MECHANICAL DESIGN MANUAL SUMMARY SHEET

SUBJECT: Damper Application Engineering

DESCRIPTION: Application of dampers in typical HVAC processes. Damper selection criteria for two position, temperature, static pressure, face and bypass and mixed air temperature controlled applications.

Specification Section: 15952

References: Johnson Controls, Inc.
Engineering Report H352

Barber-Coleman
Fundamentals of Pneumatic Controls

Johnson Controls, Inc.
Assorted Product Literature

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General

Inherent Flow: The Δρ across the damper is held constant regardless of the position of the damper plades.

In a fan/duct system; the ductwork, balancing dampers, filters, coils and fittings will also have a pressure drop across them. As the damper throttles, the flow flow rate and pressure drop through the other components of the system will be reduced. The Δρ across the damper will increase by the same amount as the Δρ across the other components is decreased.

Damper flow characteristic curves are generally shown in graph format with the percent stroke of the damper on the X-axis and the percent of the wide open flow on the Y-axis. The resulting curve is a function of two items.

First, the shape of the curve is related to how the blades move relative to one another. Thus a damper with opposed blade linkage will have a different characteristic than a damper with parallel blade linkage. Secondly, the shape of the curve is related to the differential pressure across the damper.

The inherent flow characteristic of a damper is normally determined in a certified testing laboratory. The inherent flow characteristic curves for the Johnson Control,Inc., D-1300, opposed and parallel blade dampers are shown in figure 1.

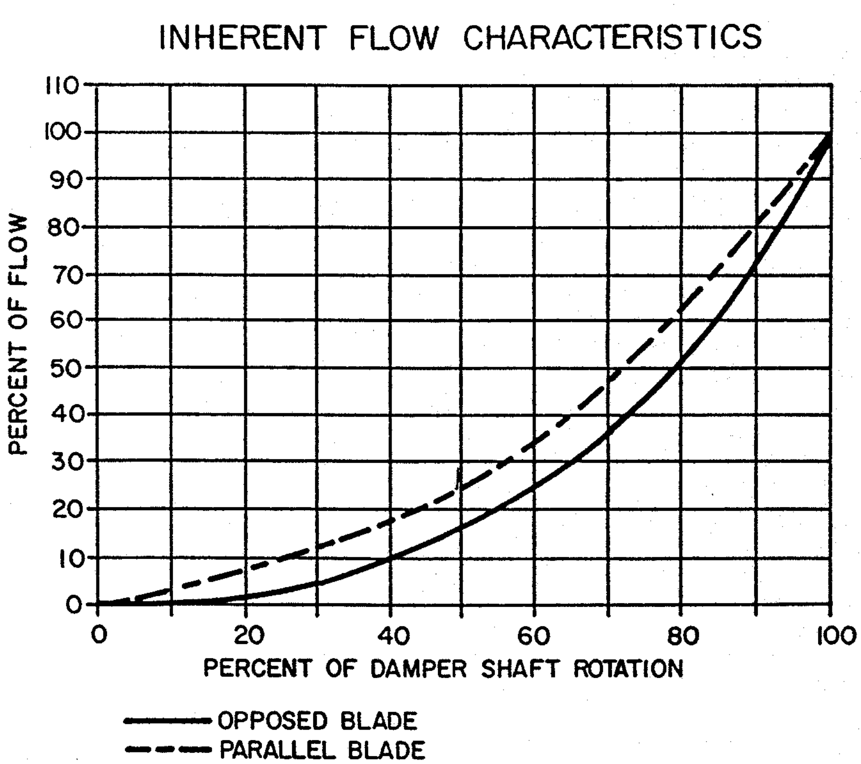


FIGURE 1

Authority: The ratio of the wide open $\Delta\rho$ through the damper to the total duct system $\Delta\rho$ at design flow.

