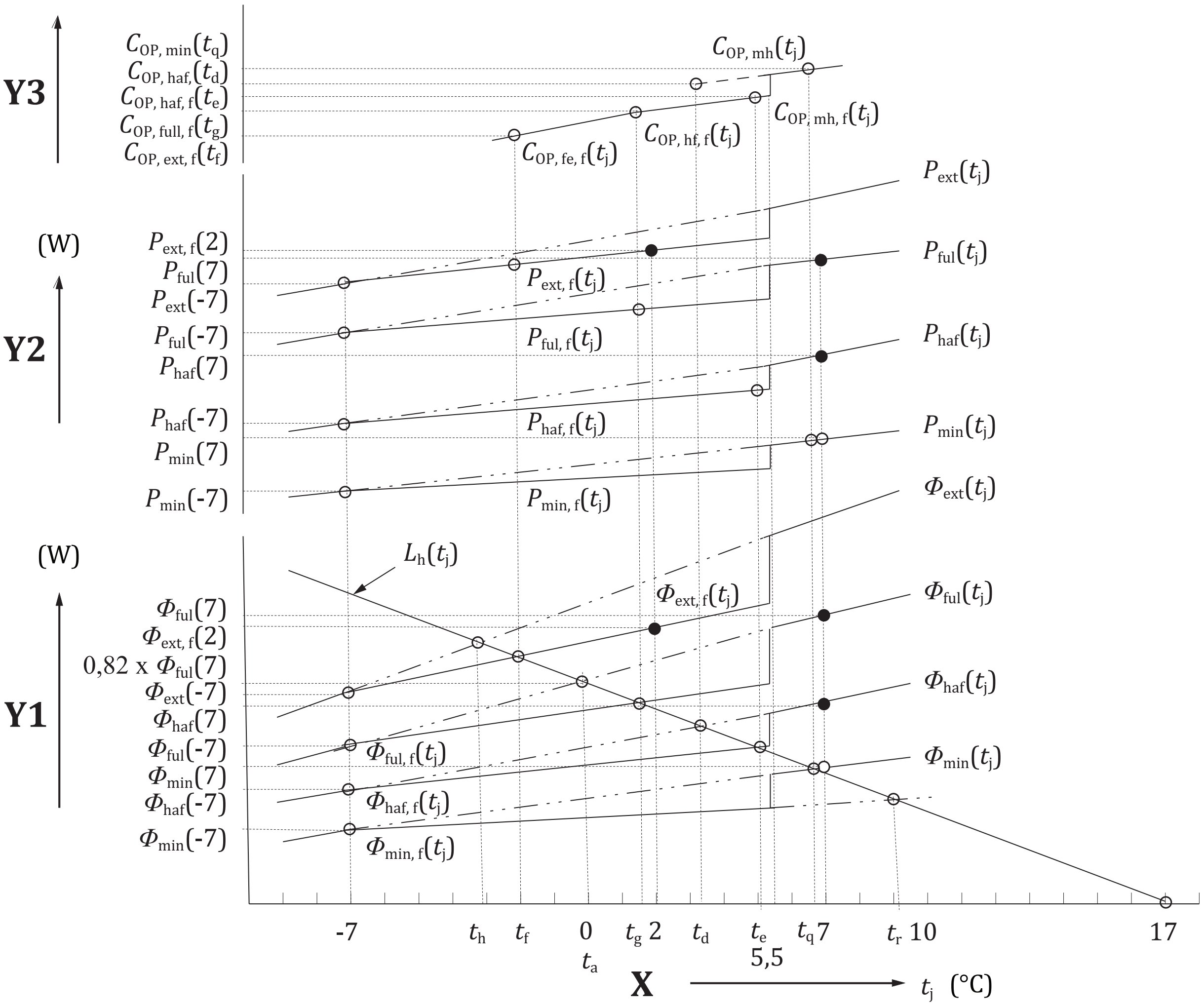
Figure A.2 — Heating capacity, power input and load for two-stage capacity units



Key

X	outdoor temperature
Y1	capacity or load
Y2	power input

Figure A.3 — Heating capacity, power input and load for multi-stage capacity units



Key

X	outdoor temperature
Y1	capacity or load
Y2	power input
Y3	coefficient of performance (COP)

Figure A.4 — Heating capacity, power input, load and COP for variable capacity units

Annex B
(informative)

Calculation of total heating seasonal performance factor (THSPF)

B.1 General

This annex applies to heating only units and reversible units.

