TRANSITIONAL METHOD FOR DETERMINATION OF THE SEPR (SEASONAL ENERGY PERFORMANCE RATIO) FOR PROCESS CHILLERS – JUNE 2016 VERS. B

1 General

This document defines the operating conditions and the methodology to define the reference SEPR for refrigeration and industrial chillers, for operation at low and medium temperature.

2 Definitions

full load
Pdesign
refrigeration ($P_{designR}$) load of the application at T_{design} conditions

Note 1: Expressed in kW.
Note 2: Power input of a chiller includes always the power input for pumps and fans to overcome pressure drop in evaporator and condenser for heat transfer fluids (e.g. brine, water, air). This power input can be calculated by volume flow times pressure drop divided by total efficiency of fan or pump.

part load
P_C(Tj)
Process cooling load of the application at a specific ambient temperature calculated as the full load multiplied by the part load ratio corresponding to the same ambient temperature T_j

part load ratio
P_R(Tj)
Value limited between 80% and 100% and proportional to the ambient temperature T_j.

declared capacity
DC
refrigeration capacity a chiller can deliver at any temperature condition A, B, C or D, as declared by the manufacturer

Note 1: The temperature conditions for part load conditions A, B, C, D are explained in the Tables 1 and 2.

capacity ratio
CR
part load or full load cooling demand divided by the declared refrigeration capacity of the chiller at the same temperature conditions

bin hours
h_j
sum of all hours occurring at a given temperature for a specific location

Note 1: The number is derived from representative weather data over the 1996-2005 period.

Note 2: For the reference refrigeration year, the specific location is Strasbourg.

energy efficiency ratio at declared capacity
EER_{DC}
declared refrigeration capacity of the chiller divided by the effective power input of a chiller at specific temperature conditions A, B, C, D

Note 1: Expressed in kW/kW.
Note 2: The temperature conditions A, B, C, and D are explained in the tables 1 and 2.

energy efficiency ratio at part load or full load conditions
EER_{PL}
refrigeration capacity at part load or full load divided by the effective power input of a chiller at specific temperature conditions

Note 1: The EER includes degradation losses when the declared capacity of the chiller is higher than the cooling capacity demand.
Note 2: Expressed in kW/kW.

reference seasonal energy performance ratio
SEPR
reference seasonal efficiency of a chiller calculated for the reference annual refrigeration demand, which is determined from mandatory conditions given in this document and used for eco-design requirements

Note 1: For calculation of SEPR, only the electricity consumption during active mode is used.
Note 2: Expressed in kWh/kWh.

active mode
mode corresponding to the hours with a refrigerating load of the application and whereby the refrigeration function of the chiller is switched on

Note 1 : The unit has to reach or maintain a temperature set point and in order to do so, the unit may switch between being operational or not operational (e.g. by on/off cycling of the compressor).

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

Note 1: As from Annex I.52 to Regulation 2015/1095[1], 'capacity control' means the ability of a process chiller to change its capacity by changing the volumetric flow rate of the refrigerant, to be indicated as 'fixed' if the process chiller cannot change its volumetric flow rate, 'staged' if the volumetric flow rate is changed or varied in series of not more than two steps, or 'variable' if the volumetric flow rate is changed or varied in series of three or more steps.

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[1] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015R1095

degradation coefficient
Cc
measure of efficiency loss due to the cycling of fixed capacity chillers

3 Air-cooled process chillers

For the purpose of calculation of SEPR as explained in Clause 5 of this transitional method, the part load ratios mentioned below shall be based on the part load ratio formulas (column 2) and not on the rounded figures (column 3) of Table 1.

The part load conditions for determining the reference SEPR are given in the following Table 1.

Table 1 – Part load conditions for reference SEPR calculation of air-cooled process chillers

	Part load ratio %		Outdoor heat exchanger	Indoor heat exchanger inlet/outlet temperatures °C	
			Inlet air temperature °C	low temperature application	medium temperature application
A	$80+20(T_A-T_D)/(T_A-T_D)$	100	35	-19/-25[a]	-2/-8[a]
B	$80+20(T_B-T_D)/(T_A-T_D)$	93	25	[b]/-25	[b]/-8
C	$80+20(T_C-T_D)/(T_A-T_D)$	87	15	[b]/-25	[b]/-8
D	$80+20(T_D-T_D)/(T_A-T_D)$	80	5	[b]/-25	[b]/-8

[a] If the unit is not allowed to operate at this inlet temperature, a lower inlet temperature can be used.
[b] With the flow rate as determined during “A” test for units with a fixed flow rate or with a fixed delta T of 6 K for units with a variable flow rate. If the resulting flow rate is below the minimum flow rate then this minimum flow rate is used with the outlet temperature.

