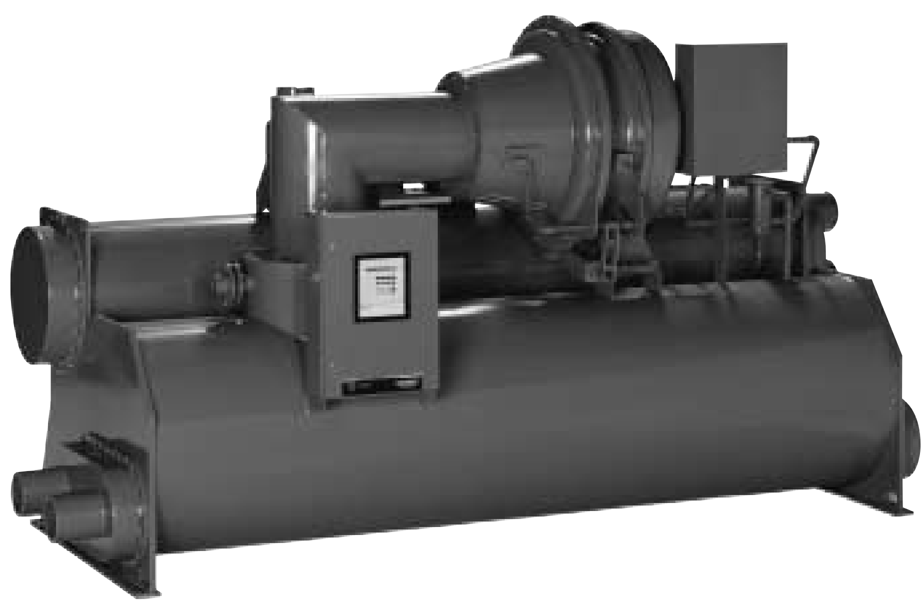
Engineering Bulletin

Full Load Efficiency



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Introduction

The combined effects of electric rate structure, full load efficiency and part load efficiency are all factors contributing to operation costs.

However, when an electric chiller operates at full load, it experiences its greatest electrical usage. This typically corresponds with high electrical use in its facility, as well as other facilities supplied by the electric utility. These times of high use, called peak, are also characteristic of more expensive consumption rate charges, per kWh, and additional demand charges, per kW.

The combination of expensive consumption rates and demand charges makes chiller full load efficiency extremely important. In many applications, full load efficiency is much more crucial than part load due to cost of electricity.

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IPLV/NPLV Indicates Performance, Not Operating Cost

The Air Conditioning and Refrigeration Institute (ARI) Standard 550/590-98 established the Integrated Part Load Value (IPLV) to "provide a single number part load performance number for water chilling products. The equation was derived to provide a representation of the average part load efficiency for a single chiller only." (ARI Standard 550/590-98, pg. 23) ARI also established the Non-Standard Part Load Value (NPLV) for chillers that are optimized at design conditions other than what is described in the standard.

Unfortunately, many people have used the standard's IPLV/NPLV value as an indicator of chiller operational cost. This was not the intent for the IPLV or NPLV value.

IPLV/NPLV Emphasizes Part Load, Not Full Load Efficiency

A chiller selected on the basis of IPLV can potentially cost the customer more to operate. A minimal IPLV does not ensure that the chiller or the chiller plant will *operate* efficiently.The IPLV number is calculated as a weighted average of four load points. The weighting is based on a "blend" of operating-hour scenarios from many different building types and 29 geographic locations.

Chiller Load	IPLV/ NPLV* Weighting	Condenser Water Temperature
100 %	0.01	85 F
75 %	0.42	75 F
50 %	0.45	65 F
25 %	0.12	65 F

*NPLV uses the same equation weighting as IPLV, but the chiller is optimized at conditions other than standard design conditions described in ARI Standard 550/590-98.

The IPLV is then calculated with the following formula:

$$IPLV = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$$

Where
A = kW/ton at 100% capacity
B = kW/ton at 75% capacity
C = kW/ton at 50% capacity
D = kW/ton at 25% capacity

In fact, because the IPLV/NPLV weighting minimizes the effects of full load, many people are ignoring the effects of full load energy requirements and the cost of operating there.

