providing insights for today's hvac system designer

Engineers Newsletter

volume 44–4

Chiller Selection Made Easier with myPLV™

This Engineers Newsletter provides insight on how the myPLV tool could be used to quickly and accurately estimate chiller performance and payback.

With the flood of competing chiller types, manufacturers and performance claims coming to the market in recent years, the analysis of the chiller with the best payback has become both more important to the building owner and more difficult for the designer.

Comprehensive building modeling tools such as EnergyPlus, TRACE™ or HAP that can compute hour-by-hour data provide the most accurate answer, but their processes can be quite daunting. And the time and information needed for such in-depth analysis may not be justified during the design process. Meanwhile, a simpler analysis method using generalized single point chiller-only metrics such as Integrated Part Load Value (IPLV) or full load performance completely disregard the specifics of the chiller(s) application.

This simpler approach ignores critical application details such as building load profile, local weather and number of chillers in the system, among others. It may provide the industry with a manageable method to set minimum performance standard; however, there is general agreement that it is a poor indicator of chiller energy use in a building. Even AHRI Standard 550-590, 2011 recognizes that single-rating metrics, developed at a standard set of conditions, does not provide a method of evaluation for a particular job. The following is an excerpt from Appendix D of the Standard.

> *In summary, it is best to use a comprehensive analysis that reflects the actual weather data, building load characteristics, operational hours, economizer capabilities and energy drawn by auxiliaries such as pumps and cooling towers, when calculating the chiller and system efficiency. The intended use of the IPLV (NPLV) rating is 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 energy codes. A single metric, such as design efficiency or IPLV shall not be used to quantify energy savings.*

Recently, Trane engineers were challenged to develop a viable alternative to the existing analysis methods that would provide an accurate indication of any chiller's installed energy performance. The mission was to provide accurate chiller performance indicators in an easy-to-use tool that bridges the gap between a full building simulation method and the overly simplistic and often misleading single metric methodologies of IPLV, NPLV, or full load chiller design performance.

The team determined that this tool must include the following criteria to provide accurate results:

- chiller type and manufacturer agnostic
- annual building load profile
- local weather
- number of chillers in the system
- chiller performance at appropriate operating points—both tons and temperatures.
- condenser water system control strategy
- simple and transparent methodology
- accurate ROI analysis based on electrical consumption and demand charges to guide users in *best* chiller selection
- easy to use if whole building modeling isn't feasible

This *Engineers Newsletter* provides a technical explanation of the use and output of the resulting analysis tool, myPLV™ (my Part Load Value). The EN will describe the approach used to address each of the above criteria to compare the benefit of one chiller selection over another for a specific building and chiller plant, be it air-cooled or water-cooled.

myPLV Overview

The intent of the myPLV program is to provide HVAC system designers with an easy-to-use, spreadsheet-driven application to accurately analyze chiller performance to determine the best return on investment.

The key to the tool's *simplicity* is that it uses bin energy analysis. The key to the tool's *accuracy* is that it creates bin conditions that are customized to the actual operation of the building and chiller, specifically, operating temperatures and time in each bin.

The myPLV tool provides no advantage to any one chiller type or manufacturer. It simply provides a bin analysis for the load profile and chiller performance entered by the program user.

Calculations use the specific chiller performance data provided by the individual manufacturers. It assumes the user will request and the manufacturers will provide accurate and verifiable chiller performance data at each user-specified chiller load point and associated condenser water temperature. Figure 1 illustrates the flow of the myPLV analysis method.

> Every AHRI certified chiller manufacturer must have the ability to provide any random operating point during certification so to provide the selected bin conditions is a reasonable request to any vendor.

The goal of the myPLV tool is to evaluate *chiller energy* (assuming proper plant operation) based on performance in a specific building type and climate zone. The tool does not account for pump or fan energy.

Figure 1. Graphical depiction of the calculation process

User input
(SI or IP units)

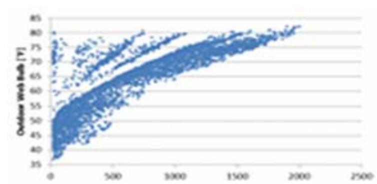
Program computation

myPLV output

Building:

- location
- type
- peak cooling load

- maps the location to a weather zone
- selects the PNNL building load data
- scales its 8,760 load data to the peak cooling load specified
- saves the weather and plant load data

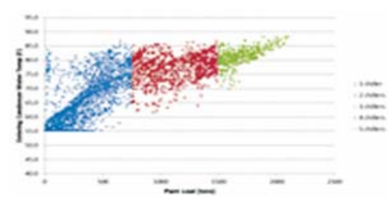


scaled building load scatter plot
(not viewable—displayed here to illustrate initial data set for plant and chiller load profiles)

Plant

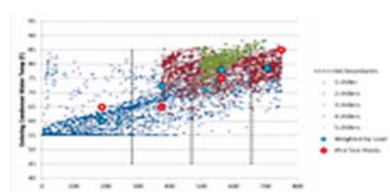
- number and size of chillers
- tower cell design performance (assuming one tower cell per chiller)
- the cooling tower control method

