Actuators for heating, ventilation, and air conditioning

Damper Actuator Applications Guide

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References

Air Movement and Control Association, Inc. (AMCA) Publication 502-89

American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) 1991 Applications Handbook, sec. 41.6

The content in this application guide is based on the standard HVAC engineering guidelines. The use of this information must be used with sound engineering judgment. Belimo Aircontrols does not take responsibility for problems caused by the concepts presented in this publication.

Introduction to Economizer Systems

Economizer Systems

Most economizer systems have one damper for the outside air (OA), return air (RA) and exhaust air (EA). The dampers work together with fans to provide the proper amount of supply air (SA) and return air (RA). The economizer portion of an air handling system is not only responsible for reducing the operating cost of the system, but more importantly, it has to provide a sufficient volume of outside air at all times to ensure good indoor air quality. The function of the economizer also affects the pressurization of the building.

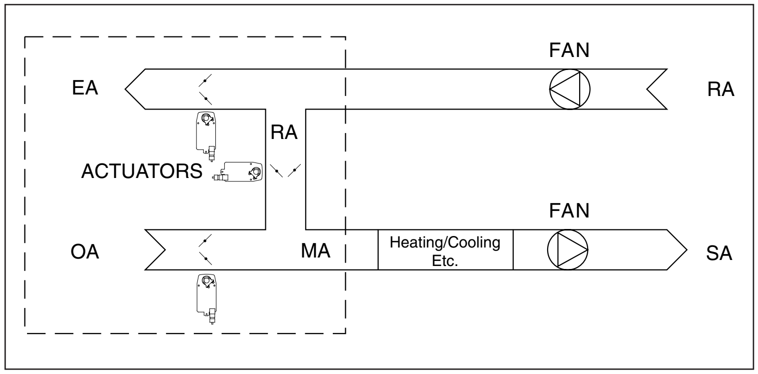


Figure 1. Economizer System

Slight positive pressure is needed to prevent infiltration of unconditioned outside air while too much pressure causes exfiltration. Incorrect pressurization may cause damage to the building structure due to condensation, freezing, mold growth, etc. Refer to Figure 1.

Indoor Air Quality

The indoor air quality and comfort are more important than the operating cost of the air handling system. If it is not adequate, absenteeism and turnover will increase, and productivity will suffer. This hidden cost can seriously affect the bottom line of any organization.

The ventilation system is the cause of almost half the indoor air quality complaints according to NIOSH (National Institute of Occupational Safety and Health). Damper control alone is itself not responsible for the indoor air quality and climate, but it has a very central role. Therefore, it is important that the dampers and actuators are selected and sized correctly.

Damper Selection

Traditionally, little attention is given to the selection of the dampers that comprise the economizer. What is worse is that the selection of the actuators that operate the dampers is usually based solely on the torque rating required to operate the dampers. The accuracy of the control is rarely considered. Without accurate damper positioning, the economizer will not function correctly, and both the indoor air quality and comfort is compromised.

Damper Selection

Opposed and Parallel Blade Dampers

For proper regulation of airflow, it is important to select and size the dampers for the correct operation. In HVAC installations, two different types of rectangular dampers are used to modulate air flow. These are parallel and opposed blade dampers.

Parallel blade dampers are designed so all the blades move in the same direction and in parallel. Refer to Figure 2

Opposed blade dampers are designed, so blades next to each other move in opposite directions. Refer to Figure 3

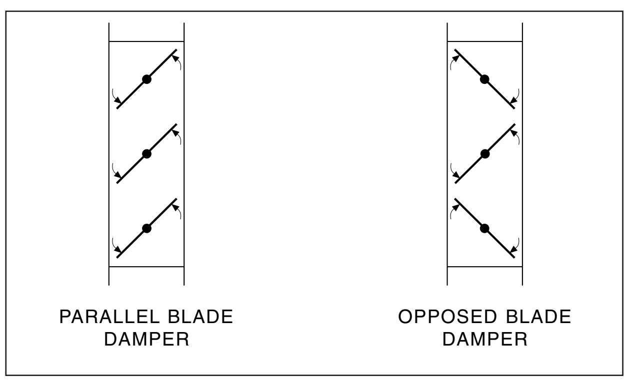


Figure 2.

