Understanding Variable Flow Systems

Part 1 of 2

By Amrish Chopra
Anergy Instruments Pvt. Ltd.
Faridabad

During the energy crisis of 1970s, a need was felt to reduce power consumption of HVAC systems. Till then, 3-way control valves were used on AHU coils to control space conditions. The control valves would restrict water flow through the coil based on load requirement, and bypass the excess water. Water circulation rate, based on peak load, remained constant irrespective of the instantaneous load. Thus pumping power also remained constant. Most HVAC systems rarely work at peak load – perhaps for few days in a year – and it was felt that substantial pumping energy could be saved by varying the flow rate to match the instantaneous load.

To vary the system flow rate, 3-way control valves at AHU coils were replaced with 2-way control valves, but then the problem of variable flow through chillers cropped up. Chillers have a tendency to freeze up at low flow rates, which could damage their tubes, and it is difficult to monitor and prevent such situations. A solution was found by creating two independent hydraulic circuits, one with constant flow for the chillers, and the other with variable flow for the distribution circuit.

Figure 1 shows a primary-constant/ secondary-variable flow chilled water system. It has two hydraulic circuits – primary and secondary. The primary circuit has its own pumps that are operated based on the number of chillers in operation. In this circuit, water flow does vary based on the number of operative chillers, but water through each operative chiller remains constant irrespective of the load. Primary pumps operate at constant speed, and are selected for pressure drop in the primary circuit.

Secondary pumps are selected for pressure drop in the secondary circuit, and it is possible to vary their flow rate by changing the pump speed using variable frequency drives. When 2-way valves vary water flow through the load and coils, it results in a change in differential pressure across the supply and return lines of the secondary circuit; a suitably located differential pressure sensor senses the change and varies the pump speed.

To achieve independent operation of primary and secondary circuits, to prevent primary and secondary pumps from working in series, and to prevent a change in the flow rate in one circuit from affecting that in the other circuit, they have to be hydraulically isolated; to achieve that, a decoupler bypass connecting the supply header to the return header is used. It permits excess flow in either circuit to flow through.

There can be three distinct conditions of flow through decoupler bypass:

No Flow through Decoupler Bypass

It happens when the load exactly matches the plant capacity and flow rates in the primary and secondary circuits are exactly the same; this is unlikely to happen often under varying load conditions.

Forward Flow through Decoupler Bypass

It happens when the plant capacity is higher than the load, flow rate in the primary circuit is higher than in the secondary circuit, and water flows from the supply header to the return header. This is a desirable condition, as the plant capacity must always be equal to or more than the load.

Reverse Flow through Decoupler Bypass

Water flow from the return to the supply header is an undesirable condition. It indicates that the plant capacity is lower than the load. In such a case, higher temperature water from return mixes with supply water and raises its temperature. Higher inlet water temperature reduces coil effectiveness and forces the control valve to demand more water. It becomes a vicious cycle: higher water flow rate in the secondary circuit means higher reverse flow through the decoupler bypass. To prevent reverse flow, some designers install a non-return valve in the decoupler bypass; however, a better solution is to increase the plant capacity by starting another chiller whenever the flow reverses.

Decoupler Bypass Sizing

Decoupler bypass carries the differential flow between the two – primary and secondary – circuits, the preferred option being to have higher plant capacity than the load, with proper staging of chillers. At any time, the maximum over-capacity can be equal to that of one chiller and, therefore, the maximum flow through the decoupler bypass can be the flow through a single chiller. Decoupler bypass should be sized for the water flow rate of the largest chiller.

Pressure drop in a decoupler bypass affects the hydraulic velocity conditions; a flow velocity of 4-6 m/s could be considered a reasonable compromise.

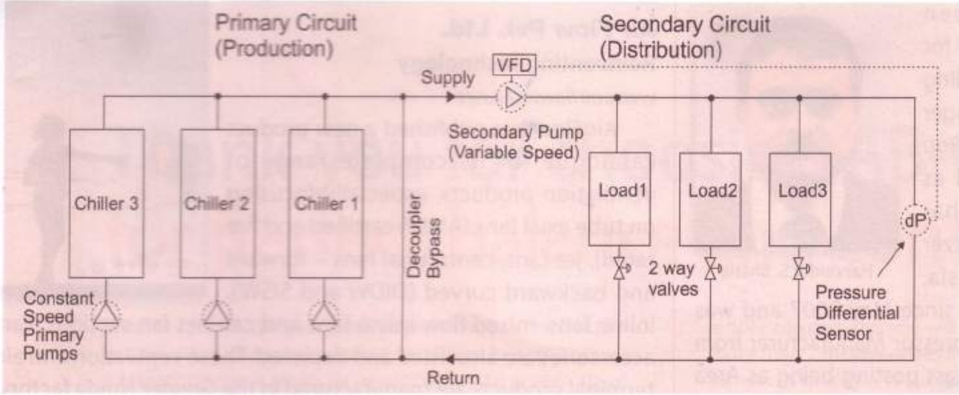

Figure 1: Primary-constant / secondary-variable flow chilled water system with decoupler bypass at primary-secondary junction