- determines how many chillers and tower cells are needed to satisfy each plant load point (hour)
- applies the tower cell performance and tower control against the outdoor load and wet-bulb temperature
- stores the 8,760 leaving tower water temperature (entering condenser) along with the individual chiller load results
- creates the **Plant Loading chart** shown



Plant loading chart
(viewable in the **myPLV Charts** tab)

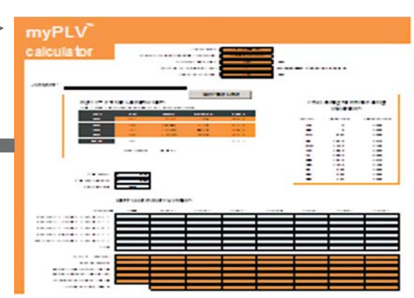
- segments the chiller loads into four operating zones (bins) based on 8,760 load points
- computes a weighted entering condenser water temperature and a fractional weighting for each bin
- records the maximum load for each month for electrical demand computations
- Creates the **Chiller Loading chart** and **Peak and Bin Loading tables**



Chiller loading chart
(viewable in **myPLV Charts** tab)

Peak and Bin Loading tables

User saves the file.
(Files can be saved separately for analysis of alternative chiller selections.)



High level data is copied to the myPLV **Bid Form** tab

Building Load Profile. Establishing a load profile is often the most difficult part of an energy and economic analysis. Fortunately, ASHRAE and Pacific Northwest National Labs (PNNL) provide a solution. As a result of various ASHRAE standards efforts, PNNL has created a library of annualized load profiles (8,760 hours of data) for various building types in all weather zones of interest. The myPLV tool incorporates 200 of these load profiles within its database. Each of the building types listed in Table 1 has been simulated within 20 climatic zones included in the myPLV database (Table 2) resulting in the 200 pre-defined data sets.

Users simply select location information and building type and enter a *peak tonnage* for their particular building. The program scales the PNNL load profile to the peak cooling tons entered. The resulting load profile can be viewed on charts generated by the tool.

Most of the building types listed in Table 1 have profiles both *with* and *without* an airside economizer. Those profiles representing systems without an airside economizer will contain loads during cooler outside conditions. Load profiles incorporating an airside economizer will eliminate most low temperature loads since the economizer will satisfy the needed cooling. For those chilled-water systems that incorporate waterside economizing (free cooling), users may wish to select load profiles with an airside economizer since the chillers will not be operating to satisfy loads during the cooler weather conditions.

A **custom load profile** can be entered for chiller plants with load profiles much different than the available buildings (i.e., process loads or data centers). Custom load profiles can be entered via the *Custom Load Input* worksheet. Users must enter 8,760 hours (one year) of data, including chiller plant load (tons), as well as the outdoor dry bulb and wet bulb temperatures. The program calculates the appropriate chiller submittal points.

To access the *Custom Load Input* worksheet, check the box adjacent to the *Region* input or choose the *Custom Load* selection in the *Region* drop down list on the *myPLV Calculator* tab.

Table 1. Building load types included in myPLV

Office	(with, without econ)	12 hour operation; 5 days a week
Hospital	(with, without econ)	24 hour operation; 7 days a week; heavier day occupancy
High rise apts	(without econ)	24 hour operation; 7 days a week; lighter day occupancy
Primary school	(with, without econ)	12 hour operation; 5 days a week; seasonal
Secondary school	(with, without econ)	12 hour operation; 5 days a week; seasonal
Hotel	(without econ)	24 hour operation; 7 days a week

Table 2. Weather zones included in myPLV

Zone	Very cold	Humid (A)	Dry (B)	Marine (C)
0		x	x	
1		x	x	
2		x	x	
3		x	x	x
4		x	x	x
5		x	x	x
6		x	x	x
7	x			
8	x			

Local Weather. Having representative weather data is key to overcoming the IPLV problem of oversimplified analysis techniques which assume the same chiller operating conditions from Jeddah, Saudi Arabia to Fairbanks, Alaska and everywhere in between.

The myPLV tool uses the 8,760 hour weather data set (TMY) contained within the PNNL load profile for a wide range of weather zones. Users may either enter a global location that maps to a standard weather zone according to the dataset contained in ASHRAE Standard 169, or enter the weather zone explicitly by selecting *By Climate Zone* in the *Region* dropdown. The selected weather conditions (ambient wet bulb and dry bulb) for each operating hour of the year are used to establish the operating conditions for the cooling tower or air-cooled condenser.

Chiller Plant Information. The number of chillers in the system and the capacity of the chillers are needed for myPLV to assess the operating conditions and time for the chiller-specific operating zones or bins.

The program assumes all chillers are equal capacity. Entering this information separate from the building peak load allows the program to account for oversizing of the plant capacity. The program outputs the plant oversizing factor per ASHRAE Standard 90.1, Appendix G for reference.

