Variable Flow Water Systems Do Not Need Balancing

By Amrish Chopra

CEO - Anergy Instruments Pvt. Ltd., Faridabad

Concluding part 3 of 3

In the July-September 2009 and October-December 2009 issues, the discussion was about advantages and disadvantages of static and dynamic balancing valves in constant and variable flow water systems. To recapitulate:

- In constant flow water systems, with 3way control valves, a balancing device is desirable. Static balancing valves can do the job economically. Dynamic balancing valves are more suitable when either the number of branch circuits is large or there is possibility of system expansion at a later date, but require more pumping energy.
- In variable flow water systems, with 2way control valves, water balancing devices are effective only when a circuit is operating at full load. At less than full load, a static balancing valve is of no use, whereas a dynamic balancing valve disturbs the proper functioning of the control valve.

In this issue the focus will be on reanalyzing the problem based on fundamentals of heat transfer and fluid flow.

Heat Transfer Basics

Heat is transferred in a heat exchanger from one fluid to another and the rate of heat transfer depends on several parameters like temperature difference between the two fluids, direction of fluid flow, heat transfer area and fluid flow velocity etc.

The heat capacity of a fluid depends on parameters like mass of fluid flow, specific heat of fluid and drop or increase in temperature between inlet and outlet of the heat exchanger. Mass of fluid flow can also be calculated from the specific gravity of fluid and fluid flow rate.

The heat transfer capacity H of a heat exchanger could be defined as:

$$H = k.Q.\Delta T$$

Where Q is the fluid flow rate, ΔT is the temperature differential, and k is a proportionality constant based on physical parameters of the heat exchanger and the fluid.

An HVAC system has several heat-exchangers/coils operating in parallel and the best overall heat transfer efficiency can only be achieved in such a system by ensuring a constant ΔT across all devices at maximum load. Engineers familiar with heat-exchanger/coil design will recollect that the fluid flow rate is calculated so as to satisfy the above condition.

The physical parameters of the heat exchanger are designed to achieve best heat transfer efficiency at maximum load with fluid flow rate as calculated above. The relationship between heat transfer capacity and fluid flow rate is highly non-linear, increase in fluid flow rate does not translate into an equivalent increase in heat transfer capacity, and may result in drop in ΔT.

Fluid Flow Basics

A fluid follows the path of least resistance. In an HVAC system several heat-exchangers/coils are connected in parallel, some closer and some far away from the fluid circulating pump. The flow through each branch circuit will depend on the sum total of resistance faced by the fluid flow, i.e., the internal resistance of the circuit and the resistance of the path from and to the circulating pump.

Two types of systems, constant flow and variable flow, are used in HVAC systems. Constant flow systems use 3way control valves, and variable flow systems use 2way control valves, to regulate the fluid flow through the coil to maintain desired conditions in the conditioned space. The circuits with above valves are shown in *Figures 1 & 2*.

As shown in *Figure 1*, a 3way control valve regulates the water flow through the coil only, the balance water flows through the