4 Water-cooled process chillers

For the purpose of calculation of SEPR as explained in Clause 5 of this transitional method, the part load ratios mentioned below shall be based on the part load ratio formulas (column 2) and not on the rounded figures (column 3) of Table 2.

The part load conditions for determining the reference SEPR are given in the following Table 2.

Table 2 – Part load conditions for reference SEPR calculation of water-cooled process chillers

	Part load ratio %	Outdoor heat exchanger	Indoor heat exchanger inlet/outlet temperatures °C

			Inlet / outlet water temperature °C	low temperature application	medium temperature application
A	$80+20(T_A-T_D)/(T_A-T_D)$	100	30/35	-19/-25[a]	-2/-8[a]
B	$80+20(T_B-T_D)/(T_A-T_D)$	93	23/[c]	[b]/-25	[b]/-8
C	$80+20(T_C-T_D)/(T_A-T_D)$	87	16/[c]	[b]/-25	[b]/-8
D	$80+20(T_D-T_D)/(T_A-T_D)$	80	9[d]/[c]	[b]/-25	[b]/-8

[a] If the unit is not allowed to operate at this inlet temperature, a lower inlet temperature can be used.

[b] With the flow rate as determined during "A" test for units with a fixed flow rate or with a fixed delta T of 6 K for units with a variable flow rate. If the resulting flow rate is below the minimum flow rate then this minimum flow rate is used with the outlet temperature.

[c] With the flow rate as determined during "A" test for units with a fixed flow rate or with a fixed delta T of 5 K for units with a variable flow rate. If the resulting flow rate is below the minimum flow rate then this minimum flow rate is used with the inlet temperature.

[d] If the required outdoor heat exchanger inlet water temperature is below the minimum inlet temperature allowable for the unit, this minimum inlet temperature is used.

5 Calculation methods for reference SEPR

5.1 General Formula for calculation of reference SEPR

The calculation of the reference SEPR that applies to all types of chillers is given by the following formula:

Reference SEPR = reference annual refrigeration demand divided by the annual electricity consumption.

This annual electricity consumption includes the electricity consumption during active mode.

NOTE: for refrigeration and industrial application, off mode and standby modes are not relevant as the appliance is running all year long.

$$SEPR = \frac{\sum_{j=1}^{n}\left[h_j \cdot P_C(T_j)\right]}{\sum_{j=1}^{n}\left[h_j \cdot \frac{P_C(T_j)}{EER_{PL}(T_j)}\right]} \qquad \text{(Eq. 1)}$$

Where:

T_j the bin temperature

j the bin number, with j {1,2,... n}

n the amount of bins

$P_c(T_j)$ the cooling load of the application for the corresponding temperature T_j.

h_j the number of bin hours occurring at the corresponding temperature T_j.

$EER_{PL}(T_j)$ the EER value of the unit for the corresponding temperature T_j.

Table 5– bin number j, outdoor temperature T_j in °C and number of hours per bin h_j corresponding to the reference refrigeration season

NOTE: the bin of Strasbourg used is based on ASHRAE 2009 (1453-RP 04.2009) climate data.

