Chapter 6

Final Control Devices

6.1 DAMPERS:

Dampers are used for the control of airflow to maintain temperatures and/or pressures. Some special types of dampers are used in HVAC equipment, such as mixing boxes and induction units, but the control dampers in air ducts and plenums are almost invariably the multi-leaf type.

Two arrangements are available: ***parallel-blade and opposed blade***. As Figure 6-1 shows, in parallel-blade operation all the blades rotate in the same (or a parallel) way. In opposed-blade operation adjacent blades rotate in opposite directions.

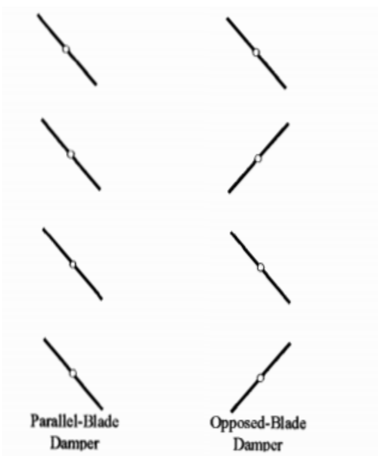


Figure 6-1Airflow Dampers

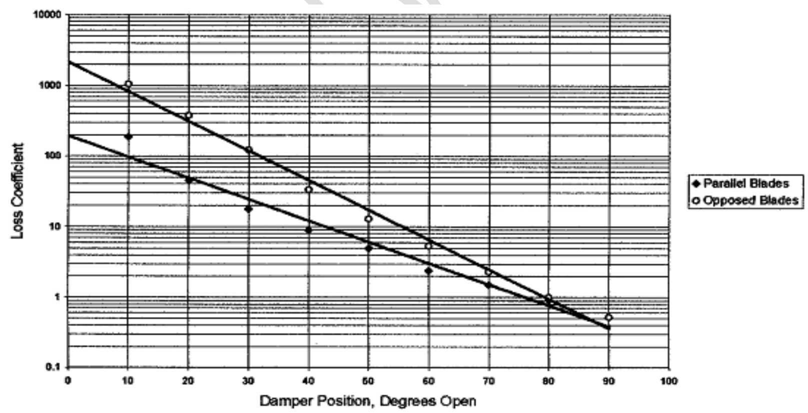


Figure 6-2 Damper flow characteristics.

6.1. I Pressure Drop:

The pressure drop through dampers can be characterized by the dimensionless loss coefficient, ***Cd, which is the ratio of the total pressure loss through the damper to the local velocity pressure:*** **Cd =** $\Delta Pt / Pv$

Where,

Cd =*loss coefficient,* ***ΔPt*** *= total pressure loss Pv=velocity pressure.*

The loss coefficient, ***Cd is a function of the blade angle and the damper type. Figure 6-2 shows the damper characteristics***. Over most of its operating range, the loss coefficient is an exponential function of blade angle for both parallel and opposed blade dampers. Notice that the loss coefficient increases more slowly as the damper closes for parallel-blade dampers than for opposed blade-dampers, parallel blades act more like ***turning vanes*** whereas opposed blades act more like ***orifices***.

