

CHILLER RETROFIT

Retrofitting a 30-Year-Old Chilled Water Distribution System

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After 30 years of modifications, the central plant chilled water distribution system could no longer supply adequate chilled water to all areas of the plant that it served. A planned office upgrade with increased loads would create additional deficiencies. Something had to be done to eliminate the past problems of providing cooling to various zones within the system and avoid air conditioning problems in a newly upgraded office area with new system furniture, carpets, and paint. The end result was a retrofitted system that not only eliminated the flow problems but is saving energy.

Original system setup

The central plant serves the office areas of five buildings at the Boeing Renton facility in Washington. System capacity is more than adequate to serve the loads. The system distribution system was originally set up as a primary-secondary system as shown in Fig. 1. The original secondary zones, Zones 1 through 3, were constant flow with three-way valves throughout the system. Zone 4 was added several years ago utilizing a three-way valve to use only as much primary water as needed. Zone 5 was added three years ago utilizing variable volume pumps in anticipation of modifying the entire system to variable volume in the future. The primary system

was set up to flow 50 to 100 percent of total capacity with a chilled water pump matched with a chiller. At a 50 percent flow rate, secondary Zones 1 through 3 would mix primary supply water with return water to maintain full flow to each zone. Balancing the zones to average primary flow to

caused comfort problems, particularly when the outside air temperature approached design day.

System retrofit

A major office upgrade with increased loading forced a serious look at the chilled water system problems. One of the primary objectives of the office upgrade was to improve comfort. This could not be done without modifying the chilled water distribution system to ensure there would be adequate chilled water flow at all times. The chilled water system was studied with the following

Chilled water distribution system was retrofitted for least energy consumption and maximum control, using variable speed drives, a good control system, and two-way valves

design characteristics in mind.

each zone was very difficult. System problems occurred primarily when one chiller and one primary pump served the loads. The secondary zones would mix primary water with return water, thus raising the chilled water supply temperature to each zone. The higher temperature was inadequate to satisfy all zones. To rectify this problem, a second chiller and primary pump were often started, which was energy inefficient but provided greater comfort.

Systems problems also occurred due to modifications that had been done over the last 30 years. Some of the zones served required higher flows than could be provided by the secondary pumps. Tertiary pumps had been installed over time to take care of localized problems without ever analyzing the entire system. The result was inadequate chilled water flow to some parts of the zones. This

▲ Supply water temperature stays constant as the load changes.

▲ Pumping power reduces with load reduction (ideally as the cube of the load).

▲ Must be simple or at least not complex.

▲ Comparative first cost must not be excessive.

▲ Both primary and auxiliary power requirements must be minimized.

Design criteria

The result of the chilled water system study indicated that a variable volume pumping system utilizing adjustable frequency drives would satisfy the itemized design characteristics identified above. Not only would the proposed system changes satisfy the primary objective of providing comfort at all times, but they would also save energy.

The chilled water distribution

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system was modified using the following design criteria and as shown in Fig. 2.

▲ A chiller pump was provided for each chiller, hydraulically decoupled from the primary distribution pumps by means of a common pipe.

▲ Load components, including coils and air handling units, were equipped with modulating two-way valves.

▲ The primary distribution pumps were equipped with adjustable frequency drives and controlled by differential pressure

sensors located at the remote locations of the various zones. The controller selected the zone with the lowest differential pressure from set point as the control point.

