Comparing Constant-Speed And Variable-Speed Centrifugal Chillers

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This column compares the performance of a typical constant-speed, two-stage centrifugal chiller with a comparable variable-speed centrifugal chiller at similar price points. In an attempt to do a comparative performance benefit based on similar chiller price, the base efficiency of the constant-speed chiller was improved by 10% by taking the additional dollars spent on a variable-speed drive and applying it to improve the design performance for the constant-speed unit (generally in the form of more effective heat exchangers). In addition, a 3% efficiency penalty was used for the variable-speed chiller to account for inverter losses. The overall performance for the constant-speed chiller is 13% better than that of the variable-speed chiller at design conditions.

The performance shown in *Figure 1* represents trends for typical performance. Specific performance will vary between product lines, and is dependent on the individual chiller selection, number of compressor stages and type of refrigerant cycle. However, the trends in *Figure 1* represent the general behavior of a constant-speed versus variable-speed comparison for all forms of centrifugal chillers. Finally, this discussion is applicable to water-cooled chillers and the data shown is for a constant condenser water flow rate.

Figure 1 shows chiller performance, in terms of kW/ton, at various load points and entering condenser water temperatures. Constant-speed performance is designated by solid lines and variable-speed performance by dotted lines.

The performance trends for a constant-speed chiller are quite different from those of the variable-speed chiller. At all entering condenser water temperatures, constant-speed chillers tend to have their best performance at full-load (100%) operation. Therefore, to optimize system efficiency, constant-speed chillers are generally run to full load before starting an additional chiller. Conversely, variable-speed chillers have performance curves that scale with the chiller speed and entering condenser water temperature. Variable-speed chiller peak performance tends to occur at loads less than full. Also, as entering condenser water temperature is reduced, compressor rotational speed is reduced and performance is further enhanced.

Observations

- Variable-speed chillers have a performance advantage at lower-than-design condenser water temperatures and chiller loads. The benefit of such operation must be evaluated using the plant load profile and then weighed against the price and benefit of other chiller options.

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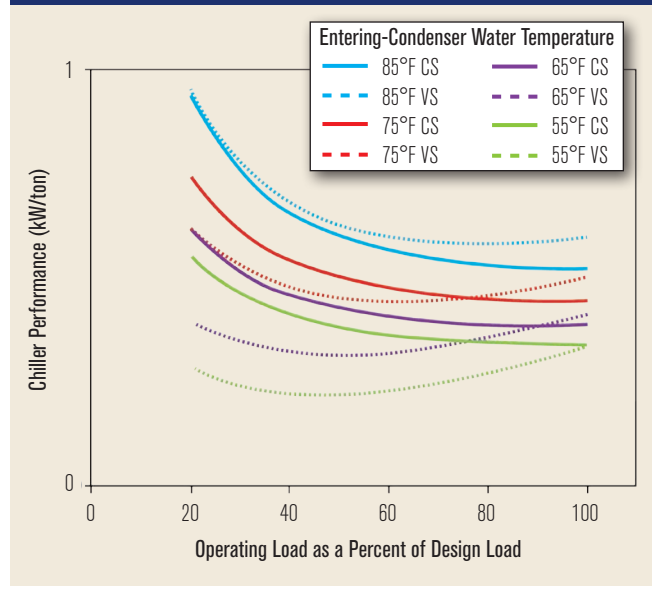
- Similar price, constant-speed chillers operate more efficiently than variable-speed chillers throughout their operating range if the entering condenser water temperature remains near design. In this case the design entering condenser water temperature was established at 85°F (29.4°C) with the compressor impeller diameter selected for this condition.
- Combining these first two observations:
  - If the tower water temperature is either controlled to be near design, or if the system is located in a consistently humid climate, the constant-speed chiller selection will likely provide better performance.
  - For variable-speed chillers a proper cooling tower control strategy must be used to take advantage of low outdoor wet-bulb conditions, when available, to achieve "lower than design" condenser water temperatures. Care should be exercised to ensure excessive condenser water pump and cooling tower fan energy do not occur when the control strategy is implemented.

FIGURE 1 Centrifugal chiller performance comparison (equivalent price) constant speed (CS) and variable speed (VS).



- If demand charges are significant, the 13% design power difference will result in a significant increase in operating cost.
- In multiple chiller plants, one might consider a combination of constant-speed and variable-speed chillers to take best advantage of reduced energy consumption as well as electrical demand charges. In these cases, the best return on investment often occurs when high efficiency variable-speed chillers are used extensively for all low load and low temperature operation. Constant-speed and variable-speed chillers are used at high load conditions when high outdoor temperatures prevail.
- The variable-speed cost adds for low voltage chillers (<=600 volts) are considerably lower than those for medium and high voltage drives (>600 volts). The benefits of variable speed must be evaluated accordingly.

In summary, variable-speed and constant-speed centrifugal chillers perform differently with respect to load and entering condenser water temperature. While both benefit from reduced condenser water temperature a variable-speed chiller benefits more. Designs should examine similar price constant-speed and variable-speed chillers, and determine the appropriate mix depending on the plant location, condenser water control, load profile, and separate consumption and demand charges. ■