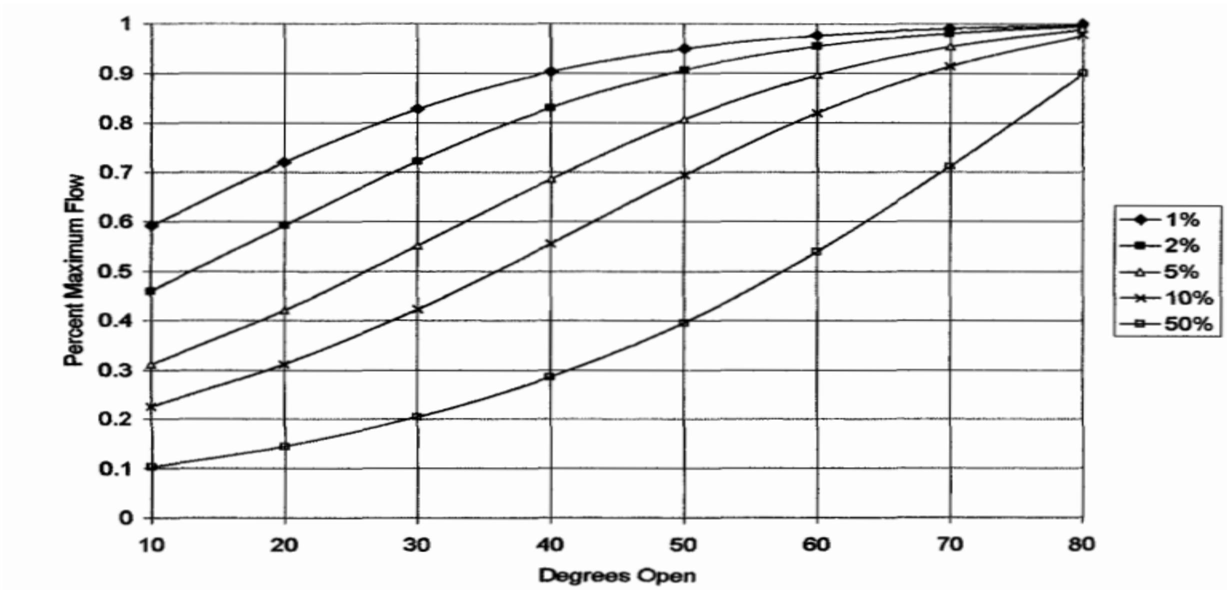


Figure 6-3 Parallel-blade damper characteristics.

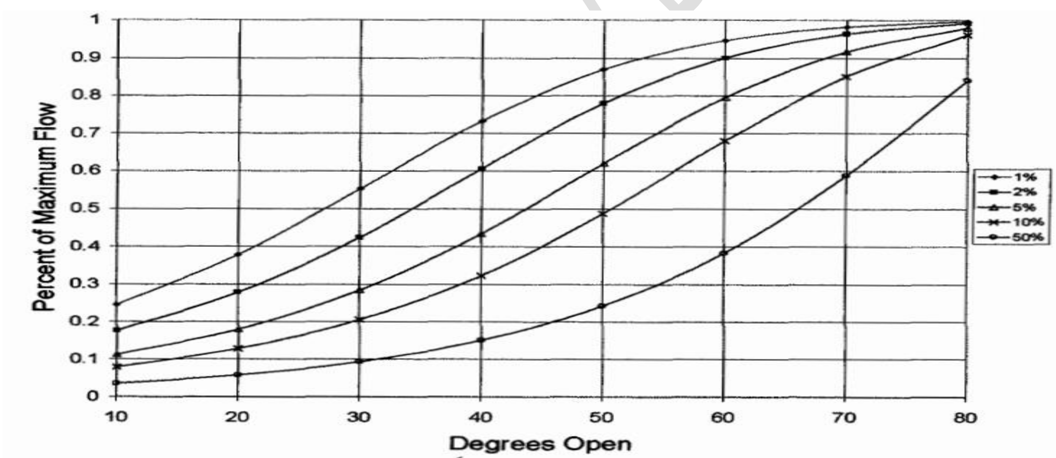


Figure 6-4 Opposed blade damper characteristics

Figures 6-3 and 6-4 show fraction of full flow versus blade angle for parallel and opposed blade dampers for various values of ∂ (∂ is expressed in percent of total system resistance). *Notice that for a typical parallel blade damper to achieve nearly linear modulating control it is necessary that the pressure drop through the damper in the full open position be from* ***20% to 50% of the total system pressure***. To get almost equivalent linearity with a typical opposed-blade damper, the wide open pressure drop through the damper need be only about ***5% to 10% of the system pressure drop.***

As most of the energy loss creates noise, the opposed-blade damper is preferable for modulating service from both noise and energy loss standpoints.

This means that dampers in outdoor or return ducts probably should be less than one-fourth of the area of the coil.

6.1.2 Leakage

Dampers are inherently leaky, the amount of leakage at close-off being a function of the damper design. Minimizing leakage increases cost; so system requirements should be the basis for selecting a damper. Most manufacturers publish leakage ratings. Damper leakage can become a serious problem in some applications. For example***, outside air dampers must have minimal leakage to prevent equipment damage due to freezing air***.

6.1.3 Operators:

Damper motors may be pneumatic, electric or hydraulic. They must have adequate power to **overcome bearing friction and air resistance, and for tight-fitting low-leakage dampers, to overcome the binding friction of the fully closed damper.**

6.1.4 Face and Bypass Dampers

Face and bypass dampers frequently are used with preheat coils, and less often with direct-expansion cooling coils. Figure 6-5 shows a typical preheat installation. The preheat coil is sized with a face velocity based on the manufacturer's recommendations, and with all the air flowing through the coil. The open face damper will have this face velocity. The face damper and coil pressure drops then can be determined from manufacturer's information.