Figure 3.

Flow Characteristics

The two types of dampers have different "inherent flow characteristics". This can be illustrated by a curve that shows the relationship between the flow rate and the position of the blades.

The inherent flow characteristics for parallel and opposed blade dampers are different, and neither has a linear characteristic. Refer to Figure 4.

Opposed blade dampers give a very slow increase in the flow when the damper begins to open.

Parallel blade dampers have an inherent curve that is not as pronounced, so the flow increases more rapidly when the damper begins to open.

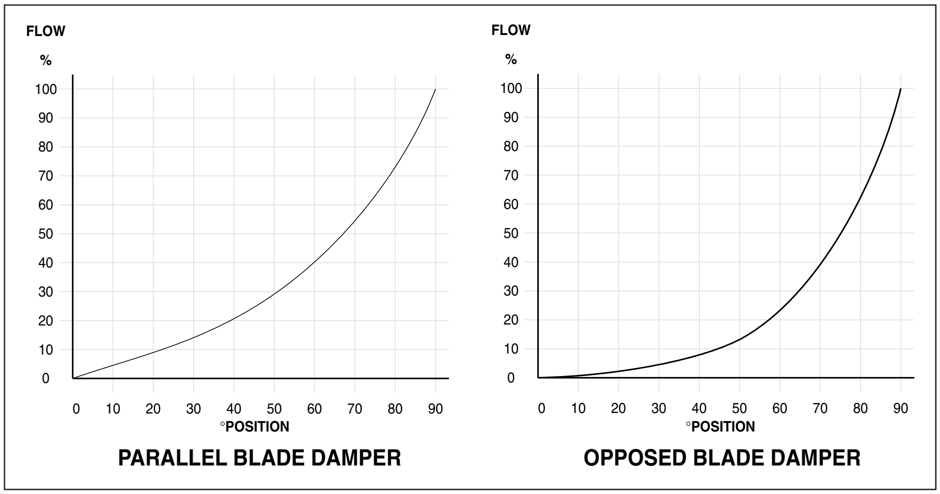


Figure 4. Inherent Characteristics of Parallel and Opposed Blade Dampers

It is very important to realize that the inherent curves are measured under laboratory conditions, with a constant differential pressure across the damper. In a real installation the curves will be distorted; refer to Figure 6 and Figure 7.

Damper Authority

When installed in a system, the damper is not the only device which affects the flow. Other parts of the system, such as the duct work, filters, coils, etc. will also restrict the flow. The damper will not control the flow in accordance to its inherent flow characteristics.

When the damper is closed (refer to Figure 5A), the full differential pressure will fall across the damper, but when open (refer to Figure 5B) the pressure drop across all other parts will be large, leaving little pressure drop across the damper.

The pressure drop across the damper changes as the damper is operated from closed to open. This distorts the flow characteristics curve. When the damper begins to open, the differential pressure is high, and the flow increases at a higher rate than what the inherent curve suggests. When the damper is almost fully open, the pressure drop across the damper will be small, compared to the total pressure drop. For example, as the damper moves from 80° to 90° opening the flow will change very little.

A damper with little resistance to airflow in the fully open position relative to the total system resistance will have a small influence, or poor authority, on the flow when it operates near the fully open position.

