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INTRODUCTION

This section familiarizes the reader with dampers, including types, construction, performance, environment capability, actuators, and linkages, and describes criteria used for proper selection and sizing of dampers. Dampers are typically chosen based on duct size and convenience of location. Rather than using duct size, criteria and methods are provided to select and properly size dampers which will produce desired control results. This can eliminate the undesirable effects of oversized dampers.

The information provided is general for all dampers. Selection and sizing of specific dampers can only be accomplished through the use of specific manufacturer’s documentation.

Dampers in HVAC systems regulate the flow of air either by modulating or two-position control. They are normally connected to actuators by linkages and operate in response to a pneumatic, electric, or electronic control signal. In theory, the application of dampers in HVAC systems closely parallels that of control valves.

DEFINITIONS

**Actuator:** A device used to operate a damper or control valve in a control system.

**Baffle:** An orifice placed in the duct to reduce the duct size to the damper size.

**Damper seals:** Construction features used to minimize the leakage through a damper.

**Damper system:** The damper plus the series resistance that relates to it (e.g., duct work, mixing boxes, diffusers, and coils).

**Damper:** A device used to regulate the flow of air in an HVAC system by modulating or two-position control.

**Drive blade:** A damper blade that is driven directly by an actuator or by a linkage, axle, or jackshaft connected to the drive blade in an adjacent damper section.

**Fire damper:** A thermally actuated damper arranged to automatically restrict the passage of fire and/or heat at a point where an opening violates the integrity of a fire partition or floor.

**Ideal damper system:** A system with a linear relationship between the percent open damper position and the percent of full airflow.

**Leakage:** The amount of air passing through a damper with a given pressure drop and a given torque holding the damper closed.

**Opposed blade damper:** A damper constructed so adjacent blades rotate opposite to each other.

**Parallel blade damper:** A damper constructed so each blade rotates in the same direction as the blade next to it.

**Smoke damper:** A damper arranged to control passage of smoke through an opening or a duct.
DAMPER SELECTION

DAMPER TYPES

PARALLEL AND OPPOSED BLADE DAMPERS

Parallel blade dampers are constructed so each blade rotates in parallel with or in the same direction as the blade next to it (Fig. 1). The rotation changes the direction of airflow and can provide mixing with only a small increase in airflow resistance.

Fig. 1. Parallel Blade Damper.

Opposed blade dampers are constructed so adjacent blades rotate opposite to each other (Fig. 2). The rotation does not change the direction of airflow, but it does increase resistance to and stratification of airflow since the air is funneled through a smaller opening. An opposed blade damper must be open further to obtain the same resistance to airflow as a parallel blade damper.

Fig. 2. Opposed Blade Damper.

ROUND DAMPERS

Round dampers (Fig. 3) are typically used to control flow in ducts that usually have high static pressure and high velocity characteristics. Round dampers can be installed in air handling systems with spiral-wound ducts in sizes similar to rectangular ducts. The smallest sizes of round dampers have a butterfly type blade while larger ones might be multiblade.

Fig. 3. Round Damper.

LOW LEAKAGE DAMPERS

Low leakage dampers minimize the amount of leakage through a fully closed damper. This can increase the energy efficiency of the control system, the comfort level in occupied spaces, and the safe operation of control elements such as coils. Low leakage is achieved through a variety of damper features and parameters, including blade edge seals, blade side seals, blade linkage, blade and frame reinforcements, and seal material.

Damper blade edge seals that work in compression between the blades e.g., cellular foam strip, (Fig. 4) are effective when blades are rigid enough to prevent misalignment and bending. Other types of blade edge seals include:

Fig. 4. Cellular Foam Blade Edge Seal.

- Snap-on seals, extruded plastic or dual durometer elastomer types (Fig. 5)
- Over-center compression seals, extruded plastic or roll-form construction (Fig. 6)
- Inflatable seals (rubber or silicone) that use the pressure differential across the damper for tight sealing when closed (Fig. 7)
In addition, damper blades can include a reinforcing element to limit blade torsion or twist (Fig. 9). Depending on the damper size and sealing requirement, this reinforcement can be on the drive blade only or on multiple blades. The design of air foil blades usually increases their torsional stiffness, much like reinforced standard blades (Fig. 10). Air foil blades also reduce noise and provide lower, full open airflow resistance at higher velocities.

Blade side seals minimize leakage between the ends of the blades and the frame (Fig. 8). One type of side seal is a stainless steel or coated spring steel spring. Other types of side seals (e.g., molded rubber parts riveted to the frame) conform to the blade cross-section profile when the damper is closed. Blade edge seals that interfere with blades closing completely could increase leakage at blade side seals.