The bypass damper should be sized so that its wide-open pressure drop is equal to the sum of the face damper and coil pressure drops.

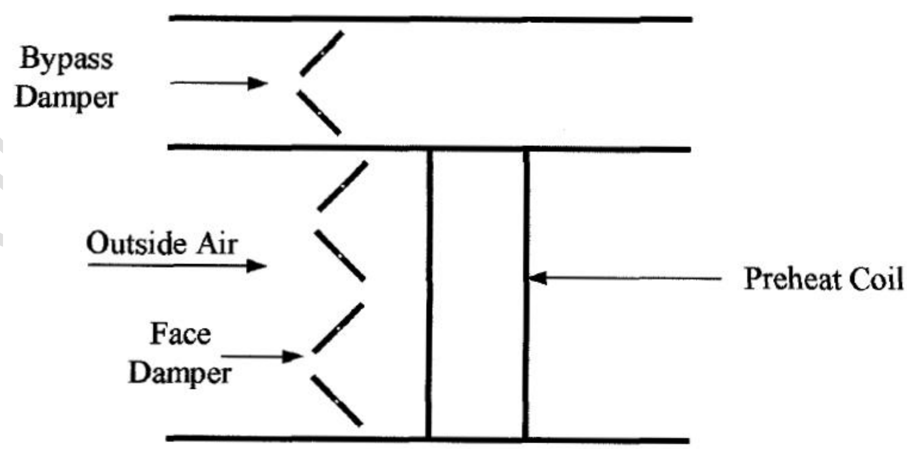


Figure 6-5 Face and bypass dampers.

6.2 Steam & Water Flow Control Valves:

The proper selection of valves for the control of steam and water flow requires an understanding of ***both the valve characteristics and the system in which the valve will be used***. The size of a heat exchanger or a coil and the fluid flow rate through it must be based on some maximum design load. But, in practice, the equipment usually operates at part load***; so the valve must control satisfactorily over the whole range of load conditions***.

6.2.1 The Flow Coefficient

Most manufacturers publish valve capacity tables based on the flow coefficient, **Cv**. In inch-pound units, **this is the flow rate in gallons of 60°F water that will pass through the valve in one minute at a one pound pressure drop**. The rated **Cv,** is established with the valve fully open. As the valve partially closes to some intermediate position the **Cv,** will decrease. The rate at which it decreases determines the shape of the curve in Figure 6-6. Some industrial valve manufacturers publish **Cv,** data for partially open valves.

The change in pressure drop and flow in relation to stroke, lift or travel of the valve stem is a function of the valve plug design. Different types of valve plugs are required to fit different control methods and fluids.

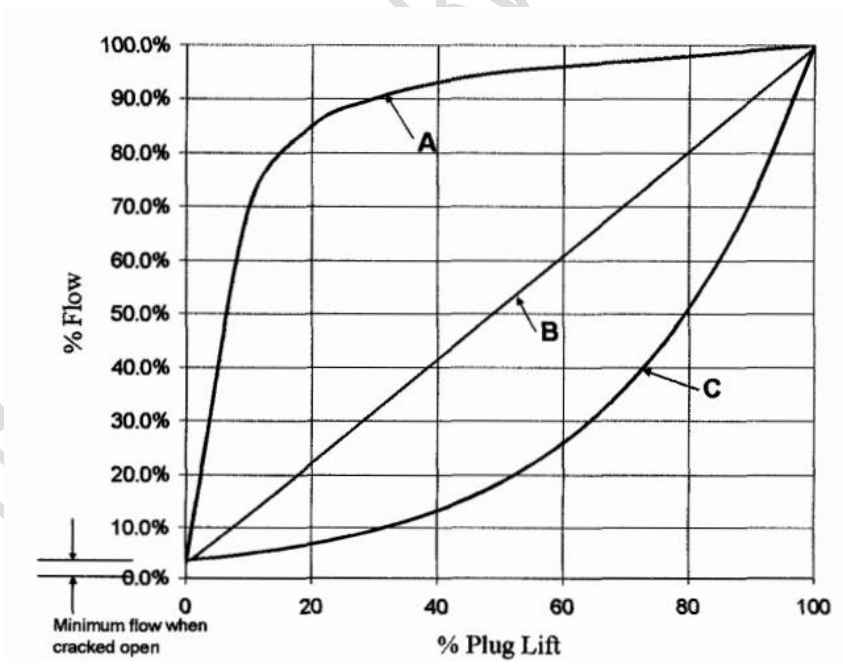


Figure 6-6 Valve characteristics

6.2.2 Two-Position Valves

These valves should be of the flat-seat or quick-opening type shown in Figure 6-7. The accompanying graph of percent flow versus percent lift (Figure 6-6, curve A) shows that nearly full flow occurs at about 20% lift. ***Two-position valves should be selected for a pressure drop of 0% to 20% of the piping system pressure differential, leaving the other 80% to 90% for the heat exchanger and its piping connections***.