B.2 Measurement of the electric power consumption during the inactive mode

The unit shall be electrically connected to the main power source after shut-down for 6 h. Indoor and outdoor temperature of 20 °C condition shall be reached. The power consumption shall be measured for one hour after the temperature conditions are stabilized. The same test is repeated with the temperature condition of 5 °C, 10 °C and then 15 °C with the stabilization period of 2 h between each test. As a reference case, each power consumption value shall be weighted by weighting factors in Table B.1 and then integrated to obtain a weighted average inactive power consumption, P_{ia}. The calculation of inactive power may also be undertaken for other climate conditions and operating schedules.

NOTE If the results of the tests at 20 °C and 5 °C are within 5 % or 1 W, then the tests at 15 °C and 10 °C are not mandatory. The average value of these results is used for the four considered temperature conditions.

Table B.1 — Default weighting factors for determination of reference inactive energy consumption

Temperature condition	5 °C	10 °C	15 °C	20 °C
Weighting factor	0,05	0,13	0,27	0,55

Inactive energy consumption (IAEC) shall be calculated by Formula (B.1).

$$C_{\mathrm{IAE}} = H_{\mathrm{ia}} \times P_{\mathrm{ia}} \quad \text{(B.1)}$$

where

C_{IAE} is the inactive energy consumption;

H_{ia} is the number of hours of inactive mode as given in Table B.2;

P_{ia} is the weighted average power consumption.

B.3 Calculation of total heating seasonal performance factor (THSPF)

Total heating seasonal performance factor (THSPF), F_{THSP}, shall be calculated by Formula (B.2).

$$F_{\mathrm{THSP}} = \frac{L_{\mathrm{HST}}}{C_{\mathrm{HSE}} + C_{\mathrm{IAE}}} \quad \text{(B.2)}$$

Calculation of L_{HST} and C_{HSE} is according to the main body of this part of ISO 16358.

Inactive energy consumption (IAEC), C_{IAE}, shall be calculated by Formula (B.1).

The default mode hours for the calculation of reference total heating seasonal performance factor are shown in Table B.2. The calculation of total heating seasonal performance factor may also be undertaken for other distributions of mode hours.

Table B.2 — Default hours by mode for the calculation of reference total heating seasonal performance factor

Unit	Active mode h	Inactive mode, H_{ia} h	Disconnected mode h
Heating only unit	2 866	4 077	1 817
Reversible unit	2 866 (Cooling operation: 1 817)	4 077	0

Annex C
(normative)

Testing and calculation method for degradation coefficient of cyclic operation

C.1 Cyclic heating test

The cyclic heating test shall be conducted in accordance with Annex A of ISO 5151 and Annex B of ISO 13253 and ISO 15042 as specified in C.2 of this annex.

Testing condition for cyclic heating test is shown in Table C.1.

Table C.1 — Temperature and humidity conditions for cyclic heating test

Test	**Indoor temperature** °C		**Outdoor temperature** °C	
	Dry-bulb	**Wet-bulb** max.	**Dry-bulb**	**Wet-bulb**
A test (required): Steady	20	15	7	6
B test (optional): Cyclic	20	15	7	6

NOTE 1 Maintain the airflow nozzles static pressure difference or velocity pressure during the ON period at the same pressure difference or velocity pressure as measured during the A test.

NOTE 2 For the variable capacity units, the cyclic test is not needed. The above is for information only.

Duration of ON and OFF interval of cyclic operation test is shown in Table C.2.