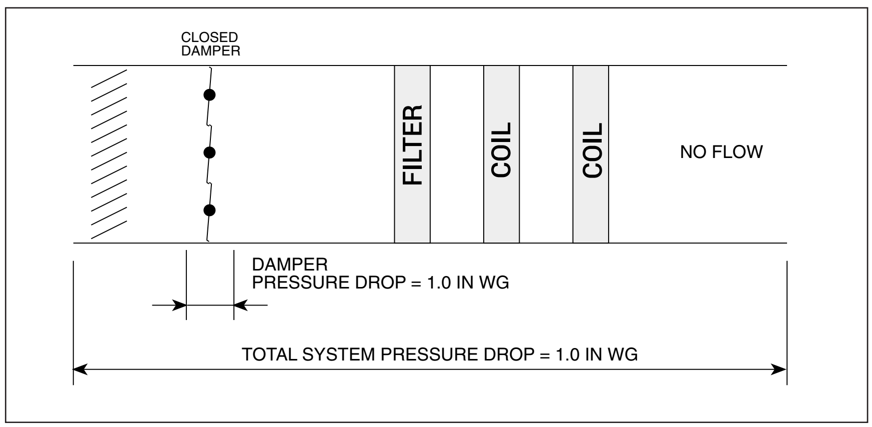


Figure 5A. Total System Pressure Drop

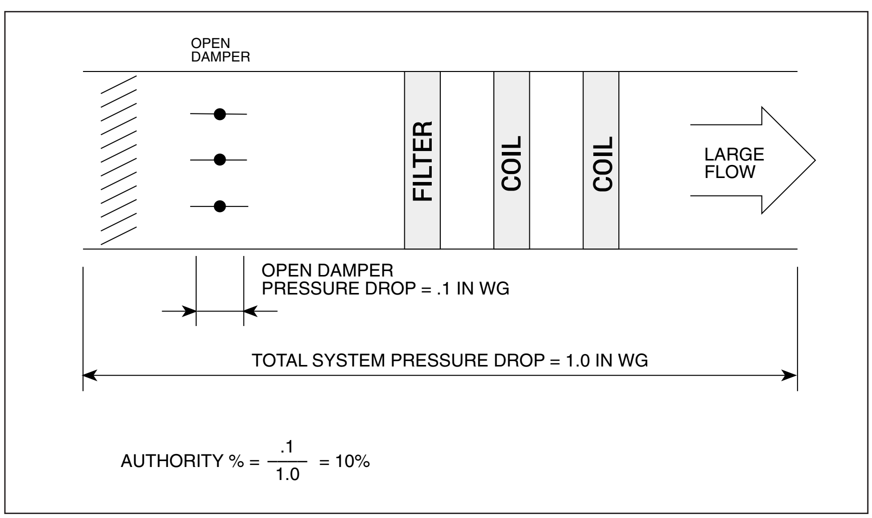


Figure 5B. Damper Pressure Drop

The resistance of the fully open damper can be expressed as a percentage of the total system resistance and is called "Damper Authority".

$$\text{Damper Authority \%} = \frac{\text{Open Damper Pressure Drop}}{\text{Total System Pressure Drop}} \times 100\%$$

Pressure variations across a damper distort the inherent characteristic curve. The installed damper response curve depends upon the damper authority. If the damper authority is 100%, the installed damper characteristic is the same as the inherent characteristic, but this will rarely happen in a real installation. Instead, a much lower number between 1% to 10% is realistic. As illustrated in Figure 6 and Figure 7, an authority of 1% shifts the inherent curve greatly.

It is very important to realize that the total system pressure drop only relates to the part of the system where the flow is controlled by the damper. Refer to Figure 8. The flow downstream of the mixing plenum (point A) is not controlled by the OA damper in a mechanically balanced system because the flow through point A is constant. The OA damper only controls the flow through the weather louver, the damper, and the OA ductwork. Therefore the authority of the OA damper is determined by the pressure drop across the OA damper as a percentage of the total differential pressure between OA and point A.

The total system pressure drop for the OA damper is measured between OA and Point A. The RA damper is measured between Point B and Point A. The EA damper is measured between Point B and EA.

If a single damper is used to control the flow through a section of an air handlers ductwork, then the total system pressure drop is the sum of the component pressure drop. Refer to Figure 5A and Figure 5B.

