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APPLYING VARIABLE VOLUME PUMPIG

To optimize system performance, the designer has a number of variations of basic primary-secondary pumping to explore.

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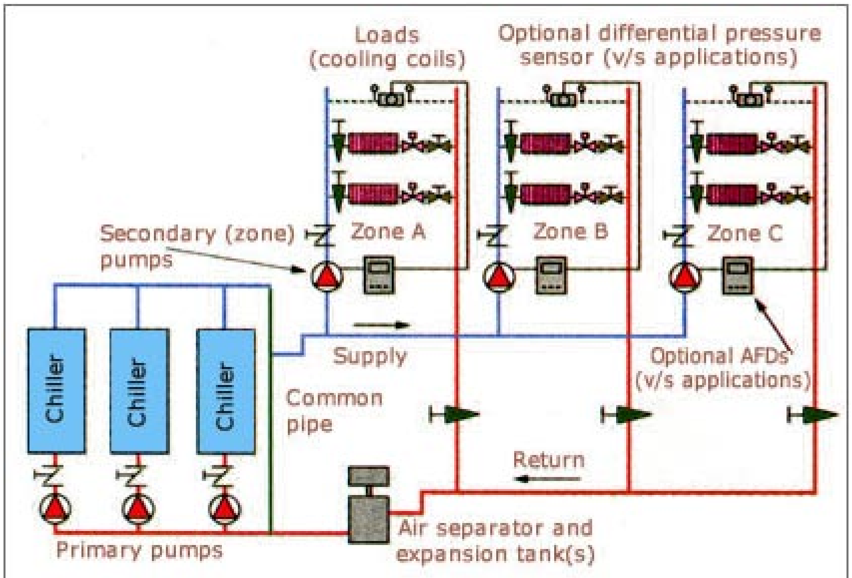
In the previous article published in the July-Sept. 1999 issue of Air Conditioning and Refrigeration Journal, "Variable, Volume Pumping Fundamentals," the concept of variable volume pumping is thoroughly developed. The example cited is a primary-secondary pumping system. Primary-Secondary pumping configurations are successfully applied by thousands worldwide and is the standard approach for many design engineers. To optimize system performance, the designer has a number of variations of basic primary-secondary pumping to explore.

- Primary-secondary Zone pumping systems
- Primary-secondary-tertiary pumping systems
- Primary variable speed pumping systems.

Each type of pumping system configuration has district advantages for the user or operator. There are also cautions to consider. Fundamental to all of these configurations is sound design principles. Without the proper application of the basics, the most sophisticated systems will not operate effectively.

Primary-secondary zone pumping systems - A variation of the traditional primary-secondary pumping scheme is primary-secondary zone pumping **(Fig 1)**. This configuration is also referred to as distributive pumping. The principle of primary-secondary pumping still apply. The difference in this design is that the main distribution pump is eliminated in favor of multiple zone or building pumps. Using this approach and under the right conditions, pumping horsepower can be saved initially and in the future. Zones close to the chiller plant are not over headed (over-pressurized) to meet the demands of the zones farther downstream. In large applications, pressure may also be reduced-saving pipe, valve, coil, and tank first cost. Gil Carlson of Bell & Gossett demonstrated the value of primary-secondary zone control[1,2] in the early 1960s.



1 Primary-secondary zone pumping.

1 Primary-secondary zone pumping

Design consideration - Each zone pump is decoupled from the chiller pumps through a common pipe. They are, however, not decoupled from each other. Essentially, they operate in parallel. The suction and discharge of the pumps are connected through shared supply and return piping. A very small pressure drop must be maintained in the pipe shared by these pumps. This pipe includes the common pipe and the shared supply and return header **(Fig 2)**. The designer must be extremely careful with the selection of the pumps and the balancing of each zone. Pumps should have the same or similar pump curves.

Pipe sizing - Friction loss in the shared piping dramatically affects the performance of zone pumped systems. As per ASHRAE's recommendation, friction loss no greater than 4 per 100 ft. of equivalent pipe should be followed. Friction loss must be calculated at the maximum flow rate expected in the future.

Pump selection - The action of pumps in the downstream zone (Pumps B and C) will affect the pump in Zone A (and vice versa), unless the distribution pipe has a very small pressure drop due to a large diameter or a very short length as shown in **Fig 2.** Friction loss in the piping is based on a squared law function. The friction loss assigned to Zone Pump A must overcome the added pressure drop in the shared pipe based on all of the pumps in full operation.