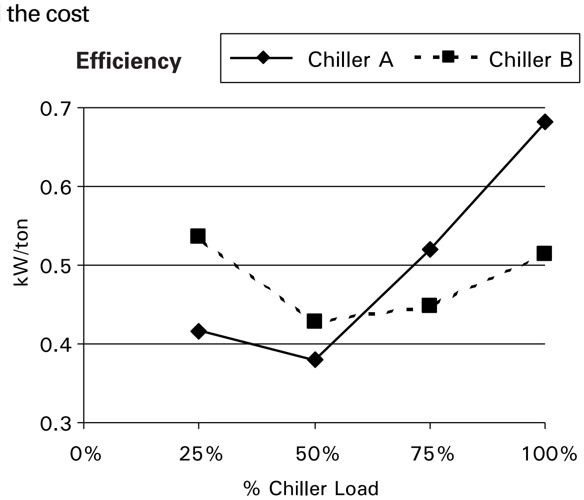
Compare the Effect of IPLV or NPLV and Full Load Efficiency on Operating Cost

To test the assumption that the unit with the best IPLV or NPLV is the most economical, we selected two chillers with nearly identical IPLV and compared the energy used by the two to determine the lowest energy consumer.

In this example, chiller A costs marginally more (1%) and has a variable frequency drive (VFD) to achieve a slightly better (3%) IPLV than chiller B. Chiller B has instead a standard starter and larger heat exchangers to achieve its IPLV, while having a better full load efficiency.

Efficiency (kW/ton)

Load	Chiller A	Chiller B
100%	.682	.514
75%	.520	.448
50%	.380	.428
25%	.416	.536
IPLV	.436	.448
Price	1.01 x Base	Base

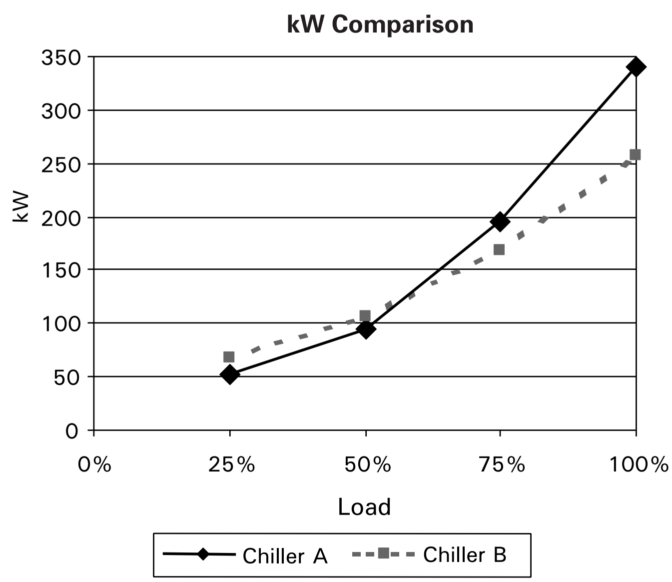


We will assume the chillers operate 3,000 hours and we will use the weighting in the new ARI Standard 550/590-98 to determine hours spent at each load point. Using 3,000 run hours, the units ran at full load for 30 hours, at 75% load for 1260, at 50% load for 1350 and at 25% load for 360 hours. When the ton-hours and kWh are calculated, the results are contradictory to the assumption that the unit with the lowest IPLV used the least amount of energy.

In this example, the chiller with the **lowest IPLV used more energy, 14,940 kWh more, not less**. More importantly, the additional energy use occurs when the chiller is most heavily loaded and the cost of energy is the greatest. This penalty can be significant with the effects of demand or the increased cost of energy during peak periods.

Operating Data				Chiller A			Chiller B		
Tons	IPLV Weighting	Hours	Ton-hours	kW/ton	kW	kWh	kW/ton	kW	kWh
500	.01	30	15000	.682	341	10230	.514	257	7710
375	.42	1260	472500	.520	195	245700	.448	168	211680
250	.45	1350	337500	.380	95	128250	.428	107	144450
125	.12	360	45000	.416	52	18720	.536	67	24120
Total Hours: 3000				Total kWh: 402900			Total kWh: 387960		