6.2.3 Modulating Valves

The position of a modulating valve is usually what is adjusted by the control system to control the controlled variable. If the valve is designed with a linear characteristic, as in Figure 6-8 and curve B in Figure 6-6, then the flow rate will vary directly with lift (or nearly so) ***for a constant pressure drop across the valve.*** By varying the angle of this V-port arrangement, curves above and below the linear relation can be obtained.

A linear characteristic valve is excellent for proportional control of steam flow because the heat output of a steam heat exchanger is directly proportional to the steam flow rate. This is so because the steam is always at the same temperature, and the latent heat of condensation varies only slightly with pressure change.

Hot water coils, however, create a different requirement, as reduction in flow will be accompanied by an increase in the temperature change of the water. The net result may be only a small reduction in heat exchange for a large reduction in flow.

To get a better relationship between valve position and heat output for this case, an equal percentage valve is used (curve C of Figure 6-6). The equal percentage valve has a plug shaped so that a percentage change in valve position produces a corresponding percentage change in flow (see Figure 6-9).

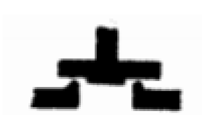
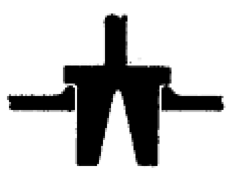
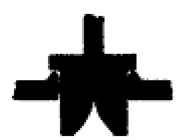




Fig. 6-7 Quick opening valve. Fig.6-8 Linear or V-port valve Fig.6-9 Equal percentage valve

It turns out that the above valve works well with the coil shown above to produce a nearly linear relationship between heat output and valve position. Figure 6-10 shows percent of capacity for the coil and percent of flow for the valve versus valve position. This figure shows how valve characteristics can be tailored to the application but we have assumed that the most of the pressure drop is due to the valve.

