Title
Best Practice for Energy Efficient Cleanrooms: Control of Chilled Water System

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Summary

Cleanroom energy benchmarking data shows that there is a variety of chilled water system designs and operation efficiency for cleanroom facilities in high-tech industries. Operating efficiency of chilled water systems is critical to the overall energy efficiency of the chiller plant, which may have a significant impact on energy use for such facilities.

Together with fans for delivering air to and from cleanrooms, chiller plants usually serve cleanroom facility and adjacent spaces simultaneously and use significant energy and water. Figure 1 shows benchmarked HVAC energy usage in a semiconductor cleanroom facility. In this case, the chillers and pumps account for more than half of the total HVAC energy use. Therefore, it is important to design, select, operate, and control chiller plants to achieve high efficiency and to lower life-cycle costs for cleanrooms and their adjacent spaces.

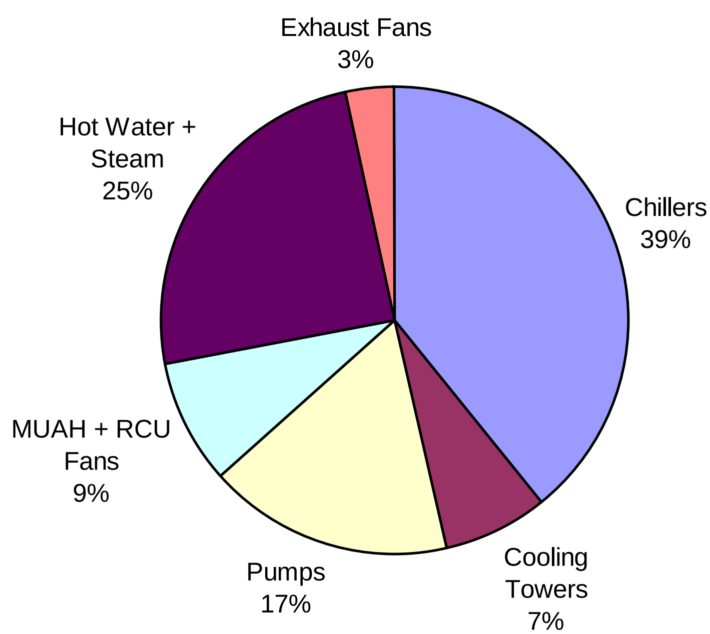

Figure 1. Benchmarked HVAC energy usages in a semiconductor cleanroom facility

Principles

The overall efficiency level of a chilled water plant is influenced by the efficiency of individual components and subsystems in the plant. Major components include chillers, primary loop chilled water pumps, secondary loop chilled water pumps, condenser water pumps, and cooling towers for water-cooled chillers. While nominal energy efficiency ratings of individual component influence the overall chiller plant efficiency, how the equipment is controlled and operated also largely determines the overall chilled water plant efficiency.

A larger temperature delta (or 'lift') of chilled water inherently is less thermally efficient for the cooling process in a chiller system, thus calling for more electric power to remove the same amount of heat. Typically a larger temperature lift is due to the fact that the chiller operates at a lower chilled water supply temperature. Therefore, properly increasing chilled water supply temperatures may improve the efficiency while meeting cooling requirements for cleanroom facilities.

Best practice approaches

Normally, for centrifugal compressor-based chillers, an increase of one degree in the chilled water supply temperature can increase the operational efficiency of the chiller by 1 to 2 percent. If a chiller can supply chilled water at 55°F, it will be approximately 15 to 30 percent more efficient than when it produces chilled water at 40°F (cooler). Based upon energy benchmarking and on-site observation, it is often feasible to implement a chilled water temperature reset to improve chiller performance whenever the system allows.

Figure 2. Chiller

Case studies

Normally, water-cooled chillers are more efficient than their air-cooled counterparts, and name-plate chiller efficiency is different than its operating efficiency. The efficiency of the chiller, however, often dominates overall chilled water plant efficiency. Water pumping energy can sometimes be significant. The best practice approach includes improving chiller and pumping efficiency.