An undersized plant is flagged in red with a negative oversize factor. In this case, the program will produce a solution; however, it will assume additional chillers are available beyond that specified with the input set.

Cooling tower performance and control impact the operating conditions of the chiller for water-cooled plants. Users enter design tower performance data and selects a cooling tower control method. Based on this information, myPLV calculates the entering condenser water temperature for each hour of the load profile.

Chiller Performance. From the previous input information, the myPLV determines the weighted average operating conditions for the chillers in the plant for bins centered on the 25, 50, 75 and 94 percent chiller load points. The program also requires the chiller's full load design performance to assess utility demand charges and to ensure an appropriate chiller is selected to satisfy the design requirements of the job.

While the use of 25, 50, and 75 percent load points is similar to IPLV methodology, the ton-hour values and condenser water temperature weightings deviate from IPLV/NPLV to reflect the application. For the last bin, 87.5 percent to 100 percent chiller loading is represented by a center-weighted point at 94 percent. This better captures the chiller performance in this region and reduces error.

Using the 94 percent point instead of 100 results in a five-point rating system with the fifth point representing the design conditions for electrical demand calculation. While not used for the myPLV energy calculations, this fifth point assures that the selection process using myPLV will still result in an appropriate chiller for the load, lift and application duty required, and provide certified performance necessary for the system design.

This bin information, along with alternate pricing requested from the qualified chiller manufacturer can be input to calculate the annual energy usage and investment payback for the various chiller alternatives—completely impartial in its analysis.

myPLV Example

MyPLV is built as a Microsoft Excel® workbook. The two worksheets that require user input to perform the calculations are the *myPLV Calculator* and *myPLV Bid Form*.

myPLV Calculator: Building and plant configuration. Figure 2 shows user inputs in blue for the building and plant configuration in the myPLV Calculator worksheet. Inputs selected for this example include:

- Location: Memphis, Tennesse
- Building type: Office building with airside economizing (standard PNNL profile is used)
- Chiller type: Water-cooled
- Building peak load: 500 tons
- Number of chillers: 2
- Chiller size: 300-ton chillers

Next, the **cooling tower design data** is input (Figure 3). In this example, two cooling tower cells are selected at a design wet bulb condition of 80°F with a 5°F tower approach.

Figure 2. myPLV user inputs for building and plant configuration

Unit of Measure	IP
Region	North America
Country	United States
State/territory	Tennessee (TN)
City/location	Memphis (3A)
Building Type and Airside Economizer	Office with Econ
Chiller Condenser Type	Water Cooled Chiller
Building Peak Load	500 tons
Number of Chillers in Plant	2
Size of Each Chiller	300 tons
Plant Capacity (Calculated Point)	600 tons
ASHRAE 90.1 app G oversize factor (Calculated Point)	20%

Figure 3. Cooling tower design inputs

Design

Tower Full Load Design Performance - Tower Wet-Bulb Approach (°F)	5.0
Outdoor ambient Wet Bulb at design conditions (°F)	80.0

Control

Tower Control Method (°F)	Fixed Tower Approach
Tower Approach Setpoint (°F)	7.0
Minimum condenser water temperature (°F)	55.0

Figure 4. Submittal point generation in myPLV

Calculate myPLV™ Conditions

myPLV™ Test and Submittal Points

Enter chiller performance values for four submittal points.

% FL	tons	ton-hrs	weighting	ECWT	Chiller kW/ton
25%	75	81,870	11.7%	64.3° F	
50%	150	275,292	39.3%	77.5° F	
75%	225	263,267	37.6%	80.1° F	
94%	282	80,562	11.5%	79.4° F	
design	300		0%	85.0° F	
	Total ton-hrs	700,991		myPLV™	
				Annualized kWh	0

The towers are operated at a fixed tower approach setpoint of 7°F with a minimum water temperature of 55°F.

The final step in this worksheet is generating the submittal points. Pressing the **Calculate myPLV Conditions** button (Figure 4) generates the submittal points for the four load bins and the full load design operating conditions shown (Table 3).

Table 3. Submittal points generated

load (%)	tons	ECWT (°F)
25	75	64.3
50	150	77.5
75	225	80.1
94	282	79.4
100	300	85 (design)

The submittal points serve three purposes:

- First, they are used along with the chillers' performance at those points to determine the chiller's *myPLV rating number.*
- Secondly, they are used in the *myPLV Bid Form* to calculate the chiller energy use and cost for a year and a simple payback period for investing in more efficient chiller technology.
- Finally, they can be specified in the *chiller guide specifications* as the chiller factory test points to ensure the customer receives the chiller performance they purchased at the most important realistic operating conditions.

myPLV Bid Form worksheet: Alternate chiller performance and payback analysis. The myPLV program automatically copies the building and plant setup and the weighted submittal points to the *myPLV Bid Form* worksheet. This worksheet allows users to perform simple payback analysis between chillers with varying efficiency and price.

