Carrier®

HVAC analysis

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ISSUES AND ANSWERS FOR THE CONSULTING/SPECIFYING COMMUNITY

In this issue...

How are you specifying your customers' chillers? Did you know that the lifetime cost of a typical 500-ton chiller could be as high as $1.8 million? Would you be surprised to know that different makes of chillers may meet your performance specifications, but that energy costs may actually differ by as much as $6,500 a year? In this issue, find out why evaluating chiller performance by taking into consideration all of the system and location factors will save your customer money over the life of the chiller.

Educate Your Customers: *System Part Load Value is summarized in Carrier's* SYNOPSIS *newsletter, which is written specifically for building owners and managers. To receive copies at no charge, call 1-800-CARRIER and request* SYNOPSIS, *Vol. 3, No. 3, or visit our website at www.carrier.com*

System Part Load Value: A Case For Chiller System Optimization

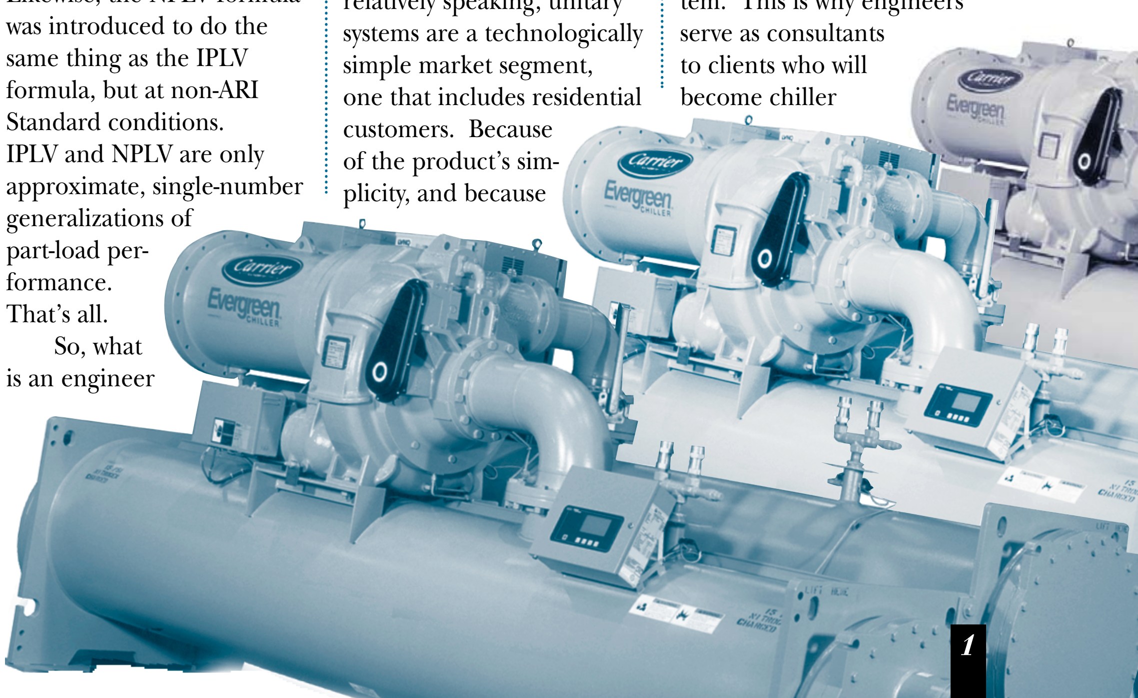
Introduction

OK. So we are agreed, the IPLV formula published in ARI Standard 550/590-1998 has its limitations. It isn't representative of any particular project, it's based on only one chiller operating alone, and its part-load weighting may or may not have any meaning for central plants with multiple chillers. ARI, in revising the standard, was trying to define a uniform, industry-wide measuring stick for part-load performance. Likewise, the NPLV formula was introduced to do the same thing as the IPLV formula, but at non-ARI Standard conditions. IPLV and NPLV are only approximate, single-number generalizations of part-load performance. That's all.

