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Heat pump water heater — Testing and rating at part load conditions and calculation of seasonal coefficient of performance for space heating

Chauffe-eau à pompe à chaleur — Essais et classification à charge partielle et calcul du coefficient de performance saisonnier

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Foreword

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This document was prepared by Technical Committee ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 6, *Testing and rating of air-conditioners and heat pumps*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Heat pumps water heaters are, at present, selected and compared at a rated condition. This condition does not represent the usual operating conditions of the equipment over a season. This operating condition can be better assessed by comparing equipment at representative reduced capacities and determining the Seasonal Coefficient of Performance.

This standard provides part load conditions and calculation methods for calculating the Seasonal Coefficient of Performance ($SCOP_{on}$ and $SCOP_{net}$) of such units when they are used to fulfil the heating demands.

Other energy consumptions can occur when the unit is not used to fulfil the heating demands such as those from a crankcase heater or when the unit is on standby. These consumptions are considered in the calculation methods for reference *SCOP*.

Reference $SCOP/SCOP_{on}/SCOP_{net}$ calculations may be based on calculated or tested values. For the purpose of $SCOP/SCOP_{on}/SCOP_{net}$, three design conditions average (A), Colder (C) and warmer (W) are considered as well as three temperature applications. In case of tested values, this standard gives the methods for testing heat pumps water heater at part load conditions.

Heat pump water heater — Testing and rating at part load conditions and calculation of seasonal coefficient of performance for space heating

1 Scope

The document specifies test conditions for determining the seasonal performance characteristics of air source heat pump water heaters for space heating with electrically driven compressors with or without supplementary heater. The purpose of this document is to rate performance of the heat pump water heaters for space heating with no operation of any supplementary heater. In the case of heat pump water heaters for space heating consisting of several parts with refrigerant or water connections, this document applies only to those designed and supplied as a complete package.

The seasonal coefficient of performance depends, inter alia, on the climate conditions and temperature regime of the space heating distribution network.

This document defines:

— three design conditions, each of them being characterized by a design temperature which represents the lowest temperature that can occur in that design condition;

— three water temperature distribution regimes, namely “temperature application” in the text.

The user of this document is free to determine the seasonal coefficient of performance for one or more of the defined design conditions and for one or more of the defined temperature applications.

This document also provides a full description of three heating seasons that can be used with the associated design conditions.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
active mode
mode corresponding to the hours with a heating load of the building and whereby the heating function of the unit is activated

Note 1 to entry: This condition can involve on/off-cycling of the unit in order to reach or maintain a required indoor air temperature.

3.2
active mode seasonal coefficient of performance
$SCOP_{on}$
average coefficient of performance of the unit in *active mode* (3.1) for the designated design condition, determined from the part load, supplementary heating capacity (where required) and *bin-specific coefficients of performance* (3.7) and weighted by the *bin hours* (3.6) where the bin condition occurs

Note 1 to entry: For calculation of $SCOP_{on}$, the energy consumption during *thermostat-off mode* (3.45), *standby mode* (3.42), *off mode* (3.34) and *crankcase heater mode* (3.17) are excluded. The energy consumption of a supplementary heater is added for the part load conditions where the declared capacity of the unit is lower than the heating load, regardless whether this supplementary heater is included in the unit or not included in the unit.

Note 2 to entry: Expressed in kWh/kWh.

3.3
annual energy consumption for heating
Q_{HE}
energy consumption required to meet the reference annual heating demand for a designated design condition and set of bin hours and calculated as the reference annual heating demand divided by the *active mode seasonal coefficient of performance* (3.2) and the energy consumption of the unit for thermostat-off-, standby-, off- and crankcase heater-mode during the heating season

Note 1 to entry: Expressed in kWh/kWh.

3.4
annual heating demand
Q_H
heating demand for a designated design condition and set of bin hours, to be used as basis for calculation of *seasonal coefficient of performance* (3.41) and calculated as the product of the *design load* (3.21) for heating and the *equivalent active mode hours for heating* (3.27)

Note 1 to entry: Expressed in kWh.

3.5
bin
outdoor temperature interval of 1 K

3.6
bin hours
h_j
hours per heating season for which an outdoor temperature occurs for each *bin* (3.5) *j*

3.7
bin-specific coefficient of performance
COP_{bin} (T_j)
coefficient of performance specific for every *bin* (3.5) *j* with outdoor temperature T_j in a heating season

3.8
bin temperature
T_j
outdoor air dry bulb temperature

Note 1 to entry: Expressed in °C.