Figure 5 displays the user-entered chiller data (blue fields) used to compute the alternate chiller comparison performance metrics.

To perform a chiller comparison users gather myPLV point performance and price information for each chiller alternate as well as the local utility rates for the cost of energy consumption and demand power (e.g., cost per kWh, cost per kW demand, ratchet rate). For this example, the needed chiller performance data corresponds to chiller operating points shown in Figure 5 (A).

An example comparison follows for five different compressor technology, water-cooled chillers:

- Fixed-speed screw compressor (Base Scrw FS)
- Variable-speed screw compressor (Scrw VS)
- Fixed-speed centrifugal compressor (Cent FS)
- Variable-speed centrifugal compressor (Cent VS)
- Variable-speed high efficiency centrifugal compressor (HiE Cent VS)

The following electrical cost data is assumed; see Figure 5 (B):

- $0.12/kWh
- $10/kW demand
- 75 percent ratchet

The performance data for the five chillers is entered into the *Water Cooled Chiller Selection* table as a base chiller followed by four optional chillers. As shown in Figure 5 (C), the column labels can be edited to reflect each alternate.

It's expected that users will enter data for the lowest cost chiller into the baseline column. The more expensive chillers are assumed to be more efficient than the baseline and therefore may payback with a lower electrical cost.

Figure 5. Data input for alternate chiller performance metrics

Save and Send

A

myPLV™ Test and Submittal Points

Enter chiller performance values for four submittal points.

% FL	tons	ton-hrs	weighting	ECWT
25%	75	81,870	11.7%	64.3° F
50%	150	275,292	39.3%	77.5° F
75%	225	263,267	37.6%	80.1° F
94%	282	80,562	11.5%	79.4° F
design	300			85.0° F
	Total ton-hrs	700,991		

Peak Loading for demand charge calculations

Month	Peak tons	Demand tons
Jan	125	375
Feb	98	375
Mar	211	375
Apr	215	375
May	428	428
Jun	426	426
Jul	500	500
Aug	453	453
Sep	442	442
Oct	298	375
Nov	177	375
Dec	171	375

B

$ per kWh	$ 0.12
$ per kW demand	$ 10.00
Ratchet Rate	75%

Water Cooled Chiller Selections

C

Conditions	Base Scrw FS	Scrw VS	Cent FS	Cent VS	HiE Cent VS	Option 5	Option 6	Option 7
kW/ton @ 25% load, ECWT = 64.3°F	0.754	0.409	0.654	0.398	0.330			
kW/ton @ 50% load, ECWT = 77.5°F	0.634	0.502	0.581	0.486	0.444			
kW/ton @ 75% load, ECWT = 80.1°F	0.598	0.552	0.543	0.502	0.471			
kW/ton @ 94% load, ECWT = 79.4°F	0.569	0.577	0.532	0.517	0.486			
kW/ton @ 100% load, ECWT = 85.0°F	0.628	0.673	0.576	0.587	0.553			
Total Cost for All Chillers	$0.00	$9,000.00	$86,000.00	$104,000.00	$142,000.00			
myPLV™ (kW/ton)	0.623	0.514	0.567	0.483	0.440			
Annual kWh	439,538	363,489	399,301	340,187	312,399			
Annual Consumption Charge	$ 52,745	$ 43,619	$ 47,916	$ 40,822	$ 37,488			
Annual Demand Charge (Est)	$ 30,613	$ 32,806	$ 28,078	$ 28,614	$ 26,957			
Total Annual Energy Charge	$ 83,357	$ 76,425	$ 75,994	$ 69,437	$ 64,445			
Simple Payback (years)		1.3 Years	11.7 Years	7.5 Years	7.5 Years			

The cost for each alternate chiller combination can be entered as the actual full price or the baseline chiller model cost can be set to zero, and the difference between the baseline chiller and the specific alternate combination entered for the other chillers. Either method results in the same values for the simple payback computation.

For each chiller considered, the *myPLV Bid Form* computes the following:

- **myPLV value**—a formulation based on the weighted bin performance
- **Annual kWh energy consumption for the chillers**—the sum of the bin calculations of ton-hours multiplied by the kW/ton performance at that bin.
- **Annual consumption charge**—the product of the annual kilowatt-hours multiplied by the dollar per kWh specified by the user.
- **Annual demand charge**—a summation for 12 months where the monthly demand tons which includes the ratchet (from the monthly Peak Loading table) is multiplied by the chillers' 100 percent load kW/ton and further multiplied by the dollar per kW demand specified by the user.
- **Total annual energy charge**—computed as the sum of the consumption and demand costs.
- **Simple payback in years**—the difference in cost (option x - baseline) divided by the difference in the annual energy charge (baseline - option x).

Note that electrical rates vary considerably with as many different rate structures as there are utilities. The computations included in the myPLV spreadsheet attempt to capture only the basic calculation for a single electrical consumption cost per kWh and a single demand cost per peak kW.