The twisting load on damper blades and/or their physical size may necessitate heavy-duty or double linkage between blades to minimize torsional bending. Bending of damper blades reduces the effectiveness of blade edge seals by lowering compression forces or by preventing complete contact between blades.
In a low leakage damper, materials for the seals are selected based on the temperature of the air being controlled. Standard seals can be upgraded to withstand higher temperatures by using a more heat resistant material. An example would be changing a blade edge seal from neoprene to silicone rubber.

When duct static pressure is relatively low but leakage must be minimal, a low leakage damper with reduced static pressure ratings may be used. Generally, as the strength of a given damper increases, velocity and static pressure drop capabilities increase.

**SMOKE DAMPERS**

Any damper that controls airflow is capable of controlling smoke. In order to apply dampers to smoke control systems properly, UL 555S, Standard for Leakage Rated Dampers for Use in Smoke Control Systems, provides classification based on leakage, differential pressure across the damper, maximum velocity when the damper is fully open, temperature, and damper size. This classification includes the specific actuator used. See Table 1 for leakage classifications.

<table>
<thead>
<tr>
<th>Leakage Classification</th>
<th>Cfm per sq ft at 1 in. wc</th>
<th>Cfm per sq ft at 4 in. wc</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>II</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>III</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>IV</td>
<td>60</td>
<td>120</td>
</tr>
</tbody>
</table>

In designing a smoke damper, a manufacturer develops a product line with Maximum A and B and Minimum A and B dimensions where:

A = Overall damper size in the direction of the blade length.
B = Overall damper size perpendicular to the blade length.

The three damper sizes tested by UL are Maximum A/Minimum B, Minimum A/Maximum B, and Maximum A/Maximum B.

Damper testing includes meeting material construction requirements, cycling, temperature degradation, dust loading, salt-spray exposure, leakage, and operation at maximum pressure and velocity.

In testing for temperature degradation, the damper is heated in the closed position for 30 minutes and then cycled to see that it operates as intended. Temperature classifications include 250F, 350F, 450F, etc., in 100F increments.

Generally, Classes I, II, III, and IV are considered appropriate for smoke control. The class specified should be based on the application requirements. For example, Classes I and II are appropriate for mixed air dampers on systems having return fans. Classes II and III are appropriate for zone dampers where more leakage is acceptable. Classes III and IV are applicable to dampers that always modulate, such as in stairwell pressurization systems.

**FIRE DAMPERS**

Fire dampers are used in HVAC systems to prevent superheated air, gases, or flames from crossing a fire barrier through an air duct. Fire dampers are usually not used in modulating airflow control applications and are designed for extreme operating environments. Fire dampers are rated in hours of exposure in a specified test environment. Construction and performance of fire dampers (Fig. 11 and 12) is governed by UL Standard 555.
MULTIPLE SECTION DAMPERS

Typically, single rectangular dampers are manufactured in incremental sizes, up to maximum horizontal and vertical limits. If system requirements dictate damper sizes larger than the maximum available, single dampers can be arranged in multiple section assemblies (Fig. 13).

Multiple section damper assemblies have the drive blades interconnected between sections so all the sections operate in unison. Figures 14 and 15 show methods of connecting drive blades and cross-connecting damper blade linkage for a multiple section damper. As a multiple section damper assembly increases in size, additional precautions are required to withstand pressure drop forces, including:

- Increased bracing at intersecting corners of individual dampers.
- Additional external supports from the damper frame near the center of the assembly to other solid structural members adjacent to the assembly.

BAFFLES

System duct sizes do not always correspond with the available sizes of a damper or multiple section damper assembly. In these cases, a baffle is used inside the duct to surround the damper (Fig. 16).
TYPICAL DAMPER CONSTRUCTION

Figure 17 shows construction of an opposed blade damper with linkage. A parallel blade damper is essentially identical except for placement of blade linkage and rotation direction of alternate blades. Higher leakage dampers have either no blade side seals or less effective sealing elements, e.g., adhesive-backed cellular foam strips.

PERFORMANCE DATA

Performance data for dampers can vary in content and form due to the many types of dampers and the philosophies of their manufacturers. When casually compared, performance ratings of different dampers may seem equivalent but are not due to differences in criteria on which the data is based. The following paragraphs discuss the types of performance data and their variations.

LEAKAGE RATINGS

Leakage ratings of dampers are the most widely publicized damper performance data. Figure 18 graphically shows typical leakage performance of dampers with side seals, but without blade edge seals. The torque necessary to achieve the indicated leakage ratings is specified at the top of the graph as 5 lb-in. per square foot of damper area. The wide performance band is explained by the note at the bottom of the graph.