Future zones - As with future load changes, future zone requirements must also be considered. Pumps must be selected with future zone characteristics in mind. The addition of an unexpected zone may require the replacement or modification of all or some of the existing zone pumps. If future zone requirements are known, the existing pumps can be selected large enough to meet future requirements.

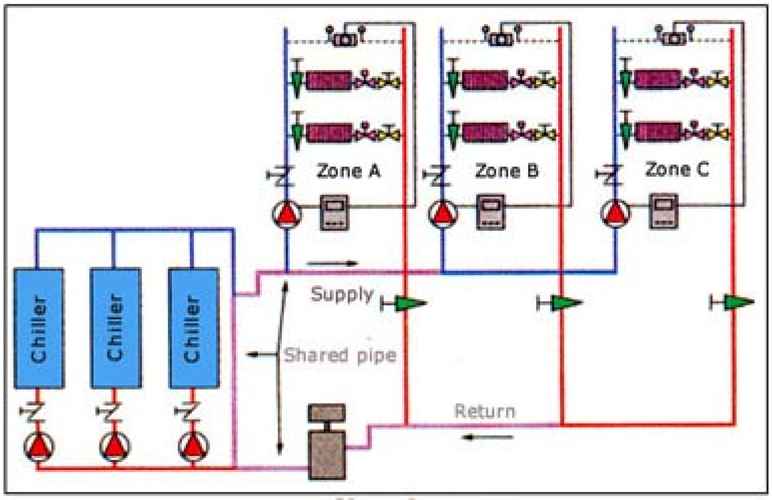
Future loads - As loads are added in the zones, pressure drops increase in the zone piping as well as in the shared piping. Existing pumps may need to be increased in size, be replaced to meet the new resistance, or sized larger in anticipation of future conditions.

Pumping compatibility - The square law relationship between the piping system and the pump is very important, especially when applying adjustable frequency drives to zone pumping. When the decision is made to apply zone pumping, the decision must also be made whether all of the pumps will be constant speed or use variable speed. Since the zone pumps are operating in parallel, the pumps' operating curves must be compatible. The point of operation of down stream pumps will affect the performance of the upstream pumps and vice versa.

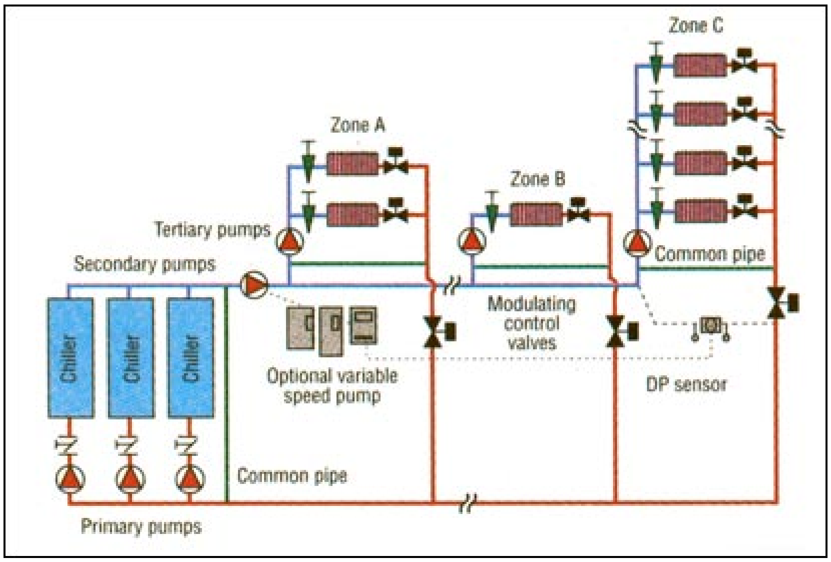
Downstream users - Since each zone pump must be capable of providing enough differential pressure to transport water from the chiller plant to the loads and back to the chiller plant, each successive zone pump must be larger in horsepower even if the zone flow rates and pressure drops are similar. In a district-type system, the customer at the end of the distribution system can require pumps of significantly greater horsepower than those close to the plant.

Controls - Each zone operates independently and requires its own variable speed controls. It is not recommended to mix constant speed and variable speed zones in the same systems.