Note 2 to entry: The relative humidity can be indicated by a corresponding wet bulb temperature.

3.9
bivalent temperature
T_{biv}
lowest outdoor temperature point at which the unit is declared to have a capacity able to meet 100 % of the heating load without supplementary heater, whether it is integrated in the unit or not

Note 1 to entry: Below this point, the unit can still provide capacity, but additional supplementary heating is necessary to fulfil the heating load.

3.10
capacity control
ability of the unit to change its capacity by changing the volumetric flow rate of the refrigerant

Note 1 to entry: Units are indicated as '*fixed*' if the unit cannot change its volumetric flow rate, '*two-staged*' if the volumetric flow rate is changed or varied in series of not more than two steps, '*multi-stage*' if the volumetric flow rate is changed or varied in series of three or four steps or '*variable*' if the volumetric flow rate is changed or varied in series of five or more steps to represent continuously variable capacity.

Note 2 to entry: Multi-stage capacity units are considered as variable capacity units in this document.

3.11
capacity ratio
CR
heating part load or full load divided by the declared heating capacity of the unit at the same temperature conditions

3.12
coefficient of performance at declared capacity

COP_d
declared heating capacity of the unit divided by the effective power input of the unit at specific temperature conditions, A, B, C, D, E, F and G, where applicable

Note 1 to entry: Expressed in kW/kW.

3.13
coefficient of performance at part load
COP_{bin}
coefficient of performance at the declared capacity, corrected with the degradation coefficient, where applicable

Note 1 to entry: When the declared capacity of the unit is higher than the heating load, the *COP* includes degradation losses. When the declared capacity of the unit is lower than the heating load (i.e. below the *bivalent temperature* (3.9) condition), the *COP* of the declared capacity is used.

Note 2 to entry: Expressed in kW/kW.

3.14
compressor-off state
condition where the compressor is not running while the unit is operating in *active mode* (3.1)

Note 1 to entry: This is the "off" phase in on/off cycling.

3.15
crankcase heater mode operating hours
H_{CK}
annual number of hours the unit is considered to be in crankcase heater mode, the value of which depends on the designated design condition and set of bin hours

Note 1 to entry: Three examples of crankcase heater mode hours are given in Annex C.

Note 2 to entry: Expressed in h.

3.16
crankcase heater mode power input
P_{CK}
power input of the unit due to crankcase heater operation mode

Note 1 to entry: Expressed in W.

3.17
crankcase heater (operation) mode
condition where the unit has activated a heating device to avoid the refrigerant migrating to the compressor in order to limit the refrigerant concentration in oil at compressor start

3.18
declared capacity in heating
Pdh
heating capacity a unit can provide at any temperature condition A, B, C, D, E, F or G, as declared by the manufacturer

Note 1 to entry: This is the capacity provided by the refrigerant cycle of the unit without supplementary heaters, even if those are integrated in the unit.

3.19
degradation coefficient
Cd
measure of efficiency loss due to the cycling

Note 1 to entry: If the *Cd* is not determined by measurement, the default degradation coefficient is 0,9.

3.20
design condition
condition characterized by a design temperature condition and that is to be associated with a set of bin hours

Note 1 to entry: Three design conditions are defined in this document.

3.21
design load
$P_{designh}$
space heating load declared by the manufacturer at *design temperature* (3.22)

Note 1 to entry: It is possible to calculate the $SCOP/SCOP_{on}/SCOP_{net}$ of a unit for more than one $P_{designh}$ value.

Note 2 to entry: Expressed in kW.

3.22
design temperature
$T_{designh}$
lowest outdoor air temperature considered for each design condition

3.23
effective power input during compressor-off state
Pc_{off}
total power input of the unit when the compressor is switched off in *active mode* (3.1), used for the determination of the *degradation coefficient* (3.19)

Note 1 to entry: Expressed in kW.

3.24
effective power input with declared capacity
Pc_{on}
total power input when the unit is operating at part load condition, used for the determination of the *degradation coefficient* (3.19)

Note 1 to entry: Expressed in kW.

3.25
electric supplementary heater
real or assumed electric supplementary heater, with a *COP* of 1, considered in the calculation of *SCOP* (3.41) and *SCOPon* (3.2)

3.26
electric supplementary heater capacity
$elbu(T_j)$
heating capacity of a real or assumed electric supplementary heater supplementing the declared capacity for heating when the capacity of the unit is lower than the heat load for a specific *bin temperature* (3.8) T_j

Note 1 to entry: Expressed in kW.

