

Appendix A to Part 4 of the Working Document on possible Ecodesign requirements for professional refrigeration products

TRANSITIONAL METHOD FOR DETERMINATION OF THE SEPR (SEASONAL ENERGY PERFORMANCE RATIO) FOR CHILLERS USED FOR REFRIGERATION APPLICATIONS (DRAFT)

1 Definitions

To be completed

2 General

For the purpose of calculation reference SEPR as explained in Chapter 5 of this transitional method, the part load ratios mentioned below shall be based on the part load ratio formulas (1st column of the tables in this chapter) and not on the rounded figures as mentioned in the 2nd column of the tables.

3 Air-cooled process chillers

For each application, units allowing or not a variation of the outlet water temperature with the outdoor temperature are considered. The variable outlet temperature shall only be applied when the control provides an outdoor air temperature dependant modification of the outlet temperature.

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

Table 1 – Part load conditions for reference SEPR calculation of air-cooled chillers on Low temperature application

Part load ratio	Part load ratio (%)	Outdoor heat exchanger	Indoor heat exchanger	
		air dry bulb temperature (°C)	Evaporator inlet/outlet temperatures (°C)	
			Fixed outlet	
A	$80\% + 20\% \cdot (T_A - T_D) / (T_A - T_D)$	100%	35	-19 / -25
B	$80\% + 20\% \cdot (T_B - T_D) / (T_A - T_D)$	93%	25	^a / -25
C	$80\% + 20\% \cdot (T_C - T_D) / (T_A - T_D)$	87%	15	^a / -25
D	$80\% + 20\% \cdot (T_D - T_D) / (T_A - T_D)$	80%	5	^a / -25

^a with the water flow rate as determined during “A” test for units with a fixed water flow rate or with a fixed ΔT of 6K for units with a variable water flow rate;) and T_A, T_B, T_C and T_D temperatures at reference points A,B,C and D respectively.

Table 2 – Part load conditions for reference SEPR calculation of air-cooled chillers on Medium temperature application

	Part load ratio	Part load ratio (%)	Outdoor heat exchanger	Indoor heat exchanger
			air dry bulb temperature (°C)	Evaporator inlet/outlet temperatures (°C)
				Fixed outlet
A	$80\% + 20\% \cdot (T_A - T_D) / (T_A - T_D)$	100%	35	-2 / -8
B	$80\% + 20\% \cdot (T_B - T_D) / (T_A - T_D)$	93%	25	^a / -8
C	$80\% + 20\% \cdot (T_C - T_D) / (T_A - T_D)$	87%	15	^a / -8
D	$80\% + 20\% \cdot (T_D - T_D) / (T_A - T_D)$	80%	5	^a / -8

^a with the water flow rate as determined during “A” test for units with a fixed water flow rate or with a fixed ΔT of 6K for units with a variable water flow rate and T_A, T_B, T_C and T_D temperatures at reference points A,B,C and D respectively.

Table 3 – Part load conditions for reference SEPR calculation of air-cooled chillers on High temperature application

	Part load ratio	Part load ratio (%)	Outdoor heat exchanger	Indoor heat exchanger
			air dry bulb temperature (°C)	Evaporator inlet/outlet temperatures (°C)
				Fixed outlet
A	$80\% + 20\% \cdot (T_A - T_D) / (T_A - T_D)$	100%	35	12/ 6
B	$80\% + 20\% \cdot (T_B - T_D) / (T_A - T_D)$	93%	25	^a / 6
C	$80\% + 20\% \cdot (T_C - T_D) / (T_A - T_D)$	87%	15	^a / 6
D	$80\% + 20\% \cdot (T_D - T_D) / (T_A - T_D)$	80%	5	^a / 6

^a with the water flow rate as determined during “A” test for units with a fixed water flow rate or with a fixed ΔT of 6K for units with a variable water flow rate.

4 Water-cooled process chillers

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

Table 4- Part load conditions for reference SEPR calculation for water-cooled chillers for Low temperature application

	Part load ratio	Part load ratio (%)	Outdoor heat exchanger	Indoor heat exchanger
			Inlet/ outlet water temperatures (°C)	Evaporator Inlet / outlet temperatures (°C)
				Fixed outlet
A	$80\% + 20\% \cdot (T_A - T_D) / (T_A - T_D)$	100%	30 / 35	-19 / -25
B	$80\% + 20\% \cdot (T_B - T_D) / (T_A - T_D)$	93%	23 / ^a	^a / -25
C	$80\% + 20\% \cdot (T_C - T_D) / (T_A - T_D)$	87%	16 / ^a	^a / -25
D	$80\% + 20\% \cdot (T_D - T_D) / (T_A - T_D)$	80%	9 / ^a	^a / -25

^a with the water flow rate as determined during "A" test for units with a fixed water flow rate or with a fixed ΔT of 6K for units with a variable water flow rate.