Table C.2 — Duration of ON and OFF interval of cyclic operation test

Unit type	Operation	Interval (min)		1 Cycle (min)
		ON	OFF	
Fixed capacity type	Full capacity operation	6	24	30
Two-stage capacity type	Minimum capacity operation	6	24	30
Multi-stage capacity type	Half capacity operation or Minimum capacity operation[a]	6	24	30
Variable capacity type	Half capacity operation or Minimum capacity operation[a]	12	48	60

[a] Minimum capacity operation cyclic test instead of half capacity operation cyclic test shall be done in case that minimum capacity steady operation is measured.

C.2 Test procedure

C.2.1 Test procedure for steady-state heating mode test (A test)

Prior to recording data during the steady-state test, operate the unit at least one hour after achieving the steady-state conditions.

Record the heating capacity and electrical power derived from the steady-state mode test. In preparing for C.2.2 cyclic tests, record the average indoor-side air volume rate derived from either pressure difference or velocity pressure for the flow nozzles and air properties.

C.2.2 Test procedure for optional cyclic heating mode test (B test)

C.2.2.1 Test condition

After completing the steady-state test, remove the Outdoor Air Enthalpy method test apparatus, if connected, and begin manual OFF/ON cycling of the unit’s compressor. The test set-up should otherwise be identical to the set-up used during the steady-state test. When testing heat pumps, leave the reversing valve during the compressor OFF cycles in the same position as used for the compressor ON cycles, unless automatically changed by the controls of the unit.

Duration of ON and OFF interval shall be in accordance with Table C.2.

Repeat the OFF/ON compressor cycling pattern until the test is completed. Allow the controls of the unit to regulate cycling of the outdoor fan.

In all cases, use the exhaust fan of the airflow measuring apparatus along with the indoor fan of the unit, if installed and operating, to approximate a step response in the indoor coil airflow.

C.2.2.2 Measurement by using the automatic exhaust fan control of airflow measuring apparatus

If the airflow measuring apparatus has a function to adjust static pressure automatically and immediately so that static pressure difference is equal to zero for ductless units or static pressure is equal to a certain external pressure value for duct units by controlling the exhaust fan operation, the difference between the value of nozzle pressure difference or velocity pressure which is measured by the airflow measuring apparatus having an automatic exhaust fan control and the value which is measured at the steady-state test shall be within 2 % within 15 s after airflow initiation. If the airflow measuring apparatus does not meet the requirements or if the apparatus does not have the ability to automatically control the exhaust fan, it may be measured by manually adjusting the exhaust fan.

C.2.2.3 Measurement by using the manual exhaust fan control of airflow measuring apparatus

Regulate the exhaust fan to quickly obtain and then maintain the flow nozzle static pressure difference or velocity pressure at the same value as was measured during the steady-state test. The pressure difference or velocity pressure should be within 2 % of the value from the steady-state test within 15 s after airflow initiation.

C.2.2.4 Data collection

After completing a minimum of two complete compressor OFF/ON cycles, determine the overall heating delivered and total electrical energy consumption during any subsequent data collection interval.

Test tolerance of the dry-bulb temperature shall be ± 2,5 °C on the indoor side and ± 5 °C on the outdoor side as specified in ISO 5151, ISO 13253 and ISO 15042.

Sample the air property, air flow rate and electrical voltage at least every 2 min during periods when air flows through the coil. Record the dry-bulb temperature of the air entering and leaving the indoor coil at equal intervals that span 10 s or less.

Integrate the heating capacity and the electrical power over complete cycles. For ducted units tested with an indoor fan installed and operating, integrate electrical power from indoor fan OFF to indoor fan OFF. For all other ducted units and for non-ducted units, integrate electrical power from compressor OFF to compressor OFF.

