Feature
Story

System Optimization:
Is fear holding us back?

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District cooling system optimization has always made good economic sense. After all, producing a cooling Btu can cost up to 2.5 times as much as a heating Btu, making it especially important to optimize cooling systems. Today, it may be one of the most cost-effective investments that a plant manager can make. Technologies certainly have improved over the years: Chillers are more efficient, and control systems are now finely tuned – both of which make optimization more achievable. But what if a plant manager discovers that the potential operating efficiency of the system is limited by its original design? Can it still be optimized?

Yes, a district cooling system can still be optimized, but it's worth a step back to understand the reasoning behind that original design. The engineers who created it undoubtedly aimed to do the right thing to meet client expectations. Nobody intentionally designs an inefficient system. However, in the quest to guarantee system reliability and complete a project on time and on budget – two laudable goals – fear of failure can result in a less-than-optimal design.

The first fear is that the system won't work under every possible operating scenario. So there may be a tendency to overdesign district cooling systems to protect system owners and operators. While good in concept, it can result in significant energy inefficiencies and higher costs.


Courtesy WM Group Engineers PC

These images from a chilled-water plant at a major university show the plant before and after numerous pumps were removed.

The second fear is that the project won't be profitable enough or will not be completed on time, and the consulting firm won't meet its productivity goals. When a project budget is tight, it is tempting to look at similar past projects and 'copy and paste' solutions onto new systems. There is nothing wrong with utilizing solutions that have proven to be successful, but to achieve maximum efficiency, the intricacies and special features of each new system must also be addressed – especially if a new plant needs to be integrated with an existing system.

The good news, though, is that good detective work, effective system redesign and comprehensive training can bring about significant change in operational efficiency. As shown in the case studies presented here, pumping system design is quite often the major inefficiency culprit. By addressing this issue and adopting new operating practices, facility designers and managers can move forward with confidence and finally realize increased energy and cost savings.

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All Pumped Up

As everyone knows, pumps installed in district cooling systems consume energy. The greater the number of pumps and the more they operate, the more energy they consume and less energy-efficient the district cooling system becomes. Different types of pumping systems consume more energy than others: Primary-second-tertiary systems are most energy-intensive, followed by primary-secondary, then variable-primary.

In the past, many chiller plants were designed with primary-secondary or primary-secondary-tertiary pumping systems. (In fact, it still happens today.) By design, the primary-secondary and primary-secondary-tertiary pumping systems mix supply and return water through a decoupler, which causes a decrease in temperature differential (delta T). A low delta T requires more chilled water to flow through the system. This not only results in increased pumping energy, it also reduces chiller operating capacity. (Chiller capacity equates to flow times delta T, divided by 24. As a result, constant primary flow with lower delta T results in a loss of chiller operating capacity.)

The loss of operating capacity means additional chillers must be used to meet the load, which causes them to operate at low-load conditions, decreasing chiller efficiency and increasing power consumption. Operating more chillers requires corollary use of cooling towers and other auxiliaries, which further increases power consumption.

Another cause of poor efficiencies is the fear of connecting multiple plants to operate as a virtual central system. Just as electric generating plants are synchronized, so can hydronic plants be synchronized. The beauty of a virtual central system is that it allows one plant to operate efficiently during the spring and fall shoulder seasons and other plants to be shut down. This reduces energy, staffing and maintenance costs. The virtual system also frees up standby equipment at each plant and helps to recover millions of dollars of investment.

Thinking Before Designing

Some engineers have their own signature plant designs. If a plant design has worked well once, the consultant does not want to change the concept and applies it to subsequent projects. Since design peer review is not common, this 'copy-and-paste' approach is rarely questioned.

A perfect example is a particular 1970s-era district cooling system that was expanded in 2005. It demonstrates how a well-thought-out design from 1970 was changed to the signature design of the new consultant in 2005.