3.27
equivalent active mode hours for heating
H_{HE}
assumed annual number of hours while the unit is assumed to operate at the design load for heating ($P_{designh}$) in order to satisfy the reference annual heating demand

Note 1 to entry: Expressed in h.

3.28
fixed outlet
water(brine) outlet temperature that is used when the control of the unit has no means to automatically vary the water(brine) outlet temperature with the outdoor temperature

3.29
heat pump water heater for space heating
air source heat pump water heater with electrically driven compressor(s) with or without supplementary heater for space heating purpose

Note 1 to entry: This is also referred to as heat pump in this document.

3.30
high temperature application
temperature application where the indoor heat exchanger water(brine) outlet temperature of 55 °C is met at design temperature

3.31
low temperature application
temperature application where the indoor heat exchanger water(brine) outlet temperature of 35 °C is met at design temperature

3.32
medium temperature application
temperature application where the indoor heat exchanger water(brine) outlet temperature of 45 °C is met at design temperature

3.33
net seasonal coefficient of performance
$SCOP_{net}$
seasonal efficiency of a unit in active heating mode without supplementary heaters which is determined from selected conditions

Note 1 to entry: For calculation of $SCOP_{net}$, the energy consumption during *active mode* (3.1) is used. This excludes the energy consumption during *thermostat-off mode* (3.45), *standby mode* (3.42), *off mode* (3.34) or that of the crankcase heater. For the part load conditions where the declared capacity of the unit is lower than the heating load, the energy consumption of a supplementary heater is not included.

Note 2 to entry: Expressed in kWh/kWh.

3.34
off mode
mode wherein the unit is completely switched off and cannot be reactivated by control device, external signal or by a timer

Note 1 to entry: Off mode means a condition in which the equipment is connected to the mains and is not providing any function. The following will also be considered as off mode: conditions providing only an indication of off mode condition; conditions providing only functionalities intended to ensure electromagnetic compatibility.

3.35
off mode operating hours
H_{OFF}
annual number of hours the unit is considered to be in *off mode* (3.34), the value of which depends on the designated design condition and set of bin hours

Note 1 to entry: Three examples of off mode operating hours are given in Annex C.

Note 2 to entry: Expressed in h.

3.36
off mode power input
P_{OFF}
power input of the unit while in *off mode* (3.34)

Note 1 to entry: Expressed in W.

3.37
operation limit temperature
TOL
outdoor temperature below which the declared capacity is equal to zero

Note 1 to entry: Expressed in °C.

3.38
part load for heating
$P_h(T_j)$
heating load at a specific *bin temperature* (3.8) T_j, calculated as the design load multiplied by the part load ratio

Note 1 to entry: Expressed in kW.

3.39
part load ratio
$pl(T_j)$
bin temperature (3.8) minus 16 °C divided by the design temperature minus 16 °C

3.40
reactivation function
function facilitating the activation of other modes, including *active mode* (3.1), by remote switch including remote control, internal sensor, timer to a condition providing additional functions, including the main function, but excluding thermostats

3.41
seasonal coefficient of performance
SCOP
overall coefficient of performance of the unit, representative for the designated design condition and set of bin hours

Note 1 to entry: *SCOP* is calculated as the *annual heating demand* (3.4) divided by the *annual energy consumption for heating* (3.3).

Note 2 to entry: Expressed in kWh/kWh.

3.42
standby mode
mode wherein the unit is switched off partially and can be reactivated by a control device (such as a remote control), an external signal or a timer

Note 1 to entry: The unit is connected to the mains, depends on signal input to work as intended and provides only the following functions, which may persist for an indefinite time: *reactivation function* (3.40), or reactivation function and only an indication of enabled reactivation function, and/or information or status display.

3.43
standby mode operating hours
H_{SB}
annual number of hours the unit is considered to be in *standby mode* (3.42), the value of which depends on the designated design condition and set of bin hours

Note 1 to entry: Three examples of standby hours are given in Annex C.

Note 2 to entry: Expressed in h.

3.44
standby mode power input
P_{SB}
power input of the unit due to *standby mode* (3.42) operation

Note 1 to entry: Expressed in W.

3.45
thermostat-off mode
mode corresponding to the hours with no heating demand of the building, whereby the heating function of the unit is switched on, but is not operational, as there is no heating demand

Note 1 to entry: Cycling on/off in *active mode* (3.1) is not considered as thermostat-off.