Also note that actual building electrical demand is based on the building meter, not just the chiller power draw. The bid form only computes demand cost on an incremental per alternate chiller basis.

Finally, the electrical demand calculations use the chiller's design kW/ton value since it assumes they will be running at peak conditions when peak demand points occur. The chiller demand charges include the impact of the ratchet value. The program provides a monthly *Peak Loading* demand data table on the *myPLV Charts* worksheet for users who wish to better understand the value and effect of the chiller(s) demand.

The **Save and Send** button allows the user to save and/or e-mail the *myPLV Bid Form* with the job appropriate myPLV Test and Submittal Points in a separate working Excel file.

myPLV Output

The remainder of this EN explains some of the intracacies of the myPLV engine to help guide users on input selections. This adds transparency to the myPLV calculations.

Load charts. A review of the load charts is recommended to ensure the load profile looks appropriate for a particular application. myPLV enables users to examine plant operation and the weather impact via two weather and load-related charts shown on the *myPLV Charts* worksheet. The first chart (see Figure 6) describes the operation of the plant as a function of the outdoor wet bulb, if the chillers are water-cooled, or as a function of outdoor dry bulb, if the plant is air-cooled. To build the chart, myPLV sums the annual hours (blue line), operating hours (red line), and cooling ton-hrs for each outdoor temperature value and plots the trend line (black line).

Consider the following when reviewing the example chart:

- Does the trend for the number of annual and operating hours look appropriate with regard to the outdoor temperature?
- Does the plant shut down (operating hours goes to zero) at a temperature that makes sense in light of economizer operation?
- The peak wet bulb temperature varies considerably for dry climates and the default selections may not represent local conditions. This may only be a problem for the data near the peak wet bulb conditions. This is important to an accurate analysis because considerations such as design cooling tower and design chiller condenser water conditions need to reflect the plant locale.
- Is the peak outdoor wet bulb (in this case, ~82°F) representative of the locale that is being reviewed?
- Is an appropriate design wet bulb specified for the tower selection?
- Is an appropriate chiller design condenser water temperature specified based on the peak wet bulb encountered?

Figure 6. Summary trends for hours and ton-hrs as a function of outdoor conditions

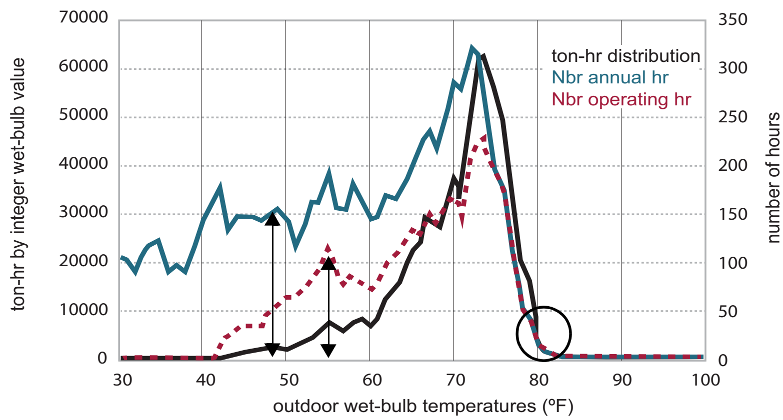
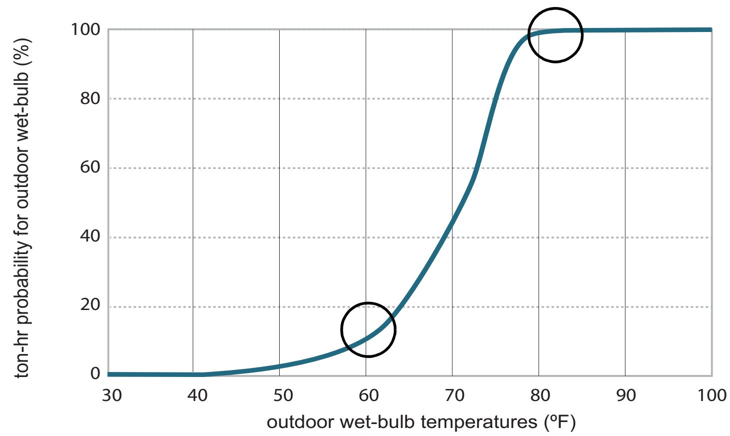


Figure 7. Load profile's percentage of cumulative ton-hrs as a function of the outdoor temperature



If the standard building profiles do not adequately reflect local conditions, then a custom load profile should be considered.

The second myPLV chart (Figure 7) displays the load profile's percentage of cumulative ton-hr as a function of the outdoor temperature. One observation from the example chart is that approximately 12 percent of the cooling ton-hr occur below a 60°F wet bulb and 100 percent of the ton-hr occur below 82°F wet bulb.