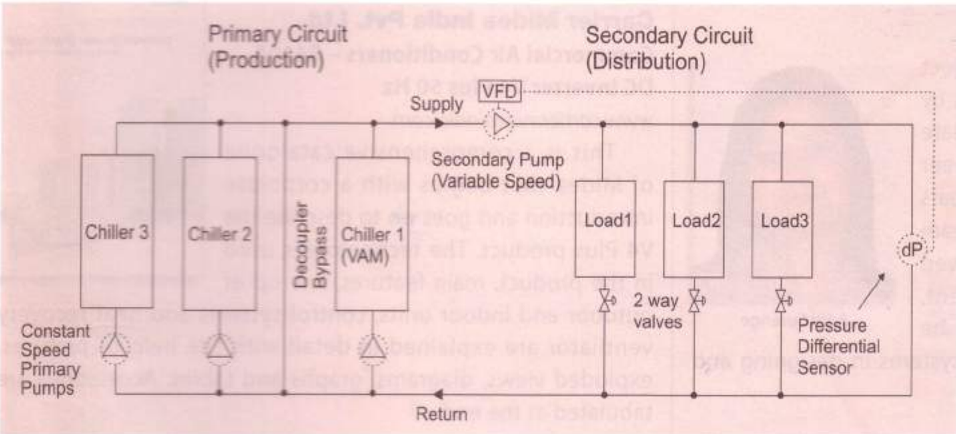

Figure 2: Decoupler bypass located between vapour absorption chiller and other chiiers

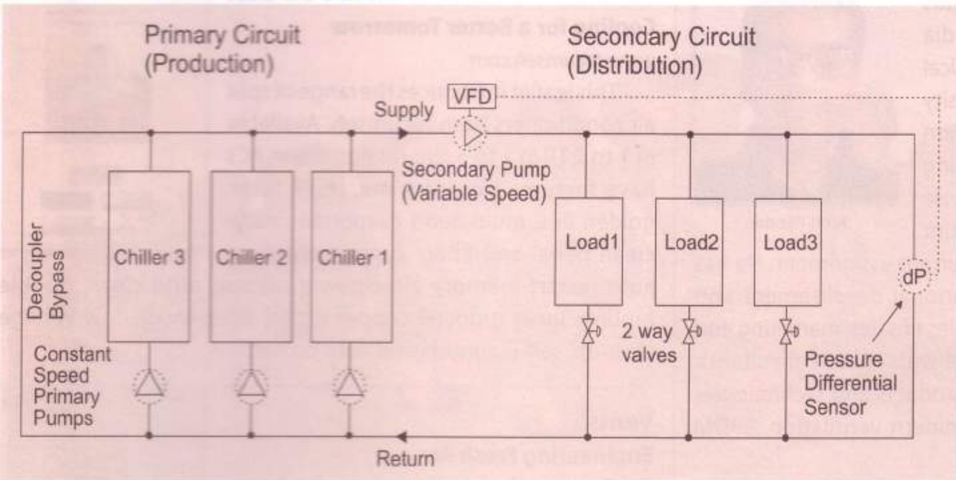

Figure 3: Decoupler bypass away from secondary circuit

independence of the two circuits; higher the pressure drop across it, lesser the hydraulic independence. Higher pressure drop can force pumps of the primary and secondary circuits to operate in series; therefore, a bypass header should be designed for minimum pressure drop. However, flow rate through the bypass header is often measured using a flow meter to stage the chillers, and flow meters operate better under high velocity conditions; a flow velocity of 4-6 m/s could be considered a reasonable compromise.

Location of Decoupler Bypass

Location of the decoupler bypass can be used advantageously for even or selective loading of chillers. *Figure 1* shows the decoupler bypass at the junction of primary and secondary circuits; it is a very common design that ensures even loading of all the operating chillers. The return water mixes with the supply water from the decoupler bypass, and all the chillers receive mixed water at the same temperature. This is the most suitable location when chillers are of similar capacity and type.

Vapour absorption chillers are sometimes used to utilize the waste heat available, and they operate best when fully loaded. The loading of such chillers could be improved by shifting the decoupler bypass away from the secondary circuit, to between the vapour absorption chiller and other chillers, as shown in *Figure 2*. In this position, the vapour absorption chiller will receive high temperature water directly from the return header without mixing with supply water from the decoupler bypass, till any other chiller is operating.

Figure 3 shows the schematic of a system where the decoupler bypass is moved to the other end of the primary circuit, away from the secondary circuit. In such an arrangement, the chiller closest to the decoupler bypass will be the least loaded, as it will get all of the low temperature water from the decoupler bypass. Part load efficiency of the whole system can be improved by selecting this chiller with a lower capacity, or with better part load operating characteristics.

The concluding part of this article will appear in the March - April 2014 issue of the Journal.