

New ARI rating allows more accurate chiller-energy specification

An accurate rating method for chiller performance is an essential tool for evaluating and comparing equipment. Now there is a new rating developed by the Air-conditioning and Refrigeration Institute (ARI) that has replaced the previous Integrated Part Load Value/Application Part Load Value (IPLV/APLV) rating. The new rating closely tracks real-world, chiller-energy performance by more accurately accounting for chiller operation at off-design conditions.

The new rating – termed IPLV/NPLV for Integrated Part Load Value/Non-standard Part Load Value – is part of the new ARI Standard 550/590-98. The new standard, which becomes effective in December 1998, also includes a revision of the evaporator fouling factor from 0.00025 to 0.0001. Starting immediately, all chiller manufacturers will begin certifying chiller performance to the new standard.

The IPLV/NPLV rating is easy to use – it can be employed exactly the same way as the old IPLV/APLV rating. In fact, to incorporate the new standard into specifications, engineers can simply replace the term “APLV” with the term “NPLV”, change the evaporator fouling factor to 0.0001, and replace any references to “ARI Standard 550-92” or “ARI Standard 590-92” with “ARI Standard 550/590-98”. No other change is required. The only change is in the way chiller manufacturers calculate the rating.

Why was the old rating changed?

Introduction of the new IPLV/NPLV rating solves several problems with the old IPLV/APLV rating, which was based on several less-than-realistic assumptions. Most notably, the IPLV/APLV rating failed as an accurate measure of chiller performance at off-design, “real-world” operating conditions. The IPLV/NPLV rating now provides a more realistic model of off-design performance.

Chillers rarely operate at design conditions, because design conditions mean the **simultaneous** occurrence of both design load and design Entering Condenser Water Temperature (ECWT) or design Entering Dry Bulb (EDB) temperature. But design ECWT or EDB occur during less than 1% of chiller operating hours. That means that over 99% of potential chiller operating hours are spent at off-design conditions: reduced loads, reduced ECWT/EDB, or both. The IPLV/NPLV rating accounts for this more accurately.

How has the rating changed?

To understand the new rating, it is necessary to look at the factors involved in the old IPLV/APLV rating.

As it stood, the old IPLV/APLV rating was still a much better indicator of chiller performance than the design kW/Ton rating, because it took into account some off-design conditions. Unfortunately, the old rating was based on limited assumptions that weren't accurate for the operation of most buildings.

Old assumptions

- Atlanta weather data was used to represent the average weather for the entire U.S. The result was that the rating was somewhat skewed toward warmer and more humid weather.
- The old rating improperly represented design conditions as occurring more often

than they do in the real world. Specifically, the old rating said 17% of chiller operating hours were spent at design conditions of 100% load and 85°F ECWT (for water-cooled chillers) or 95°F EDB (for air-cooled chillers). In reality, these conditions occur simultaneously during less than 1% of chiller operating hours.

- The old rating used an antiquated rule-of-thumb that assumed that for every 10% reduction in load, ECWT declined 2.5°F and EDB declined 4°F. However, in the real world, the ECWT decline averages 4°F and the EDB decline averages 6°F per 10% load reduction.
- The old rating assumed all buildings had an airside economizer and operated 12 hours/day, 5 days/week. However, a 1992 DOE study (combined with a BOMA study) found that only 32% of commercial buildings have both of these operational characteristics. The result was the old rating underestimated chiller operating hours for over two-thirds of the buildings.

New assumptions

By avoiding these misleading assumptions, the new IPLV/NPLV rating overcomes the limitations of the old IPLV/APLV rating.

- The new rating uses national weather data, based on a weighted average of the 29 cities where 80% of the chillers were purchased over a 25-year period, as reported by ARI.
- The new rating recognizes that most operating hours are spent at off-design conditions.
- The new rating factors in the effect of colder ECWT and colder EDB.
- The new rating uses weighted averages of four different building operating scenarios:
 - 24 hours/day, 7 days/week, without an airside economizer
 - 24 hours/day, 7 days/week, with an airside economizer
 - 12 hours/day, 5 days/week, without an airside economizer
 - 12 hours/day, 5 days/week, with an airside economizer

Comparison of old and new ratings

Each rating is a blending of the kW/Ton at four rating points: 100%, 75%, 50%, and 25% load. The formulas used to calculate the ratings are a bit complex, which makes comparison of the old and new ratings difficult. It is more instructive to compare the four points that make up each rating. A comparison of the old and new rating points in Table 1 illustrates the two major changes.