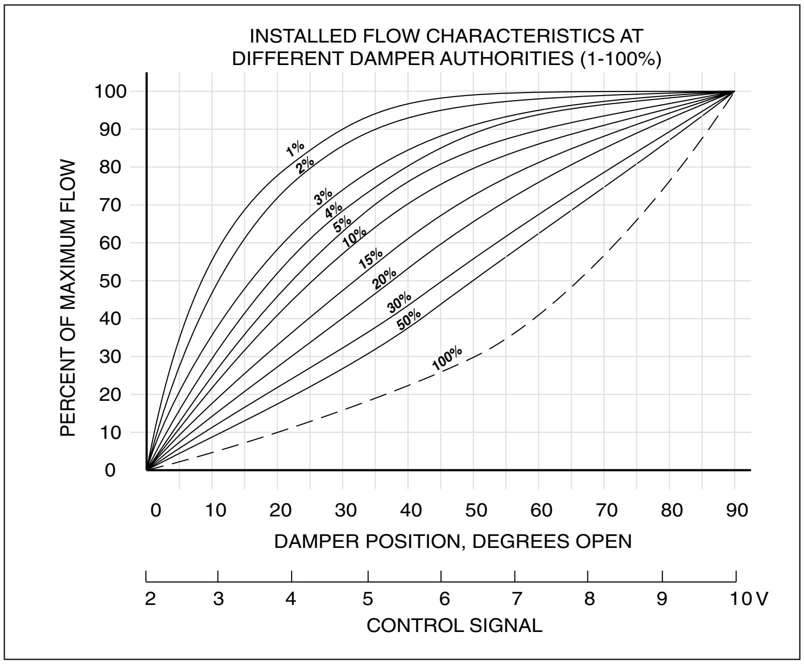


Figure 6. Parallel Blade Damper Flow Characteristics

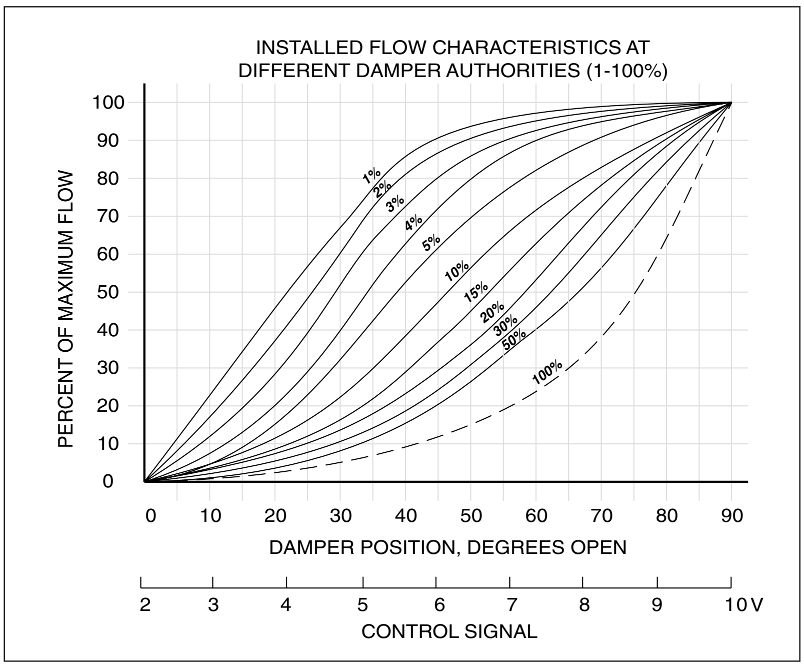


Figure 7. Opposed Blade Damper Flow Characteristics

Combined Flow

The sizing of the OA, RA and EA dampers installed in an Economizer is very important because it determines the installed damper characteristics. If the dampers have been properly sized, their characteristics will complement each other so the total flow will be constant. The pressure at points A and B will remain constant regardless of the OA/RA mixing ratio. Refer to Figure 9.

The OA damper modulates the OA flow. When it is fully open, a large portion of the differential pressure will fall across the weather louver and the OA duct work, resulting in a relatively small differential pressure across the OA damper. When the OA damper is completely closed, the full differential pressure will fall across the OA damper. The authority of the OA damper is the differential pressure across the damper when it is fully open, as a percentage of the differential pressure between point A and OA. The calculation of this percentage number is shown as an example in Figure 10.

The authority of the RA damper is the differential pressure across the damper, when it is fully open as a percentage of the differential pressure between points A and B.

The authority of the EA damper is determined by the fully open differential pressure and the differential pressure between point B and EA.

The dampers usually operate in unison. As the OA and EA dampers close, the RA damper opens. The dampers should be sized to compliment each other. An increase in the OA flow is matched by an equal decrease in the RA flow. The total flow should be constant regardless of the mixing ratio between OA and RA flow. The pressure in the mixing plenum should also be constant. Unfortunately, this is sometimes difficult to accomplish because the dampers have a non-linear characteristic, and most dampers are poorly matched. These factors result in a non-linear OA/RA mixing ratio, a variable combined flow (MA) and pressure variations in the mixing plenum, which may affect the building pressure. Refer to Figure 11.

