Benefits of Testing and Balancing: Controllability

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Testing and Balancing can affect an HVAC System in some less than obvious ways – one way being the controllability of a system.

The ability of a device to control flow, whether it's air or water, depends on the range of motion under which that device functions during normal operation. Reducing this range reduces the resolution of the device, thus reducing the controllability of the device. Keep in mind that the resolution itself may not be linear and varies depending on how linear the flow is through the device. Also, we shouldn't confuse resolution with the throttling range or sensitivity of a controller. Although both help to improve controllability, for our purposes we will only be examining the resolution of the controlled device.

For example, let's look at a control valve on a reheat coil. Note that for this example we'll assume that the space load calculations are accurate. A situation where a system was not balanced might look like Figure 1. Here the valve can't stroke to the full open position because the design flow is reached when it is less than 50 percent open. This is also typical of valves that are oversized. The space temperature is satisfied before it has a chance to fully open. A side effect is poor comfort control, increased sound level, and poor performance.

If the system is balanced properly, then the range of motion will be similar to the graph shown in Figure 2. The valve can stroke almost 100 percent to deliver design flow, therefore the resolution is maximized. The result is improved comfort control, reduced noise, and ultimately improved performance.

Now look at how this actually affects space temperature. As resolution decreases, the small changes in valve movement result in large changes in flow and consequently larger fluctuations in space temperature.

Referring to Figure 3, we see an example of space temperature under proportional control where the reheat system was not balanced. With proportional control, the controller only gives a signal when the space temperature falls outside of the "dead band". In our example, if the space temperature falls to less than 70 degrees, the control valve opens to heat the air. If the system was not balanced properly, then only a small change in the control valve would cause the space temperature rise above the set point.

Figure 4 shows an example of a well-balanced, proportionally-controlled reheat system. A small movement in the control valve results in a much smaller