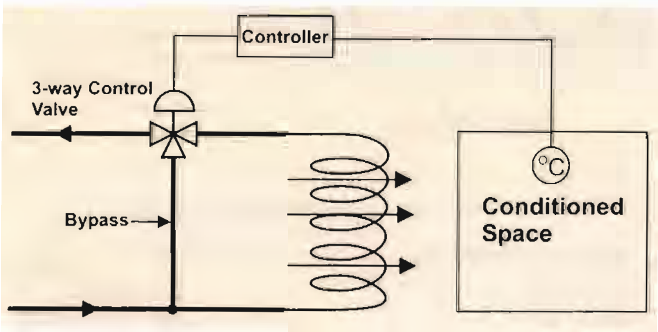

Figure 1

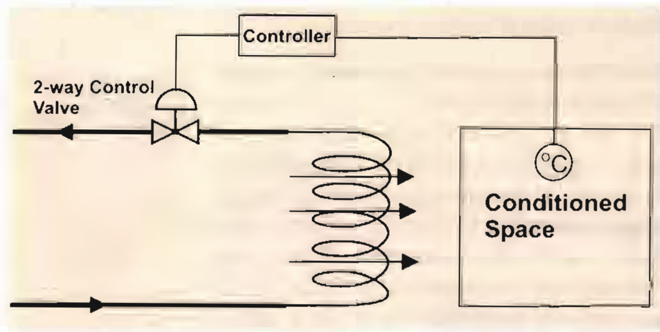

Figure 2

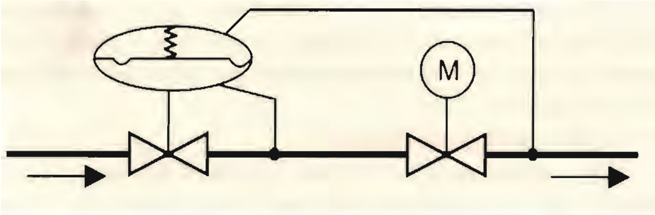

Figure 3: Schemetic of dynamic balancing-cum-control valve (DBCV)

bypass line, and it does not have any control over the water flowing through the complete circuit.

A 2way control valve acts differently, as shown in *Figure 2*, there being no bypass line, the flow through the circuit and the coil is the same and it controls both.

Combining the Basics of Heat Transfer and Fluid Flow

Constant ΔT across a heat exchanger is the prime requirement, constant fluid flow at maximum load being secondary, a derived value.

The circulating pump discharge capacity is the sum total of fluid flow requirement of all the circuits at maximum load.

No circuit could be permitted to overdraw the fluid flow above the calculated value to avoid starvation of other circuits.

Some fluid flow control device has to be provided in each circuit to prevent overflow.

In variable flow systems, a 2way control valve could itself be used as a maximum flow-limiting device whereas in constant flow systems a separate device, in addition to a 3way control valve, has to be used to limit the maximum flow through the complete circuit.

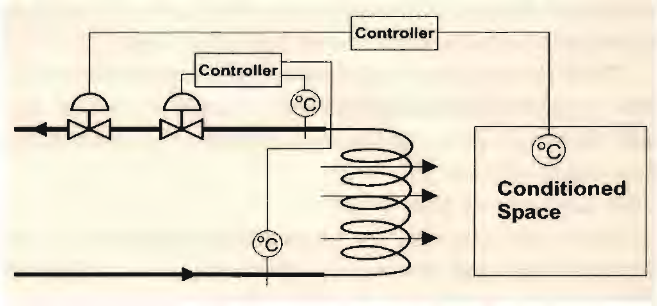

Figure 4

The Past

Constant flow water systems were used in the early days, to keep the design simple and may be due to absence of reliable pump motor speed control devices. In such systems, 3way control valves were used to maintain space conditions and in addition globe valves were provided to limit the maximum fluid flow, by adding resistance to the fluid flow. As changing the resistance of even a single circuit affected the flows through all the circuits, the concept of proportional balancing came into being. In this, the total pumped flow is distributed to a circuit in proportion to its share. To ease the cumbersome balancing process, the globe valves were replaced by balancing valves with better-defined flow characteristics and then by dynamic balancing valves.

These systems were simple but inefficient, the constant fluid flow consumed same pumping energy irrespective of load and, also, the drop in ΔT due to flow through bypass line reduced the heat transfer efficiency.

The Legacy of the Past

Times have changed, the technologies have changed, the constant flow water systems have given way, the variable flow water systems have become the order of the day, but the mindset of balancing the fluid flows has remained a de-facto standard, pushing the prime requirement of limiting the maximum flow rate to oblivion.

A number of articles have appeared in international journals in last two decades on this topic but the ambiguity remains, resulting in the introduction of a new breed of products like dynamic balancing-cum-control valves (DBCV), pressure independent control valves (PICV).