Note: For further details on this topic reference the book, "Dampers and Airflow Control" by Laurence G. Felker and Travis L. Felker, published by ASHRAE, 2010.

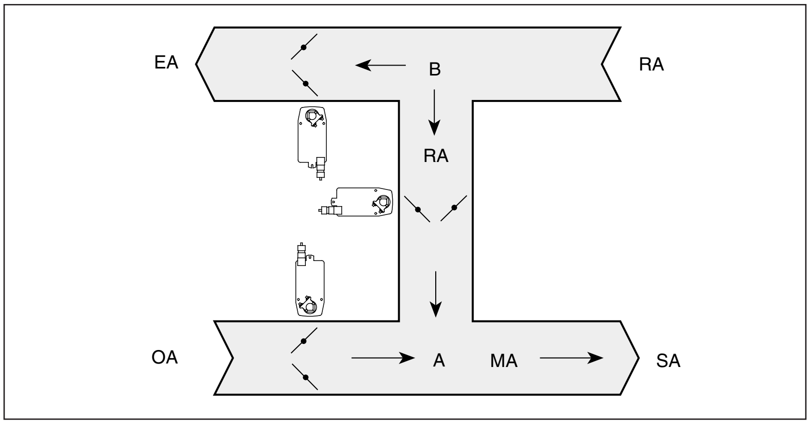


Figure 8. Economizer Airflow

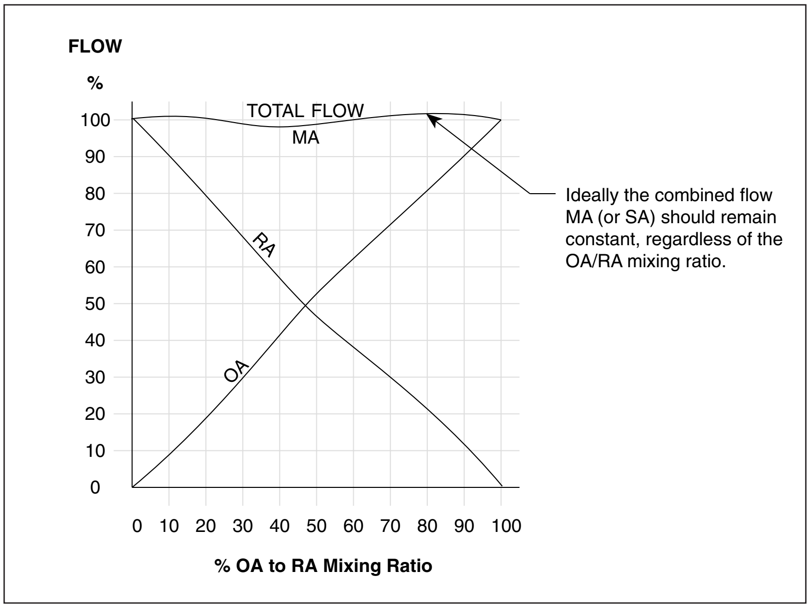


Figure 9. Ideal OA/RA Mixing Ratio

Additional Considerations

Ventilation Minimum Position

The indoor air quality is dependent upon the amount of outside air that is introduced into the building. The economizer varies the mixing ratio of outside and return air to meet the varying conditions. At 100% outside air, maximum free cooling is provided, and when the cooling load changes, the mixing ratio is changed until the outside air volume is reduced to a specified minimum volume which satisfies the indoor quality requirements. Often the economizer is at the minimum position and provides the minimum volume of outside air when there is a need for mechanical cooling or heating. At an intermediate load, the mixing ratio is changed to maintain a constant mixed air (MA) temperature.

The air balancer can set minimum OA ventilation airflow with several methods; the most common is use a pitot-tube traverse if adequate duct length is available to get a velocity pressure profile uniform enough for good readings.

