Report on Application of High Efficiency Chillers

May 2015

Executive Summary

The Code of Practice for Energy Efficiency of Building Services Installation (Building Energy Code or BEC) set out the corresponding minimum coefficient of performance[1] (COP) at full load at the specified standard rating condition for different types of chillers. These requirements are considered as the basic energy performance for various types of chillers. According to the survey conducted in this study, there are plenty of chillers with energy performance at least 10% (i.e. high efficiency chillers) above the statutory requirements under the BEC. Therefore, there are plenty of high efficiency chillers in the local market if you want more efficient chillers.

Some opinions considered that a chiller is not always running at full load. The full load COP may not be fully representative to the chiller efficiency especially some chillers are operating with variable frequency drives (VFDs), which can adjust the chiller output to match the cooling load so that a better energy performance can be achieved. Alternatively, Integrated Part Load Value (IPLV) as defined in AHRI 550/590 is a commonly used parameter to describe the energy performance of a chiller in part-load condition.

In this paper, the result of the market survey in high efficiency chillers in local market will be discussed. This survey was based on the information about major chillers model collected from the suppliers and/or their agents in Hong Kong. The survey focused on the chillers with the cooling capacity ranging from 40kW to 1,800kW and the full load COP is at least 10% above the statutory requirements in BEC.

Design Energy Efficiency Standards of chiller

Chillers are major energy consuming equipment and are widely used to provide air-conditioning to commercial buildings. It is not exaggerated to say that over half of the electricity consumption in a commercial building is used by chillers and associated equipment. That is why the energy efficiency of the chillers is crucial to the overall energy performance of the buildings, which depends on many factors such as type of chillers (e.g. air or water cooled chiller), chiller water temperatures set points, condenser

[1] The COP of chillers is usually expressed as the cooling capacity over the power input at the specific operating conditions.

water temperatures entering chillers or ambient temperature, part load performance of chillers, types of refrigerant used, types of compressors used, single or multiple units put together in operation, and the maintenance conditions etc.

Building Energy Code (BEC) sets out minimum requirements on the full load COP of air cooled and water-cooled chillers (Table 6.12b of BEC is extracted below). These requirements are considered as the basic energy performance for various types of chillers. However, since the chiller is always running in part-load condition rather full load condition in reality, decisions solely based on the requirement in full load condition under BEC may not necessarily result in achieving good energy performance in the system.

Table 6.12b : Minimum Coefficient of Performance for Chiller[@2] at Full Load

Air-cooled

Type of compressor	Reciprocating		Scroll	Screw	Centrifugal
Capacity Range (kW)	Below 400 kW	400 kW & above	All Ratings	All Ratings	All Ratings
Minimum COP at cooling (free air flow[@1])	2.6	2.8	2.7	2.9	2.8

Water-cooled

Type of compressor	Reciprocating			Scroll			Screw			Centrifugal		
Capacity Range (kW)	Below 500 kW	500 to 1000 kW	Above 1000 kW	Below 500 kW	500 to 1000 kW	Above 1000 kW	Below 500 kW	500 to 1000 kW	Above 1000 kW	Below 500 kW	500 to 1000 kW	Above 1000 kW
Minimum COP (Cooling)	4.1	4.6	5.2	4.1	4.6	5.2	4.6	4.7	5.5	5.1	5.6	5.7

Note – The above table is extracted from Table 6.12b of the Building Energy Code (BEC)

By contrast, the Integrated Part Load Value (IPLV) as defined in AHRI 550/590[2] is used by many manufacturers worldwide to describe the energy performance of a chiller in standard part-load condition for easy comparison. According to AHRI, the IPLV is computed by equation (1) where the weighting factors are based on the weighted average of the most common building types and climate conditions for cities in the United States.

Equation (1): $IPLV = 0.01A + 0.42B + 0.45C + 0.12D$

[2] http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/AHRI%20standards%20pdfs/AHRI%20Standard%20550-590%20%28I-P%29-2011.pdf

where A = COP at 100% full capacity at condenser water temperature 29.4°C for water cooled condenser and ambient temperature 35°C for air cooled condenser;

B = COP at 75% full capacity at condenser water temperature 23.9°C for water cooled condenser and ambient temperature 26.7°C for air cooled condenser;

C = COP at 50% full capacity at condenser water temperature 18.3°C for water cooled condenser and ambient temperature 18.3°C for air cooled condenser;

D = COP at 25% full capacity at condenser water temperature 18.3°C for water cooled condenser and ambient temperature 12.8°C for air cooled condenser.

