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A critical comparison of energy efficiency evaluation for condensing units in Chinese National Standard and EU Regulation

Y. HUANG[1], Y.Y. JIANG[1] , J.Y. ZHANG[1], Z.B. ZHANG*[2]
[1]DC Center, Jiangsu Posts & Telecommunications Planning and Designing Institute Co, Ltd., Nanjing, China
[2]Engineering Laboratory of Energy System Conversion and Emission Reduction of Jiangsu Province, School of Energy and Mechanical Engineering, Nanjing Normal University, Nanjing, China

KEYWORD: Condensing unit; Chinese National Standard; EU Eco-design Regulation; COP; SEPR; Energy efficiency evaluation
ABSTRACT: For the energy efficiency evaluation of condensing units, the European (EU) Eco-design Regulation No 2015/1095 sets ecological standards, and Chinese National Standard GB/T 21363-2008 makes requirements on the performance of the units. In this paper, a critical comparison of the energy efficiency evaluation of condensing units for medium temperature application set in No 2015/1095 and GB 21363-2008 is made and illustrated by a time table of the Copeland Condensing Units to be admitted to Chinese and European market. With a typical condensing unit as the sample, charts are developed and the numerical relationship of coefficient of performance (COP) and Season Energy Performance Ratio (SEPR) is calculated to find the disparity between No 2015/1095 and GB/T 21363-2008. It is concluded that GB/T 21363-2008 requires the COP threshold values too much higher than No 2015/1095 does but considers little ecological environmental protection.

1 INTRODUCTION

Energy resource and the climate changes are two big challenges related to the human survival and development. With the flourishing refrigerating industry and production, the condensing units applied in refrigerating equipments are generally divided into two types: for low temperature (LT) application, and for medium temperature (MT) application, both of which are widely applied in cooling and refrigerating industry (Liu et al. 2011). Considering the energy-saving requirements worldwide, regulations of energy efficiency evaluation are becoming more and more important in building a fair and healthy market and promoting energy conservation (Mahlia & Saidur, 2010).

To improve the environmental performance of energy-consuming products and help control environmental pollution, the EU Commission officially released the ecological requirements for energy-related products directive (termed energy-using products directive before 2009) since 2005 and keeps updating ever after. In 2015, EU Commission released Eco-design Regulation No 2015/1095 (referred to as No 2015/1095 hereafter) which specifically sets strict standards for condensing units by introducing Seasonal Energy Performance Ratio (SEPR) and threshold values for condensing units with different capacities when taking global warming potential (GWP) values of refrigerant into evaluation.

Compared to EU Regulations, Chinese National Standard focuses more on the performance of the condensing units rather than ecological concern. The coefficient of performance (COP) has always been a critical value in judging the performance of the units from Chinese first comprehensive standard for condensing unit JB/T 9056-1999 Positive Displacement Refrigerant Compressor Condensing Units to Chinese national standard GB/T 21363-2008 (referred to as GB/T 21363-2008 hereafter), which is in current effect.

With the energy efficiency evaluation of condensing units as the target, different focuses in GB 21363-2008 and its counterpart No 2015/1095 are discussed in the following section. Thereafter, with a Copeland condensing units with medium evaporating temperature as a sample, a detailed comparison is made particularly on threshold values and energy performances of condensing units specified in GB 21363-2008 and No 2015/1095 to find the difference and the disparity.

2 GENERAL COMPARISON BETWEEN NO 2015/1095 AND GB 21363-2008

2.1 *The EU Eco-design Regulation No 2015/1095*

COP means the cooling capacity divided by the power input, and SEPR is the efficiency ratio of a condensing unit for providing cooling at standard rating conditions, representative of the variations in load and ambient temperature throughout the year. Compared to COP, SEPR is a new standard that reflects the annual energy consumption level more objectively and effectively (Zhang et al, 2010). No 2015/1095 makes specific requirements on the threshold values of COP for condensing units with a cooling capacity of up to 5kW (MT application) and 2kW (LT application) and SEPR for condensing units with a cooling capacity of more than 5kW/2kW respectively in two stages. More specifically, small condensing units (units with MT/LT and cooling capacity lower than 5kW/2kW) and large condensing units (units with MT/LT and cooling capacity within 5~50kW/ 2~20kW) are respectively required to meet the set threshold values till 1 July 2016 and 1 July 2018. Detailed values are shown in Fig 1 (for COP) and Fig 2 (for SEPR).