First, the new rating assumes that only 1% of chiller operating hours are spent at design conditions, instead of the 17% assumed by the old rating. Second, the new rating assumes that ECWT and EDB decline more rapidly than the old rating did.

How closely does the new rating predict performance?

Using these new assumptions, how closely does the new IPLV/NPLV rating track chiller performance? To find out, let's do a detailed energy analysis of an example chiller, and then compare that performance to both the old and new IPLV ratings.

We'll start by using weather data from Atlanta, Dallas, Baltimore, Chicago, and New York City. A load line, with internal loads averaging about 40% of the total load, was then superimposed on this weather data. For chiller efficiency, part-load curves from the major chiller manufacturers were averaged together to create "the generic centrifugal chiller". Weighted average kW/Ton values were then calculated for the four different building operating scenarios. The results are shown in Figure 1.

A quick perusal of Figure 1 clearly indicates the improved accuracy of the new IPLV/NPLV rating. It is equally accurate for screw and reciprocating chillers.

What are the benefits of the new rating?

With the new IPLV/NPLV rating, engineers now have a more accurate and convenient specification tool. It is an easy way to gauge actual chiller performance, because the new rating accounts for more realistic operating conditions. In addition, only a detailed energy analysis could provide a more comprehensive indication of actual performance.

The new rating will allow owners to make more informed capital-investment decisions, because it will provide a more realistic estimate of actual chiller operating costs. Plus, it will help determine more accurate paybacks in both new-construction and replacement projects. The old rating would add as much as 25% more time to the chiller-investment payback period. This often influenced decision-makers to choose less efficient chillers in new construction projects, or delay the replacement of inefficient chillers in renovation projects.

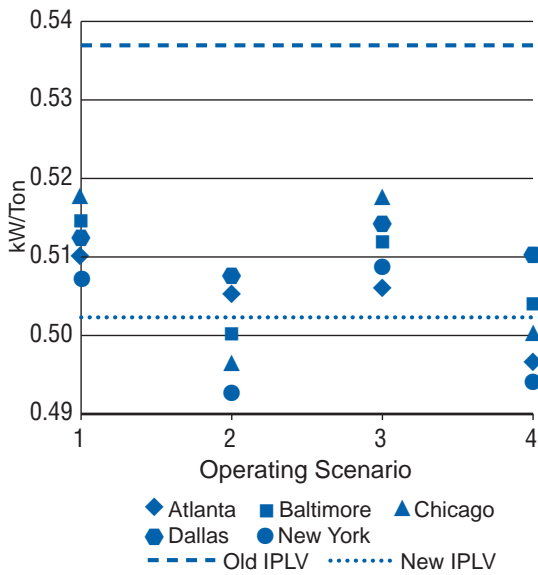
Table 1: Comparison of Old and New Rating Points

Rating Point	Load (%)	Weighting (%)		ECWT (°F)		EDB (°F)	
		Old	New	Old	New	Old	New
A	100	17	1	85.00	85.00	95.00	95.00
B	75	39	42	78.75	75.00	85.00	80.00
C	50	33	45	72.50	65.00	75.00	65.00
D	25	11	12	66.25	65.00 ¹	65.00	55.00 ²

Notes:

1. Would have been 55°F, but industry testing facilities incapable of testing that low.
2. Would have been 50°F, but industry testing facilities incapable of testing that low.

Figure 1. New and Old IPLV Ratings as Predictors of Chiller Performance



The environmental impact of such chiller-replacement decisions can be staggering. If only 10% more of the existing, inefficient, CFC chillers were replaced with more efficient units, global warming could be reduced by a half-million tons of CO₂ over a five-year period. The phase-out of CFC refrigerants would also be accelerated.

What about multiple-chiller plants?

Appendix D of the new standard states that the new rating was developed for single-chiller plants, and is not representative of multiple-chiller plants. It further states that individual chillers in a multiple-chiller plant spend, on average, more operating hours at higher loads than would a single chiller handling the same duty.

What the Appendix doesn't say is that the investigation of multiple-chiller plants was never undertaken. So, it was unknown whether the new rating was accurate for multiple-chiller plants.

That investigation has now been conducted by YORK, one of the developers of the new rating. The investigation found that the new rating accurately tracks the performance of multiple-chiller plants, as well as single-chiller plants.

The explanation is rather simple. It is true that individual chillers in a multiple-chiller plant spend, on average, more operating hours at higher loads than would a single chiller handling the same duty. However, it is also true that those additional high-load operating hours are spent at lower ECWT/EDB. The result is that chillers in a multiple-chiller plant use the same or even less energy than a single chiller handling the same duty.

