EXECUTIVE SUMMARY

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VARIABLE PRIMARY FLOW CHILLED WATER SYSTEMS: POTENTIAL BENEFITS AND APPLICATION ISSUES

William P. Bahnfleth, Ph.D., P.E. and Eric Peyer
The Pennsylvania State University
Indoor Environment Center
Department of Architectural Engineering

The use of variable primary flow pumping (variable flow through chiller evaporators) in chilled water systems is increasing due to its perceived potential to reduce energy consumption and initial cost relative to more conventional pumping arrangements. Neither the conditions under which significant energy savings are realized nor the likely magnitude of savings are well documented.

To characterize current thinking on the use of variable primary flow chilled water systems, literature review; surveys of designers, owners, and chiller manufacturers; and additional correspondence were synthesized into a composite portrait of prevailing practices and attitudes.

To quantify the energy use and economic benefits of variable primary flow, an extensive parametric simulation study was conducted that compared variable primary flow system energy use with that of other common system types. System types included in the study were constant flow/primary-only, constant primary flow/variable secondary flow, and primary/secondary with a check valve installed in the decoupler. Parameters varied included load type, number of chillers in the central plant, temperature difference vs. part load characteristics, and climate.

State of the Art Review Findings

There is growing support for variable primary flow among chiller manufacturers and system designers, owners, and operators. Modern chiller controls are capable of practical variable primary flow operation. Advances in capacity controls, freeze protection, and flow detection have increased chiller stability—a particular concern in variable primary flow applications because evaporator flow rates can change abruptly during chiller staging. Manufacturers are providing more detailed variable flow application guidance than in the recent past, including recommended chilled water tube velocity ranges and maximum rates of flow variation for most chiller models.

Variable primary flow systems are perceived to be more complicated than comparable primary/secondary systems. This is partly because chiller staging requires more care in order to achieve stable operation and realize anticipated energy savings. Chiller isolation valves should open and close at a rate that is consistent with the response time of the chiller's capacity control. The low flow bypass control required in most variable primary flow systems adds further complexity. The bypass and valve should be sized for the minimum required flow rate of the largest chiller and should be located close to the plant. Flow measurement devices must have sufficient turndown to measure flow throughout the anticipated range.

Over half of the survey respondents had designed or operated variable primary flow systems. Those who had no variable primary flow experience identified lack of guidance as a key reason why they had not. Owners cited reduced operating costs, lower first cost, smaller space requirement due to fewer plant components, and ability to improve chiller loading in systems experiencing low chilled water ΔT as advantages of variable primary flow systems over primary/secondary systems. While most claims of variable primary flow superiority over other system alternatives revolve around energy and first cost savings, there is little quantitative evidence in the open literature. Most arguments in favor of variable

primary flow are anecdotal. Designers and system owners with variable primary flow experience generally are willing to consider the use of variable primary flow for future projects.

Parametric Study Findings

Variable flow, primary-only systems reduced total annual plant energy by 3 to 8-percent, first cost by 4 to 8-percent, and life cycle cost by 3 to 5-percent relative to conventional constant primary flow/variable secondary flow systems. Several parameters significantly influenced energy savings and economic benefits of the variable primary flow system relative to other system alternatives. These included the number of chillers, climate, and chilled water temperature differential. The following factors tended to maximize variable primary flow energy savings relative to other system alternatives:

- Chilled water plants with fewer chillers
- Longer, hotter cooling season
- Less than design chilled water temperature differential

Load type had little impact on variable primary flow energy savings. The magnitude of savings was much larger for greater cooling loads, but when savings were standardized on a per design ton basis the differences were relatively small.

Chilled water pumps and chiller auxiliaries accounted for essentially all savings. Differences in chiller energy use were not significant from system type to system type. Variable flow, primary-only systems chilled water pump energy use was 25 to 50 percent lower than that of primary/secondary chilled water systems. In systems with two or more chillers configured in parallel, chiller auxiliary energy savings were 13 percent or more relative to primary/secondary.

The addition of a bypass check valve to the constant flow primary/variable flow secondary system resulted in total plant energy savings of up to 4 percent and a life cycle cost savings of up to 2 percent. Savings occurred only when chilled water ΔT's were less than the design value. Chilled water pump savings were 5 percent or less and chiller auxiliary savings were 13 percent or less.

Conclusion

In view of both the state-of-the-art review and parametric study results obtained in this project, it can be concluded that variable primary flow is a feasible and potentially beneficial approach to chilled water pumping system design. However, the magnitude of energy and economic benefits varies considerably with the application and is obtained at the cost of more complex and possibly less stable system control. The literature on effective application of variable primary flow is growing and should promote its appropriate and effective use in the future.