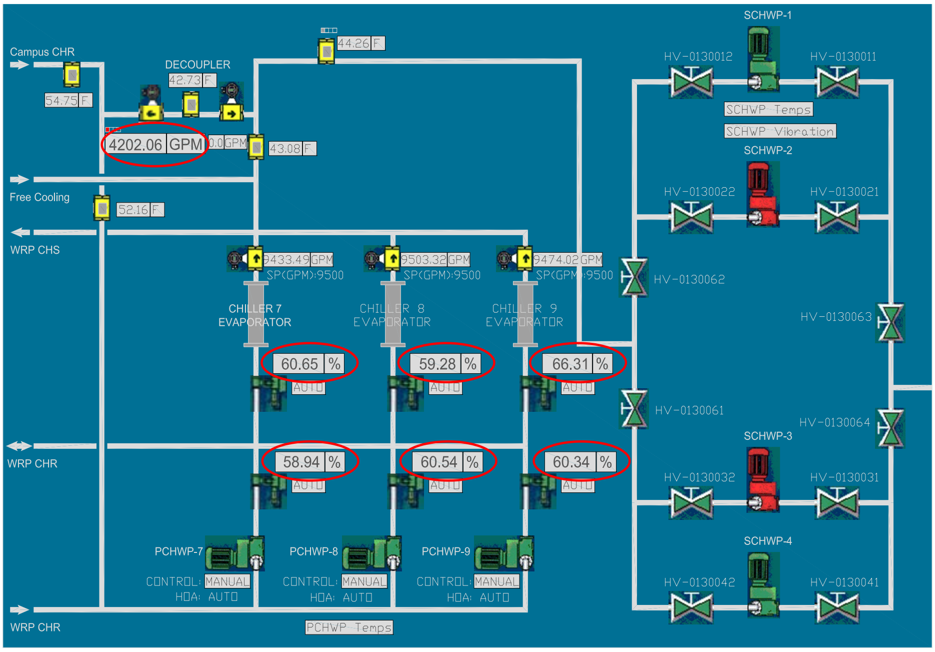
The 1970 design was comprised of two banks of series counterflow chillers with a variable-primary system. The system was designed with a solid vision and worked great for more than 25 years. When the system was expanded in 2005, however, the variable-primary system was converted to a primary-secondary system. As a result, the system's energy consumption per ton-hour has increased over the past five years. Also during expansion, the total system pumping head was increased from 275 ft to 350 ft. Now the only way to run the plant is to keep the valves partially closed to eat up the excessive pressure.

Figure 1 shows the plant's primary pump operation after the 2005 expansion. The pumps' constant operating speed delivers a high flow to the chillers, requiring throttling of two valves in series to maintain the desired flow through the chillers. In fact, since the two valves in series are only partially open, the system experiences a substantial pressure loss, causing the pumps to work harder and consume more energy. The plant decoupler recycles thousands of gallons of water, further reducing the chilled-water delta T.

At the same plant, the total pumping head for the condenser water is approximately 90 ft. The condenser water pumps, however, were overdesigned with 130 ft of head at the given flow. Once again, similar to the chilled-water system, two valves in series were throttled to maintain the desired flow. Again, this increases the amount of energy used to operate the pumps.

Work is now under way to convert the pumping system back to a right-sized variable-primary configuration.

Figure 1. Screen Capture From a Building Management System. This screen capture shows the primary pumps in operation as a primary-secondary pumping system. The two valves in series must remain partially closed (shown here ranging from only 58.94 percent open to 66.31 percent open) to correct for the oversized primary pumps and high flow (4,202 gpm) through the decoupler, further reducing delta T.



Source: Confidential.

Courtesy WM Group Engineers PC.

Pumping system design significantly affects district cooling system efficiency. Quite often, numerous pumps can be removed to save a facility energy and money. Hemant Mehta is shown here with 23 pumps that were removed from an 18,600-ton chilled-water system. Nine additional pumps were bypassed. The facility is reporting nearly $1 million in annual cost savings.

Case Study: Major Cancer Center

In many instances, system optimization can be achieved with simple solutions. Such was the case at a major cancer center that had been aggressively expanding its facility and, as a result, experiencing substantial cost increases for infrastructure – specifically cooling and power. Plus, its location makes it subject to an electrical peak-power-reduction program to ease the grid's load.

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The cancer center realized that its four chilled-water systems, totaling 18,600 tons of capacity and serving multiple buildings across the campus, were a major electrical power draw. The cancer center brought in WM Group to review the chilled-water system to determine how to simplify the system and reduce peak electric power use. The firm prepared a feasibility study, which included a detailed survey of site chilled-water generation, distribution and utilization systems, and made these observations:

- The system was an ideal candidate for conversion to a virtual central cooling system.
- All chilled-water plants had primary-secondary-tertiary pumping systems.
- The design delta T was 12 degrees F, while actual delta T on a peak day was 10.7 F; it was even lower during part-load conditions.
- A total of 375 ft of pump head had been installed at one plant, with a total of 200 ft of pump head installed at another. The benchmark for these size systems is around 160 ft.
- Multiple expansion tanks were on line. To maintain a single system pressurization point, only one expansion tank should have been on line when only one plant was operating.