For typical dampers, leakage increases more significantly with the number of blades than with the length of the blades. The data shown applies to a combination of damper heights and widths. For example, a damper 48 in. high x 12 in. wide is the area equivalent of a damper 12 in. high x 48 in. wide. However, there is significantly more leakage with the 48 in. high x 12 in. wide damper, due to the increased number of blades. Using the leakage performance graph in Figure 18, the range of leakage for these two dampers (4.0 ft² each) at 1.0 in. wc is:

\[
\text{Leakage} = \text{Area} \times \text{Rating/ft}^2
\]

Minimum Leakage = 4.0 x 10.0 (min) = 40 ft³/min

Maximum Leakage = 4.0 x 26.0 (max) = 104 ft³/min

Performance characteristics for low leakage dampers differ from standard dampers. Figure 19 shows typical pressure drop/leakage rating relationship for low leakage dampers. Specific leakage ratings for horizontal (A) and vertical (B) damper dimensions are listed and the torque required has been increased to a flat value for any single section to accommodate light compression blade edge seals.

Using the leakage ratings in Figure 19, the leakage of the two dampers in the previous example at 1.0 in. wc is:

12 in. (A) + 48 in. (B) = 2 cfm + 43 cfm = 45 cfm

If the A and B dimensions are reversed, the leakage is as follows:

48 in. (A) + 12 in. (B) = 7.2 cfm + 12 cfm = 19.2 cfm

Other methods of conveying leakage ratings are a tabular format (e.g., leakage per area in cfm/ft²) and a percentage basis. The tabular format lists specific ratings for each individual damper size. Leakage per area must include sizes of interest. The percentage basis leakage rating is meaningless unless complete conditions including total airflow that the data is based on are also stated.

In many cases, damper data indicates that it is certified by an industry association. Certification means that tests were done under conditions defined by an association of manufacturers but is not a rating by an approval body. For applications other than smoke and fire, there are no approval bodies governing damper leakage or any other performance characteristics.
Fig. 17. Typical (Opposed Blade) Damper Construction.

Fig. 18. Graphic Presentation of Leakage Performance.

Fig. 19. Low Leakage Dampers.
TORQUE REQUIREMENTS

Operating and close-off torque requirements of dampers and their actuator sizing guidelines are typically shown in manufacturer specifications. Occasionally a brief explanation of the theory or basis for the actuator torque ratings accompanies this data.

Two conditions must be considered when establishing minimum torque requirements of a damper. One is closing torque which is the torque required to force the blades together sufficiently to achieve minimum possible leakage. The other is the dynamic torque required to overcome the effect of high velocity airflow over the blades. The maximum dynamic torque will occur somewhere in the middle two-thirds of the blade rotation depending on the damper design.

VELOCITY RATINGS

Approach velocity of the air is an important physical limitation that applies to all dampers and should be considered when sizing dampers. Generally, the maximum velocity rating increases as the overall performance rating of a damper increases. In practical terms, a higher velocity rating of one damper compared to another indicates the former damper has stiffer blade and linkage design and that the bearings may also be capable of higher loads. The velocity rating of control dampers is usually a statement of the maximum value allowed for the particular design under conditions of normal (not excessive) turbulence. Velocity ratings must be severely reduced under excessively turbulent conditions.

Uneven velocity profiles due to locations near fan discharges, duct transitions, and elbows require derating of the velocity value.

TEMPERATURE RATINGS

The maximum operating temperature of control dampers is the maximum temperature at which they will function normally. Increased temperature ratings on dampers indicate that bearings and seals are constructed of heat resistant materials. Stated temperature limits apply to the operating life that would be expected under normal ambient conditions.

PRESSURE RATINGS

The pressure rating of a control damper is the maximum static pressure differential which may be applied across the assembly when the blades are closed. Excessive leakage (caused by deflection of blades) and abnormally high operating torque (due to forces on blades, and loads on bearings and linkages) can result from high differential pressure. In extreme cases, physical damage to the dampers could occur. Typical ratings are stated in Table 2.

<table>
<thead>
<tr>
<th>Damper Type</th>
<th>Pressure Differential in. wc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Damper</td>
<td>3</td>
</tr>
<tr>
<td>Standard and High Temperature, Low Leakage Damper</td>
<td>6</td>
</tr>
<tr>
<td>Low Static, Low Leakage Damper</td>
<td>2</td>
</tr>
</tbody>
</table>

The ratings are probably conservative for smaller sizes since damper blades tend to deflect more as their length increases. An alternative method is a listing of differential static capability as a function of damper blade lengths, such as Table 3.

