HVAC&R ENGINEERING

update

Use only NPLV to specify chiller efficiency

Designers may be missing an opportunity to provide additional value for their clients if their chiller-efficiency specifications prevent them from getting what they want from the bidding process: chillers with equal annual energy consumption at the best capital cost. The problem occurs when two measures of chiller efficiency—the design-efficiency rating and the Non-standard Part Load Value (NPLV) rating—are both used in the specification.

Designers may be missing an opportunity to provide additional value for their clients

This *HVAC&R Engineering Update* clarifies the application of these ratings to help designers write the most effective specification for chiller efficiency.

A chiller selection with a design-efficiency rating of 0.576 kW/TR could have an NPLV rating between 0.55 and 0.35 kW/TR.

Test your NPLV IQ

First, it helps to clarify the meaning of the NPLV rating[1]. To understand the rating's applicability, there are three presuppositions that must be challenged:

1) **True** or **False:** A chiller's NPLV rating measures only its off-design efficiency.

Answer: **False.** The NPLV rating includes both off-design efficiency and design efficiency.

2) **True** or **False:** The IPLV rating is a subset of the NPLV rating.

Answer: **True.** The NPLV rating allows for efficiency measurements at a wide range of conditions. The Integrated Part Load Value (IPLV) rating is targeted to a very specific situation: when the project's design conditions are equal to the ARI standard conditions. We will refer only to the NPLV rating throughout this *Update* for brevity.

3) **True** or **False:** A chiller will automatically have a good NPLV rating if it has good efficiency at design conditions, which is the simultaneous occurrence of *both* design load *and* design cooling-tower-water temperature (or design outdoor-ambient temperature, if air-cooled).

Answer: **False.** Chillers can have the same design efficiency, but have NPLV ratings that vary widely, depending on capital cost. For example, chillers with design efficiencies of 0.576 kW/TR can have NPLV ratings that vary anywhere between 0.55 and 0.35 kW/TR. That's because chiller selections can have different off-design efficiencies. Of course, off-design performance is of paramount importance because chillers, including those in

1. NPLV rating can be measured in kW/TR, COP, or EER. This Update uses kW/TR.

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multiple-chiller plants, operate most of the time at partial loads and/or at off-design, cooling-tower-water temperatures (or off-design, outdoor-ambient temperatures). While it is possible to make a chiller with both good design efficiency and good NPLV rating, it exacts a cost premium. Fortunately, designers can save money for their clients by changing the way chiller efficiency is specified.

Unintended consequences

Writing a chiller-efficiency specification that includes both the NPLV rating and the design-efficiency rating can result in unintended consequences. To understand why, let's look at an example of what happens when both efficiency ratings are specified. Let's begin by comparing two 1,000 TR chillers (see Table 1).

	Specified Chiller	Option A Chiller
NPLV Rating	0.466 kW/TR	0.466 kW/TR
Design Efficiency	0.562 kW/TR	0.576 kW/TR
Annual Energy	Base	Base
Capital Cost	$250,000	$240,000

Table 1: 1,000 TR Chiller Comparisons

In this example, the Specified Chiller has an NPLV rating of 0.466 kW/TR, a design efficiency of 0.562 kW/TR, and costs $250,000. Option A Chiller, which costs only $240,000, also has an NPLV rating of 0.466 kW/TR, but a design efficiency of 0.576 kW/TR, which is higher than the Specified Chiller. Because both chillers have equal NPLV ratings, they have very similar annual energy consumption (remember, the NPLV rating includes both off-design and design efficiency). If the specification contained only the NPLV rating, Option A Chiller might be a very attractive choice.

However, if the specification requires that a chiller meet both the NPLV rating and the design-efficiency rating, Option A Chiller can't meet both ratings and, therefore, can't be bid. It may be a function of compressor size, impeller diameter, or rotational tip-speed. Regardless, the manufacturer of Option A Chiller will usually need to modify it by adding more heat-exchanger surface to meet the design-efficiency rating. The performance of this new chiller is shown in Table 2 as Option B Chiller.