Duct temperature measurements can be used to set the minimum position or to verify the ventilation setting with the following formula. Good results require the use of accurate temperature sensors and at least ten degrees difference between the outside air and the return air. In the example below, if the OA damper ventilation minimum position is set correctly, the mixed air temperature will be 69°

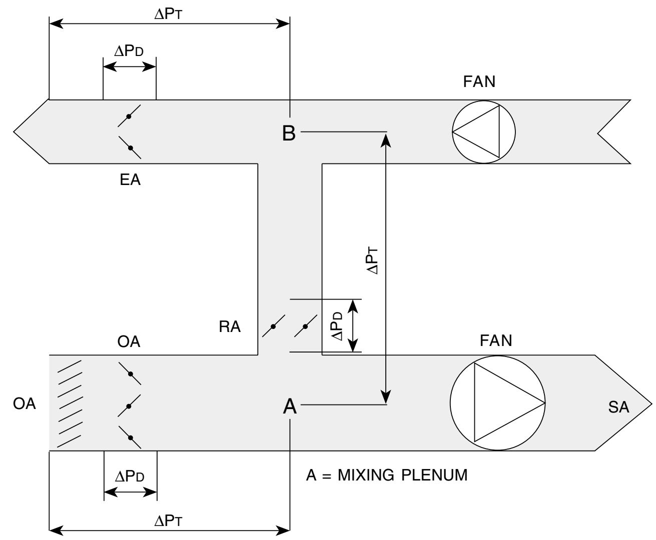
MAT = OAT (%OA) + RAT (%RA)

- MAT = mixed air temperature = xx°
- RAT = return air temperature = 70°
- OAT = outside air temperature = 60°
- % OA = % OA volume = 10%
- % RA = % RA volume = 90%

MAT = 60°(.10) + 70°(.90) = 69°

The minimum amount of outside air volume intake is controlled by limiting the modulation of the dampers to a minimum position. Precise and repeatable minimum position accuracy is required because a small positioning error will have a disproportionately large effect upon the minimum outside air volume.

An alternative solution is to use two OA dampers. One is modulated in unison with the RA and EA dampers, as described above. The other damper is smaller and is opened when the fan is running. This damper supplies the minimum OA volume and may be modulated to achieve variable flow settings in VAV AHU's. Refer to Figure 12.



$$\text{Authority} = \frac{\text{Pressure drop over damper}}{\text{Total pressure drop}} = \frac{\Delta P_D}{\Delta P_T} \times 100\%$$

Example: OA ΔP_D = .01 in. W.G.
ΔP_T = .125 in. W.G.

$$\text{Authority} = \frac{.01}{.125} \times 100\% = 8\%$$

Figure 10. Damper Authority Calculation

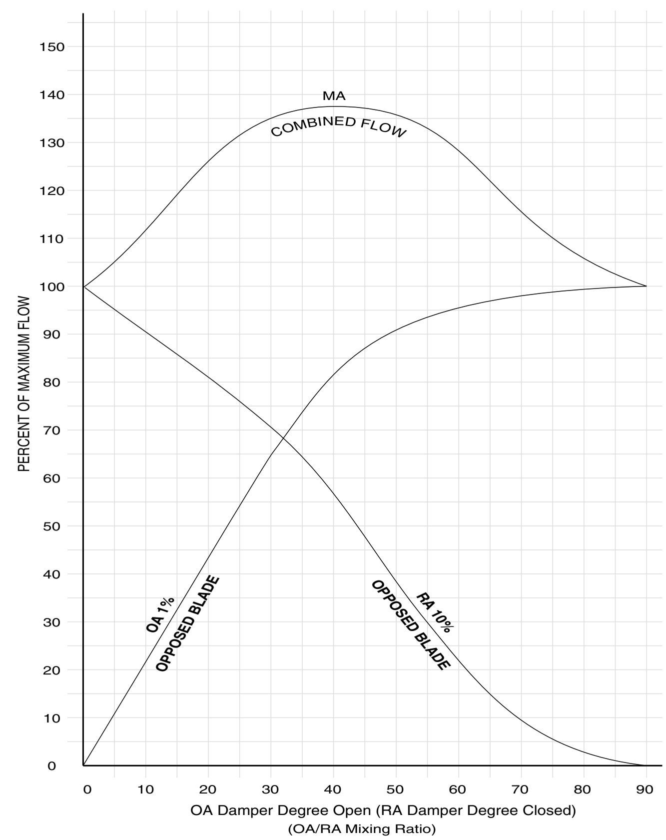


Figure 11. Poorly Matched Dampers

Building Pressure

No building is completely tight. Therefore a slight positive pressure is required, in order to prevent any infiltration of outside air into the building. Leakage of air into the building can cause severe problems with the indoor climate and the building structure, especially the heating season.