Degradation coefficient (C_D) shall be calculated by Formula (C.1).

$$C_\mathrm{D} = \frac{1 - \dfrac{\phi_\mathrm{ful(cyc)} / P_\mathrm{ful(cyc)}}{\phi_\mathrm{ful} / P_\mathrm{ful}}}{1 - \phi_\mathrm{ful(cyc)} / \phi_\mathrm{ful}} = \frac{1 - \dfrac{C_\mathrm{OP,\,ful(cyc)}}{C_\mathrm{OP,\,ful}}}{1 - F_\mathrm{HL,ful}} \tag{C.1}$$

where

$\phi_\mathrm{ful(cyc)}$ is the capacity (W) of air conditioner when operated for heating with the rated operating capacity tested by the method specified in C.2.2;

$P_\mathrm{ful(cyc)}$ is the heating power consumption (W) when operated for heating with the rated operating capacity tested by the method specified in C.2.2;

ϕ_ful is the capacity (W) of air conditioner when operated for heating with the rated operating capacity tested by the method specified in C.2.1;

P_ful is the heating power consumption (W) when operated for heating with the rated operating capacity tested by the method specified in C.2.1;

$C_\mathrm{OP,\,ful(cyc)}$ is the coefficient of performance of air conditioner when operated for heating with the rated operating capacity tested by the method specified in C.2.2;

$C_\mathrm{OP,\,ful}$ is the coefficient of performance of air conditioner when operated for heating with the rated operating capacity tested by the method specified in C.2.1;

$F_\mathrm{HL,\,ful}$ is the ratio of $\phi_\mathrm{ful(cyc)}$ and ϕ_ful.

Formula (C.1) can be applied for half heating capacity cyclic operation $\phi_\mathrm{haf(cyc)}$ and minimum heating capacity cyclic operation $\phi_\mathrm{min(cyc)}$.

Annex D
(informative)

Calculating method for seasonal performance factor when setting a specific heating load

A specific heating load widely varies from region to region on the globe depending on climate conditions, building structures and the situations in which air conditioners and heat pumps (hereinafter referred to as equipment) are used.

In order to evaluate and compare different seasonal performance factors of the equipment, it is desirable that a representative heating load is established.

For this purpose, this annex is given to establish a minimum, representative heating load and to show an evaluation method of the equipment operating at the conditions fixed by this load.

This annex also specifies a calculation method for seasonal performance factor of the equipment installed in a specific region or in a specific building.

D.1 Heating seasonal performance factor (HSPF)

Calculation of heating seasonal performance factor (HSPF) is made in accordance with the provisions specified in the main body for each type of equipment.

D.1.1 Setting of bin hours of outdoor temperature which requires heating in a specific region

Bin hours of outdoor temperature which requires heating during the heating season shall be set.

D.1.2 Setting of a specific heating load, L_h

a) An outdoor temperature at 100 % heating load shall be set.

b) The lowest outdoor temperature occurred is determined from the data in D.1.1, but it is desirable to exclude the abnormal condition which is thought to be unusual.

c) A load of a specific building is calculated to determine the required heating capacity at the 100 % load outdoor temperature.

d) 0 % load outdoor temperature shall be set based on the calculated load of the specific building and the purpose of using the equipment.

e) From these, a load curve is obtained.

D.1.3 Outdoor temperature characteristics of equipment

Outdoor temperature characteristics of equipment relative to heating capacity and power input are obtained from the main body.

Annex E
(informative)

Calculating method for temperature when defined load line crosses each capacity line

Defined load $L_h(t_j)$ is calculated by Formula (E.1), which is the same as Formula (2) of the main body.

$$L_h(t_j)=\frac{\phi_{ful}(t_{100})\times(t_0-t_j)}{(t_0-t_{100})} \tag{E.1}$$

In case of t_{100} = 0 °C, $\phi_{ful}(t_{100}) = \phi_{ful}(7) \times 0{,}82$

Each capacity characteristic $\phi_{ful}(t_j)$ is given by Formula (E.2) as done by Formulae (3), (12) and (22) in the main body, and $\phi_{ful,\,f}(t_j)$ is given by Formula (E.3) as done by Formulae (4), (13), (23) and (24) in the main body.

$$\phi_{ful}(t_j)=\phi_{ful}(-7)+\frac{\phi_{ful}(7)-\phi_{ful}(-7)}{(7-(-7))}\times(t_j+7) \tag{E.2}$$

$$\phi_{ful,f}(t_j)=\phi_{ful}(-7)+\frac{\phi_{ful,f}(2)-\phi_{ful}(-7)}{(2-(-7))}\times(t_j+7) \tag{E.3}$$