So, what is an engineer to do? Well, the first thing is to recognize the limitations of the standard. IPLV and NPLV should be used as a starting point, not an end point. The second is to understand that by their very simplicity, that is to identify part-load performance by a single universal figure, their usefulness as a tool may be unsatisfactory.

The Seasonal Energy Efficiency Ratio (SEER), developed by ARI for unitary equipment, is the same sort of indicator. But the case can be argued that, relatively speaking, unitary systems are a technologically simple market segment, one that includes residential customers. Because of the product's simplicity, and because of the large number of novice customers who are not trained in the fine details of refrigeration equipment, a uniform, single-number method of comparison is appropriate.

Chilled water systems, on the other hand, are comparatively complicated with multiple pieces of equipment that have interdependent performance relationships. Moreover, a chilled water system requires a far greater financial investment by the owner to both install and operate the system. This is why engineers serve as consultants to clients who will become chiller



owners. It seems inappropriate then to give a client technical counsel using a method better suited to residential applications.

For the consulting engineer, IPLV or NPLV can only be a good starting point.

Why Should I Worry?

Start by asking the question: "How do chillers get specified?" In many cases the answer is to make a copy of an old specification, mark it up in the format that exists, get it retyped, and then fill in the schedule on the drawings. Done. Is that how it should be done? That depends.

If your client is focused simply on minimizing first cost, it doesn't really matter. Specify a chiller that's reasonable on energy use, that fits the budget, and be done with it. But rarely is that the case.

Somewhere in most projects, usually on the client's side of the table, there is someone who is concerned about energy. Indeed, many corporations now have energy managers whose job it is to watch such things. They may even have established minimum energy standards that govern new construction. And just like their get-it-done-cheap counterparts, sophisticated clients also have budgets; the difference is that they are willing to consider the economic trade-offs between first cost and operating costs.

Retrofit projects are an increasingly important area of the consulting business, especially with the evolution of energy service companies (ESCOs) from the utility industry. ESCOs are a new breed of competitor to consulting engineers. They market themselves as experts in energy efficiency, and sell chiller retrofits on the basis of guaranteed savings. You can be certain that when energy savings come with financial guarantees, the successful consultants are basing their chiller selection on something more than an IPLV rating from the catalog.

If I Don't Use IPLV or Full-load kW/Ton, What Should I Use?

The footnotes in ARI 550/590-1998 recommend performing a comprehensive analysis using actual weather data, building load characteristics, the number of chillers, operational hours, economizer capabilities, and the energy drawn by auxiliaries such as pumps and cooling towers.

But that's a lot of work, and many consultants cannot sell the fees it takes to do that much work. Unfortunately, consulting engineering services are becoming similar commodities, there isn't much to distinguish one firm from the next. Lack of technical differentiation increases price competition that in turn decreases the time available to worry about chiller efficiency or optimization. It is hard enough just getting the systems designed, drawn and specified in the time allotted, let alone perform a detailed, application-specific part-load analysis.

That is why Carrier developed Chiller System Optimizer.

What is Chiller System Optimizer?

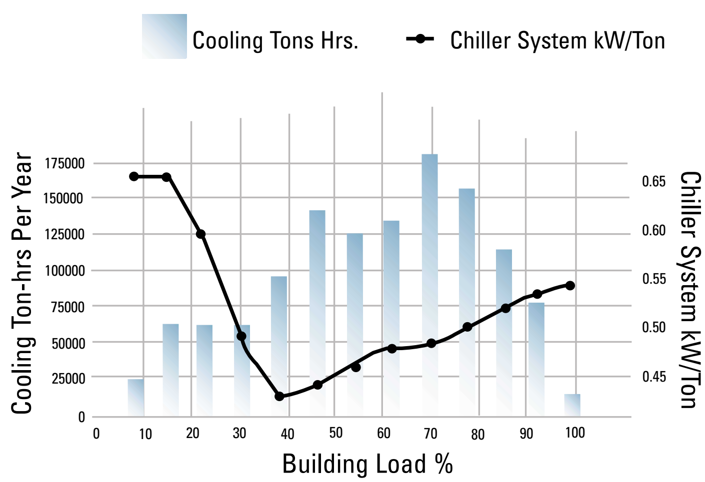
Chiller System Optimizer is a non-manufacturer specific software program that simplifies chilled water system analysis. Working together with your local Carrier representative, the software allows you to evaluate chiller performance by taking into consideration all of the system and location factors recommended by ARI.