Figure 3 shows the variations in water-cooled chiller efficiency for a group of cleanroom facilities. The chilled water temperatures ranged from 36 to 40°F, while the chiller efficiency ranged from 0.4 to 1.2 kW per ton. The best practice water-cooled chiller efficiency was 0.4 kW/ton based upon the benchmarked data, for chillers producing 43°F chilled water. On the other hand, the least efficient chiller was operating with 36°F degree chilled water temperature. The chillers with higher chilled water temperatures tended to be operating more efficiently. For example, in once case, chillers operating at higher chilled water temperatures such as 55°F, and lower condenser water temperatures such as 74°F, can operate at even better efficiency, e.g., 0.31 kW/ton.

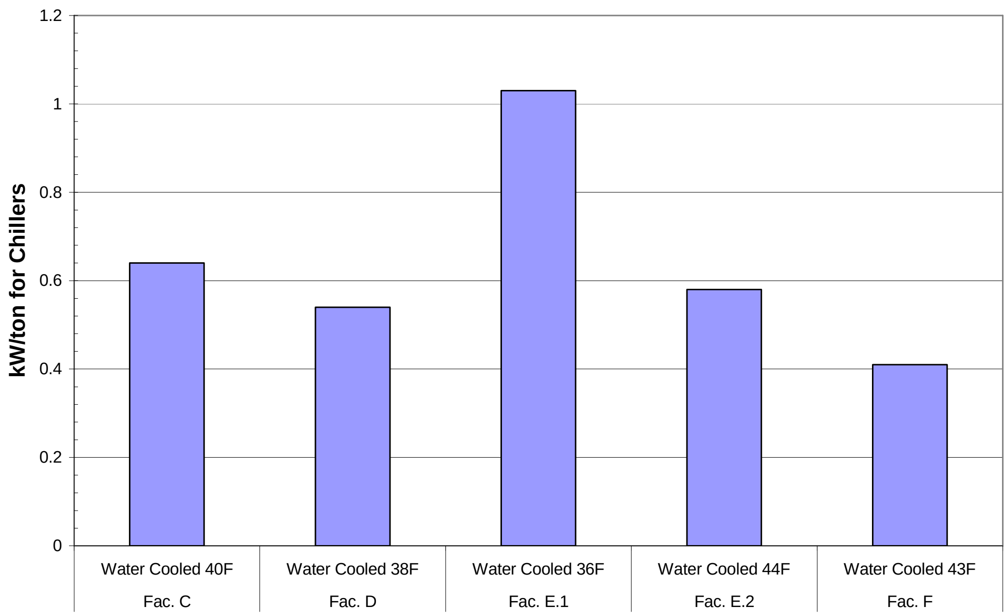

Figure 3. Water-cooled chiller efficiency

One of the energy-efficiency measures is to set the temperature based on the outside air temperature. Because lowering the chilled water temperature difference would entail higher water flowrate, and increase the electric demand for pumping power. The trade-off of increased pumping power requirements and increased chiller efficiency should be considered, however. The best practice approach can be applied to any chilled water systems including glycol-chilled water systems.

It's obvious that opportunities exist to improve operating chiller efficiency as illustrated in the figure. In general, measures such as chilled water temperature reset, improving control, and providing VFD for fan motors may improve the operating efficiency of chillers. The following include best practice in control and operation of chilled water systems.

Depending on the outside air conditions at certain time of the day or night, the supply temperature of chilled water may be increased to improve operating efficiency of the chiller. During the nighttime hours on dry days, the amount of dehumidification of the air stream in the makeup air handler is usually lower and the cooling intensity becomes lower. In such a case, measures of increasing supply temperature may be feasible.

Related best practice

- Right sizing
- Cooling tower and condenser optimization
- Variable speed chillers including chiller efficiency
- Variable speed pumping
- Free cooling
- Dual temperature cooling loops

References and resources

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