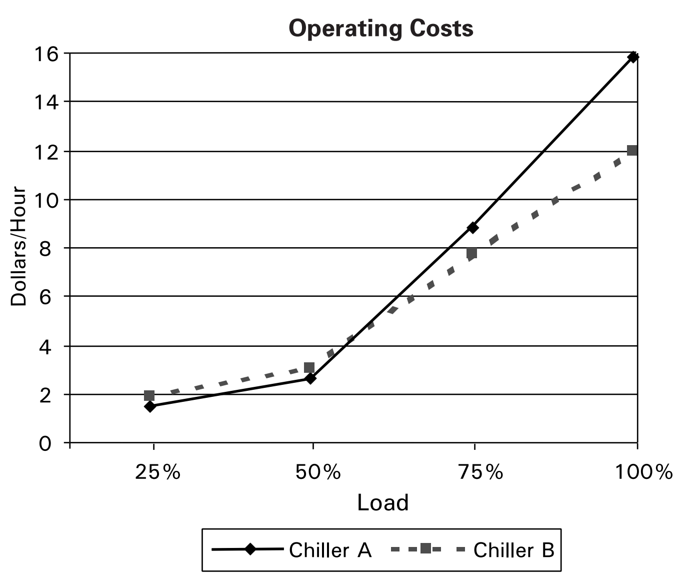
The IPLV/NPLV value is calculated by kW/ton but the chiller uses energy by the kW. So if the chart were to reflect the energy the chillers are actually using, it would look like this.



Applying an example energy rate of:
- $.0282/kWh off peak (at or below 50% load)
- $.04653/kWh on peak (above 50% load)

changes the vertical axis to reflect the cost of operation. The results can be seen on the chart on the right.

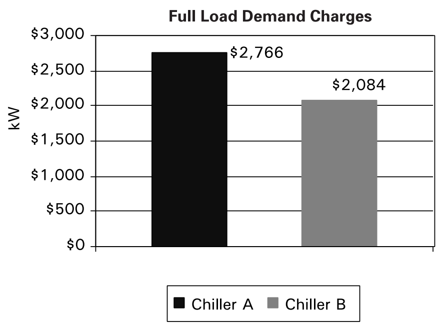
It becomes apparent that chiller efficiency can be most important at higher load conditions, which is when the cost of energy can be the greatest. There can be dramatic savings for good full load efficiency and the benefit comes when the cost of energy is the highest.



The Impact of Demand Charge is Significant

Don't forget the demand charge. Full load electricity requirements often define the rate structure and the demand charges a facility will pay for the next 6 months to a year.

In our example, the difference in full load kW in this comparison is 84 kW (341 kW – 257 kW). Using the demand rate in Ft. Myers, FL, the difference in demand between the two installations is $681.24/month (84 kW x $8.11/kW)!



Expensive peak electrical charges may not change in the future. Electrical deregulation is predicted to cause a shift to real time pricing instead of the structured rate we have today. Real time prices would follow the laws of supply and demand. This means that the electrical prices would be the highest during the greatest demand, at peak and at full load. Even today, many utilities charge double for on-peak consumption.

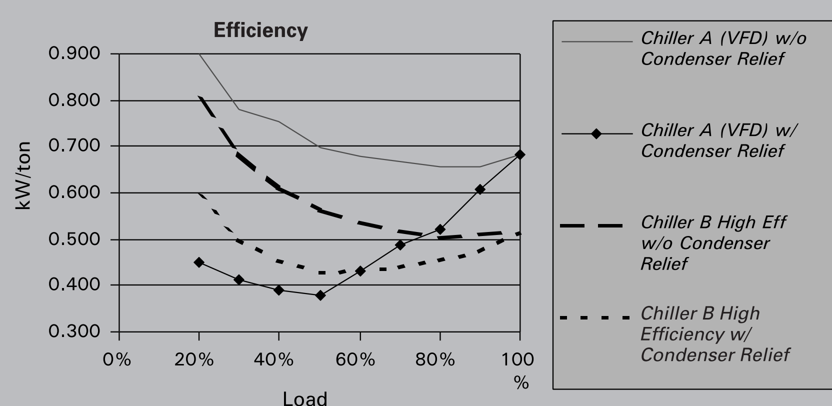
Deregulation will create a greater disparity between on-peak and off-peak pricing. Some industry experts believe on-peak rates be four to five times the price of off-peak rates. This will make the effect of chiller full load efficiency on operating costs even more dramatic.

Important!
Chiller A used a variable frequency drive to achieve its IPLV value. A chiller with a VFD needs cold condenser water to maximize performance. In the comparison above, we used the ARI condenser water relief schedule.