Like $\phi_{ful}(t_j)$ and $\phi_{ful,f}(t_j)$, $\phi_{ext}(t_j)$and $\phi_{ext,f}(t_j)$are calculated by Formulae (E.4) and (E.5) respectively, $\phi_{haf}(t_j)$and $\phi_{haf,f}(t_j)$by Formulae (E.6) and (E.7) respectively, and $\phi_{min}(t_j)$ and $\phi_{min,f}(t_j)$ by Formulae (E.8) and (E.9) respectively.

$$\phi_{ext}(t_j)=\phi_{ext}(-7)+\frac{\phi_{ext}(2)-\phi_{ext}(-7)}{(2-(-7))}\times(t_j+7) \tag{E.4}$$

$$\phi_{ext,f}(t_j)=\phi_{ext}(-7)+\frac{\phi_{ext,f}(2)-\phi_{ext}(-7)}{(2-(-7))}\times(t_j+7) \tag{E.5}$$

$$\phi_{haf}(t_j)=\phi_{haf}(-7)+\frac{\phi_{haf}(7)-\phi_{haf}(-7)}{(7-(-7))}\times(t_j+7) \tag{E.6}$$

$$\phi_{haf,f}(t_j)=\phi_{haf}(-7)+\frac{\phi_{haf,f}(2)-\phi_{haf}(-7)}{(2-(-7))}\times(t_j+7) \tag{E.7}$$

$$\phi_{min}(t_j)=\phi_{min}(-7)+\frac{\phi_{min}(7)-\phi_{min}(-7)}{(7-(-7))}\times(t_j+7) \tag{E.8}$$

$$\phi_{min,f}(t_j)=\phi_{min}(-7)+\frac{\phi_{min,f}(2)-\phi_{min}(-7)}{(2-(-7))}\times(t_j+7) \tag{E.9}$$

Crossing point of full capacity operation line and load line, t_a, is calculated by Formulae (E.1) and (E.2).

$$L_h(t_j)=\phi_{ful}(t_j)$$

$$\phi_{\text{ful}}(t_{100})\times\frac{(t_0-t_{\text{a}})}{(t_0-t_{100})}=\phi_{\text{ful}}(-7)+\frac{\phi_{\text{ful}}(7)-\phi_{\text{ful}}(-7)}{(7-(-7))}\times(t_{\text{a}}+7) \tag{E.10}$$

Then, t_{a} is given by Formula (E.11).

$$t_{\text{a}}=\frac{14\phi_{\text{ful}}(t_{100})t_0-14\phi_{\text{ful}}(-7)(t_0-t_{100})-7(\phi_{\text{ful}}(7)-\phi_{\text{ful}}(-7))(t_0-t_{100})}{14\phi_{\text{ful}}(t_{100})+(\phi_{\text{ful}}(7)-\phi_{\text{ful}}(-7))(t_0-t_{100})} \tag{E.11}$$

Crossing point of full capacity defrosting operation line and load line, t_{g}, is calculated by Formulae (E.1) and (E.3).

$$\phi_{\text{ful}}(t_{100})\times\frac{(t_0-t_{\text{g}})}{(t_0-t_{100})}=\phi_{\text{ful}}(-7)+\frac{\phi_{\text{ful,f}}(2)-\phi_{\text{ful}}(-7)}{(2-(-7))}\times(t_{\text{g}}+7) \tag{E.12}$$

Then, t_{g} is given by Formula (E.13).

$$t_{\text{g}}=\frac{9\phi_{\text{ful}}(t_{100})t_0-9\phi_{\text{ful}}(-7)(t_0-t_{100})-7(\phi_{\text{ful,f}}(2)-\phi_{\text{ful}}(-7))(t_0-t_{100})}{9\phi_{\text{ful}}(t_{100})+(\phi_{\text{ful,f}}(2)-\phi_{\text{ful}}(-7))(t_0-t_{100})} \tag{E.13}$$

Crossing point of extended capacity operation line and load line, t_{h}, is calculated by Formulae (E.1) and (E.4).