j	Tj	hj
1	-19	0,08
2	-18	0,41
3	-17	0,65
4	-16	1,05
5	-15	1,74
6	-14	2,98
7	-13	3,79
8	-12	5,69
9	-11	8,94
10	-10	11,81
11	-9	17,29
12	-8	20,02
13	-7	28,73
14	-6	39,71
15	-5	56,61
16	-4	76,36
17	-3	106,07
18	-2	153,22
19	-1	203,41
20	0	247,98
21	1	282,01
22	2	275,91
23	3	300,61
24	4	310,77
25	5	336,48
26	6	350,48
27	7	363,49
28	8	368,91
29	9	371,63
30	10	377,32
31	11	376,53
32	12	386,42
33	13	389,84
34	14	384,45
35	15	370,45
36	16	344,96
37	17	328,02
38	18	305,36
39	19	261,87
40	20	223,90
41	21	196,31
42	22	163,04
43	23	141,78
44	24	121,93
45	25	104,46
46	26	85,77
47	27	71,54
48	28	56,57
49	29	43,35
50	30	31,02
51	31	20,21
52	32	11,85
53	33	8,17
54	34	3,83
55	35	2,09
56	36	1,21
57	37	0,52
58	38	0,40

The cooling load $P_C(T_j)$ can be determined by multiplying the full load value ($P_{designR}$) with the part load ratio $P_R(Tj)$ for each corresponding bin. These part load ratios are calculated in Tables 1 and 2.

For ambient temperatures lower than 5°C the part load ratio shall be constant and equal to 0.8.
For ambient temperatures above 35°C the part load ratio shall be constant and equal to 1.0.

5.2 Calculation procedure for determination of EER_{PL} values at part load conditions A, B, C and D

In part load condition A (full load), the declared capacity of a unit is considered equal to the refrigeration load ($P_{designR}$).

In part load conditions B, C, and D there can be 2 possibilities:

1) If the declared capacity (DC) of a chiller matches with the required refrigeration load, the corresponding EER_{DC} value of the chiller is to be used. This may occur with variable capacity chillers.

$$EER_{PL}(T_{B,\, C\ or\ D}) = EER_{DC}(T_{B,\, C\ or\ D}) \qquad \text{(Eq. 2)}$$

2) If the declared capacity of a chiller is higher than the required refrigeration load, the chiller has to cycle on/off. This may occur with fixed capacity or variable capacity chillers. In such cases, a degradation coefficient (Cc) has to be used to calculate the corresponding EER_{PL} value. Such calculation is explained below.

5.2.1 Calculation procedure for fixed capacity chillers

Due to difficulties that will occur during on/off cycling, perform a capacity test at A to D temperature conditions according to EN 14511-3, where applicable.

In that case, the capacity ratio (CR) is required. CR is the ratio of the cooling load (P_c) over the declared capacity (DC) of the unit at the same temperature conditions, calculated according to (Eq. 3).

$$CR = P_R(T_j) \times \frac{P_{designR}}{DC} \qquad \text{(Eq. 3)}$$

where

- $P_R(T_j)$ is the part load ratio for the corresponding temperature T_j
- $P_{designR}$ is the full load value
- *DC* is the declared capacity of the unit at the same temperature conditions as for part load conditions B, C and D

Then, for each part load conditions B, C and D, the EER_{PL} is calculated according to (Eq. 4).

$$EER_{PL(B,C,D)} = EER_{DC(B,C,D)} \times \frac{CR_{(B,C,D)}}{Cc_{(B,C,D)} \times CR_{(B,C,D)} + (1 - Cc_{(B,C,D)})} \qquad \text{(Eq. 4)}$$

Where

EER_{DC}	is the EER corresponding to the declared capacity (DC) of the chiller at the same temperature conditions as for part load conditions B, C, D.
Cc	is the degradation coefficients for chillers for part load conditions B, C, D
CR	is the capacity ratios for part load conditions B, C, D

For chillers, the degradation due to the pressure equalization effect when the chiller restarts can be considered as negligible. The only effect that will impact the EER at cycling is the remaining power input when the compressor is switching off.

The electrical power input during the compressor off state of the unit is measured during 5 min after the compressor has been switched off for 10 min. The compressor shall be switched off by increasing the set point in cooling mode.

The degradation coefficient (Cc) is determined for each part load ratio by (Eq. 5):

$$Cc = 1 - \frac{P_{Coff}}{P_{Con}} \qquad \text{(Eq. 5)}$$

where

P_{Coff}	is the effective power input during compressor off state
P_{Con}	is the effective power input with declared capacity

In order to measure a power input that is consistent with the definition of the effective power input, if the liquid pump or the fan is an integral part of the unit and in operation during compressor-off state, the available static pressure shall also be measured and the total compressor-off power input be corrected from the power input of the liquid pump or fan to provide this available static pressure, as described in EN 14511-3. In case the correction obtains a larger value than the measured value for the power input during compressor-off state, then the power input during compressor off state is set to zero.