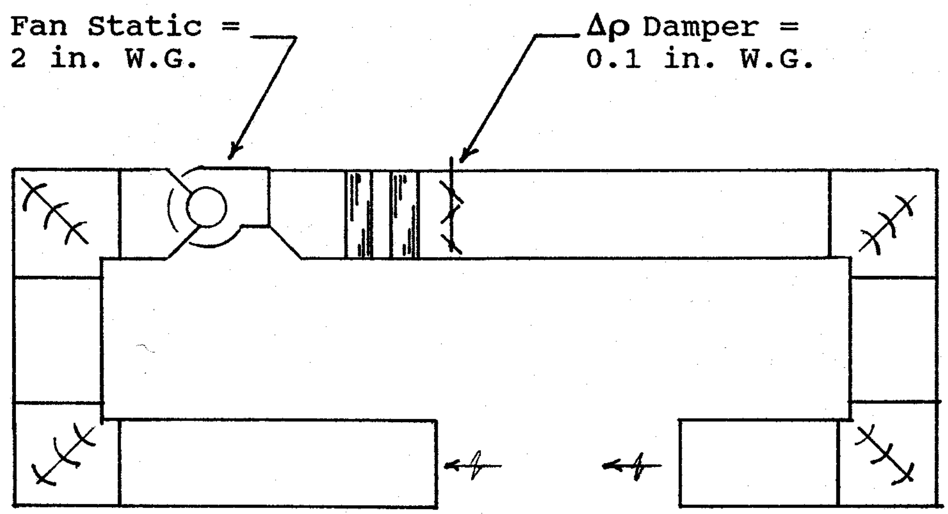
Authority = $(\Delta\rho_a \div \Delta\rho_t) \times 100$

Where: $\Delta\rho_a$ = pressure drop across wide open damper

$\Delta\rho_t$ = total pressure drop in that portion of the system in which the damper is to be installed.

The value of $\Delta\rho_t$ is generally equal to the total pressure drop which can be expected across the damper in the closed position.

The damper shown in Figure 2 has an authority of 5%.



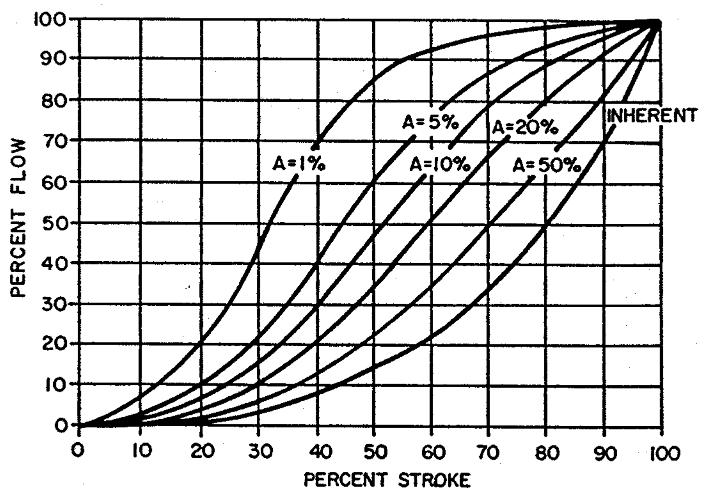
$$\%DamperAuthority = \frac{0.1}{2}(100) = 5\%$$

Figure 2

If the damper authority is known, the **installed damper flow characteristic curve** can be determined. The installed flow characteristic curve is the actual flow characteristic obtained when the damper is applied to a given air handling system. It takes into consideration the pressure shift to the damper.

Figures 3 and 4 show a family of installed characteristic curves. Each curve is labeled based on percent of damper authority. Therefore a curve labeled "A=5%" would reflect the relationship between percent of damper stroke verses percent of wide open flow for an installation with a damper authority of 5%. Figure 3 is appropriate for dampers with opposed blade linkages. Figure 4 is appropriate for dampers with parallel blade linkages.

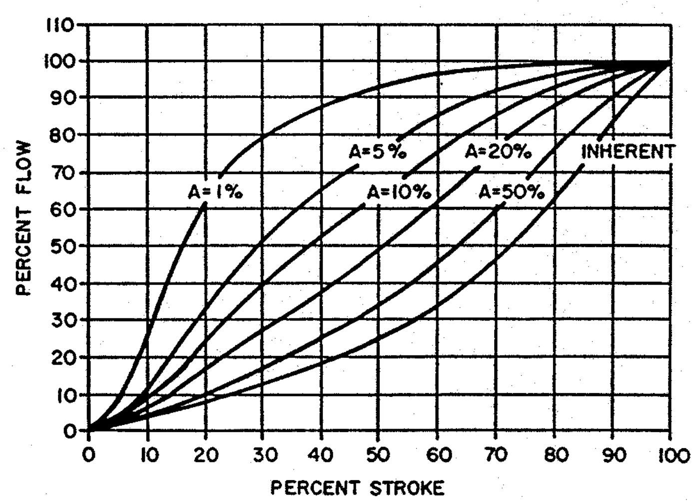
DAMPER FLOW CHARACTERISTIC (OPPOSED)



% AUTHORITY = $(\Delta P_{damper} \div \Delta P_{duct\ system}) * 100$

FIGURE 3

DAMPER FLOW CHARACTERISTIC (PARALLEL)



% AUTHORITY = $(\Delta P_{damper} \div \Delta P_{duct\ system}) * 100$

FIGURE 4

Damper Applications

The application of the damper will determine which installed damper flow characteristic will provide the best control. The value of the damper authority which matches the desired flow characteristic is used to determine the wide open pressure drop through the damper. the correct damper can then be selected. There are five basic damper applications; 2-position, temperature control, static pressure control, face and bypass and mixed air control.