<table>
<thead>
<tr>
<th>Damper Length (in.)</th>
<th>Max Close-Off Static (in. wc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>48</td>
<td>4</td>
</tr>
</tbody>
</table>

UL CLASSIFICATION (FIRE/SMOKE)

Performance criteria for fire or smoke dampers bearing the UL rating are contained in specifications UL 555 (Standard for Safety/Fire Dampers and Ceiling Dampers) and UL 555S (Standard for Leakage Rated Dampers for Use in Smoke Control Systems). These two specifications govern the design, performance, installation, and marking (labeling) of the devices bearing the UL classification.

APPLICATION ENVIRONMENT

Most HVAC system requirements can be met using standard dampers from major manufacturers. Many manufacturers also build custom dampers with special features to satisfy particular application requirements. Custom features or modifications include blade reinforcement, heavy duty linkage, bearings, axles and frames, special seals, and construction or finish of corrosion resistant materials. The application must be carefully examined to ensure job requirements are met. Some of these special features add significantly to the cost of the damper so they should be furnished only when needed.

VELOCITY

As the velocity in a system increases, dampers in the system encounter higher forces. The impact pressure of the air movement increases the bending force on the damper blades and the airflow over the damper blades may cause a torque or
twist on the blades. Because the blade profile of conventional sheet metal dampers is not streamlined, the stresses imposed on the damper blades due to air movement are dynamic in nature rather than static. To strengthen the damper blades, the gage of metal and the number and depth of longitudinal bends can be increased or reinforcing plates can be spot welded to the blade to increase the blade cross-section. Strengthened dampers also require heavy duty linkage, bearings, and frame. The dynamic and static stresses and linkage and bearing loads all mean that large actuators are needed.

**STATIC PRESSURE**

The maximum static pressure that an air handling system can develop across a damper occurs when the damper is fully closed. As the damper opens, system airflow increases and a portion of the total pressure is converted to velocity pressure and the forces on the damper become more dynamic than static. It is important to determine the maximum possible static pressure in normal operation and to consider this when selecting dampers.

**TEMPERATURE**

Some dampers are capable of satisfactory operation in the temperature range of –40 to 400°F, primarily to meet high temperature requirements. A maximum temperature rating of 200°F is usually satisfactory for HVAC use. The specific temperature range for a given damper can be found in the manufacturer specifications.

**CORROSION**

Dampers used in conventional HVAC systems typically require galvanizing or zinc plating for corrosion protection. Damper applications that may encounter corrosive elements and require additional protection include:

- Buildings in immediate coastal areas where salt spray can enter with the outdoor air.
- Outdoor air applications where the outdoor air damper is located very close to the outdoor air intake, when the outdoor air intake is not protected from rain or snow by fixed louvers, or when the velocity of the outdoor air intake is in the range of 750 to 1000 fpm or more.
- Face dampers near spray coils.
- Dampers near electronic air cleaners with in-place washers.
- Dampers near spray humidifiers.
- Dampers used in cooling tower applications.
- Dampers in exhaust ducts that carry corrosive fumes or vapors.

All aluminum or all stainless steel construction is preferred in many cases. Optionally, protective finishes are available. The requirement for corrosion resistant dampers usually necessitates a custom built damper.

**TURBULENCE**

The flow of air in an air handling system is turbulent. Excessive turbulence or pulsations can have the same effects on dampers as increasing air velocity. There is a direct relationship between air velocity and the turbulence caused by airflow through a damper. The effects of moderate turbulence can be noticed on dampers located near abrupt duct transitions or near elbows without turning vanes. Effects of severe turbulence, capable of destroying a damper, can be noticed on dampers located in close proximity to a fan. A damper located near the discharge of a fan should be inspected during actual operation over a full range of positions (from full open to full closed) to be certain no severe vibration occurs (due to the damper being in resonance with a frequency generated by the fan blades). If the damper encounters severe vibration, the vibration may be decreased by adding stiffening members to the damper blades, extra damper linkage, or additional actuators. The preferred method for preventing these damper problems is initial selection of a location with minimal turbulence. However, if high turbulence cannot be avoided, a custom heavy duty damper may be required.

**NUCLEAR/SEISMIC APPLICATIONS**

Damper applications in nuclear power plants and other similar facilities must be fully compatible with safety system designs and meet all applicable regulations. Some dampers in nuclear facilities are required to operate during and after an earthquake. Seismic or earthquake susceptibility requirements vary and are specific for each individual job or geographic location. Seismic certification involves verification (usually through testing) that the control device can withstand specified levels of vibration. Test procedures include low-frequency, high-amplitude, multiaxial vibration. The tests vary in intensity, not only with different geographic locations but also with the physical elevation within the building. Therefore, test requirements for nuclear facilities must be carefully reviewed to accommodate all applications.