If we put a chiller on a test block, where we have control of both the load and the ECWT/EDB, we can see why this is so. If ECWT/EDB is held constant while the load is reduced, a chiller sees relatively little change in kW/Ton – usually only 5 to 6%. However, if the load is held constant while the ECWT/EDB is reduced, kW/Ton can fall by 45 to 50%! The use of multiple chillers in a plant only affects the load each chiller sees, not the ECWT/EDB. So multiple chillers have very little effect on chiller-plant average kW/Ton.

Table 2 shows an example comparing the average plant kW/Ton for chiller plants using one through six chillers to handle the same cooling duty. The kW/Ton at design conditions for each chiller was 0.583, and the new IPLV was 0.488.

Clearly, the kW/Ton averages from 0.482 to 0.492 are not only close to one another, but also close to the new IPLV rating of 0.488 (by the way, the old IPLV would have been a misleading 0.522). This demonstrates that the rating can be used to predict chiller performance in multiple-chiller systems, as well as single-chiller systems.

What should be done now?

In addition to substituting “NPLV” for “APLV”, “0.0001” for “0.00025” and “550/590-98” for both “550-92” and “590-92” in their specifications, engineers can now eliminate the specification of design kW/Ton. A design kW/Ton rating is merely an efficiency at one condition – a condition that occurs during less than 1% of chiller operating hours. It provides *no indication of off-design performance*, which can vary widely from chiller to chiller. In fact, chillers with the best design kW/Ton may have the worst IPLV/NPLV performance because they were optimized for design conditions.

It's true that design kW can affect demand costs, but this only becomes signifi-

Table 2: Average Chiller-Plant kW/Ton vs. New IPLV of 0.488

Operating Scenario ¹	Number of Chillers in Plant					
	One	Two	Three	Four	Five	Six
1	0.496	0.476	0.475	0.479	0.481	0.482
2	0.474	0.485	0.484	0.492	0.492	0.496
3	0.494	0.489	0.481	0.486	0.488	0.490
4	0.487	0.481	0.489	0.496	0.496	0.501
Avg.	0.488	0.483	0.482	0.488	0.489	0.492
Δ IPLV%	+0.4	-1.0	-1.2	+0.2	+0.2	+0.8

Notes:

- 1. Scenario 1 = 24 hours/day, 7 days/week operation, without airside economizer
- Scenario 2 = 24 hours/day, 7 days/week operation, with airside economizer
- Scenario 3 = 12 hours/day, 5 days/week operation, without airside economizer
- Scenario 4 = 12 hours/day, 5 days/week operation, with airside economizer

cant with ratcheted rate structures. Ratchets are likely to disappear, and demand costs become less important, with the advent of electric-utility deregulation and real-time pricing.

In addition, the thermal flywheel of the building moves the peak load on the chillers back a few hours later than the peak kW draw for the building itself. The maximum daily ECWT/EDB also occurs in the later afternoon. As a result, the chillers usually contribute only 80 to 90% of their monthly peaks to the actual building peaks.

Instead of specifying design kW/Ton, the specification should be written so the chiller manufacturer isn't restricted from bidding "equal efficiency." Doing so allows the manufacturer to meet the specified IPLV/NPLV rating, even if the chiller has a different design kW/Ton.

Nevertheless, it is still necessary to specify maximum full-load amps for wire sizing. That's because current requirements at design conditions will dictate the wiring size required to handle the load. Thus, full-load amps should be in the specification, but it should be specified as a maximum – the same way overall equipment dimensions are specified so that all manufacturers can fit the space.

A new standard for a new era

The introduction of the new IPLV/NPLV rating is a tremendous development for engineers and owners alike. It is the best basis to date for writing a chiller-efficiency specification. Nothing short of a detailed energy analysis is better at determining chiller performance for both single- and multiple-chiller plants.

With the IPLV/NPLV rating, engineers can easily produce a more accurate specification. Simply use the IPLV/NPLV number as provided by the manufacturer.

The IPLV/NPLV rating also helps owners ascertain the best chiller for their application. Comparisons of chiller performance can be made quickly and confidently. Using the rating also makes it easy to project annual energy costs using this formula:

$$\text{Annual Energy Costs} = \text{NPLV} \times \text{\$/kWh} \times \text{Average Chiller Load} \times \text{Operating Hours}$$

For more information about the new IPLV/NPLV rating, contact your local YORK office.