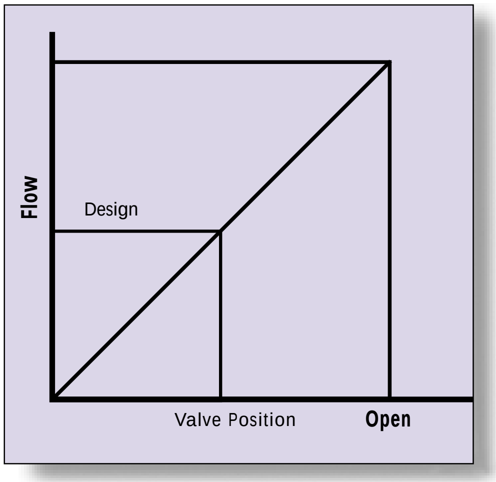

Figure 1: *Valve Position vs. Flow*

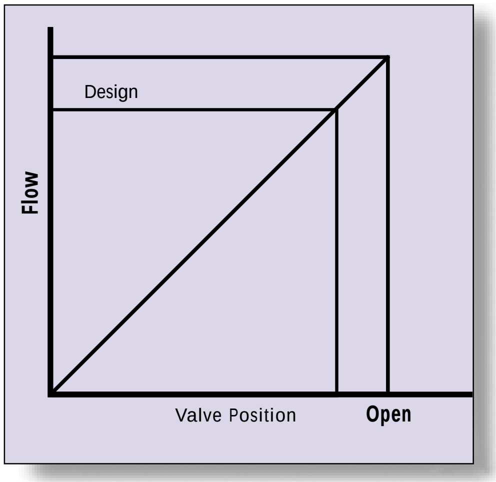

Figure 2: *Valve Position vs. Flow*

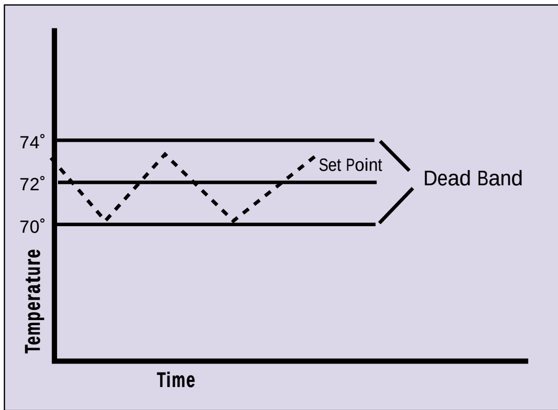

Figure 3: *Proportional Control: Temperature*

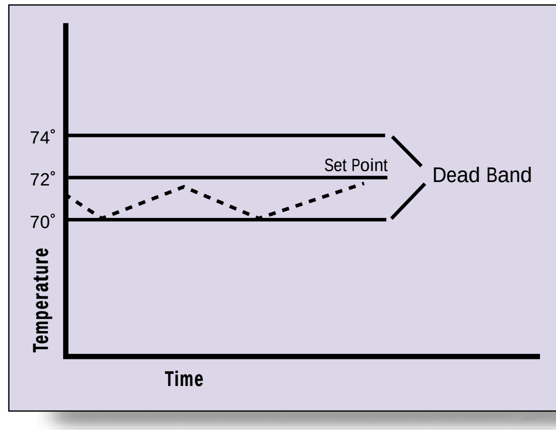

Figure 4: *Proportional Control: Temperature*

change in space temperature. Here, it does not fluctuate as much because the control valve can place the space temperature within the dead band without overshooting the set point.

Another device which depends on maximum range of motion to ensure its controllability is a pressure independent VAV box. An ideal VAV system would be designed so that the velocity entering any given box is equal to the next. However, quite frequently this is not the case and we see a condition as displayed in Figure 5. Remember that this example was used to illustrate the importance of range of motion.

Figure 5 shows an example of the flow pattern of a VAV box which is delivering design flow with only a small opening of the damper. This is the result of either excessive static pressure in the system or an oversized VAV box. Not only is the range of motion narrow, but the flow sensor will not sense the proper flow because the velocity is much higher above and below the sensor. Again, as with the control valve example, a small movement in the damper will yield an increasingly larger change in flow, as the range of motion decreases. This can be illustrated quantitatively by the following table:

Design cfm	Range of Motion	Resolution
600	5 degrees	120 cfm per degree
600	30 degrees	20 cfm per degree

The choice of 30 degrees was not arbitrary. Rather, it represents approximately 70 percent of the dampers full range of motion; 45 degrees. When balancing a VAV system, a conscious effort should be made to maximize the range of motion of all the boxes without risking a situation where a box might open 100 percent. Although there is no correct percentage to which you can balance, 70 percent is usually a safe starting point. Note that depending on how linear the device is, this number may vary.

Figure 6 illustrates the use of volume dampers to aid in achieving the desired range of motion and improved controllability.

All too often, the value of testing and balancing is overlooked. Implementing simple balancing techniques can, in most cases, eliminate the need for complex control solutions. ■

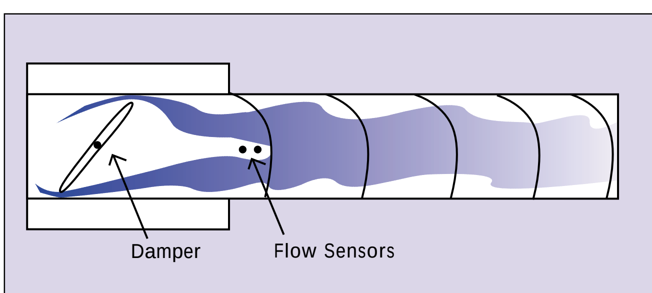

Figure 5: *Pressure Independent VAV Box*

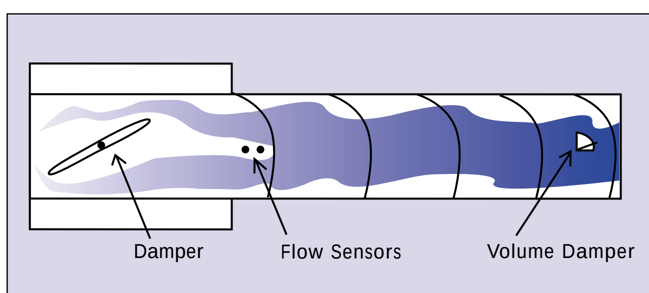

Figure 6: *Pressure Independent VAV Box*