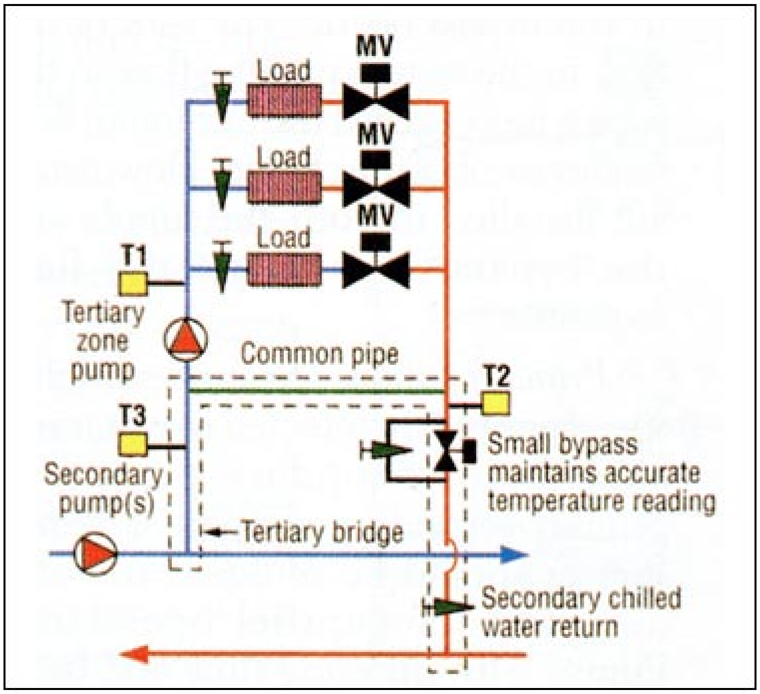
Balance - Balance is a critical factor in the design and operation of a zone-pumped system. If the system is not properly balanced, the return distribution pipe may be over-pressurized. Over pressurization will compound the system problems. Valves can lift off their seats, resulting in hunting and poor temperature control.



2 Shared piping.



Primary-Secondary-tertiary (tertiary) pumping systems- Another variation of primary-secondary pumping is tertiary pumping **(Fig.3)** Secondary pumps distribute the chilled waters from the central plant to the connected buildings or zones. Individual buildings or zones are decoupled from the distribution loop through a tertiary bridge. A major advantage of tertiary pumping is that the individual zones are hydraulically and thermally decoupled. This allows the designer some flexibility to control leach zone independently, relative to differential pressure and temperature. Zones may be a collection of coils, air handlers, or entire buildings. This advantages is ultimately expressed in district cooling and heating systems where individual users are decoupled through the means of gasketed plate heat exchangers (GPX). When GPX are used, cross contamination of HVAC fluids may also be prevents. The operator of the distribution system is isolated from the users and is not subjected to potential excessive static pressure.



4. Tertiary zone bridge

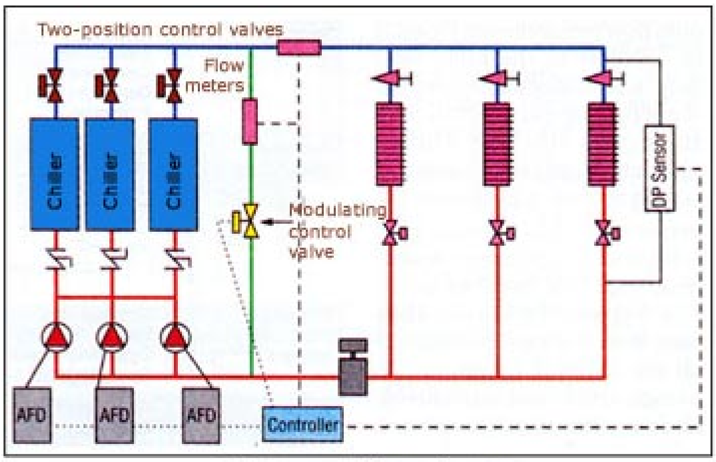
• **Design consideration -** The addition of tertiary pumps may increase the initial-connected horsepower of the system but the level of control is increased. Under the right conditions, overall operating cost can be reduced. To optimize the performance of a tertiary-pumped system, control of the tertiary bridge modulating valve is critical.