One of the program's unique features is that it calculates the System Part Load Value (SPLV) as an alternative to ARI's standard IPLV and NPLV indicators. Like IPLV and NPLV, SPLV is a single numerical indicator of part-load performance. The difference is that it is calculated specifically for your project using actual weather data, actual load characteristics, actual equipment performance, and the anticipated operating hours and control sequence of multiple chillers. SPLV is an accurate, representative indication of chiller performance operating under project-specific conditions. Chiller System Optimizer also provides the equipment schedule criteria used to specify chillers that are optimized for your specific project.

Most important, when calculating life cycle costs, Chiller System Optimizer also considers the operation and energy use of system auxiliaries such as pumps

FIGURE 1

Typical System Performance Profile Taken From Chiller System Optimizer Output



Peak building load:	**1,000 tons**
Number of chillers:	**Two at 500 tons each**
Chiller type:	**Electric centrifugal using R-134a**
Chiller design conditions:	**LCHWT 44°F (2.4 gpm/ton)**
	ECWT 85°F (3.0 gpm/ton)
Full-load power:	**0.597 kW/ton**
NPLV:	**0.534 kW/ton**

and cooling towers. This allows the engineer to evaluate and design a truly optimized system.

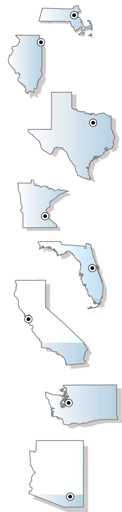
So, How Does Chiller System Optimizer and SPLV Help?

Using current standards, engineers specify chillers using IPLV, NPLV or full-load kW per ton. Some may even still use APLV[1]. "But what do those values mean?" you ask. The answer is: not much. IPLV and NPLV are, at best, coarse indicators of anticipated performance at certain specific conditions. Full-load kW per ton is a meaningful performance indicator only for chillers that operate continuously at full load. Chiller System Optimizer and SPLV help the engineer develop and understand meaningful indicators of chiller and system performance.

There is a misconception that chillers operate most efficiently at full load. People often tend to think of a chiller's overall efficiency in terms of the full-load kW per ton. The truth is that a chiller can operate most efficiently wherever you want it to operate most efficiently. Manufacturers have at their disposal huge assortments of compressor and heat exchanger combinations. For a given size of chiller, a manufacturer may have upwards of 10,000 different combinations of compressors, impellers, heat exchanger shells and tubes. If desired, at a given entering condenser water temperature, a chiller can be selected to be most efficient at full load, 50% load, or anywhere in between. But condenser water temperature can change with the weather, so the best chiller selection will be a compromise that considers cooling tower operation to achieve the best part-load efficiency during the period of time the chiller operates most.

TABLE 1

Performance of a Typical Building System, Weather is the Only Factor Changed in Each City



	Competitor A (R123 Centrifugal)			Competitor B (R134a Centrifugal)			SPLV Variation Between Chillers
	Chiller Full Load kW/ton	Chiller NPLV	SPLV	Chiller Full Load kW/ton	Chiller NPLV	SPLV	
BOSTON	0.597	0.506	0.505	0.597	0.534	0.483	-4.55%
CHICAGO	0.597	0.506	0.508	0.597	0.534	0.492	-3.25%
DALLAS	0.597	0.506	0.515	0.597	0.534	0.512	-0.59%
MINNEAPOLIS	0.597	0.506	0.506	0.597	0.534	0.488	-3.69%
ORLANDO	0.597	0.506	0.526	0.597	0.534	0.529	0.57%
SAN FANCISCO	0.597	0.506	0.494	0.597	0.534	0.445	-11.01%
SEATTLE	0.597	0.506	0.497	0.597	0.534	0.449	-10.69%
TUCSON	0.597	0.506	0.494	0.597	0.534	0.467	-5.78%
Minimum			0.494			0.445	
Maximum			0.526			0.529	
SPLV Variation Between Sites			6.48%			18.88%	