Because of the additional heat-exchanger surface, Option B Chiller will have an improved NPLV rating of 0.448 kW/TR, resulting in Annual Energy that is 4% better than the Specified Chiller. But in meeting the design-efficiency specification, it has also become more expensive. In our example, it costs $31,000 more than Option A Chiller.

Specifying design efficiency has complicated matters. Instead of equalizing energy consumption as a basis for comparing costs, now both annual energy consumption and pricing are unequal. This is not what the specification was meant to accomplish.

Suppose the Specified Chiller and Option B Chiller are bid by two different manufacturers. What is the impact of the specification on bid day? The manufacturer of the Specified Chiller has no incentive to lower his price below $270,000, so that's where the chiller price settles out. This is one of the unintended consequences of competitive bidding.

Specifically, the owner in our example is likely to end up purchasing the Specified Chiller, but will pay about $20,000 more and get no additional energy savings, simply because Option A Chiller did not satisfy the design-efficiency specification and could not be bid. This is illustrated in Table 3.

This example demonstrates why specifying design efficiency may not provide the best benefit for the client.

	Specified Chiller	Option A Chiller	Option B Chiller
NPLV Rating	0.466 kW/TR	~~0.466 kW/TR~~	0.448 kW/TR
Design Efficiency	0.562 kW/TR	~~0.576 kW/TR~~	0.562 kW/TR
Annual Energy	Base	~~Base~~	−4%
Capital Cost	$250,000	~~$240,000~~	$271,000

Table 2: Impact of Specifying Both NPLV and Design Efficiency

	Specified Chiller	Option A Chiller	Option B Chiller	Specified & Purchased Chiller
NPLV Rating	0.462 kW/TR	0.462 kW/TR	0.448 kW/TR	0.462 kW/TR
Design Efficiency	0.562 kW/TR	0.576 kW/TR		0.562 kW/TR
Annual Energy	Base	Base	−4%	Base
Capital Cost	$250,000	$240,000	$271,000	$270,000

Table 3 : Bid-Day Results

Why specify design efficiency?

Although including the design-efficiency rating may hurt owner value, there is still a tendency to use it. There are two reasons why this is so. Designers assume that the design-efficiency rating will impact electric-demand charges. Others are concerned that it may affect power-wiring size. It pays to examine each of these reasons to see if using the design-efficiency rating is really warranted and, if it is, how restrictive it must be.

Does a chiller's design-efficiency rating impact electric-demand charges?

Consider the aforementioned Option A Chiller, which has a design efficiency of 0.576 kW/TR. At first glance, that chiller would appear to cause higher electric-demand charges than the Specified Chiller, which has a design efficiency of 0.562 kW/TR. But is that really the case?

Chiller peak kW usually has little impact on building demand because of heat-load timing. The building's kW and the chiller's kW typically peak at different times of the day. This phenomenon can be referred to as the "flywheel effect" of the building's demand versus the chiller's demand, and is illustrated in Figure 1.

Most air-conditioned buildings reach their peak electric demand between 10:00 AM and 3:00 PM. That's when occupancy is usually at its highest, which maximizes the "people" load. Higher occupancy also translates into more heat generated by lights, elevators, cafeterias, office equipment, etc. When these factors are combined, the building encounters its peak kW draw in late morning to early afternoon.

Surprisingly, most chillers reach peak electric demand between 3:00 PM and 7:00 PM. Why so late? At about 12:00 PM, the sun's rays strike the ground at the most direct angle. Through convection, the ground then heats the ambient air to its highest dry-bulb temperature at about 2:00 PM. Once the air temperature is at its maximum, the heat is slowly conducted through the building skin, a process that peaks building heat load around 4:00 PM. In parallel, the wet-bulb temperature of the ambient air also reaches its maximum later in the day.