This chart illustrates the opportunity for waterside economizing (free cooling). For example, the best opportunity for waterside economizing is when outdoor wet-bulb conditions are approximately 45°F and below. However, the data on this graph indicates the percentage of annualized cooling load below 45°F is near zero—indicating little to no waterside economizing benefit.

Users need to be especially mindful of the operation of the building at low temperatures when evaluating a waterside economizing opportunity.

Also note that the PNNL load profiles used in myPLV were developed for ASHRAE Standard 90.1-2010. Per this ASHRAE Standard, at low temperature outdoor conditions, mechanical ventilation is provided to the rooms. As a result, there is a natural economizing effect because most of the cooling load for the building is satisfied at these conditions. However, if the actual building has less outdoor air ventilation or the ventilation is pre-conditioned to room-neutral conditions, then a significant chiller plant cooling load may exist that the PNNL load profile incorporated in the myPLV tool does not include.

Cooling tower performance and control (water-cooled plants). Cooling tower design performance, operating limits and control method are required inputs for myPLV to calculate the correct 8,760 hour chiller load point Entering Condenser Water Temperature (ECWT). With this information the program can generate the appropriate submittal point ECWT data.

As illustrated in the earlier example, cooling tower design performance is specified by the user by entering *Design Full Load Tower Wet-Bulb Approach* and the *Design Outdoor Wet-Bulb Temperature* (Figure 3). Tower control is specified by selecting one of four control methods along with the corresponding control setpoint and the minimum allowed condenser water temperature.

The program performs two calculations to determine the correct ECWT for each operating hour and takes the maximum temperature of the two.

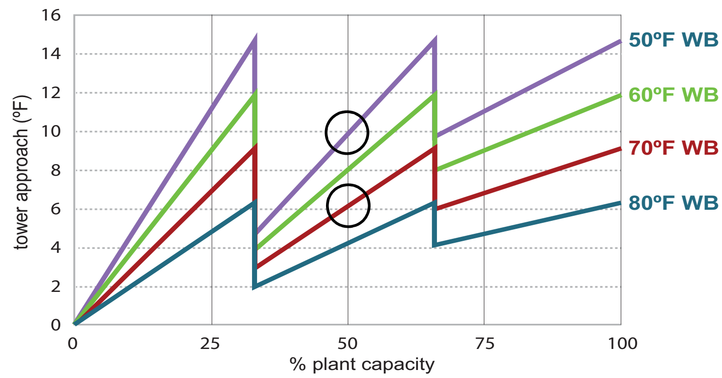
First, myPLV determines the ECWT based on tower performance at full fan power as illustrated in Figure 8. The program computes the ECWT as a sum of the ambient wet-bulb temperature plus the tower approach. Since this computation reflects tower operation at full fan power, the value computed is the lowest ECWT possible.

The second calculation is based on the user selected *Cooling Tower Control Method.* The four tower control selections supported are listed below and discussed in the next section:

- chiller tower optimization
- fixed tower approach
- fixed temperature
- full tower fan flow

Generally speaking, the *operating ECWT* provided by the tower for any hour may be quite different from the entering condenser water temperature based on full fan power, since the cooling tower fans are actively controlled to a setpoint condition. As long as the tower control setpoint is causing the fan speed to operate below its maximum speed, the cooling tower provides a water temperature based on the method of control. The *lowest ECWT* is only used when the control method causes the tower fans to operate at maximum speed.

Figure 8. Tower approach assumed for full fan power



Cooling tower performance curves used for the ecwt prediction. The tower cell performance was specified to be a 7°F approach at a 78°F wet bulb.

ECWT Example. Assume the chiller plant is operating at a 50-percent load point and the tower control is asked to supply 75-degree water (see Figure 8). If the outdoor wet bulb is 50°F (purple line), the tower approach would be 10°F if the tower fans were running full speed. This results in a *lowest ECWT* of 60°F (50°F WB + 10°F approach).

Since the control system calls for 75°F water, the tower fans are slowed (or cycled) until the *operating ECWT* is 75°F. If, however, the outdoor wet bulb temperature is 70°F (red line), then the tower approach is 6°F and the lowest leaving tower temperature at full fan flow is 76°F (70°F WB + 6°F approach).

In the latter case, myPLV program returns an *operating ECWT* of 76°F, even though the setpoint was 75°F.

So what causes the saw tooth pattern? In order to simplify the myPLV program, the chiller and tower cell sequencing is assumed to occur at the chiller design tonnage. Since three chillers were specified for the plant, chillers and tower cells are turned on at 33 percent and 67 percent of the plant capacity. At these steps, the amount of heat rejection to the tower cells is redistributed to the additional tower cells and the active towers' heat rejection and therefore the tower approach drops accordingly.

Also note that the tower approach increases as the ambient wet bulb temperature decreases. This is due to the reduced latent heat capacity of the air at lower temperatures.

Tower control methods. The following provides more detail for each control method within the myPLV tool. Note that any of the following control methods may specify a low ECWT that cannot be achieved by the cooling tower operating at full fan power. In this case the ECWT used by myPLV for this load point is the ECWT operating at *full fan power* (the higher value).