**ACTUATORS AND LINKAGES**

**NORMALLY OPEN/NORMALLY CLOSED**

Actuators open and close dampers according to an electric, electronic, or pneumatic signal from a controller. Actuators provide normally open or normally closed damper operation. In a normally closed application, the damper blades are closed
when either no control signal is applied or power to the actuator is lost. The damper blades will open in a normally open application. Selection is based on the desired damper position when power or air is removed from the actuator.

ACTUATOR MOUNTING ALTERNATIVES

Actuators can be installed externally (outside a duct) or internally (inside a duct). See Figures 20 and 21.

POSITIVE POSITIONERS

Some actuators are equipped with position-sensing feedback controls or circuits that are called positive-positioners. The feedback system senses the actuator position, whether rotation or stroke, and compares it to the position dictated by the control signal (input). If some outside force (e.g., friction or torque on damper blades) disturbs the actuator position, the feedback mechanism causes the actuator to correct its position. It also minimizes any effect of hysteresis inherent in the actuator. It is not recommended to use more than one positive positioner per bank of dampers (multiple sections connected together).

MULTIPLE ACTUATORS

Multiple actuators can drive sections of a multiple section damper (Fig. 22) in unison. Multiple sections should be all linked together both in vertical and horizontal stacks. When all sections are linked together, actuators should all have the same operating range, torque, and stroke to prevent damper blade twist and binding.

Multiple actuators can also be used for unison operation of two or more dampers in different locations. All actuators in this arrangement must have the same input signal (e.g., voltage, pressure, current), timing, and stroke to provide uniform opening and closing.
JACKSHAFTS

A jackshaft allows a single actuator to drive adjacent vertical sections of a multiple section damper assembly with evenly distributed force (Fig. 23). It provides adjustability and uniform synchronized section-to-section operation.

ACTUATOR SELECTION

One method of selecting actuators for damper applications is based on the number of square feet of damper to be positioned related to a specific actuator. This data is usually provided in tabular form in the manufacturer specifications and is valid for specified static pressure and velocity levels only.

Another method of selecting actuators relates the total blade width dimension of single and multisection dampers to the actuator capability. The ratings of actuators are based on this dimension and are given in tabular form in the manufacturer specifications.

Fig. 23. Damper Jackshaft Application.

DAMPER SIZING

Dampers are typically chosen based on duct size and convenience of location. However, selection by these criteria frequently results in oversized dampers which produce undesirable system control results. Proper selection and sizing of dampers provides the following benefits:

— Lower installation cost because damper sizes are smaller.
— In addition, smaller actuators or a fewer number of them are required.
— Reduced energy costs because smaller damper size allows less overall leakage.
— Improved control characteristics (rangeability) because the ratio of total damper flow to minimum controllable flow is increased.
— Improved operating characteristics (linearity).

When selecting a damper, it is necessary to consider the operating characteristics and capacities so the desired system control is achieved. These items are discussed, along with damper sizing, in this section.

SYSTEM CHARACTERISTICS

The damper system consists of the damper plus the series resistance that relates to that particular damper (e.g., duct work, mixing boxes, diffusers, and coils).

Figure 24 shows a typical control loop for a damper system. The thermostat in the space contains the sensing element and controller. The difference between the control point and setpoint determines the correction signal from the controller. The controller directs the actuator to open or close the damper. The position of the damper determines the volume of the air flowing and ultimately the temperature of the space.

Fig. 24. Control Loop for a Damper System.
Stability of space temperature is important in providing a comfortable, energy-efficient environment. The most significant factor in achieving stability of a control loop is the gain of the system elements. The gain of a damper system is the ratio of the change in airflow to the change in signal to the actuator.

In an ideal damper system, the gain is linear over the entire operating range (e.g., a small increase in space temperature results in a small increase in cooling airflow). The more linear the system, the more constant the system gain and the more stable the system operation over its entire range.

**DAMPER CHARACTERISTICS**

**INHERENT CHARACTERISTIC**

The relationship between damper blade position and airflow through the damper is defined as the inherent characteristic. The inherent characteristic is defined at a constant pressure drop with no series resistance (coils, filters, louvers, diffusers, or other items).

Figure 25 shows the inherent airflow characteristic curves of parallel and opposed blade dampers. This difference in airflow is important when selecting the proper damper for a system.