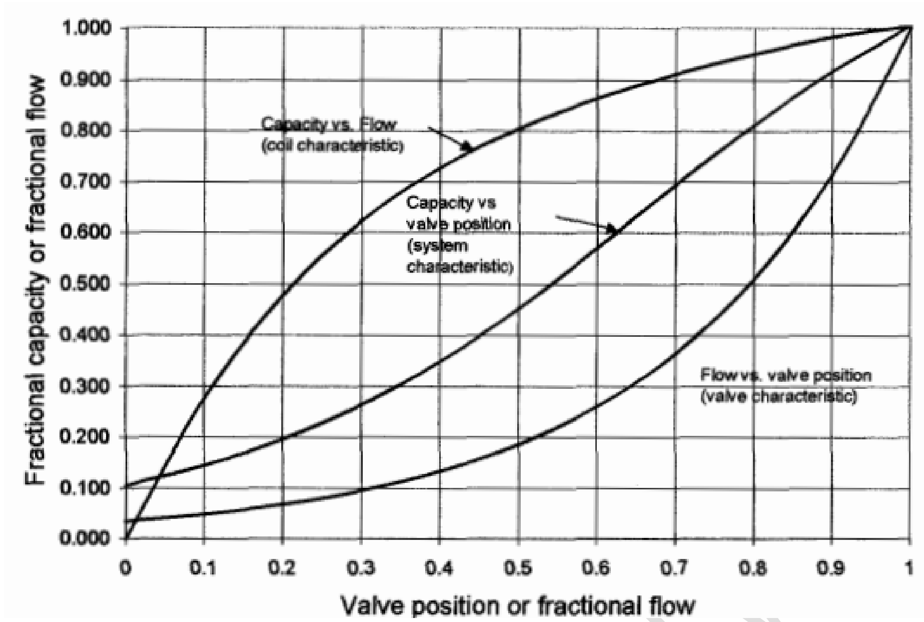


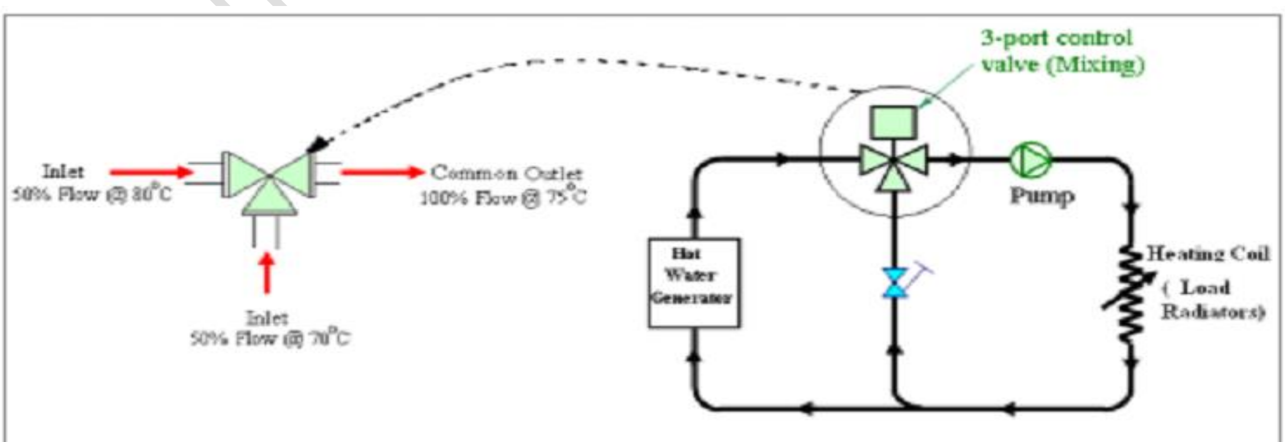
Figure 6-10. Matching heating coil and valve characteristics

6-2-4 Three Way Valve

Three-way valves have three ports and can be piped for by-pass application either in mixing or diverting service. There are two basic arrangements for three-way valves: ***mixing valves (two inlets, one outlet) and diverting valves (one inlet, two outlets).*** There are several different physical types of valves. ***Globe valves, ball valves and butterfly valves are all commonly used in the HVAC industry***.

a- Mixing Valves

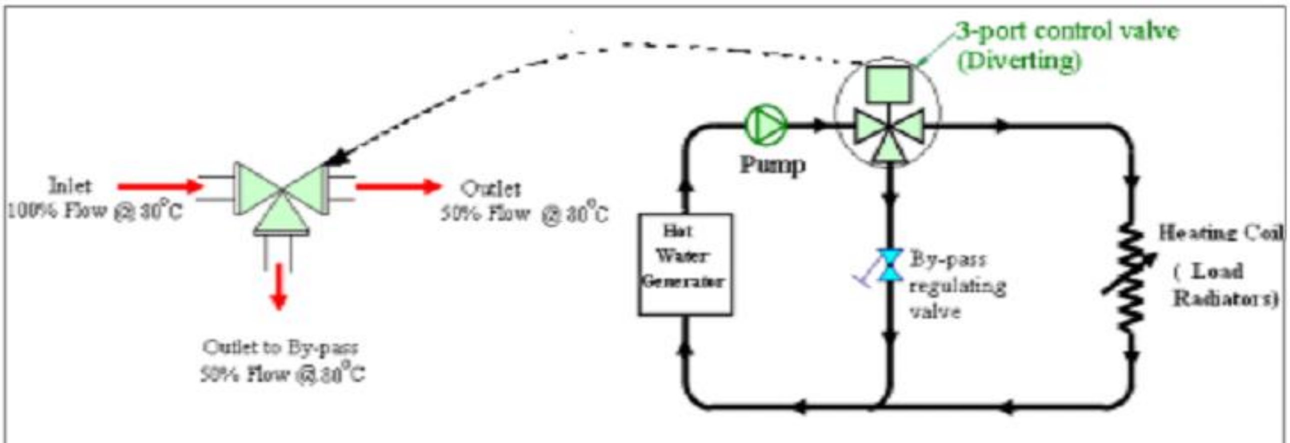
A three-port valve with two inlet flows and one common outlet flow is defined as a mixing valve, and so provides a variable temperature outlet at a constant flow rate. A three-port motorized valve can be used to mix, in varying proportions, two flows of different temperatures while maintaining a constant rate of flow in the common outlet port. ***A Mixing Valve is used normally for radiator circuits.***