The pressurizing of a building depends upon a number of factors; the economizer is just one of them. If the economizer system can not maintain a constant pressure in the mixing plenum (Point A in Figure 12), the pressurization of the building will be affected.

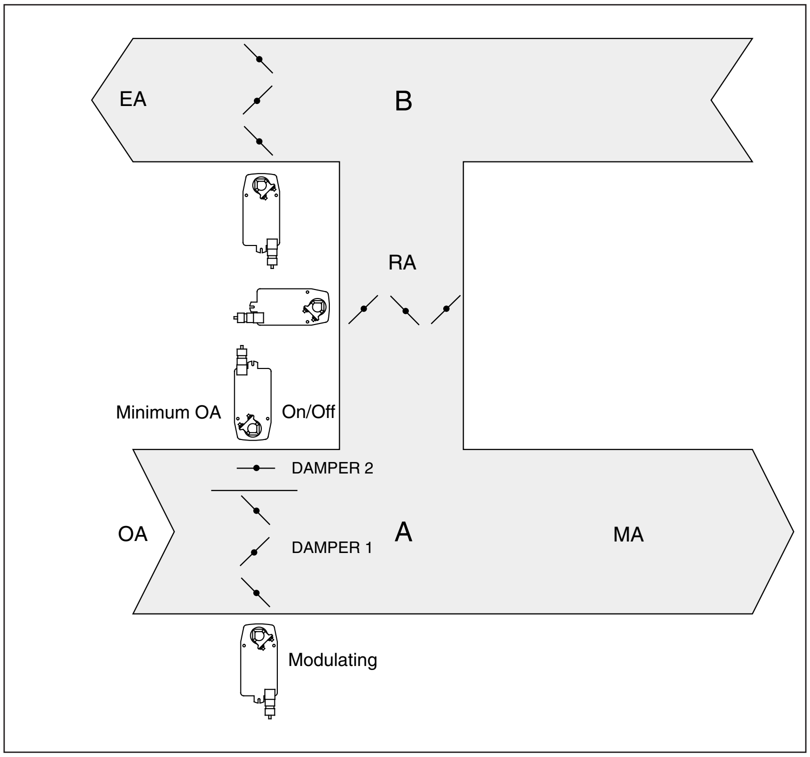


Figure 12. Dedicated Ventilation Damper

Mixed Air Temperature Control

The mixed air temperature control is accomplished by varying the mixing ratio between the outside and return air. There are many things that can complicate this function and cause stability problems.

If the dampers are poorly matched, the mixing ratio will not change as a linear function when the dampers are operated. An additional complication is that the pressure in the mixing plenum will not stay constant. The mixed air temperature will change a lot with some damper movements, while other damper movements will produce a small change in the mixed air temperature. This nonlinear function causes stability problems for the mixed air temperature control. Refer to the next section, "Optimizing Economizer Systems" for potential solutions to these issues.

Actuators

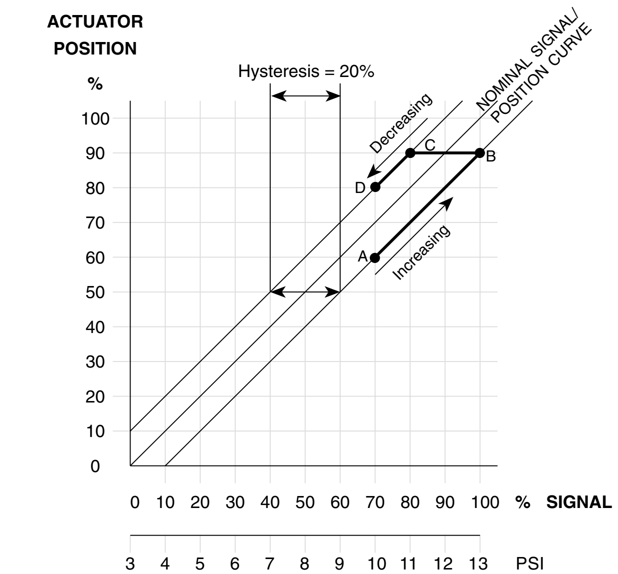
The dampers are subject to forces which increase friction when the fans are running. The resistance created by this friction must be overcome by the actuators. There are also dynamic forces that act upon the damper blades, that tend to turn them either clockwise or counterclockwise, depending upon the position of the blades. The actuators must be able to overcome these forces to position the dampers accurately.