Table 5 - Part load conditions for reference SEPR calculation for water-cooled chillers for Medium temperature application

	Part load ratio	Part load ratio (%)	Outdoor heat exchanger	Indoor heat exchanger
			Inlet/ outlet water temperatures (°C)	Evaporator Inlet / outlet temperatures (°C)
				Fixed outlet
A	$80\% + 20\% \cdot (T_A - T_D) / (T_A - T_D)$	100%	30 / 35	-2 / -8
B	$80\% + 20\% \cdot (T_B - T_D) / (T_A - T_D)$	93%	23 / ^a	^a / -8
C	$80\% + 20\% \cdot (T_C - T_D) / (T_A - T_D)$	87%	16 / ^a	^a / -8
D	$80\% + 20\% \cdot (T_D - T_D) / (T_A - T_D)$	80%	9 / ^a	^a / -8

^a with the water flow rate as determined during "A" test for units with a fixed water flow rate or with a fixed ΔT of 6K for units with a variable water flow rate.

Table 6- Part load conditions for reference SEPR calculation for water-cooled chillers for High temperature application

	Part load ratio	Part load ratio (%)	Outdoor heat exchanger	Indoor heat exchanger
			Inlet/ outlet water temperatures (°C)	Evaporator Inlet / outlet temperatures (°C)
				Fixed outlet
A	$80\% + 20\% \cdot (T_A - T_D) / (T_A - T_D)$	100%	30 / 35	12/ 6
B	$80\% + 20\% \cdot (T_B - T_D) / (T_A - T_D)$	93%	23 / ^a	^a / 6
C	$80\% + 20\% \cdot (T_C - T_D) / (T_A - T_D)$	87%	16 / ^a	^a / 6
D	$80\% + 20\% \cdot (T_D - T_D) / (T_A - T_D)$	80%	9 / ^a	^a / 6

^a with the water flow rate as determined during "A" test for units with a fixed water flow rate or with a fixed ΔT of 6K for units with a variable water flow rate.

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 units is given by the following formula:

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

This annual electricity consumption includes the power consumption during active mode

NOTE : for refrigeration application, on mode and standby modes do not exist. The appliance is running always.

$$\text{SEPR} = \frac{\sum_{j=1}^n h_j \cdot P_R (T_j)}{\sum_{j=1}^n h_j \cdot \left(\frac{P_R (T_j)}{\text{COP}_{PL} (T_j)} \right)} \quad (\text{Eq. 1})$$

Where :

T_j = the bin temperature

j = the bin number, with $j \in \{1, 2, \dots, n\}$

n = the amount of bins

$P_R(T_j)$ = the cooling demand of the building for the corresponding temperature T_j .

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

$\text{COP}(T_j)$ = the COP values of the unit for the corresponding temperature T_j .

Table 7 – bin number j, outdoor temperature Tj in °C and number of hours per bin hj corresponding to the reference refrigeration season

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

NOTE: the bin of Strassbourg is used based on ASHRAE 2009 climate data.

The refrigeration demand $P_R(T_j)$ can be determined by multiplying the full load value ($P_{designR}$) with the part load ratio % for each corresponding bin. This part load ratios % are calculated in Table 1 to 6.

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

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

$$COP_{PL}(T_A) = COP_{designR} \quad (\text{Eq. 2})$$

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

- 1) If the declared capacity (DC) of a unit matches with the required refrigeration loads, the corresponding COP_{DC} value of the unit is to be used. This may occur with variable capacity units.

$$COP_{PL}(T_{B,C \text{ or } D}) = COP_{DC} \quad (\text{Eq. 3})$$

- 2) If the declared capacity of a unit is higher than the required refrigeration loads, the unit has to cycle on/off. This may occur with fixed capacity or variable capacity units. In such cases, a degradation factor (Cd or Cc) has to be used to calculate the corresponding COP_{PL} value. Such calculation is explained below .

5.2.1 For Air-cooled process chillers

5.2.1.1 Calculation procedure for fixed capacity units

For each part load conditions B,C,D the COP is calculated as follows:

$$COP_{PL}(T_{B,C,D}) = COP_{DC} * (1 - Cd * (1 - CR)) \quad (\text{Eq. 4})$$

Where

COP_{DC} = the COP corresponding to the declared capacity (DC) of the unit at the same temperature conditions as for part load conditions B,C,D.

Cd = the degradation coefficient for air-cooled chillers, determined as indicated in section 5.2.1.1.1

CR = the capacity ratio

The capacity ratio is the ratio of the refrigeration demand (P_R) over the declared capacity (DC) of the unit at the same temperature conditions:

$$CR[(T)_{B,C \text{ or } D}] = \frac{PC(T_{B,C \text{ or } D})}{DC(T_{B,C \text{ or } D})} \quad (\text{Eq. 5})$$

5.2.1.1.1 The determination of the Cd value:

Option 1: fixed Cd value

The value of Cd can be set once for all, between 0.1 and 0.25. This option takes into account the fact that the determination of the coefficient of degradation may be difficult, since the applications differ far more than in air-conditioning and heat pump units.

Option 2: Cd value determined through testing

When there is a cooling demand, the compressor is on and the total power consumption includes all electrical auxiliary devices.