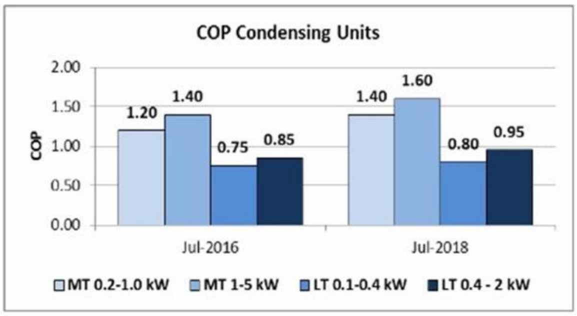

Figure 1 The COP threshold values of small condensing unit

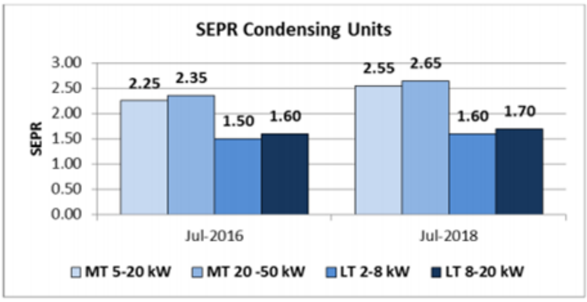

Figure 2 The SEPR threshold values of large condensing unit

What's more, for condensing units to be charged with refrigerant with global warming potential (GWP) lower than 150, COP values can be lower by a maximum of 15% and SEPR values by a maximum of 10%.

2.2 *Chinese National Standard*

In 1999, National Bureau of Machinery Industry of China issued the first comprehensive national standard on condensing unit JB/T 9056-1999 Positive Displacement Refrigerant Compressor Condensing Units. The standard mainly makes requirements on the unit performance such as insulation and refrigerating capacity and proposes 6 performance tests methods and details.

In 2008, it was revised and issued as Chinese national standard GB/T 21363-2008 (referred to as GB/T 21363-2008 hereafter) with an identical title. Compared to JB/T 9056-1999, the revision introduces more specific details on unit performance based on the frame of classifying the condensing unit into three types according to their evaporation temperatures. The most important improvement is the specific requirement on COP of condensing units for medium and low temperature applications. Also, it requires different COP values for different condenser of air cooling unit, water cooling unit and evaporative cooling air unit.

2.3 *General comparison*

GB/T 21363-2008 classifies condensing units and specifies threshold values first based on evaporating temperature (MT at -7℃, and LT at -23℃). For condensing units with different evaporating temperature, the values of COP are required to reach different thresholds according to their refrigerating capacities. In No 2015/1095, condensing units are not only classified and specified with threshold values based on refrigerating capacity and evaporating temperature, but also required to reach COP threshold values for small condensing units with rated capacity lower than 5kw(MT) and 2Kw(LT) and SPER threshold values for lager condensing units with a rated capacity higher than 5kw(MT) and 2kW(LT) and use the refrigerant with the required GWP according to a set timetable.

Considering the requirements of refrigerant GWP values in EU Regulations, the energy efficiency thresholds in No 2015/1095 and GB/T 21363-2008 are compared for condensing units with medium evaporating temperature using refrigerant with GWP＞150 in table 1 and table 2.