$$\phi_{\text{ful}}(t_{100})\times\frac{(t_0-t_{\text{h}})}{(t_0-t_{100})}=\phi_{\text{ext}}(-7)+\frac{\phi_{\text{ext}}(2)-\phi_{\text{ext}}(-7)}{(2-(-7))}\times(t_{\text{h}}+7) \tag{E.14}$$

Then, t_{h} is given by Formula (E.15).

$$t_{\text{h}}=\frac{9\phi_{\text{ful}}(t_{100})t_0-9\phi_{\text{ext}}(-7)(t_0-t_{100})-7(\phi_{\text{ext}}(2)-\phi_{\text{ext}}(-7))(t_0-t_{100})}{9\phi_{\text{ful}}(t_{100})+(\phi_{\text{ext}}(2)-\phi_{\text{ext}}(-7))(t_0-t_{100})} \tag{E.15}$$

Crossing point of extended capacity defrosting operation line and load line, t_{f}, is calculated by Formulae (E.1) and (E.5).

$$\phi_{\text{ful}}(t_{100})\times\frac{(t_0-t_{\text{f}})}{(t_0-t_{100})}=\phi_{\text{ext}}(-7)+\frac{\phi_{\text{ext,f}}(2)-\phi_{\text{ext}}(-7)}{(2-(-7))}\times(t_{\text{f}}+7) \tag{E.16}$$

Then, t_{f} is given by Formula (E.17).

$$t_{\text{f}}=\frac{9\phi_{\text{ful}}(t_{100})t_0-9\phi_{\text{ext}}(-7)(t_0-t_{100})-7(\phi_{\text{ext,f}}(2)-\phi_{\text{ext}}(-7))(t_0-t_{100})}{9\phi_{\text{ful}}(t_{100})+(\phi_{\text{ext,f}}(2)-\phi_{\text{ext}}(-7))(t_0-t_{100})} \tag{E.17}$$

Crossing point of half capacity operation line and load line, t_{d}, is calculated by Formulae (E.1) and (E.6).

$$\phi_{\text{ful}}(t_{100})\times\frac{(t_0-t_{\text{d}})}{(t_0-t_{100})}=\phi_{\text{haf}}(-7)+\frac{\phi_{\text{haf}}(7)-\phi_{\text{haf}}(-7)}{(7-(-7))}\times(t_{\text{d}}+7) \tag{E.18}$$

Then, t_{d} is given by Formula (E.19).

$$t_{\text{d}}=\frac{14\phi_{\text{ful}}(t_{100})t_0-14\phi_{\text{haf}}(-7)(t_0-t_{100})-7(\phi_{\text{haf}}(7)-\phi_{\text{haf}}(-7))(t_0-t_{100})}{14\phi_{\text{ful}}(t_{100})+(\phi_{\text{haf}}(7)-\phi_{\text{haf}}(-7))(t_0-t_{100})} \tag{E.19}$$

Crossing point of half capacity defrosting operation line and load line, t_{e}, is calculated by Formulae (E.1) and (E.7).

$$\phi_{\text{ful}}(t_{100})\times\frac{(t_0-t_{\text{e}})}{(t_0-t_{100})}=\phi_{\text{haf}}(-7)+\frac{\phi_{\text{haf,f}}(2)-\phi_{\text{haf}}(-7)}{(2-(-7))}\times(t_{\text{e}}+7) \tag{E.20}$$

Then, t_{e} is given by Formula (E.21).

$$t_e = \frac{9\phi_{\mathrm{ful}}(t_{100})t_0 - 9\phi_{\mathrm{haf}}(-7)(t_0 - t_{100}) - 7(\phi_{\mathrm{haf,f}}(2) - \phi_{\mathrm{haf}}(-7))(t_0 - t_{100})}{9\phi_{\mathrm{ful}}(t_{100}) + (\phi_{\mathrm{haf,f}}(2) - \phi_{\mathrm{haf}}(-7))(t_0 - t_{100})} \tag{E.21}$$

Crossing point of minimum capacity operation line and load line, t_q, is calculated by Formulae (E.1) and (E.8).