Another way to improve efficiency is to purchase a more efficient chiller at full load. You can see the efficiency plotted on the chart with the dotted line. With resources spent on better full load efficiency instead of a VFD, the efficiency benefit is universal, irrespective of the ability to have "off design" conditions. A high efficiency chiller at full load will reduce electrical consumption of the chiller with or without cold condenser water. The most significant energy savings will be at full load, when the cost of energy is the highest.

ARI Condenser Relief **	
Load	Entering Condenser Water Temp
100%	85
75%	75
50%	65
25%	65

**ARI condenser relief may or may not be realistic for your geographical region. In Vancouver, BC, it may be relevant. In Key West, Florida it is not achievable. The solid line on the graph below shows how the chiller with a VFD would perform if there weren't condenser relief.



Estimate Operating Costs Accurately and Quickly with System Analyzer™ Computer Software

Full load efficiency is very important, but considering the large capital investment of purchasing larger chillers and chiller plants, it is reasonable to do a comprehensive operating cost analysis. To do an analysis, there are easy-to-use computer software programs available.

One such program is System Analyzer™; a Microsoft Windows™-based energy and economic analysis program. It will calculate building loads, energy consumption, and annual operating cost, and then compare equipment alternatives. Analyses can include:

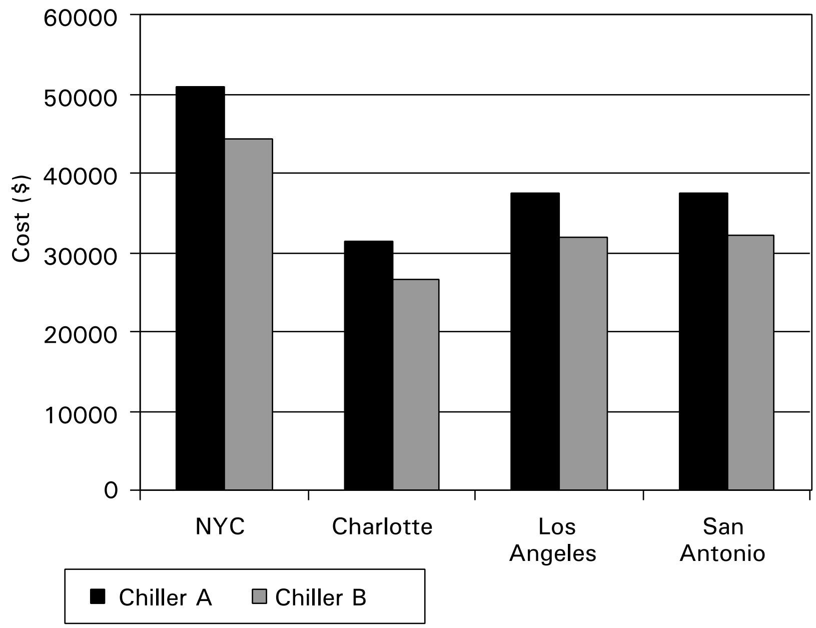
- Weather data
- Building load characteristics
- Number of chillers and HVAC system options
- Operational hours
- Electrical Rate Structure
- Economizer capabilities

A highly powerful analysis tool, such as System Analyzer™, can do a comparison of chiller system performance in a matter of minutes.

The following chart compares the chillers from the previous example in four different cities.

An analysis using a blended utility rate that assumed the same cost of energy at peak and off peak would not show this obvious disparity.

Chiller Yearly Cost Comparison



Conclusion

A low IPLV does not guarantee low operating costs. ARI Standard 550/590-98 established the IPLV number to compare efficiency performance of individual chillers. However, the IPLV number is not meant for economic analysis. Demand charges, time-of-day rates, load profile, and operational hours are just a few of the many factors that have a large affect on the operational energy costs of the chiller(s). Factors such as these can vary widely by installation and the IPLV, being an average, cannot take these into account.

Attention to full load efficiency will minimize the cost of higher utility rates with associated demand charges and the extreme effects of real time pricing during peak periods. Excellent full load efficiency guarantees excellent part load efficiency with or without the ability to get cold condenser water. The best system evaluation involves an appreciation for the utility rates you pay as well as a realistic understanding of the load and operating conditions of the facility. Make sure you're getting the savings you expect.

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