WM Group concluded the following:

- All plants should be interconnected to work as one virtual central system.
- The interconnection would further reduce the pumping head requirement to 130 ft.
- All the tertiary pumps in the main campus and building booster pumps should be removed or bypassed. The existing injection valves should be bypassed or set to be completely open at all times.
- More than 32 pumps should be decommissioned, of which 23 should be removed from the site.

The cancer center received a $662,000 grant from a state energy agency to optimize the system. The conversion enabled the cancer center to operate fewer chillers at low-load conditions. Instead, more chillers were able to run at their 'sweet point,' and less manpower was needed for their operation. One operator was particularly satisfied with the changes that were made: He said he can now talk next to the chillers without shouting!

Operating chillers at an optimum load, removing 23 pumps and bypassing nine more allowed the cancer center to reduce its peak power demand by 1.1 MW. The WM Group study estimated an annual cost reduction of $600,000; the client is reporting an actual annual savings of about $1 million per year.

Numerous other district cooling systems have similar optimization opportunities. In fact, a university medical center in the same city had a study conducted and was able to remove more than 20 pumps, which reduced the peak power demand by 700 kW. The annual savings are estimated at more than $600,000.

In another example, a Pfizer Inc. facility had three connected chiller plants, each operating as a dedicated plant to serve offices, manufacturing, laboratories and a data center. Due to the critical nature of these functions, the idea of making any changes to their chilled-water service had always been viewed as too risky. During winter months, one 2,000-ton chiller was supporting only about 300 tons of a very critical manufacturing process load. A hydraulic analysis showed, however, that this plant along with its cooling tower could safely be shut down, with the load transferred to another plant. The plant configuration was subsequently changed, and the site has operated in this manner for two years now, saving significant amounts of energy. "Had WM Group not instilled the confidence in our operators to overcome the fear of failure, the savings would never have been realized," says Bill Geiling, CEM, Pfizer's manager of plant engineering and maintenance, chiller plant operations.

Training Makes a Difference

Whether they are identifying if a system needs optimization or maintaining an optimized system so it stays on track, system operators are critical to district cooling system success. Unfortunately, not all of them have received the training they need to optimize the operation of their plants – facilities that cost millions of dollars to build and millions more to run. Without thorough knowledge of their entire system and its capabilities, these operators may not be prepared to make the best operational decisions. As an industry, we need to step up to the plate and ensure the proper training of our operators on an ongoing basis. We need to empower them to make good operating decisions that provide top service reliability while delivering savings to the bottom line.

Getting the Best Possible Design

The fear factor can be powerful. It can result in overdesigned systems or the specification of technologies that aren't the right fit. Either way, significant energy inefficiencies and higher costs result.

To avoid these pitfalls, system owners who are building a new plant or renovating an old one need to do their homework as they hire their consultants. Does that particular consultant have a 'signature' design? What can be learned by evaluating the consultant's past designs? Once the consultant is hired, clients need to ask detailed questions during the design process: What calculations brought them to their design conclusions? Why are they specifying what they are? What options have they evaluated? Could a peer review be conducted?

Owners with existing plants that are not undergoing a major build or renovation should take a look at what they might do better. They could save hundreds of thousands of dollars each year through system optimization. In fact, most could reduce energy requirements by 20 percent to 50 percent with a payback of less than two years. And once the system is fixed, a good operator training program could help maintain optimal system efficiency year after year.

Hemant R. Mehta, PE, is president and chief executive officer of WM Group Engineers PC. Mehta's experience in optimizing the performance and improving efficiencies of existing utility plants has enabled many facilities to save millions in capital and operating costs. Mehta cofounded WM Group Engineers in 2000, after working at Syska Hennessy from 1975 to 2000. He has a master of science in mechanical engineering from Oklahoma State University and a bachelor of science from Heald Engineering College. In June 2010, Mehta was named Energy Engineer of the Year by the New York Chapter of the Association of Energy Engineers. He may be reached at hmehta@wmgroupeng.com.