Mixing Valve in Heating Application

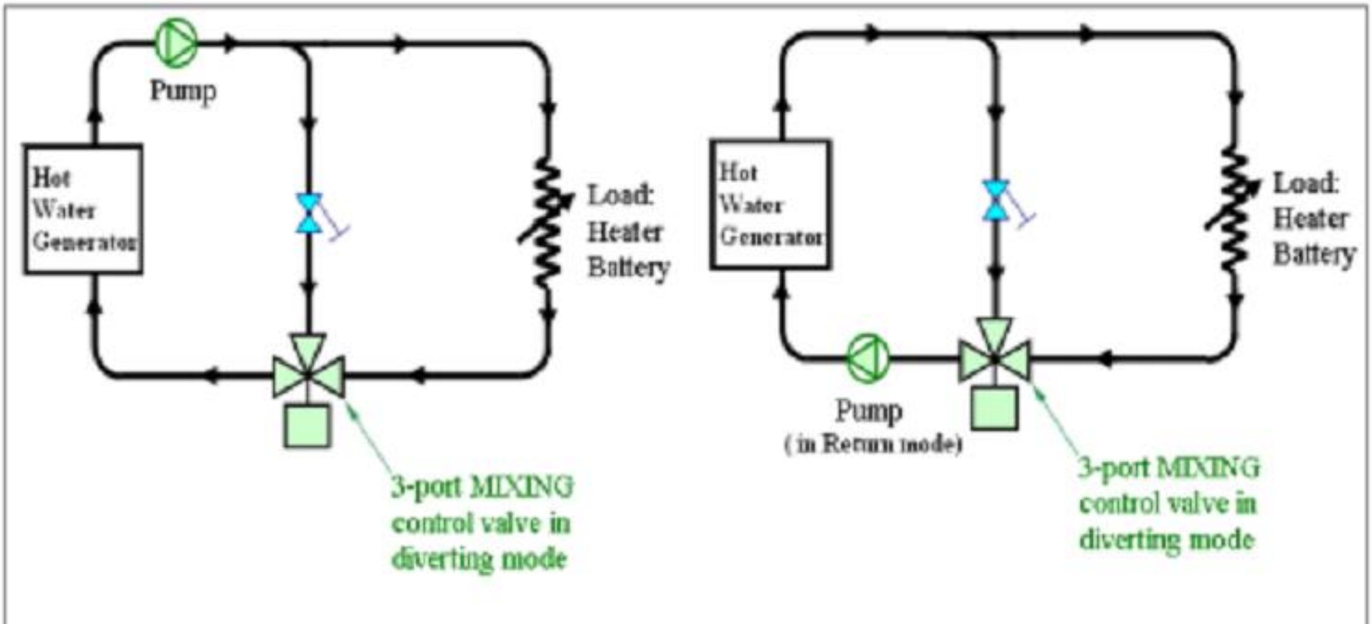
b- Diverting Valves

3-port valve may also be used to divert, the valve will have one inlet and two outlets and provides a constant temperature and variable flow rate. The diagram below shows a diverting valve with some typical water flow rates and temperatures. A diverting valve is used normally for circuits with convective heat transfer such as; heat exchangers, cooling coil. Diverting valves in bypass applications are placed upstream of the coil. The supply water enters the inlet port and is directed to either the coil branch or the bypass branch depending on the signal from the controller to the valve actuator.



Diverting Valve in Heating Applications

In the above example, when the valve is in the fail position the supply water is bypassed around the coil. As the stem position modulates from 0-100%, the flow reduces in the bypass and increases in the coil until full flow to the coil is achieved at a stem position of 100%. A mixing valve can also be used in a bypass application to control the flow through the coil by placing the valve downstream of the coil. The flow through the coil is still controlled by the stem position of the mixing valve. The location of the three-way valve will not affect the operation of the system. The mixing valves can be used as diverting mode of operation as shown below.