Once the set point is reached, the cooling demand is satisfied. The compressor is then off but there is still a remaining power consumption due to the other auxiliary devices (electronics, fans etc.). The degradation coefficient is due to two effects:

- 1) the power consumption of the unit when the compressor is off
- 2) the pressure equalization that reduces the cooling capacity when the unit is restarted.

For determining the degradation factor Cd, the unit is cycled on for 6 min and then off for 24 min for an approximately 20 % part load by switching on and off the compressor.

If it is not possible to make the measurements with the required uncertainty of measurement when using a cycling interval of 6/24 min, then another cycling interval shall be chosen but not representing a greater part load ratio than 50 % (i.e. 10/10 min).

During this cyclic test, the delivered refrigeration capacity is integrated over the on/off interval. Then the cyclic COP is obtained by dividing the integrated refrigeration capacity (kWh) by the electrical energy used by the unit over the same on/off interval.

The energy ratio (ER) is calculated by dividing the time integrated refrigeration capacity (kWh) by the refrigeration energy (kWh) that would have been delivered by the unit running continuously for the same time interval (i.e. 30 min).

The degradation coefficient Cd is calculated as the ratio of the cyclic COP to the continuous (steadystate) COP (for the same ambient test conditions) according to following formula:

$$C_d = \frac{1 - \frac{COP_{cyclic}}{COP_{continuous}}}{1 - COP} \quad (\text{Eq. 6})$$

If the degradation coefficient Cd has been determined for cooling (function) mode, it can be applied for heating (function) mode and vice versa.

If the degradation coefficient Cd is not measured, a default value of 0.25 shall be used.

5.2.1.2 Calculation procedure for variable capacity units

Determine the declared capacity and COP_{PL} at the closest step or increment of the capacity control of the unit to reach the required refrigeration load. If this step does not allow reaching the required refrigeration load, determine the capacity and COP_{PL} at the defined part load temperatures for the steps on either side of the required refrigeration load. The part load capacity and the COP_{PL} at the required refrigeration load are then determined by linear interpolation between the results obtained from these two steps.

If the smallest control step of the unit is higher than the required refrigeration load, the COP_{PL} at the required part load ratio is calculated using Eq. 4 as for fixed capacity units.

The refrigeration load reached with capacity control of the unit shall be at least equal to the required refrigeration load. If the refrigeration load can not be met with capacity control, the step control mode in the calculation tool can be used where no coefficient of degradation is considered except for the lowest step.

5.2.2 Water-cooled process chillers

5.2.2.1 Calculation procedure for fixed capacity units

For each part load conditions B,C,D the COP_{PL} is calculated as follows:

$$COP_{PL}(T_{B,C \text{ or } D}) = COP_{DC}(T_{B,C \text{ or } D}) \times \left[\frac{CR(T_{B,C \text{ or } D})}{C_c \times CR(T_{B,C \text{ or } D}) + (1 - C_c)} \right] \quad (\text{Eq. 7})$$

Where

COP_{DC} = the COP corresponding to the declared capacity (DC) of the unit at the same temperature conditions as for part load conditions B,C,D.

C_c = the degradation coefficient for water-cooled chillers, determined as indicated in section 5.2.2.1.1

CR = the capacity ratio, as in Eq.5 .

5.2.2.1.1 Determination of C_c :

Option 1: fixed C_c value

The value of C_c can be set once for all at a fixed value between 0.1 and 0.25. This option takes into account the fact that the determination of the coefficient of degradation may be difficult, since the applications differ far more in refrigeration than in air-conditioning and heat pump units.

Option 2: C_c value determined through testing

For water-cooled chillers, the degradation coefficient C_c due to the pressure equalisation effect when the unit restarts can be considered as negligible.

The only effect that will impact the COP 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 when the compressor is switched off for at least 10 min.

The degradation coefficient C_c is determined for each part load ratio as follows:

$$C_c = 1 - \frac{\text{measured power of compressor off state}}{\text{total power input (full capacity at the part load conditions)}} \quad (\text{Eq. 8})$$

If C_c is not determined by test then the default degradation coefficient C_c shall be 0.25

5.2.2.2 Calculation procedure for variable capacity control units

Determine the declared capacity and COP_{PL} at the closest step or increment of the capacity control of the unit to reach the required refrigeration load. If this step does not allow reaching the required refrigeration load, determine the capacity and COP_{PL} at the defined part load temperatures for the steps on either side of the required refrigeration load. The part load capacity and the COP_{PL} at the required refrigeration load are then determined by linear interpolation between the results obtained from these two steps.

If the smallest control step of the unit is higher than the required refrigeration load, the COP_{PL} at the required part load ratio is calculated using Eq 7 as for fixed capacity units.

The refrigeration load reached with capacity control of the unit shall be at least equal to the required refrigeration load. If the refrigeration load can not be met with capacity control, the step control mode in the calculation tool can be used where no coefficient of degradation is considered except for the lowest step.

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

The COP values at each bin are determined via interpolation of the COP values at part load conditions A,B,C,D as mentioned in the tables of chapter 3 of this transitional method

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

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

Figure 1: Schematic overview of the SEPR calculation points