Tertiary bridge design - The same design criteria used for the secondary bridge should be followed[3] **(Fig. 4)**

Temperature sensor locations - Proper valve control requires that temperature sensors are located at the supply water temperature to the tertiary zone, T1; return temperature to the chiller plant, T2 (a low flow bypass is maintained across the return control valve to provide an accurate water temperature); and the supply water temperature from the chiller plant, T3. Proper control permits the zone to operate at the highest possible temperature without losing humidity control in the zone. This maximizes the flow through each coil and control valve providing better heat transfer and valve authority. Maximizing the flow in the tertiary also reduces the amount of waters from the secondary. This reduces the flow in the secondary and may result in the reduction of the number of chillers online in the chiller plant.

Secondary pumps - Secondary pumps are selected for present flow to minimize initial horsepower. The pressure droo across the control valve of the highest head zone must be included. Consideration should be given for future flow conditions. Careful selection will permit the use of present flow pumps under future conditions. Since the secondary pumps are typically the largest pumps in the system, adjustable frequency drives and controls should be considered if economically justifiable.

Tertiary pumps - Tertiary pumps are selected based on the flow and head requirements for the Zone or building load. These pumps are often low horsepower and do not need to be of variable speed unless it is economically justifiable. If variable speed is elected, differential pressure sensors are located across the largest, farthest load and two-way control valve. Consideration must also be given to low flow conditions. These are similar to the design parameters for primary-secondary pumping systems.[3] Zones close to the chiller plant may operate under high distribution piping differential head. If the differential head is sufficient at all times, tertiary pumps may not be required for the nearby zones.



5 Primary variable speed pumping

Primary variable speed pumping systems - This type of system is not a variation of primary-secondary pumping. The concept behind primary variable speed pumping is the elimination of the secondary pumps to reduce first cost, space requirements, and maintenance **(Fig.5)** Constant volume is no longer maintained through the chillers. Variable system flow is directly achieved through the modulation of flow through the chillers. Primary variable speed pumping systems are especially attractive in primary pumped retrofit situations since space may not be available for additional pumps and piping.

• **Design considerations -** Control logic and sequencing for the pumps and chillers is the heart of this type of system. With the advent of more sophisticated microprocessor controls, the potential problems associated with underflowing or overflowing the chillers can be addressed. Operation of the variable speeds pumps is also provided through the microprocessor control.

Chillers - Multiple chillers are required to maximize the turndown capacity of the chilled water plant. With only one chiller, the low-flow range is limited to the minimum flow of the single chiller. Multiple chillers lower the minimum flow limitation. The designer must know the minimum flow requirements for each chiller. Chillers of the same size, efficiency, and manufacture simplify efficiency, and simplify the control sequence. Close coordination with the chiller manufacturer is highly recommended, especially in retrofit applications.

Common pipe - The common pipe is not eliminated in variable speed pumping. It is modified into a low-flow bypass. To ensure that minimum flow is always maintained through the chiller, a bypass with a modulating control valve is employed. As loads diminish, system flow reduces. When the system flow approaches the minimum flow requirement of the chiller, the modulating two-way valve in the bypass opens. The sum of the flow in the system plus the flow in the bypass must exceed the minimum flow requirement of the chillers. Flowmeters are installed in both the supply and the bypass to calculate the flow sequence.

Differential pressure sensor locations - The principle method of pump control is differential pressure transmitters. As with other variable sped systems, the largest, farthest loads are usually the most critically to monitor. Sensors close to the chiller plant provide valuable information for minimizing system differential pressure during low flow conditions.

Conclusion

There are many ways modern HVAC systems can be pumped. Each method has its own advantages and disadvantages to the user or operator **(Table 1)**. The designer must consider presents system use, plans for the future, cost considerations, and the ability level of the operator. With more tools in the toolbox, the engineer is better equipped to make the decision, "Which system is the best for my client"?

Table 1 - Advantages and Disadvantages of various pumping systems

Pumping System Type	Advantages	Disadvantages
Primary-secondary	• Simplicity of: Design Installation Operation Design flexibility First cost	• Near Zone over-pressurization • No thermal isolation
Primary-secondary	• Lower present	• Controls complexity

	horsepower • Lower future horsepower • Lower system pressure	• Pumps oversized for future need • Design inflexibility for: Future expansion Retrofit Downstream pumps get larger No thermal isolation Secondary return over-pressurization
Primary-secondary-tertiary	• Thermal isolation • Design flexibility • Operating flexibility • Operating cost	• Controls complexity • Near zone over-pressurization • First cost
Primary variable speed	• First cost • Operating cost • Retrofit of primary pumping applications	• Operating cost • Controls complexity • Inflexibility in: Equipment selection Equipment sizing System expansion Retrofit of non-direct pumped systems

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