Two Position

In this application the damper is maintained in either its fully open or closed position depending on the condition of a binary input. The shape of the installed damper flow characteristic is not important since the damper is not used as a modulated device. The only requirement is that it must be possible to obtain the wide open design flow rate through the damper with a pressure drop which is less than or equal to the value specified. Generally, dampers used for this application are duct sized to provide the lowest wide open presure drop possible. The exception is the case where the damper size is reduced to minimize leakage. The amount of air which leaks through a closed damper is related to the damper size, construction, and differential pressure drop across the damper.

Temperature Control

Dampers are frequently utilized to regulate the amount of conditioned (supply) air which is introduced into a zone. A variable volume terminal air box is a good example of this application. Varying amounts of supply air are used to compensate for the heat gains or losses within the space. The amount of sensible energy transferred to or from the room by the supply air can be determined by the following equation:

$$\text{Sensible Heat Transfer (BTUH)} = (1.08)(\text{CFM})(T_{sa}-T_t)$$

Where:
- CFM = Flow rate through the damper
- T_{sa} = Temperature of the supply air
- T_t = Temperature of the room air

If the supply and room air temperatures are being maintained at setpoint, the flow rate into the room will be directly proportional to the amount of heat transfer required to maintain the space temperature setpoint. As a result a linear damper characteristic is desired for this application.

Authority Recommendations (Temperature Control)

1. For opposed blade dampers, size for an authority of between 8 and 10 percent to obtain linear installed flow characteristics.

2. For parallel blade dampers, size for an authority of between 20 and 25 percent to obtain linear installed flow characteristics.

Static Pressure Control

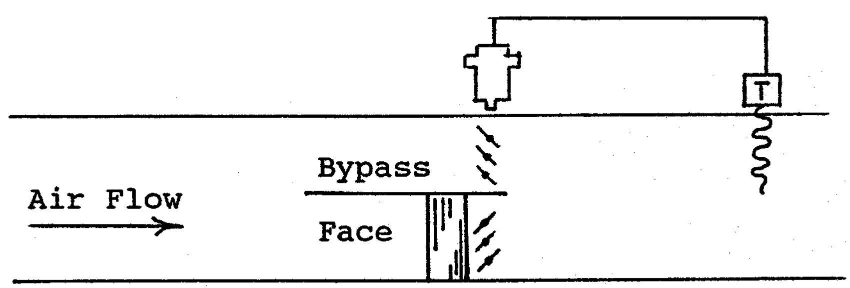
In this application the damper is modulated as required to maintain a static pressure setpoint at some downstream point in the ductwork. The damper is generally installed near the fan discharge. This application is less common today with the advent of variable speed drives or the use of inlet vanes to control fan capacity.

For guidance in using this application, see Johnson Controls, Inc. Engineering Report: H352.

Face and Bypass

The parallel blade damper lends itself to the face and bypass application because it provides for better downstream air mixing. Figure 5 shows the recommended method of installing parallel blade dampers to enhance mixing.

The face and bypass dampers should be sized so that the combined flow rate through them is relatively constant. Most manufacturers arbitrarily install coil face dampers which are the same size as the coil face area. Since coils must be selected with relatively low velocities (300-500 fpm) the face damper, which is the same size as the coil, will have a very low pressure drop and damper authority. As a result, it probably won't have the desired linear flow characteristic. To compensate the bypass section damper should be downsized.



Face and Bypass Configuration

Figure 5

To achieve a relatively constant flow rate through the face and bypass sections, it is desirable to have the same full flow resistance in both the coil face and bypass sections. The bypass damper should then be sized so that its full flow resistance would be equal to the sum of the full flow resistance to the coil and the coil face damper. Figure 6 can be used to size the damper in the bypass section.