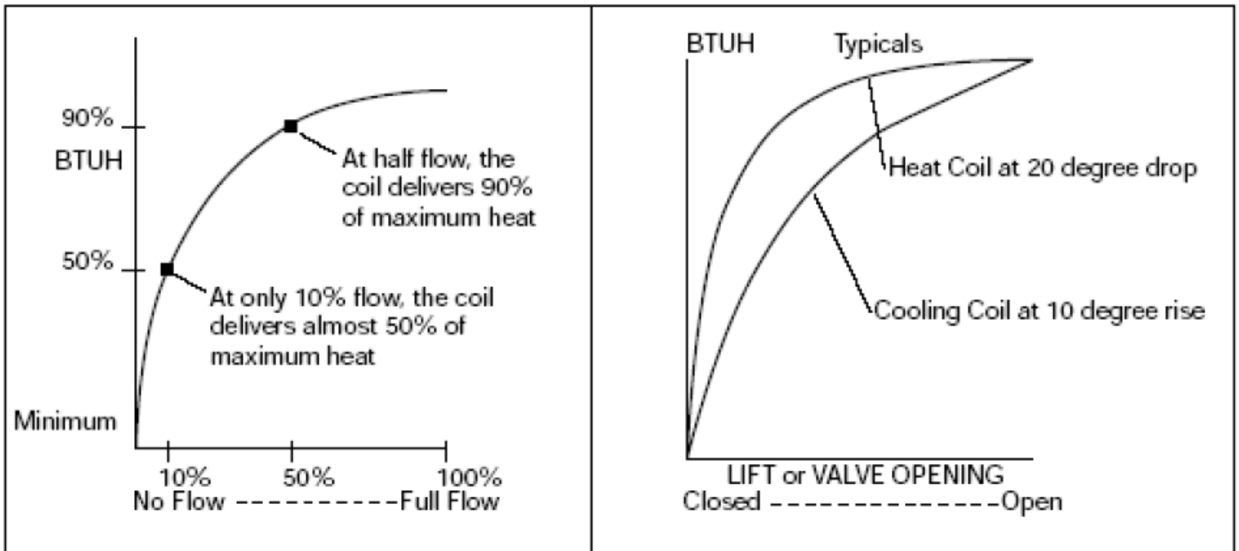
3-Port Mixing Valve As Diverting Valve Application

In the above diagrams the pump position is important since the system will not operate properly if the pump is not in the correct part of the circuit. It is possible to place the pump in the return pipes and some suppliers recommend this due to the way that the 3-port valves are constructed.

6-3 Coil Characteristics

a) Heating Coils

Figure below shows the relationship between the heat emission and the flow of water through a typical heating coil. Different types of coils have different characteristics, but the basic "convex" shape remains essentially the same; the only difference is how pronounced the curvature. This depends upon the type of heat exchanger, the water side temperature drop, the air side temperature rise, and on the relative values of the water and the air.



Response Curve of Heating Coil **Response Curve for Cooling Coil**

The "convex" shape of the curve means that when the flow increases from zero, the heat emission increases at a high rate in the beginning, but as the flow is increased, the rate of increase decreases.

The reason for this is that at small flows, the water takes a long time to pass the coil, so the temperature drop of the water will be large (effective use). Conversely, when the flow is increased, the water spends less time inside the coil and the temperature drop of the water is less.

A coil is selected for a specific airflow and heat emission. A specific temperature drop of the water flow through the coil is produced only at these design conditions. This is the "design temperature drop". On the air side, there is a design temperature rise.