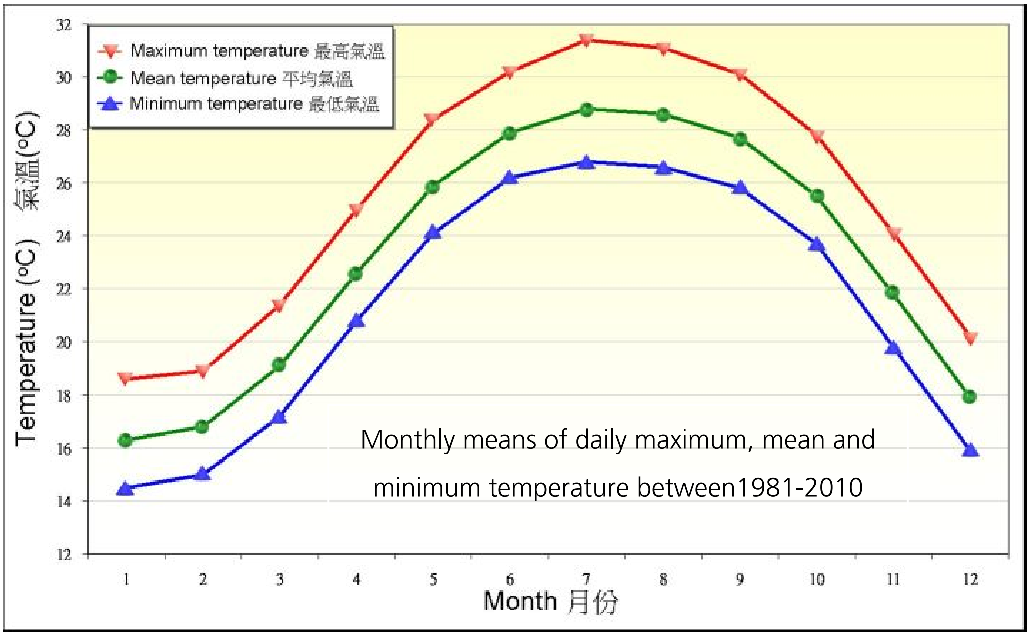
✧ Flow rate 3.0 gpm/ton[3], Fouling factor Allowance 0.00025 h.ft^2.°F/Btu

However, the use of IPLV should be careful as the rating condition may be different from local context. According to the clause D2 in Appendix D of AHRI Standard 550/590, there are many issues to consider when estimating the energy efficiency of chillers in reality. Chiller efficiency is only one of factors which affect the total energy consumption of a chiller plant. It is for this reason that AHRI suggests the use of building energy analysis programs to carry out a comprehensive analysis that reflects the actual weather data, building load characteristics, operational hours, economizer capabilities and energy drawn by auxiliaries when calculating the overall system efficiency including chillers. It lets the designer have better understanding to the overall energy performance of the system. Having said that, IPLV is still widely used to compare the performance of similar technologies, enabling a side-by-side relative comparison, and to provide a second certifiable rating point that can be referenced by other energy codes like ASHARE 90.1.

Selection Considerations

When selecting a chiller, capacity is critical. For the chiller with constant speed drive, an oversized chiller not only entails more capital cost and more space for installation, it also entails more costs for all those associated facilities such as the electrical power supply, piping system as well as chilled water pumps. Furthermore, oversized chiller will consume more electricity due to poor energy performance in part load condition. On the contrary, a chiller with variable frequency drive (VFD) to adjust output to suit the cooling load demand can have better energy performance in part load condition. So, consideration can be given to use larger capacity chillers with VFD instead of using a few small capacity chiller because larger chiller usually have higher COP. However, a comprehensive analysis is necessary to optimize the energy performance of the system and choose suitable chillers.

IPLV is one of the key factors on the choice of chillers having said that it has limitation in representing the actual chiller performance under diverse operation and climate conditions. According to records, the ambient outdoor temperature and the condenser water temperature are typically between 24°C to 32°C and between 23°C to 30°C respectively during most of summer time in Hong Kong. Therefore, using chiller with higher IPLV does not necessarily achieve a better energy performance during summer in Hong Kong as the testing condition for various cooling load of the chiller in the determination of IPLV mismatches with local climate conditions.



Market Survey

In early 2015, a market survey was conducted to collect information on major models of chillers available from local suppliers and/or their agents in Hong Kong. The survey was based on the following criteria:-

- Cooling capacity ranged from 40 kW to 1,800 kW; and

- At least 10% above the minimum COP for chillers at full load as stated in the Code of Practice for Energy Efficiency of Building Services Installation (BEC[3]) 2012 edition (Rev.1).

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[3] http://www.beeo.emsd.gov.hk/en/mibec_beeo_codtechguidelines.html

Table 1: Summary on chillers with full load COP at least 10% above the minimum COP statutory requirements under the BEC

Type of Chillers	Compressor Type	Cooling Capacity Range (kW)	Range of Full load COP	(IPLV or equivalent) Range	Quantity (nos.)
Air-cooled	Scroll	58-540	3.00 - 4.86	4.5 - 6.08	59
	Screw	106-1604	3.19 - 4.15	4.26 - 5.86	59
	Centrifugal	320-1750	3.43 - 3.65	6.22 - 6.62	13
Total					131
Water cooled	Scroll	175-300	4.86	8.4	2
	Screw	276-1583	5.22 - 6.07	8.4- 9.35	18
	Centrifugal	440-1759	5.88 - 6.51	10.53 - 11.5	6
Total					26

From the above summary, it was noted that 131 nos. of air-cooled chiller models and 26 nos. of water cooled chiller models with full load COP at least 10% above the statutory requirements under the BEC. This indicates that there are plenty of high efficiency chillers available in the market, especially air-cooled chillers.

Conclusion

From the survey, there are quite a lot of water cooled and air-cooled chillers having full load COP at least 10% above the minimum COP requirement stipulated in the Code of Practice for energy efficiency of Building Services Installation (BEC). This indicates that there are plenty of high efficiency chillers available in the market, especially air-cooled chillers if you want more energy efficient chillers.

Some chillers are not always running at full load, especially those chillers operating with variable frequency drives (VFDs) to regulate chiller output to match the cooling load so that a better energy performance can be achieved. Hence, apart from full load COP, it is suggested to consider Integrated Part Load Value (IPLV) as another key parameter for the selection of chillers, taking into consideration energy performance of a chiller in part-load condition. Moreover, if resource is allowed, a comprehensive analysis can be carried out to optimize the energy performance of the air-conditioning system.

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