The higher wet-bulb temperature raises the cooling-tower-water temperature, which raises the head pressure against which chillers must work, hurting energy efficiency. When these factors are combined, the chiller sees its peak load, peak head, and, therefore, peak kW in late afternoon, hours after the building has passed its peak.

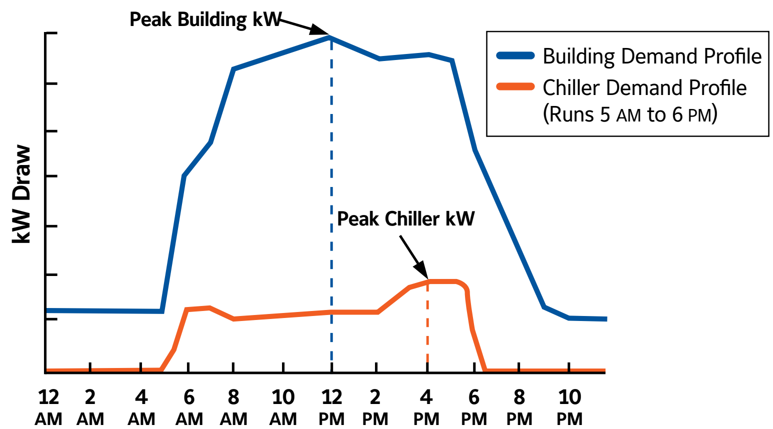

Figure 1: Building Demand vs. Chiller Demand

If the chiller is being used to cool a process, then its power profile will typically be flatter than shown in Figure 1, and its demand *will* have an impact on total demand. During the one or two peak-cooling months, Option A Chiller may have a slightly higher demand charge. However, the fact that both chillers have the same NPLV rating means that Option A Chiller must have a better off-design efficiency. So during the many months of off-design operation, Option A Chiller will likely have lower demand charges. Hence, annual demand charges may actually be less. If a chiller is cooling a process, and demand is ratcheted year-round, then chiller kW could impact building demand. However, the number of applications in this situation is relatively small.

Use only NPLV to specify chiller efficiency

When energy codes or utility rebates require inclusion of the design-efficiency rating in the specification, it is better to specify the *maximum* kW or kW/TR required by the code or rebate. That's because a lower value could result in higher capital costs with no reduction in annual energy costs. This disparity is leading more code-writing agencies to recognize the NPLV rating.

For all these reasons, small differences in the design efficiencies between chillers usually have little impact on the demand charges incurred by the building.

Do small differences in design efficiency affect the size of the power wiring?
The correlation between design efficiency and wiring size is usually a non-issue, because a given wire size can handle a range of amps. Thus, a chiller with a higher design kW/TR will not necessarily require larger wire. In fact, about 90% of the time, it will not, because the wiring size can already handle slightly higher amperage.

In any case, a better way to ensure proper wiring size is to specify maximum full-load amps and minimum power factor at the chiller starter.

Conclusion

Chiller-efficiency specifications that specify both the NPLV rating and the design-efficiency rating may hinder the designer's ability to meet the owner's goals, if the objective of the specification is attaining the lowest capital cost for similar annual energy. That's because the two ratings can create inequalities in annual energy-consumption comparisons, which also result in higher capital costs passed on to the owner. Also, the design-efficiency rating usually has little practical impact on electrical-demand charges and wiring size.

Instead of using both ratings, the best chiller-efficiency spec uses the NPLV rating by itself. For power-wire sizing, specifying the maximum full-load amps and the minimum power factor eliminates all ambiguity about actual size requirements. If energy codes or utility rebates require that the specification include the design-efficiency rating, the maximum allowable kW or kW/TR should be specified.

Use only NPLV to specify chiller efficiency. It minimizes capital costs and energy expenditures.

Printed on recycled paper.

PUBL-6143 (909) Supersedes 160.00-PM32 (307)
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www.johnsoncontrols.com

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