Full tower fan flow. . This selection determines the ECWT that results from the cooling tower running at full fan speed (lowest ECWT) for each hour's conditions (see Figure 8). However, if the result is a temperature less than the minimum user-specified value, the temperature will be set to the minimum value specified.

Fixed temperature. This control method is typical of many installations that run the cooling towers to a constant temperature setpoint. This selection requires a temperature setpoint entry by users. This method of control was described in the previous ECWT example.

Fixed tower approach. This selection computes an ECWT equal to the outdoor wet-bulb temperature value plus the tower approach setpoint entered by the user. If this method results in a temperature value less than the minimum user-specified value, the temperature will be set to the minimum value specified.

Chiller-tower optimization. . This selection simulates a Trane algorithm for a dynamic and optimally changing ECWT setpoint as a function of chiller loading and ambient wet-bulb temperature. As with other control methods, if this method results in a temperature value less than the minimum condenser water temperature specified, the minimum temperature setpoint value will be used.

The tower control strategies for Chiller Tower Optimization, Full Tower Fan Flow, and Fixed Tower Approach will yield similar *looking* results for submittal point ECWTs since each of those control methods' resulting condenser water temperatures will be moving with the outdoor wet bulb. The main difference is how the particular control mode affects tower fan power which is not part of the myPLV analysis.

However, the *Fixed Temperature* selection can dramatically change the chiller selection points since this control method creates a minimum condenser water temperature at all wet-bulb temperatures. Depending on the user-specified fixed setpoint, the submittal point ECWTs may be higher than the other control methods (high fixed setpoint) or close to the *Full Tower Fan Flow* ECWT (low fixed setpoint). In any case, this minimum is reflected in the weighted condenser water temperatures for the four binned performance points.

Chiller Loading Chart. The scatter plot on the *myPLV Charts* worksheet detailing the myPLV/IPLV entering condenser water temperatures for the chillers deserves some explanation. Figure 9 shows the chart for a three-chiller plant with the chillers sized at 750 tons.

The plot shows the load and ECWT for each hour of chiller operation. The small blue data points detail those conditions where only one chiller is operating. The maroon points detail the operating conditions when two chillers are operating, and the green data points show where all three chillers are running.

In other words, the first chiller runs at all conditions detailed by the blue, maroon, and green data points. The second chiller runs at the conditions detailed by the maroon and green data points. Finally the third chiller only runs at the conditions shown with green data points.

The chart is broken up into four bins with three dashed vertical lines as separators. The first vertical line is positioned midway between the 25 and 50 percent bin points at a 37.5 percent chiller load (281 tons). The second is positioned midway between the 50 and 75 percent bin points at 62.5 percent (469 tons). Finally, the third vertical dashed line is positioned 12.5 percent to the right of the 75 percent bin point at 87.5 percent (656 tons).

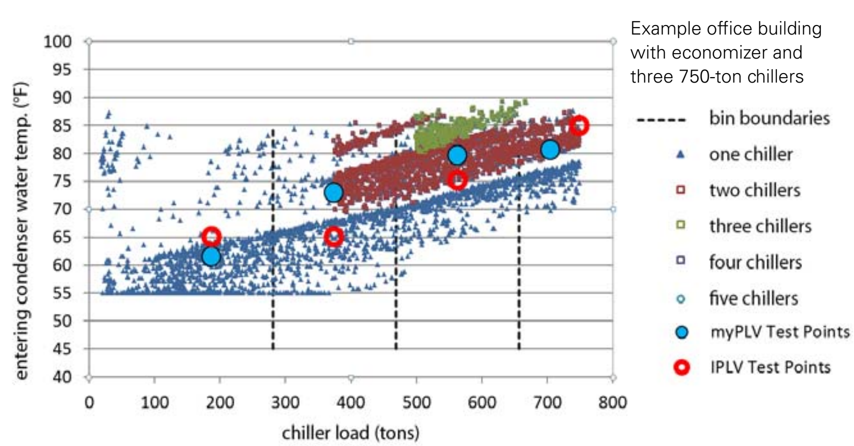
For this example, a 55°F minimum condenser water temperature was specified and therefore, the minimum condenser water temperature for all the load points was at 55°F.

The myPLV and IPLV rating points are also illustrated on the plot—the blue circles and the red open circles respectively. The blue myPLV circles represent the load in tons at the 25, 50, 75 and 94 percent load points, and the corresponding myPLV submittal point condenser water temperatures.

Note that the myPLV point ECWT are a ton-hr weighted temperature of all the load points in each bin. The open red IPLV circles are shown for comparison and represent the condenser water temperature for the IPLV rating points. This allows users to determine if there are significant differences between IPLV ECWT and actual ECWT.