![Fig. 25. Parallel versus Opposed Blade Damper Inherent Airflow Characteristic Curves at Constant Pressure Drop.](image)

**INSTALLED CHARACTERISTIC**

The inherent characteristic is based on a constant pressure drop across the damper. This is frequently not the case in practical applications. Series resistance elements such as duct resistance, coils, and louvers, cause the pressure drop to vary as the damper changes position (Fig. 26 and 27). The resulting installed characteristic (Fig. 28) is determined by the ratio of series resistance elements to damper resistance and will vary for parallel and opposed blade damper.

Series resistance modifies the damper airflow characteristic. The greater the series resistance, the greater the modification. The ratio of series resistance to damper resistance is called the characteristic ratio. Figures 29 and 30 show modified characteristics for parallel and opposed blade dampers based on various ratios of series resistance to full open damper resistance.
To achieve performance closest to the ideal linear flow characteristic, a characteristic ratio of 2.5 for parallel blade dampers (Fig. 29) and 10 for opposed blade dampers (Fig. 30) should be used. The percent of the total resistance needed by the damper can be determined by:

\[
\text{Total resistance (100\%) } = \frac{\text{damper resistance + series resistance}}{\text{series resistance}}
\]

\[
\text{Characteristic ratio (Fig. 29 and 30) } = \frac{\text{series resistance}}{\text{damper resistance}}
\]

Substituting (total resistance – damper resistance) for series resistance:

\[
\text{Characteristic ratio } = \frac{\text{total resistance – damper resistance}}{\text{damper resistance}}
\]

or

\[
\text{Characteristic ratio } = \frac{\text{total resistance}}{\text{damper resistance}} - 1
\]

For parallel blade dampers:

\[
2.5 = \frac{100}{\text{damper resistance}} - 1
\]

Damper resistance = 29\% of total resistance

or

\[
\frac{29}{100 - 29} = 41\% \text{ of series resistance}
\]

For opposed blade dampers:

\[
10 = \frac{100}{\text{damper resistance}} - 1
\]

or damper resistance = 9\% of total resistance

\[
\frac{9}{100 - 9} = 10\% \text{ of series resistance}
\]

For example, if a coil (Fig. 31) with a pressure drop of 0.55 (in. wc) is located in series with an opposed blade damper, the damper should have a pressure drop of 0.06 (10 percent of 0.55 = 0.06).

**Fig. 30. Damper System Characteristics of Opposed Blade Dampers.**

**DETERMINING DAMPER SIZE**

The desired relationship of damper resistance to series resistance developed in DAMPER CHARACTERISTICS is used to determine the desired damper pressure drop. This pressure drop is then used in the damper sizing procedure in Table 4.

For example, for a 36 by 64 in. (2304 in²) duct with an airflow of 20,000 cfm and a pressure drop of 0.06 across a parallel blade damper, determined the damper size as shown in Table 5.
Table 4. Damper Sizing Procedure.

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
</tr>
</thead>
</table>
| 1    | Calculate the approach velocity:  
Approach velocity (fpm) = \( \frac{\text{Airflow (cfm)}}{\text{Duct Area (in}^2\text{)}} \times 144 \text{ in}^2 \text{/ ft}^2 \) |
| 2    | Using the approach velocity from Step 1, calculate a correction factor:  
Correction factor = \( \frac{10^6}{[\text{Approach velocity (fpm)}]^2} \) |
| 3    | Calculate the pressure drop at 1000 fpm:  
Pressure drop at 1000 fpm = Pressure drop at approach velocity x correction factor (Step 2) |
| 4    | Calculate free area ratio\(^a\):  
For pressure drops (Step 3) \( \geq 0.23\):  
Ratio = \( [1 + (21.3265 \times \text{pressure drop})]^{-0.3903} \)  
For pressure drops (Step 3) \(< 0.23\):  
Ratio = \( [1 + (79.7448 \times \text{pressure drop})]^{-0.2340} \) |
| 5    | Calculate damper area (in\(^2\)):  
For parallel blade dampers:  
Damper area (in\(^2\)) = \( \left( \frac{\text{Duct area (in}^2\text{)} \times \text{ratio}}{0.37} \right) 0.9085 \)  
For opposed blade dampers:  
Damper area (in\(^2\)) = \( \left( \frac{\text{Duct area (in}^2\text{)} \times \text{ratio}}{0.3810} \right) 0.9217 \)

\(^a\) The free area of a damper is the open portion of the damper through which air flows. The free area ratio is the open area in a damper divided by the total duct area.

Table 5. Damper Sizing Example.