Table 1 threshold values of small condensing units for medium temperature in Chinese and European market

Rated capacity pA	CN(2008 COP)	EU(2016 COP)	EU(2018 COP)	
0.2kW≤p_A≤1kW	1.80	1.20	1.40	
1kW<p_A≤3kW	1.80	1.40	1.60	p_A≤5kW
3kW<p_A≤5kW	2.20	1.40	1.60	

Table 2 threshold values of larger condensing units for medium temperature in Chinese and European market

Rated capacity pA	CN(2008 COP)	EU(2016 SEPR)	EU(2018 SEPR)	
5kW<p_A≤12kW	2.20	2.25	2.55	
12kW<p_A≤20kW	2.20	2.25	2.55	5kW< p_A≤50kW
20kW<p_A≤50kW	2.20	2.35	2.65	

Meanwhile, based on No 2015/1095 and GB/T 21363-2008, a time table of threshold values of condensing units admittable in Chinese and European market is charted in Figure 3. As can be seen, although EU Commission Regulation specifies lower COP threshold values than Chinese National Standard, it takes GWP of the refrigerant into consideration when raises the COP threshold values of the condensing units. Yet GB/T 21363-2008 requires only COP threshold values on condensing units.

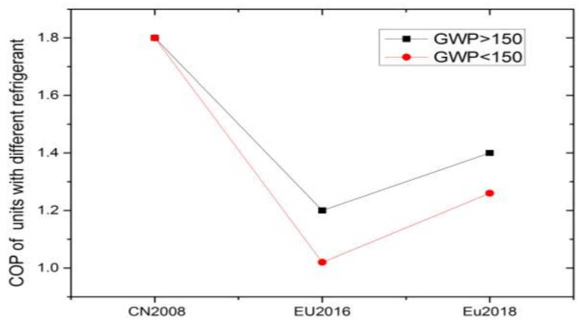

Figure 3 time table of COP threshold values of small condensing units using different refrigerant admittable in Chinese and European market

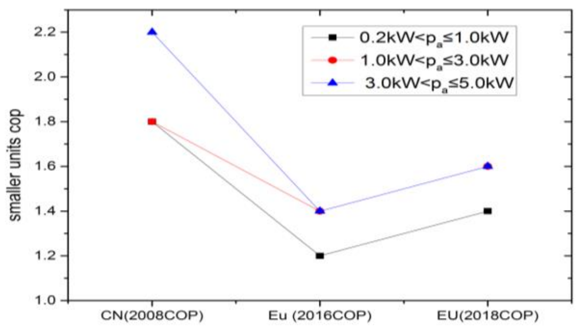

Figure 4 time table of COP threshold values of small condensing units of different cooling capacity in Chinese and European market

Meanwhile, for small condensing units of different cooling capacity, EU Commission Regulation

3 SAMPLE STUDY AND DISCUSSION

For large condensing units, GB/T 21363-2008 still sets COP threshold values while No 2015/1095 makes requirements on SEPR values. To have a clearer understanding, this paper employs a Copeland large air-cooled condensing unit for MT application as the sample to find the numerical relationship between SEPR in No 2015/1095 and COP in GB/T 21363-2008.

3.1 *Sample condensing unit*

By using the Emerson Technologies Selection Software Select7MEA, a Copeland condensing unit model Z9-4MH-25X for MT application is employed as sample unit, whose performance parameters are presented in Table 3 (Emerson Climate Technologies, 2011).

Table 3 Performance parameters of the sample unit Z9-4MH-25X

Item	Values
Capacity kW	38.40
Total Power Input kW	17.50
Evaporating Temperature:	-10.0 ℃
Ambient Temperature	32.0 ℃
Suction Return Temperature:	10.0 ℃
COP	2.20
Compressor Current 400V, A	29.55
Mass Flow g/s	337.00
Heat Rejection kW	53.50
Condensing Temp. ℃	43.1

3.2 *Numerical calculation*

According to the requirement for professional refrigeration products in No 2015/1095, this paper use the transitional method for determination of the SEPR for air-cooled condensing units.(Duda, 2011)

3.2.1 part load conditions

When calculating COP/SEPR of the unit, load conditions of the condensing unit shall be taken into consideration since different load conditions lead to different COP and SEPR. Table 4 lists all part load conditions related.