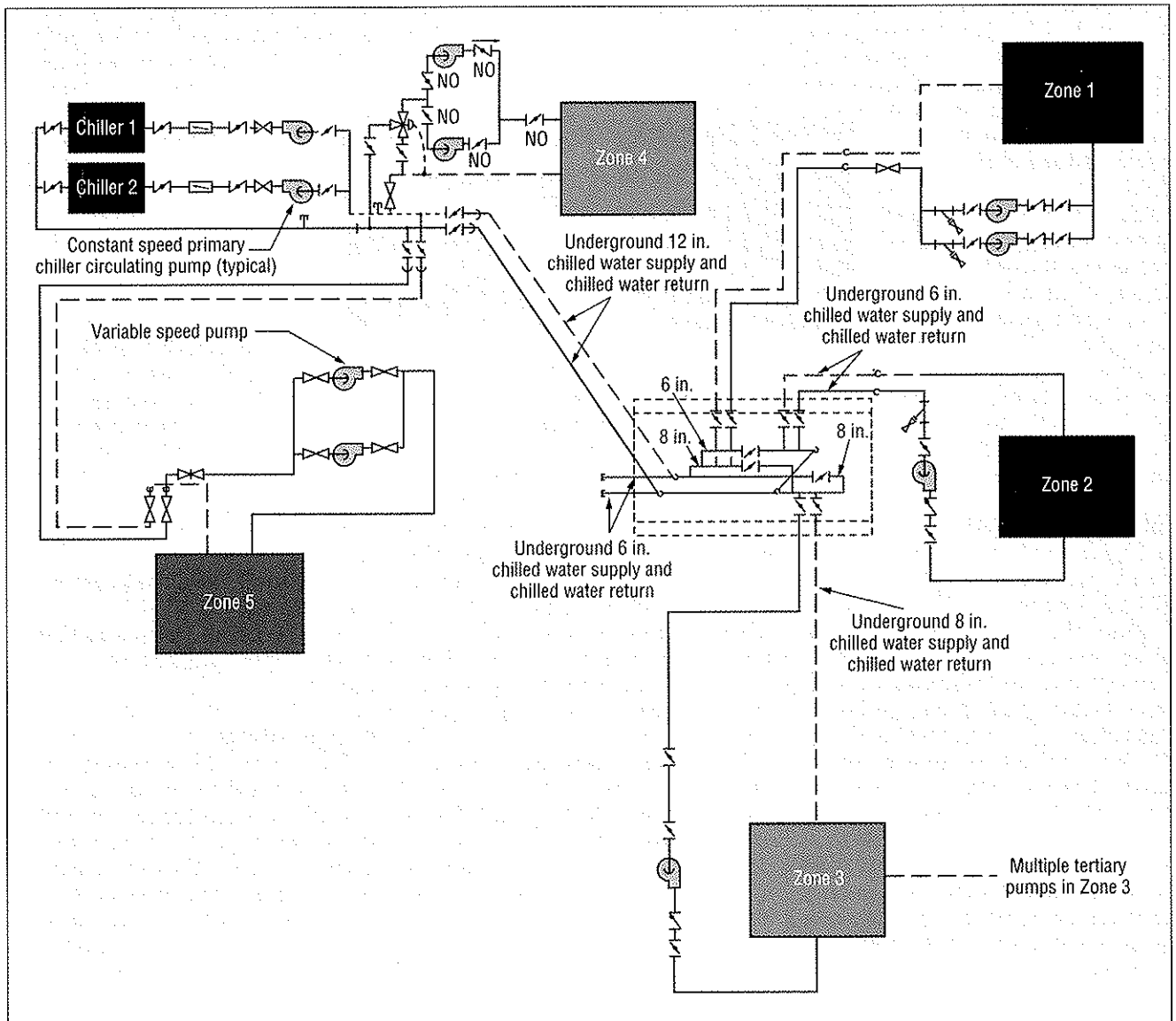
▲ The primary distribution system was equipped with three pumps, each sized for a third of the total capacity.

▲ The secondary distribution pumps, Zones 1 through 3, were equipped with adjustable frequency drives and controlled by differential pressure sensors located at the remote locations of the zones. These three zones had

experienced flow problems and had the greatest opportunity for energy savings.

▲ Secondary Zones 1 through 3 were equipped with two pumps, each sized for 50 percent of the capacity.

▲ The primary distribution system and each secondary zone were provided with a controller to optimize pump operation. Power input to the pumps and flow and head output from the pumps are measured, and efficiency is calculated. The efficiency and flow are used to



1 Original chilled water system setup.

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select when to start and stop the pumps to minimize energy usage.