In order to measure a power input that is consistent with the definition of the effective power input, if the liquid pump or fan is not an integral part of the unit, the compressor-off power input shall be corrected from the fraction of the pump or fan power input that is necessary to overcome the internal static pressure difference as described in EN 14511-3.

To determine if the liquid pump or fan is operating the control signal shall be measured. If no control signal is available, it shall be assumed that the liquid pump or fan is operating.

If the degradation coefficient Cc is not measured, a default value of 0,9 shall be used.

5.2.2 Calculation procedure for variable capacity chillers

Determine the declared capacity and EER_{PL} at the closest step or increment of the capacity control of the chiller to reach the required refrigeration load. If this step allows to reach the required cooling load within ± 3 % (e.g. between 103 kW and 97 kW for a required cooling load of 100 kW), the target capacity is considered as achieved and the measured EER can be used. If this step does not allow to reach the required refrigeration part load within ± 3 % (e.g. between 103 kW and 97 kW for a required cooling load of 100 kW), determine the capacity and the effective power input at the defined part load temperatures for the steps on either side of the required refrigeration load. The part load power input at the required refrigeration part load is then determined by linear interpolation between the results obtained from these two steps. The EER_{PL} is then determined by the required refrigeration part load divided by the interpolated part load power input.

If the smallest control step of the chiller is higher than the required refrigeration load, the EER_{PL} at the required part load ratio is calculated using Equation (4) as for fixed capacity process chillers.

5.3 Calculation procedure for determination of EER_{PL} values at other part load conditions, different than part load conditions A, B, C and D

The EER values at each bin are determined via interpolation of the EER values at part load conditions A, B, C, D as mentioned in the tables of chapters 3 and 4 of this transitional method.

For part load conditions above part load condition A, the same EER values as for condition A are used.

For part load conditions below part load condition D, the same EER values as for condition D are used.

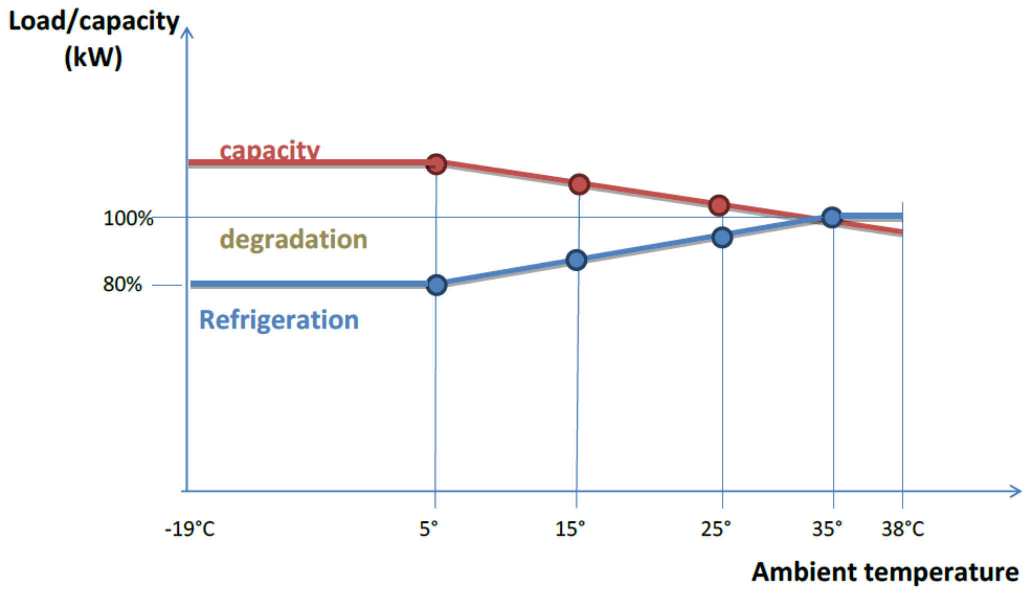

Figure 1: Schematic overview of the SEPR calculation points for a fixed capacity unit