$$\phi_{\mathrm{ful}}(t_{100}) \times \frac{(t_0 - t_q)}{(t_0 - t_{100})} = \phi_{\mathrm{min}}(-7) + \frac{\phi_{\mathrm{min}}(7) - \phi_{\mathrm{min}}(-7)}{(7-(-7))} \times (t_q + 7) \tag{E.22}$$

Then, t_q is given by Formula (E.23).

$$t_q = \frac{14\phi_{\mathrm{ful}}(t_{100})t_0 - 14\phi_{\mathrm{min}}(-7)(t_0 - t_{100}) - 7(\phi_{\mathrm{min}}(7) - \phi_{\mathrm{min}}(-7))(t_0 - t_{100})}{14\phi_{\mathrm{ful}}(t_{100}) + (\phi_{\mathrm{min}}(7) - \phi_{\mathrm{min}}(-7))(t_0 - t_{100})} \tag{E.23}$$

Crossing point of minimum capacity defrosting operation line and load line, t_r, is calculated by Formulae (E.1) and (E.9).

$$\phi_{\mathrm{ful}}(t_{100}) \times \frac{(t_0 - t_r)}{(t_0 - t_{100})} = \phi_{\mathrm{min}}(-7) + \frac{\phi_{\mathrm{min,f}}(2) - \phi_{\mathrm{min}}(-7)}{(2-(-7))} \times (t_r + 7) \tag{E.24}$$

Then, t_r is given by Formula (E.25).

$$t_r = \frac{9\phi_{\mathrm{ful}}(t_{100})t_0 - 9\phi_{\mathrm{min}}(-7)(t_0 - t_{100}) - 7(\phi_{\mathrm{min,f}}(2) - \phi_{\mathrm{min}}(-7))(t_0 - t_{100})}{9\phi_{\mathrm{ful}}(t_{100}) + (\phi_{\mathrm{min,f}}(2) - \phi_{\mathrm{min}}(-7))(t_0 - t_{100})} \tag{E.25}$$

Using default $\phi(-7) = 0{,}64 \times \phi(7)$ in Table 1 of the main body, $\phi(t_j)$ becomes Formula (E.26).

$$\phi(t_j) = \phi(7)\left(0{,}64 + \frac{(1-0{,}64)}{14} \times (t_j + 7)\right) \tag{E.26}$$

Default $\phi(-7) = 0{,}734 \times \phi(2)$ is determined from Formula (E.26). Using this and another default $\phi_{,f}(2) = \phi(2)/1{,}12$ in Table 1 of the main body, $\phi(-7) = 0{,}734 \times 1{,}12\phi_{,f}(2)$.

Therefore, $\phi_{,f}(t_j)$ becomes Formula (E.27).

$$\phi_{,f}(t_j) = \phi_{,f}(2)\left(0{,}734 \times 1{,}12 + \frac{(1-0{,}734 \times 1{,}12)}{9} \times (t_j + 7)\right) \tag{E.27}$$

When $L_h(t_j) = \phi(t_j)$ or $\phi_{,f}(t_j)$ at temperature t_j, right sections of Formulae (E.1) and (E.26) or (E.27) are the same. Therefore, temperature t is calculated by Formula (E.28) or (E.29).

$$t = \frac{0{,}82 - \dfrac{\phi(7)}{\phi_{\mathrm{ful}}(7)}\left(0{,}64 + \dfrac{(1-0{,}64) \times 7}{14}\right)}{\dfrac{0{,}82}{17} + \dfrac{\phi(7)}{\phi_{\mathrm{ful}}(7)}\left(\dfrac{1-0{,}64}{14}\right)} \tag{E.28}$$

$$t = \frac{0{,}82 - \dfrac{\phi_{,f}(2)}{\phi_{\mathrm{ful}}(7)}\left(\dfrac{7 + (0{,}734 \times 1{,}12 \times 2)}{9}\right)}{\dfrac{0{,}82}{17} + \dfrac{\phi_{,f}(2)}{\phi_{\mathrm{ful}}(7)}\left(\dfrac{1-0{,}734 \times 1{,}12}{9}\right)} \tag{E.29}$$

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