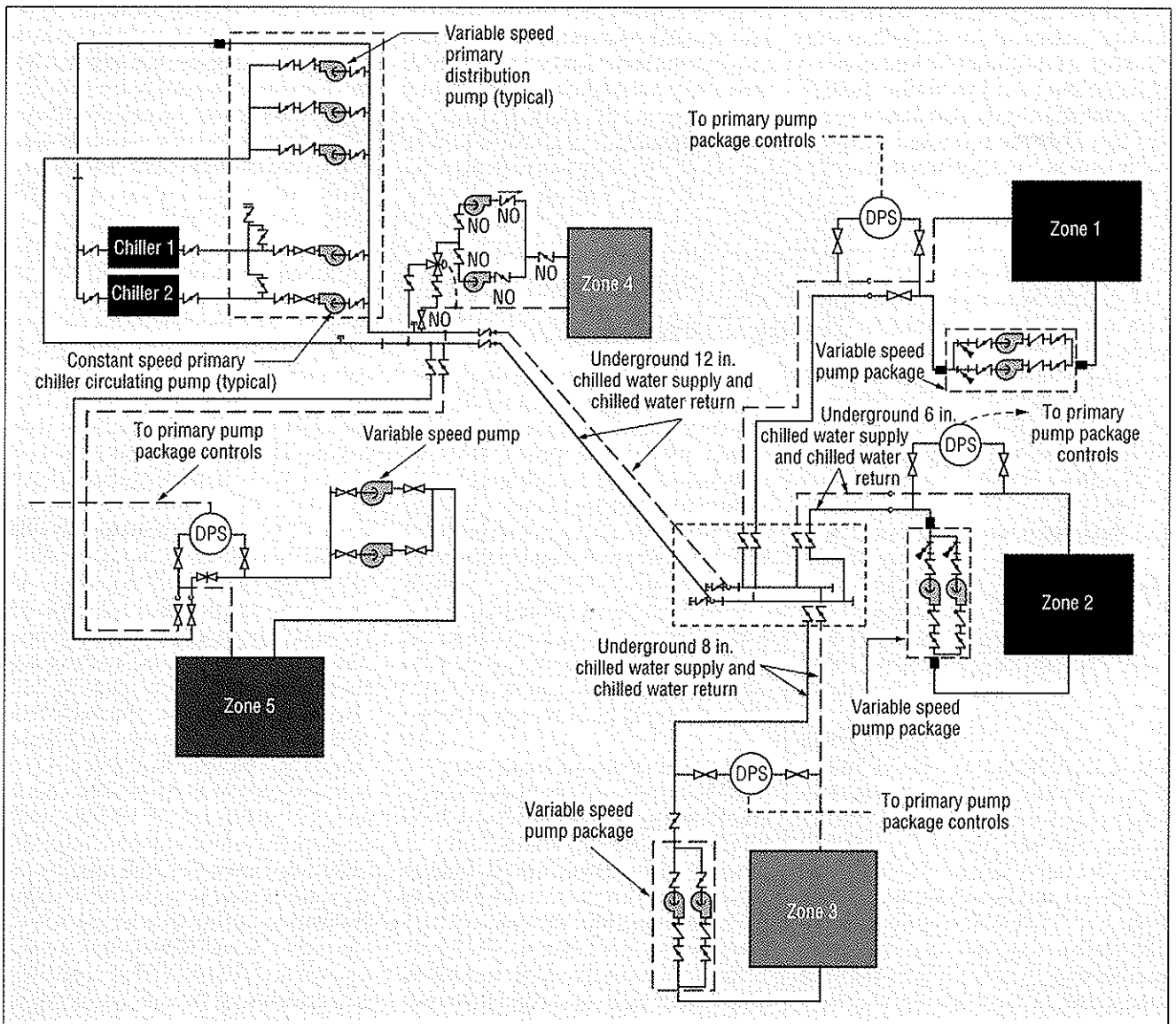
Sole source supplier

The system was constructed and put into operation utilizing a sole source supplier for the pump packages, which included pumps, variable speed drives, controls, wiring, and related hardware. With a sole source supplier who factory tested the variable volume system prior to installation, we knew where to go if anything was not working to satisfaction. Previous experi-

ences with variable volume pumping systems indicated that a lot of things can go wrong to keep the system from working properly. In a typical system, parties involved can include the general contractor, mechanical subcontractor, electrical subcontractor, controls subcontractor, pump supplier, and variable speed drive supplier. If something is not working properly, there is often a battle over whose responsibility it is. With a sole source supplier, the responsibility was very clear.

Summary

After construction was completed and the chilled water system was put into operation, it was tested and data were compared to the factory tests. The results compared favorably. After a summer of operation, the system met all expectations. There were no indications of inadequate chilled water flow to any zone. Energy saved also met or exceeded expectations. Table 1 is an example of energy savings on a typical summer day with an outside air temperature of 70 F.



2 Modified chilled water system.

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As can be seen from the actual measured energy, there is a significant saving in pump energy on a typical summer day in the Seattle area. The measured pump energy saving is 56.85 kw or 83.75 kw, depending on if one or two primary chilled water pumps were in operation under the old system. As outside air temperatures grow cooler, the energy savings increase. These savings are continuous over the entire year.

Not factored into the energy savings calculation above is the chiller energy savings on those days when in the past a second chiller was started to help rectify the chilled water flow problem even though the load did not demand the second chiller. This amounts to 535 kw of additional energy savings over that time frame.

Table 1—An example of energy savings on a typical summer day with an outside air temperature of 70 F.

Zone	Pump energy use, kw	Pump energy use with old system, kw	Remarks
Secondary 1	1.95	6.71	
Secondary 2	1.51	10.1	
Secondary 3	3.1	31.6	This zone had multiple tertiary pumps, which were removed as part of the retrofit
Secondary 4	Not measured	Not measured, no change in energy use	Small pump—no modifications were made to this zone
Secondary 5	Not measured	Not measured—no change in energy use	No modifications were made; was previously retrofitted to variable volume flow
Primary	11.6	26.9 or 53.8	Depends on if one chiller or two are in operation
Total	18.16	75.01 or 101.91	Depends on if one chiller or two are in operation

Conclusion

A 30-year-old chilled water distribution system with numerous modifications over the years can be successfully retrofitted not only to regain control but also to provide substantial energy savings over the lifetime of the system. The use of variable speed drives, a good control sys-

tem, and two-way chilled water control valves were the key elements of the system. A well thoughtout design and the use of a single source for the chilled water pumping packages were also key elements in assuring the system would function well and achieve the expected benefits.

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