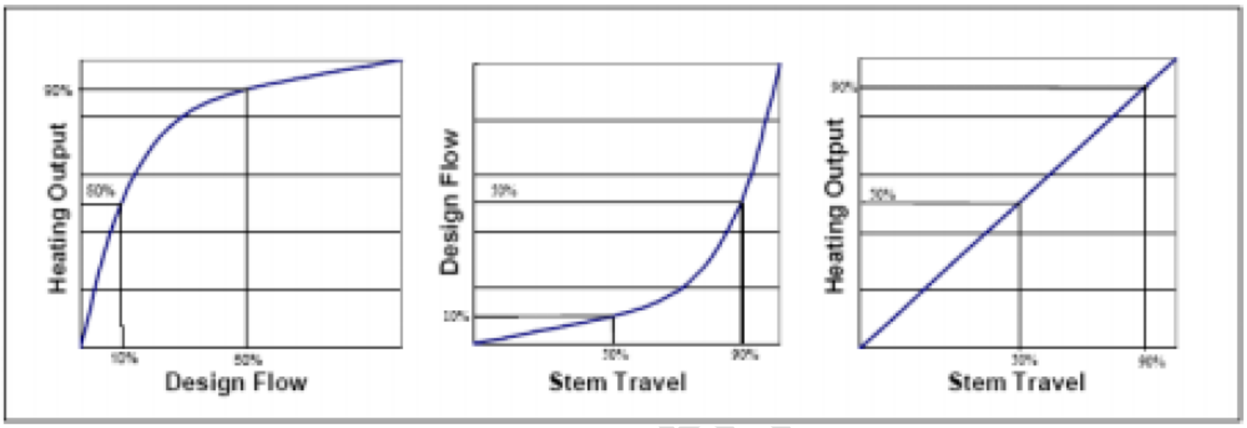
b) Cooling coils

The characteristics of cooling coil resemble a heating coil. The cooling coil at 8 to 12 degree rise is very similar to the heating coil at a high drop. Total heat also includes the latent heat removal (moisture). Dehumidification is a very important aspect, but with respect to the stability aspects of the temperature control, it is the sensible heat curve that is of the determining factor. The curve is much closer to the linear than that of a typical heating coil. The water side drop is 10° instead of 20°; the air side change is from 75° to 55° instead of from 70° to may be 120°. Strictly speaking a typical cooling coil needs a different valve characteristic than a heating coil.

The summary from above:

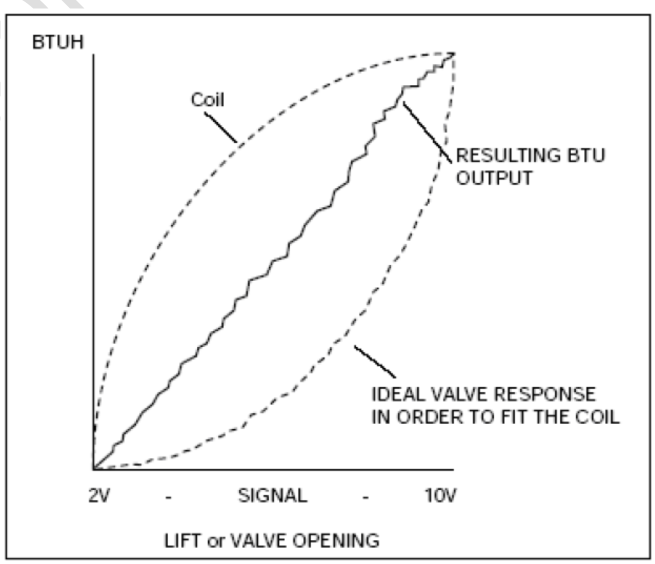
Control valves used with cooling coils need to have a performance characteristic that is "opposite" to the coil. Equal percentage control valves are typically used for two-way applications. For three-way applications, equal percentage is used on the terminal port and linear is used on the bypass port.

Figure below shows an equal percentage control valve properly matched to a cooling coil. The result is that the valve stem movement is linear with the cooling coil capacity. In other words, a valve stroked 50% will provide 50% cooling.



The **controllability** is an important parameter in matching coil to valve characteristic. The best control stability is accomplished when there is a linear relationship between the position of the valve stem and the heat output from the coil.

Heat transfer laws give a relationship between water flow and heat output in a system as shown below and also between valve position and water flow.



6-4 Solenoid valve:

It is an electrically operated magnetic valve, which consists of a coil wound around a sleeve of non-magnetic substance. When energized, the coil carries an electrical current and becomes a magnet.

Inside the sleeve is a movable iron core, which will be attracted by the magnetic field of force to remain suspended in a midway position inside the sleeve. The iron core movement opens the valve. When the coil is de-energized, the iron core returns to its normal position to close the valve. This type is normally closed. Others are available which are normally open; these close when the coil is energized.

There are many uses for this type of valve, such as in defrost systems, multiple evaporator systems and pump-down cycles. In effect, it is used wherever it is necessary to stop the flow of refrigerant to a specific section of pipework on particular applications.

<u>Questions and Answers</u>

1- Define the following: Damper, Control valve, Damper pressure loss coefficient, Valve Flow Coefficient**,** Three Way Valve, Mixing valve, Diverting Valve

2- How the pressure drop through dampers can be characterized?

3- Draw a piping circuit of boiler, pump, heating coil, by-pass regulating valve, and three-way valve which used for the following services:

- Mixing.
- Diverting.
- Mixing valve in driving valve applications**.**

4- Draw a graphical relations showing how heating coil and valve characteristics can be matching?

5- Rationalize the following :

- The opposed-blade damper is preferable for modulating control? .
- Outside air dampers must have minimal leakage?
- Two-position valves should be selected for a pressure drop of 0% to 20% of the piping system pressure differential?
- Modulating Valves should be designed with a linear characteristic?
- The use of three-way valves should be minimized in some piping circuits?