Table 4 Part load conditions for reference SEPR calculation on MT application

R_{ef}	Part load ratio ($PL(T_{ref})$)	$PL(T_{ref})$ (%)	Outdoor heat exchanger air dry bulb temperature (℃)(T_{ref})	Suction side condition Saturated evaporating temperature [a] (℃)
A	$60\%+40\%*(T_A - T_D)/(T_A - T_D)$	100%	32	-10 [a]
B	$60\%+40\%*(T_B - T_D)/(T_A - T_D)$	90%	25	-10 [a]
C	$60\%+40\%*(T_C - T_D)/(T_A - T_D)$	75%	15	-10 [a]
D	$60\%+40\%*(T_D - T_D)/(T_A - T_D)$	60%	5	-10 [a]

3.2.2 General Formula for calculation of SEPR

Annual electricity consumption during active mode can be obtained in Eq 1:

$$\mathrm{SEPR} = \frac{R_d}{E_c} \qquad (1)$$

where Rd= reference annual refrigeration demand, Ec= annual electricity consumption.

Since the sample air-condition units used has no standby modes, Eq 2 is employed to calculate the SEPR of the selected units:

$$SEPR = \frac{\sum_{j=1}^{n} h_j \cdot P_R(T_j)}{\sum_{j=1}^{n} h_j \cdot \left(\frac{P_R(T_j)}{COP_{PL}(T_j)} \right)} \qquad (2)$$

where T_j = the bin temperature; j = the bin number, with j ϵ {1,2, ... ,n}; P_R(Tj) = the refrigeration demand for the corresponding bin temperature T_j; h_j = the number of bin hours occurring at the corresponding bin temperature T_j; $COP_{PL}(T_j)$ = the COP values of the unit for the corresponding bin temperature T_j.

3.2.3 Calculation procedure for determination of COPPL values

In full load condition A, the declared capacity of a unit is considered equal to the refrigeration load, as in Eq 3:

$$COP_{PL}(T_A) = COP_{designR} \qquad (3)$$

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

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

$$COP_{PL}(T_{B,C,D}) = COP_{DC} \qquad (4)$$

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) has to be used to calculate the corresponding COPPL value.

This paper makes assumptions:

-that the declared capacity of the unit = the required refrigeration loads, 38kW

-useful superheat 100%

-Suction Gas return=10℃

-the selected unit is a fixed capacity unit

3.2.4 Calculation procedure for fixed capacity units

For the unit that can not achieve the required load by means of capacity modulation (e.g. Only by ON/OFF), degradation factor Cd = 0.25 (according to prEN14825) is used.

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

$$COP_{PL}(T_{B,\ C,\ D}) = COP_{DC} \cdot (1 - C_d \cdot (1 - C_R)) \qquad (5)$$

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_d = the degradation coefficient, set at a fixed value of 0.25; C_R = 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:

$$C_R(T_{B,C,D}) = \frac{P_C(T_{B,CorD})}{DC(T_{B,CorD})} \qquad (6)$$

3.2.5 Calculation procedure for determination of COPPL values at other part load conditions, different than part load conditions A, B, C, and D

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

For load conditions above 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.

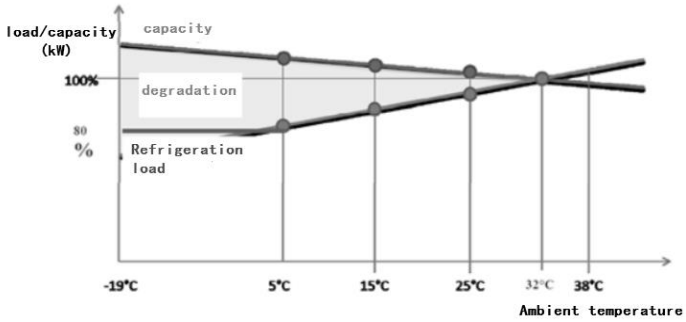

Figure 5 schematic overview of the SEPR calculation points

By calculating, the COP values of the selected units that meet the requirements of GB/T 21363-2008 is converted to the SEPR 2.95 in No 2015/1095, as in Table 5.