To be so selective, it is necessary to first know where the most efficient point should be. That is a function of building load profile, hours of operation, the number of chillers operating at any given time, and the energy consumption of pumps, cooling towers and other auxiliaries (the same familiar list). Figure 1 shows a typical building load profile overlaid with a plot of the system chiller profile. It can be seen that most of the time the building load is between 46 and 84% of full load. Conversely, the chiller efficiency varies, reaching its minimum during periods when the building load is at about 39% of full load. The weighted average operating point for the chiller is at about 0.483 kW/ton. This is the SPLV.

What Does The SPLV Tell Me?

In the example in Figure 1, the chillers modeled have a full-load energy consumption of 0.597 kW per ton and an NPLV of 0.534 kW/ton. In this system and location, the chiller's actual part-load energy consumption, the SPLV, is about 0.483 kW per ton. This is over 19% better than the full-load measure and nearly 10% better than the NPLV measure.

The time of operation also varies significantly from the ARI standard in Figure 2.

But Does It Really Make Any Difference?

We wondered the same thing, so we took an example project and made comparisons between eight different cities using the Chiller System Optimizer software. Table 1 shows the performance of a typical building system with a 1,000-ton load served by two 500-ton centrifugal chillers. The system is identical for each city shown: the same chillers, pumps, cooling towers and control sequence. Weather data was the only thing

[1]Application Part Load Value. APLV was eliminated from the ARI standard.

changed for each city. Also, two different makes of centrifugal chillers, were compared in each city. The chillers were selected with identical full-load kW per ton ratings. To remain objective in this discussion, we did not include a Carrier chiller.

The results are surprising. If you take the identical specification prepared for a project in Orlando and use it for a project in San Francisco, the actual performance may vary by nearly 19%. Also, depending upon which make chiller is selected, the variation in performance can be as much as 11% at the same site even if both chillers meet the specification with identical full-load kW per ton ratings.

So, What Does That Mean to Me?

Let's look at the most pronounced example, San Francisco. If the engineer's specification defines the minimum chiller performance as simply 0.597 kW per ton at full load, all things being equal, the actual performance will vary by more than 11% depending on the make of chiller selected. Also, note that the Competitor B chiller with the larger NPLV (0.534) will actually operate more efficiently than Competitor A machine (0.506) when evaluated as part of the overall system using site-specific information. Why? Because NPLV (and IPLV) is calculated at a very narrowly defined profile that is not often representative of what is actually happening in the system.

If the Competitor B chiller is installed, it will operate at about 0.445 kW/ton on average. This is nearly17% better than the indicated NPLV and more than 25% better than the full-load rating. Is that what you expected? Is that what your client expected? Would your client be surprised to know that, in spite of both chillers meeting the engineer's specifications, if he ends up with the wrong chiller it will cost him more than $6,500 each year[2] in higher energy cost? Over the life of the chillers that adds up to an additional $163,000! Was that in the budget? Is it possible that your client would like to be part of that life cycle decision?

OK, I Agree. But Optimization Analysis Still Takes a Lot of Time.

Not any more. In the old days, optimizing the chiller and system selections would take days of tedious calculations.