The values on the X-axis represent the pressure drop across the coil at design flow. The pressure drop across the face damper is generally insignificant compared to the coil pressure drop so it is ignored. The values on the Y-axis represent the recommended size for the bypass damper in percent of the size of the coil.

Example:(Bypass Damper Sizing)

Assume the coil, of a face and bypass air handling unit, has a face area of 10 ft^2 and a pressure drop of 0.2 in. W.G. at a design flow rate fo 5000 cfm. The value of the Y-axis corresponding to the intersection of the 500 fpm curve and the 0.2 from the X-axis is approximately 40%. Therefore, the area of the bypass damper should be 40% of the area of the coil or 4 ft^2.

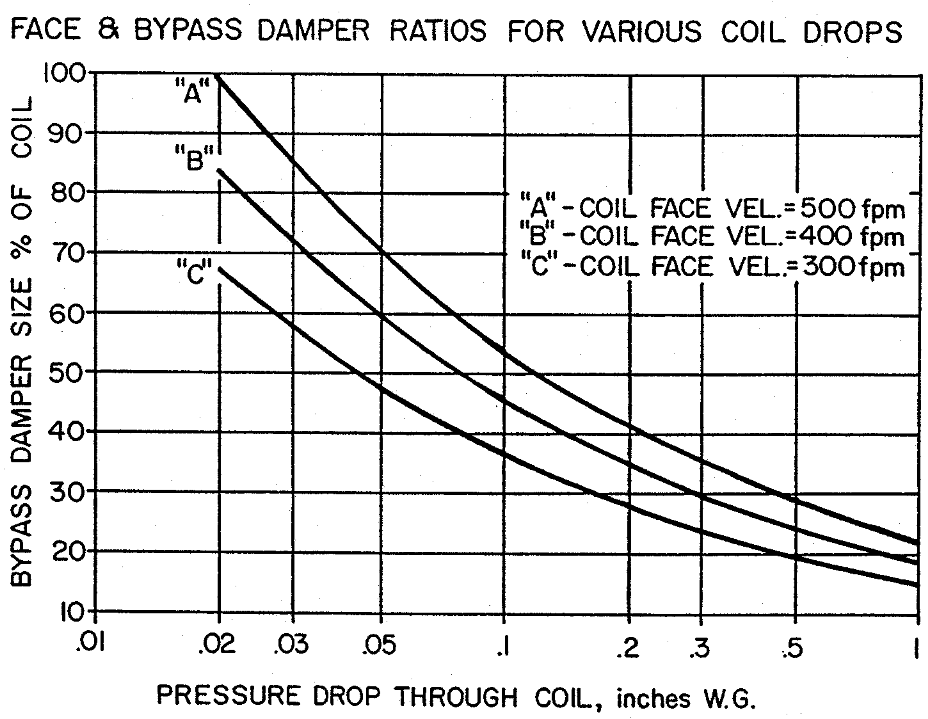


Figure 6

Mixed Air Temperature Control

Dampers are frequently utilized to regulate the flow rate of two air streams so the temperature of the mixed air stream can be maintained at some predetermined temperature. Economizer cycle control is an example of this application.

There are two independent conditions which should be satisfied when sizing dampers for this application. The first condition involves matching the dampers so that the combined flow rate through them is held relatively constant regardless of their position. **This is very important!** Figure 8 illustrates a set of well matched dampers while Figure 9 illustrates a set of poorly matched dampers.