Table 5 equivalent threshold values of lager condensing units for medium temperature in Chinese and European market

Rated capacity pA	CN(2008 SEPR)	EU(2016 SEPR)	EU(2018 SEPR)	
5kW<p_A≤ 12kW	2.95	2.25	2.55	5kW <p_A≤ 50kW
12kW<p≤ 20kW	2.95	2.25	2.55	
20kW<p≤ 50kW	2.95	2.35	2.65	

3.3 *Results and discussion*

In Table 5, it can be found that the values of SEPR in GB/T 21363-2008 are still a lot higher than the values of SEPR in No 2015/1095, as is charted in Figure 6.

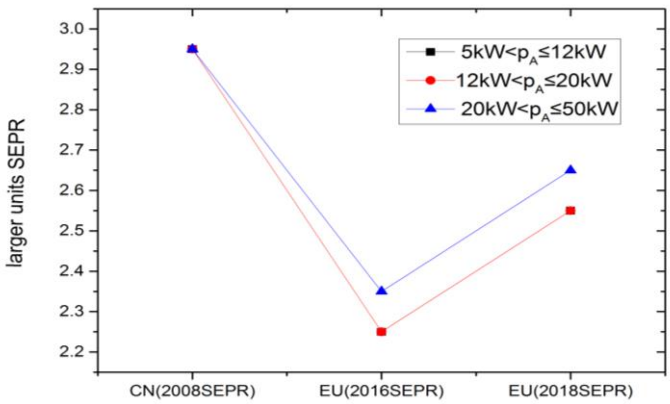

Figure 6 a time table of SEPR threshold values of lager units in No 2015/1095 and GB/T 21363-2008

In 2008, the threshold values of condensing units with a capacity of 5kW to 50 kW are set at 2.95, being 31% (compared to 2016) and 15.70% (compared to 2018) higher than the threshold values in No 2015/1095. However, overly high threshold values of energy performance in GB/T 21363-2008 for condensing units put great pressure to the manufacturer and push the products upgrade too high. On the contrast, No 2015/1095 raises the threshold values of energy performance steadily so that manufacturers have enough time to upgrade technology and launch new products. (Lin & Liang, 2013)

It can be inferred that the essence of No 2015/1095 is embodied in its ecological meaning: with the development of technology, condensing units using higher GWP or higher energy consumption will be eliminated gradually from European market.(Zhang et al, 2013)

The energy efficiency upgrading of condensing units can lead to a chain effect that concerns energy consumption, greenhouse gas emission, consumption in the market as well as the whole industry of fluid machinery.(Mahlia et al, 2010; De Kleine et al, 2011; Grignon-Masse et al, 2011) For enterprises, condenser design should start from designing and estimating heat exchanger based on the lumped parameter method and then experiences the repeated experimental trial. (Chu et al, 2009)

4 CONCLUSION

The EU Commission Regulation No 2015/1095 and Chinese national standard GB/T 21363-2008 both intensely affect the refrigeration and air conditioning systems, but they work in different ways and will lead to different results.

Compared to EU regulation, Chinese National Standards pay more attention to the functionality of the condensing units rather than the ecological environmental protection. Although GB/T 21363-2008 requires the threshold COP values, these COP values are too high for the current Chinese market and will increase the cost of production. Meanwhile, No 2015/1095 makes policies for condensing units using refrigerants with GWP higher and lower than 150.

It can be concluded that Chinese enterprises should optimize the design of condensing units to enhance the energy performance with considering the ecological environmental protection; authorities should take the ecological environmental protection into consideration when making the products regulation.

Acknowledgments

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