Note: The chiller-tower optimization control strategy calculation and, in some cases, the fixed-tower approach setpoint may assume the chiller can run reliably at a condenser water temperature that is slightly above the design point. This is typically a good optimization assumption and may work well to reduce overall system energy. However, users should review the scatter plot of the computed ECWT to decide if the tower control method or chiller design point should be modified.

Figure 9. myPLV/IPLV entering condenser water temperatures for the chiller



Air-cooled vs water-cooled. The myPLV computations become simpler when an air-cooled device is considered. For the case of air-cooled chillers, the entering condenser temperature comes directly from the outdoor dry-bulb temperature in the weather data.Therefore, the bin analysis used to compute a weighted condenser condition is processed directly on the outdoor dry-bulb value, in contrast to evaluating a cooling tower control method for a water-cooled chiller.

Summary

myPLV is based on bin methodology that leverages the PNNL Energy Plus modeling results to create an easy-to-use methodology to guide chiller selection based on specific user conditions.

The accuracy for the condenser conditions is achieved by adjusting ECWT for load, outdoor air wet bulb, and tower control and by the use of ton-hr weighting for the myPLV submittal points.

These submittal points enable users to gather actual certified performance data from chiller manufacturers at meaningful weighted conditions and then convert them to energy usage and cost.

The result is a simple, accurate and transparent chiller analysis tool that can be used to analyze any chiller's performance to make a more informed choice for the chiller equipment.

If a complete plant energy analysis is necessary, a full energy model using a tool such as TRACE® Chiller Plant Analyzer should be used for analysis.

Visit **www.trane.com/myPLV** to download the latest version of myPLV™

By Brian Sullivan, systems engineer, and Jeanne Harshaw, program manager, Trane. You can find this and previous issues of the Engineers Newsletter at www.trane.com/engineersnewsletter. To comment, send e-mail to ENL@trane.com.

References

[1] ASHRAE/IES 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings.

[2] EnergyPlus files developed by Pacific Northwest National Labs (PNNL) The web site for the PNNL files can be found at http://www.energycodes.gov/development/commercial/90.1_models.

www.Trane.com/bookstore

Learn HVAC design strategies and earn credit

On-demand continuing education credit for LEED® and AIA. 90-minute on-demand programs that are available free of charge. New courses include:

- *Variable-speed Compressors on Chillers,*
- *Coil Selection and Optimization, and*
- *Evaluating Sound Data.*

All courses are available at www.trane.com/continuingeducation.

Engineers Newsletters. Quarterly articles that cover timely topics related to the design, application and/or operation of commercial HVAC systems. Subscribe at www.trane.com/EN.

Air conditioning clinics. A series of educational presentations that teach HVAC fundamentals, equipment, and systems. The series includes full-color student workbooks, which can be purchased individually. Approved by the American Institute of Architects for 1.5 (Health, Safety and Welfare) learning units. Contact your local Trane office to sign up for training in your area.

Engineers Newsletter Live. A series of 90-minute programs that provide technical and educational information on specific aspects of HVAC design and control. Topics range from water- and airside system strategies to ASHRAE standards and industry codes. Contact your local Trane office for a schedule or view past programs by visiting www.trane.com/ENL.

Application manuals. Comprehensive reference guides that can increase your working knowledge of commercial HVAC systems. Topics range from component combinations and innovative design concepts to system control strategies, industry issues, and fundamentals. The following are just a few examples:

- **Central Geothermal Systems** discusses proper design and control of central geothermal bidirectional cascade systems that use borefields. This manual covers central geothermal system piping, system design considerations, and airside considerations. (SYS-APM009-EN, February 2011)
- **Chilled-Water VAV Systems** discusses the advantages and drawbacks of the system, reviews the various components that make up the system, proposes solutions to common design challenges, explores several system variations, and discusses system-level control. (SYS-APM008-EN, updated May 2012)
- **Water-Source and Ground-Source Heat Pump Systems** examines chilled-water-system components, configurations, options, and control strategies. The goal is to provide system designers with options they can use to satisfy the building owners' desires. (SYS-APM010-EN, updated November 2013)

Visit **www.trane.com/bookstore** for a complete list of manuals available to order.

Visit www.Trane.com/TRACE to download your 30-day trial

TRACE™700 v6.3.2 Now Available

The latest version of TRACE 700, version 6.3.2, allows designers and engineers to run cooling plants much closer to optimal behavior with **optimal sequencing** type. In addition we've partnered with Hewlett-Packard to add sophisticated evaporative cooling features and improve reports and **expanded energy recovery** options to support growing trends in data center system design.

ASHRAE Standard 170 ventilation calculations have been added to offer direct support when designing for health care facilities. Choose ventilation requirements for Standard 170, 62.1 or a combination of both.

Visit **www.Trane.com/TRACE** to view version details or download a free 30-day trial. While you're there read about the winning teamwork of Trane C.D.S. group and industry leaders at the ASHRAE Energy Modeling Conference LowDown Show Down.

Trane,
A business of Ingersoll Rand

For more information, contact your local Trane office or e-mail us at comfort@trane.com