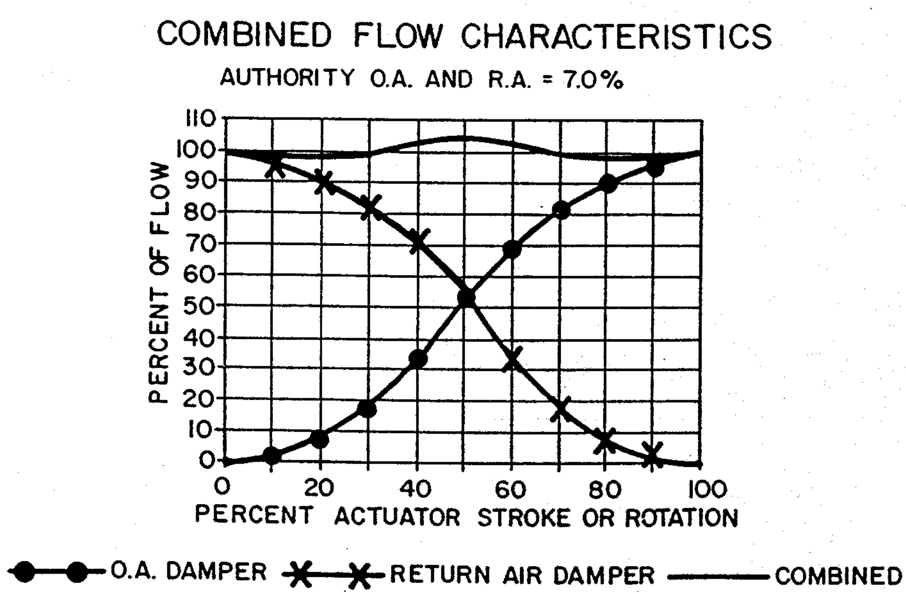


Figure 8

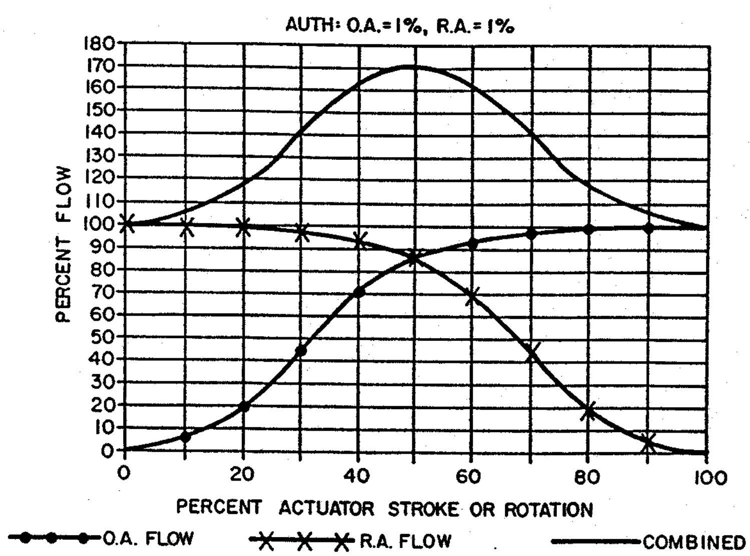


Figure 9

Instability in both temperature and static pressure control loops can occur if the variation in the combined flow characteristics is excessive. Large variations can cause mixing plenum pressure to fluctuate significantly as the dampers are modulated. In turn, the flow rate of each air stream will vary in an unpredictable manner which can make it very difficult to maintain a mixed air setpoint. In extreme cases, this instability can cascade and cause fluctuation in the supply fan static pressure control loop of a variable air volume system. Generally, if the magnitude of the combined flow characteristics does not deviate by more than 15% from the nominal value of 100%, the dampers are adequately matched to one another. The graph shown in Figure 10 can be used to match the authorities of the two dampers to provide a nearly constant combined flow rate.

Figure 10 is valid if both mixing dampers have either opposed or parallel blade linkages. It is not valid if one damper has opposed blade linkage and the other has parallel blade linkage. To use the graph, locate the intersection of the vertical line drawn through the authority of the first damper whith the appropriate curve on the graph. Make sure to use the curve which applies to the type of dampers being installed (opposed or parallel linkage). Now draw a horizontal line from this point of the intersection to the Y-axis. The corresponding value on the Y-axis is the desired damper authority for the second damper. Thus if an opposed blade outdoor air damper with an authority of 5% is installed, the opposed blade return air damper should have an authority of approximately 10% to provide a near constant combined flow characteristic.