FIGURE 2

SPLV

	25% Load	50% Load	75% Load	100% Load
ARI Standard Weighting Factors	0.120	0.450	0.420	0.010
Weighting Factors for Figure 1 Example	0.067	0.308	0.437	0.188

Today, using Carrier's Chiller System Optimizer can help you optimize the chiller and system for a specific project can be accomplished in a matter of hours. All you need to know is the peak load of your project building and the load at one or two other points (e.g. the conditions where load equals zero). The program interpolates a load profile based on the facility operating hours you define. For unusual applications, the program allows you to specify the actual building load profile. Other features:

- *Weather is selected from actual weather data for 189 cities in the United States or 180 international locations.*
- *You can specify exact chiller performance from selections prepared by Carrier or other manufacturers. In addition, the program has performance templates of actual chillers from Carrier, Trane, York and McQuay. The model will also accept different combinations of chiller size, type and manufacturer up to a total of 12 chillers.*
- *You can compare different chiller sequencing control options.*
- *Cooling tower performance can be approximated, or it can be accurately defined. Carrier has included a cooling tower performance algorithm in the software (provided by Baltimore Aircoil) to predict the actual tower performance.*
- *You are able to define specific economic criteria for your project: life cycle period, currency, different inflation rates for assorted items, energy rates for natural gas, electricity and steam, and the minimum rate of return.*
- *Costs for equipment, construction, maintenance, water treatment and other factors can be included.*
- *The program automatically performs the life cycle cost analysis between different options and systems that you define.*

When Should I Use Chiller System Optimizer?

Chiller System Optimizer fits into the design process in several locations. First, during preliminary design. When cooling loads have been approximated and the engineer is working with the architect to develop the building concept, Chiller System Optimizer can help determine the type of chilled water system to use. This allows the engineer to define space requirements for chillers, pumps and cooling towers. Second, during detailed design, Chiller System Optimizer can be used to define the exact criteria to be used in the chiller specifications. Also, in retrofit projects, Chiller System Optimizer helps

2 Estimate of annual energy cost based on electrical rates of $0.05 per kilowatt-hour and $7.50 per kilowatt demand, and includes the energy cost of pumps and cooling towers.

the engineer to specify chillers and equipment that will be truly optimized, providing the best return on investment for their client.

Literally speaking, the time to use Chiller System Optimizer is now. Consider this:

- *The time and expense of performing chilled water system optimization the old fashioned way has driven engineers into using simplified methods of specifying chilled water equipment that aren't indicative of true system performance.*
- *Chiller System Optimizer will allow you to prepare better analysis for your clients, simply and easily using software that is not manufacturer specific.*
- *For the consulting engineer, the ability to perform meaningful optimization analysis at minimum cost is an important competitive differentiator, and provides real value to your client.*
- *Clients are expecting more from engineers. The consulting world is changing in the wake of performance contracting, design-build programs, and competitive pressure on fees.*
- *Chilled water systems are becoming more complex, and the options available to choose from are more varied and confusing than ever.*
- *Contact your local Carrier representative and see for yourself how Chiller System Optimization can define your next project.*

GLOSSARY

APLV Application Part Load Value is a single number, part-load efficiency indicator* calculated using the ARI method referenced to selected conditions. APLV was introduced in ARI Standard 550-1988, but deleted from the 1998 edition.

IPLV Integrated Part Load Value is a single number, part-load efficiency indicator* calculated using the ARI method at standard rating conditions. Introduced in ARI Standard 550-1986, the definition of IPLV was changed in ARI Standard 550/590-1998 to more closely reflect actual operating experience found in the field for a single chiller.

NPLV Non-Standard Part Load Value is a single number, part-load efficiency indicator* calculated using the ARI method referenced to rating conditions other than ARI standard. The 1998 standard adopted NPLV for situations when a single chiller is not intended to operate at standard ARI rating conditions.

SPLV System Part Load Value is a project-specific, single number, part-load efficiency indicator introduced by Carrier that is calculated using the equation form defined in ARI 550/590- 1998. Unlike IPLV or NPLV, the factors used to calculate SPLV are project specific and consider multiple-chiller applications, actual operating hours, and project-specific operating conditions.

* ARI Standard 550-88 uses the term "figure of merit". The word "indicator" is used as a clarification. The use of a single number performance value is to provide an *indication* of equipment performance relative to other equipment at defined operating conditions.