3.46
thermostat-off mode operating hours
H_{TO}
annual number of hours the unit is considered to be in *thermostat-off mode* (3.45), the value of which depends on the designated design condition and set of bin hours

Note 1 to entry: Three examples of standby hours are given in Annex C.

Note 2 to entry: Expressed in h.

3.47
thermostat-off mode power input
P_{TO}
power input of the unit due to *thermostat-off mode* (3.45) operation

Note 1 to entry: Expressed in W.

3.52
variable outlet
water(brine) outlet temperature that is used when the control of the unit has means to automatically vary the water(brine) outlet temperature with the outdoor temperature

4 Symbols

Symbol	Definition	Units
Cd	Degradation coefficient	—
COP	Coefficient of performance	kW/kW
COP_{bin}	Coefficient of performance at part load	kW/kW
$COP_{bin}(T_j)$	Bin-specific coefficient of performance	kW/kW
COP_d	Coefficient of performance at the declared capacity	kW/kW
CR	Capacity ratio	kW/kW
EEI	Energy efficiency index of liquid pump	—
h_j	Bin hours	h
H_{HE}	Equivalent active mode hours for heating	h
H_{CK}	Crankcase heater mode operating hours	h
H_{OFF}	Off mode operating hours	h
H_{SB}	Standby mode operating hours	h
H_{TO}	Thermostat-off mode operating hours	h
j	Bin number	—
n	Total number of bin	—
P_{CK}	Crankcase heater mode power input	W
Pc_{off}	Effective power input during compressor-off state	kW
Pc_{on}	Effective power input with declared capacity	kW
Pdh	Declared capacity in heating	kW
$P_{designh}$	Design load heating	kW
$P_h(T_j)$	Part load for heating	kW
P_{OFF}	Off mode power input	W
P_{SB}	Standby mode power input	W
P_{TO}	Thermostat-off mode power input	W
$pl(T_j)$	Part load ratio for bin temperature T_j	—
Q_H	Annual heating demand	kWh
Q_{HE}	Annual energy consumption for heating	kWh
$SCOP$	Seasonal coefficient of performance	kW/kW
$SCOP_{net}$	Net seasonal coefficient of performance	kW/kW
$SCOP_{on}$	Active mode seasonal coefficient of performance	kW/kW
T_{biv}	Bivalent temperature	°C
$T_{designh}$	Design temperature conditions for heating	°C
T_j	Bin temperature (outdoor temperature)	°C
T_{ol}	Operation limit temperature	°C

Symbol	Definition	Units
elbu(T_j)	electric supplementary heater capacity	kW

5 Installation requirements

5.1 Test apparatus and uncertainties of measurement

The test apparatus shall be designed in such a way that all requirements for adjustment of set values, stability criteria and uncertainties of measurement according to this document can be fulfilled.

Water systems or other heat transfer liquid systems shall be sufficiently free of entrained gas as to ensure that the measured results are not significantly influenced.

The inlet and outlet water temperatures of the heat pump shall be measured in the center of the flow and as close as possible to the unit. The response time of the temperature sensor and the sampling interval shall be chosen to maintain the uncertainties in Table 1.

Ducted air systems shall be sufficiently airtight to ensure that the measured results are not significantly influenced by exchange of air with the surroundings.

When performing measurements, set the highest room temperature on the unit/system control device. If, in the instructions, the manufacturer indicates a value for the temperature set on the control device for a given part load conditions, this value shall be used.

Temperature and pressure measuring points shall be arranged in order to obtain mean significant values.

For free air intake temperature measurements, it is required either:

— to have at least one sensor per square meter, with not less than four measuring points and by restricting to 20 the number of sensors equally distributed on the free air surface; or

— to use a sampling device that shall be completed by four sensors for checking uniformity if the surface area is greater than 1 m^2.

Air temperature sensors shall be placed at a maximum distance of 0,25 m from the free air surface.

For water and brine, the density and specific heat in Formulae (2), (3) and (4) shall be determined in the temperature conditions measured near the volume flow measuring device.

The uncertainties of measurement shall not exceed the values specified in Table 1.

Table 1 — Uncertainties of measurement

Measured quantity	Unit	Uncertainty
Liquid		
Temperature	°C	±0,15 K
Temperature difference	K	±0,15 K
Volume flow	m^3/s	±1 %
Static pressure difference	kPa	±1 kPa (≤20 kPa) ±5 % (>20 kPa)
Concentration (for brine)	%	2 %
Air		
Dry bulb temperature	°C	±0,2 K
Wet bulb temperature	°C	±0,4 K
Volume flow	m^3/s	±5 %