A DBCV has two control orifices in series, operating in one housing, as shown in *Figure 3*. One control orifice is similar to a normal control valve and operates to the dictates of a sensor located in the conditioned space, while the other orifice operates to the dictates of the pressure differential across the first orifice. Any change in differential pressure pushes a membrane or a piston against a spring to change the orifice opening.

The construction of this valve is complicated and use of flexible diaphragm or piston, rubber 'O' rings, seals and narrow pressure sensing passages vulnerable to the vagaries of water quality and water borne debris make its long term reliability a suspect.

Its spring loaded orifice responds instantaneously to any pressure variations and this feature may be necessary in an automotive shock absorber, from where its design is inspired, but is unacceptable in HVAC systems which generally have large thermal inertia. It results in excessive wear and tear of its own as well as other system components. As a matter of fact, special effort is put to slow down the present age controllers, capable of fast reaction times due to high processing speeds, to the order of several MHz, of microprocessors, to match the HVAC system requirements, to prevent unnecessary wear and tear of actuators, valves, dampers and other system components.

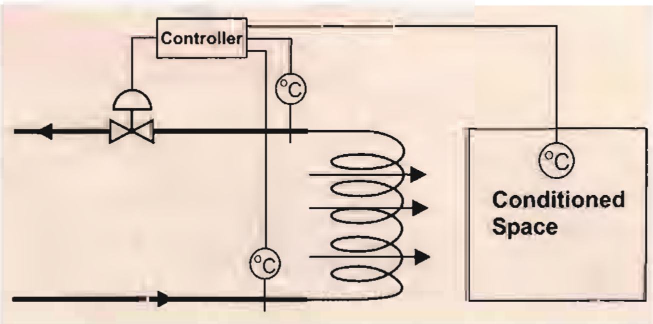

Figure 5

The present mindset of system balancing is due for an overhaul as it belongs to an era of constant flow water systems and is the result of lack of understanding of basic tenets of heat transfer and fluid flow.

The Present and Future

The variable flow water systems, which are the order of the day and are likely to continue in near future also, have pumps with variable frequency drives. It is possible to change the pumped flow based on load, a pressure sensor is generally provided near the farthest load to ensure required flow. Variable flow accommodates change in flow rate of a circuit without affecting the flow through the other circuits, subject to the maximum pumping capacity, i.e., the sum total of the maximum flows of all the circuits should not exceed the pump capacity. In simple terms no circuit should overdraw the design maximum flow.

As explained earlier any overflow through a heat exchanger results in drop in ΔT and, therefore, its measurement could easily be used to limit the water flow to the designed maximum. Then, each heat-exchanger/coil circuit will require two sets of controls:

- One to regulate the fluid flow through the coil so as to maintain desired space conditions
- Other to limit the maximum fluid flow so as not to let the ΔT drop below the desired value.

This can be achieved as shown in *Figure 4*, wherein two control valves are used in series, one operating to the dictates of conditioned space sensor/controller and the other operating to the dictates of ΔT sensors/controller. Any reduction in ΔT can be used to close down the other control valve and thus reduce and limit the rate of fluid flow through the heat exchanger.

Such a system ensures a constant ΔT across all heat exchangers, which is the primary requirement for the efficient operation of heat exchangers connected in parallel, by preventing excessive flow through heat exchangers closer to the pumps or with less internal resistance.

The above system can be further simplified, as shown in *Figure 5*, by using only one control valve to control the rate of fluid flow to the dictates of a sensor in the conditioned space as well as to prevent any drop in ΔT.

The only condition being that now that a single control valve has to take up the entire pressure drop across a circuit:

- It should have a high shut-off pressure rating
- And should have a wide rangeability/turn-down-ratio

This system, at optimal cost, not only ensures best operating efficiency at the start-up but also all along the life of the HVAC system, as it takes care of changes in heat-exchange efficiency due scaling, fouling etc., by keeping ΔT constant.

Reference

Gil Avery, James B. Rishel - *"Case against balancing valves"* - ASHRAE JOURNAL July, 2009.