<table>
<thead>
<tr>
<th>Step</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approach velocity (fpm) = ( \frac{20,000 \text{ cfm}}{2304 \text{ in}^2} \times 144 \text{ in}^2 \text{/ ft}^2 = 1250 \text{ fpm} )</td>
</tr>
<tr>
<td>2</td>
<td>Correction factor = ( \frac{10^6}{1250^2} = 0.64 )</td>
</tr>
<tr>
<td>3</td>
<td>Pressure drop at 1000 fpm = 0.6 in. wc x 0.64 = 0.38 in. wc</td>
</tr>
</tbody>
</table>
| 4    | Free area ratio = \( [1 + (79.7448 \times 0.038)]^{-0.2340} \)  
= 4.03^{-0.2340}  
= 0.722 |
| 5    | Damper area (parallel blades) = \( \left( \frac{2304 \text{ in}^2 \times 0.722}{0.37} \right) 0.9085 \)  
= 4496 \times 0.9085  
= 2083 in\(^2\) |
A damper size of 36 by 58 in. (2088 in²) would be selected for this application since, 36 in. is the largest damper dimension which will fit in the 36 in. width of the duct.

OTHER DAMPER SIZING CONSIDERATIONS

TWO-POSITION CONTROL

1. Typically, duct size parallel blade dampers are selected as they present a lower pressure drop compared to opposed blade dampers of equal size.
2. Check that the damper meets maximum velocity, maximum static pressure, and leakage requirements.

MODULATING CONTROL

1. Determine application requirements and select parallel or opposed blade damper.
2. Check that the damper meets maximum velocity, maximum static pressure, and leakage requirements.

OVERSIZED DAMPER CHARACTERISTICS

DAMPER PERFORMANCE

An oversized damper is one that has a characteristic ratio higher than 2.5 for parallel blade dampers or 10 for opposed blade dampers. The resultant characteristic curve of an oversized damper can be seen in Figures 29 and 30 represented by the high ratio curves. These are well above the ideal linear curve.

The result of oversizing is that a large percentage of the full airflow occurs when the damper is open to only a small percentage of its full rotation.

By using a smaller damper, the percentage of the pressure drop increases across the damper. The performance curve shifts from the oversized curve, through the linear curve, and towards the inherent curve which is based on 100 percent of the system pressure drop across the damper. The oversized damper characteristic is based upon a majority of the system pressure drop being across the series resistance rather than the damper.

The actual curve can approach the linear curve if the proper initial resistance ratio for the damper has been selected. See Figure 32. An oversized parallel blade damper causes a greater deviation from the linear characteristic than an oversized opposed blade damper which can be corrected by selecting a smaller damper to take more of the total pressure drop.

CONTROL SYSTEM SENSITIVITY

An oversized damper with a nonlinear characteristic curve causes the sensitivity of the system to change throughout the damper operating range as shown in Figure 33. The first 50 percent of the opening results in 85 percent of the airflow; the last 50 percent, only 15 percent of the airflow. As the percent damper opening varies, the sensitivities of the system at the associated damper positions are considerably different. Increasing sensitivity can cause the system to hunt or cycle resulting in poor control. As the characteristic curve of the damper becomes more linear, the sensitivity of the system becomes more constant and allows more stable control.
DAMPER PRESSURE DROP

If the duct size, damper size, and the airflow are known, use the method in Table 6 to determine the actual pressure drop across the damper:

For example, for a 2304 in² parallel blade damper in a 2600 in² duct with an airflow of 20,000 cfm, determine the pressure drop across the damper as shown in Table 7.