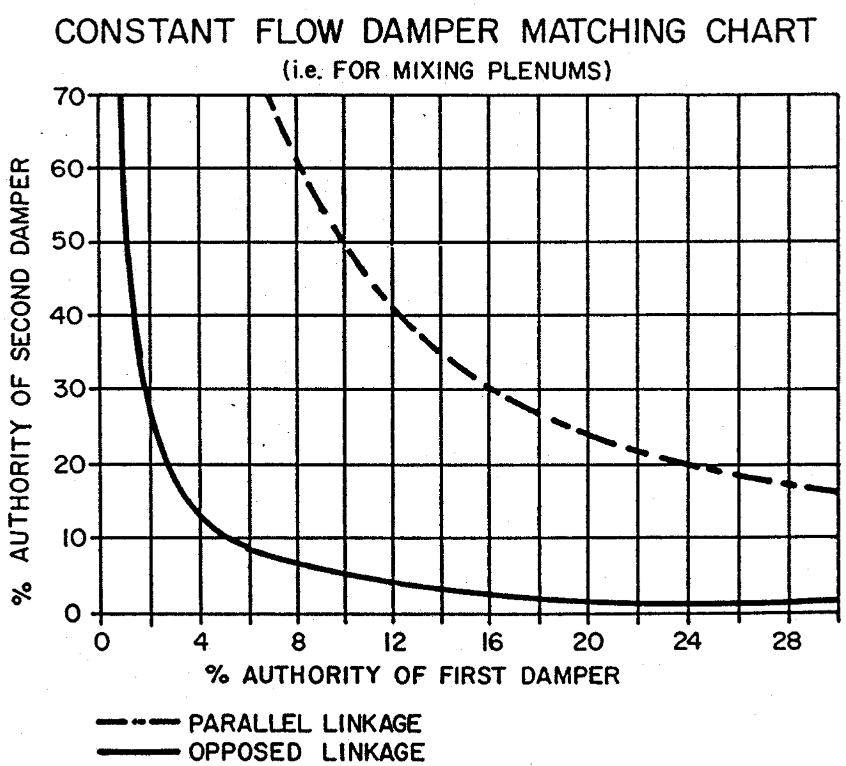


Figure 10

In most cases, it is not practical to select a damper with an authority greater than 50%. There are diminishing gains in trying to achieve a characteristic similar to the inherent damper characteristic after an authority of 50% is achieved. In other words, the damper pressure drop will increase significantly while the installed flow characteristic changes only slightly for authorities greater than 50%.

The second condition which must be considered when selecting dampers for mixed air control invloves matching the damper flow characteristics with the process dynamics of mixed air control.

When two air streams are mixed together, the resulting mixed air temperature can be determined by the following wquation:

$$T_M = ((T_1)(Flow_1)+(T_2)(Flow_2)) \div (Flow_1+Flow_2)$$

Where: T_M = Temperature of mixed air stream
T_1 = Temperature of air stream #1
T_2 = Temperature of air stream #2
$Flow_1$ = Flow rate of air stream #1
$Flow_2$ = Flow rate of air stream #2

Ideally, a percent change in the output of the controller would be matched with a like percent change in the value of the mixed air temperature under all operating conditions. Unfortunately due to the non-linear processes involved and the effect of different outdoor air temperatures, this desired condition is almost impossible to achieve.

A compromise which provides an acceptable solution for meeting both the constant flow requirement as well as matching the process dynamics, is to select the mixing dampers to have linear flow characteristics. Thus if job conditions permit, the outdoor, return and exhaust air dampers should all be sized for an authority of 8-10 percent for opposed blade dampers and 20-25 percent for parallel blade dampers.

Sometimes, due to space considerations, the outdoor air damper is installed at the louver. As a result of this installation, the outdoor air damper is significantly oversized and the velocity through the damper is kept between 300-500 fpm. This is required to prevent the entrainment of rain, snow and dirt.

When this situation exists, it will not be possible to size the outdoor air damper for linear characteristics. This louver size damper will likely have an authority which is less than the desired 8-10 perceent for opposed blade or 20-25 percent for parallel blade dampers. To compensate Figure 10 should be used to determine the authority of the return air damper. This will minimize the opportunity for instability. The exhaust air damper should be sized for the same authority as the outdoor air damper.

Unfortunately, in many installations duct sized dampers are arbitrarily installed in the outdoor air louver, return air duct and exhaust air duct. These installations have historically been troublesome, particularly when less sophisticated controllers are used. In many cases when Proportional (P) or Proportional + Integral (PI) type controllers are installed, the only way to achieve stability is to lower the controller gain. In the case of the P only controller, this is undesirable because the throttling range will increase or, simply, the average amount of deviation from setpoint will increase. For PI controllers, the low gain can cause sluggish performance and provide slow response to system changes. The only good solution would be to utilize a controller which is capable of on-line readjustment of its gain to match the process dynamics. This can be accomplished by installtion of a self-tuning controller.

Authority Recommendations (Mixed Air Control)

1. If the outdoor air damper is installed in a duct (not a louver) size it for an authority of 8-10% for opposed blade dampers and 20-25% for parallel blade dampers. The return air dampers should should be selected using the same criteria.

2. If the outdoor air damper must be installed at the louver face, its size may match the louver. For the design flow rate and damper size determine the authority of the outdoor air damper. Use Figure 10 to determine the authority of the return air damper. Select the exhaust air damper for the same authority as the outdoor air damper.