Load Matching And Capacity Control

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This column is the fourth in a series exploring refrigeration and heat pump concepts without using jargon.

In the May column we considered ways to measure refrigeration system efficiency and skirted round the issue of how to improve it. The simple answer to this is to find ways to reduce the electrical input required to achieve the necessary throughput of pies, beer or pallets without reducing the quality of the product. Since pretty much everything in the system is variable (including the quantity of product being processed, the cleanliness of the heat input and output devices and of course the weather), it follows that the cooling demand required of the plant will not always be the same.

Most systems very rarely run at maximum capacity. They are designed for a hot summer day when the overall temperature lift will be at a maximum. If the cooling load is a function of ambient temperature, then warm weather is a double whammy: the load is high and the temperature lift is also high.

Things that freeze stuff in batches (including ice rinks and thermal storage systems as well as food factories) have a high heat load at the start of the freezing process, but this quickly reduces as it becomes more difficult to take out the remaining heat from the middle of the stuff. Most refrigerating systems, including water chillers, operate most of the time on less than 70% load, and some of them may usually operate on less than 50% load.

To decide on an efficiency improvement strategy, it is necessary first to determine what is expected of the plant as the load varies. Many compressors become progressively less efficient as they reduce capacity, particularly screw compressors with slide valve control. Others will tend to reduce electrical consumption in proportion to load reduction, but might only be able to change the load in quite large steps.

With some system designs it is even conceivable that the plant becomes more efficient as it offloads, particularly if the compressor speed can be changed to match the requirement, or if the full surface area of the heat input and output devices can be used when only a portion of the full cooling capacity is required. If your efficiency improvement strategy is not based upon a right understanding of this key behavior of the plant, then it is likely to give poor results.

If the compressor is most efficient when on full load, then the cooling requirement can still be matched by arranging the sys-

tem so the compressor runs at full load for a portion of the time and then switches off.

The Earl of Essex, commander of the Parliamentary forces at the start of the English Civil War in 1642, is said to have remarked "stone dead hath no fellow" when calling for the death penalty for the Earl of Strafford, principal advisor to King Charles. Certainly, the compressor cannot consume any less energy than when it is not running, so a system that is most efficient on full load will give the highest pies per kWh if it alternates between running flat out and switching off. However, too many stops and starts per hour will also hurt the efficiency (and perhaps the reliability) so some folk prefer their plant to match the heat load exactly in order to avoid stops and starts.

The key to combining both strategies is to make sure that the temperature control band is not too narrow. A wider band will allow the compressor to load up to its peak efficiency and run for a reasonable length of time. It will then switch off, and will stay off until the control temperature rises up through the band and triggers a restart. For example, if the control band is only 1°F (0.6°C) wide and the plant is 50% loaded, then it could run all day on 50% of full load (which would typically consume as much as 70% of full power). If it was loaded up and then switched off, it might cycle on and off again quite rapidly.

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Tonto explains how to loosen the reins to improve efficiency.

For example, if one on-off cycle takes five minutes, there will be 12 starts per hour, which would be inefficient and potentially damaging. However, simply changing the control band to make it ±3°F (±1.7°C) would cause the compressor to start, load up to 100% and run like that for 15 minutes before switching off for a further 15 minutes—only two starts per hour. It is a common mistake to think that tight temperature control equals good practice in all respects.

If it is OK to loosen the reins a little, plant efficiency may be much improved, provided product quality is not affected. With chilled water systems, fitting a larger tank can have the same effect as widening the control band, provided it does not push the operating temperature of the chiller lower than it needs to be.

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