Table 6. Damper Pressure Drop Calculation Procedures

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a. Determine the number of sections required. The area of the damper must not exceed the maximum size for a single section. If the damper area exceeds the single section area: b. Divide the area of the damper, the area of the duct, and the airflow by the number of damper sections. c. Use the values from Step b in the following Steps.</td>
</tr>
<tr>
<td>2</td>
<td>Calculate the free area ratio: For parallel blade dampers, the free area ratio is found: $\text{Ratio} = \left(0.00005149 \times \text{damper area in}^2\right)^{0.1007} \times \frac{\text{Damper area (in}^2\text{)}}{\text{Duct area (in}^2\text{)}}$ For opposed blade dampers, the free area ratio is found: $\text{Ratio} = \left(0.00001159 \times \text{damper area in}^2\right)^{0.0849} \times \frac{\text{Damper area (in}^2\text{)}}{\text{Duct area (in}^2\text{)}}$</td>
</tr>
<tr>
<td>3</td>
<td>Using the ratio from Step 1, calculate the pressure drop at 1000 fpm. For ratios $\leq 0.5$: $\text{Pressure drop (in. wc)} = -0.04689 \times (1 - \text{ratio}^{-2.562})$ For ratios $&gt; 0.5$: $\text{Pressure drop (in. wc)} = -0.01254 \times (1 - \text{ratio}^{-4.274})$</td>
</tr>
<tr>
<td>4</td>
<td>Calculate the approach velocity: $\text{Approach velocity (fpm)} = \frac{\text{Airflow (cfm)}}{\text{Duct Area (in}^2\text{)}} \times \frac{144 \text{ in}^2}{1 \text{ ft}^2}$</td>
</tr>
<tr>
<td>5</td>
<td>Using the approach velocity from Step 3, calculate a correction factor: $\text{Correction factor} = \frac{10^6}{[\text{Approach velocity (fpm)}]^2}$</td>
</tr>
<tr>
<td>6</td>
<td>Calculate the pressure drop across the damper: $\text{Pressure drop (in. wc)} = \frac{\text{Pressure drop (in. wc) at 1000 fpm (Step 2)}}{\text{Correction factor (Step 4)}}$</td>
</tr>
</tbody>
</table>

a The free area of a damper is the open portion of the damper through which air flows. The free area ratio is the open area in a damper divided by the total duct area.
Table 7. Pressure Drop Calculation Example.

<table>
<thead>
<tr>
<th>Step</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not applicable</td>
</tr>
<tr>
<td>2</td>
<td>Free area ratio (parallel blades) = ((0.00005149 \times 2304 \text{ in}^2) \times \frac{0.1007}{2600 \text{ in}^2} = 0.8068 \times 0.8862 = 0.715)</td>
</tr>
<tr>
<td>3</td>
<td>Pressure drop at 1000 fpm = (-0.01254 \times (1 - 0.715) - 4.274) = (-0.01254 \times -3.1947) = 0.0401 in. wc</td>
</tr>
<tr>
<td>4</td>
<td>Approach velocity = (\frac{20,000 \text{ cfm}}{2600 \text{ in}^2} \times \frac{144 \text{ in}^2}{1 \text{ ft}^2} = 1108 \text{ fpm})</td>
</tr>
<tr>
<td>5</td>
<td>Correction factor = (\frac{10^6}{1108^2} = 0.815)</td>
</tr>
<tr>
<td>6</td>
<td>Pressure drop across damper = (\frac{0.0401 \text{ in. wc}}{0.815} = 0.049 \text{ in. wc})</td>
</tr>
</tbody>
</table>

Had the duct size been 2304 in\(^2\), the same size as the damper, the pressure drop would have been lower (0.029).

**DAMPER APPLICATIONS**

The Table 8 indicates the damper types typically used in common control applications.

<table>
<thead>
<tr>
<th>Control Application</th>
<th>Damper Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Air</td>
<td>Parallel</td>
</tr>
<tr>
<td>Outdoor Air or Exhaust Air</td>
<td>Opposed</td>
</tr>
<tr>
<td>(with Weather Louver or Bird Screen)</td>
<td>Parallel</td>
</tr>
<tr>
<td>(without Weather Louver or Bird Screen)</td>
<td>Parallel</td>
</tr>
<tr>
<td>Coil Face</td>
<td>Opposed</td>
</tr>
<tr>
<td>Bypass</td>
<td>Opposed</td>
</tr>
<tr>
<td>(with Perforated Baffle)</td>
<td>Parallel</td>
</tr>
<tr>
<td>(without Perforated Baffle)</td>
<td>Parallel</td>
</tr>
<tr>
<td>Two-Position (all applications)</td>
<td>Parallel</td>
</tr>
</tbody>
</table>

**MIXED AIR CONTROL**

Figure 34 shows a mixed air control system. All three dampers (outdoor, exhaust, and return air) are the primary source of pressure drop in their individual system so parallel blade dampers are selected to obtain linear control.
**FACE AND BYPASS CONTROL**

Figure 37 shows a face and bypass damper application. The system pressure drop is relatively constant across the bypass damper so a parallel blade damper is used for minimum pressure drop at full flow. The system pressure drop across the face damper shifts from the coil to the damper as the damper closes so an opposed blade damper is used for more linear control. The face damper should be equal to the coil size to prevent stratification (hot and cold spots) across the coil.

**THROTTLING CONTROL**

Either parallel or opposed blade dampers can be used for throttling applications. If the primary resistance of the system is the damper, parallel blade dampers are preferred. However, if significant series resistance exists, like a reheat coil, opposed blade dampers should be used.