The actuators are usually controlled by a modulating control signal, most commonly 2-10VDC. Ideally, the dampers should be repositioned in direct proportion to the control signal, and follow a “Nominal Signal/Position Curve”.

Hysteresis

All actuators have some hysteresis, which means that there is one position/signal curve for increasing signals, and a slightly different curve for decreasing signals. The actual position will be slightly different if it is an increasing or decreasing signal. Refer to Figure 13.

The control signal has to be changed by a certain value in order to reverse the movement of the actuator. This “dead zone” is the hysteresis, and often is expressed as a percentage of the control signal range. Most actuators are connected to the dampers via a linkage, which has an inherent play (slack). The actuator can move back and forth a few percent before the damper begins to move. This is also a form of hysteresis, which adds to the hysteresis of the actuator, so the total hysteresis can be quite large.



EXAMPLE:

	Point A	Signal is 70%, and the position is 60%
	Point B	Signal is increased to 100%, the position is 90%
	Point C	Signal is decreased to 80%, the position remains at 90%
	Point D	Signal is decreased to 70%, the position will be 80%

The signal is the same in points A and D; the position is different 80% instead of 60%. The resulting actuator position will be different, depending upon whether it is controlled by an increasing or decreasing control signal.

Figure 13. Hysteresis

Hysteresis creates two serious problems. First, it adds to the stability problems of the mixed air temperature control. Second, it makes the positioning of the actuators very inaccurate; this is especially serious concerning the minimum position of the outside air damper. If the control signal is increased from zero (closed OA damper) to the value that represents the minimum position of the OA damper, a lower than desired minimum position will result. If the control signal is decreased from a high value to the value that represents the minimum position of the OA damper, a higher than desired minimum position will result. This difference in the minimum position will have a very large impact upon the minimum outside air volume. Refer to Figure 16.

Do not confuse hysteresis with the "resolution." Resolution is the smallest increment the actuator will move when fine and slow changes in the control signal are made.

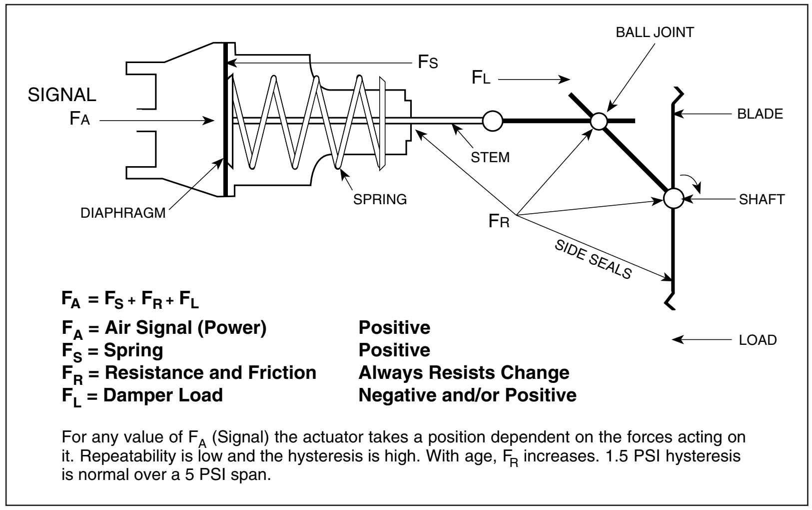


Figure 14. Pneumatic Actuator

Some installed actuators can modulate the dampers very smoothly as long as the control signal is continually changed in the same direction. The hysteresis will only reveal itself when the movement of the damper is reversed. Therefore the hysteresis should be measured by first increasing the signal to 40% for example, then decreasing the signal very carefully until the damper and actuator begin to move. If the damper starts to close at 25% signal, the hysteresis is 40 - 25 = 15%. The difference in the signal is the hysteresis. This test must be done with the fans running, applying force to the damper which the actuator must overcome. Hysteresis should be measured at different points of the damper movement with a particular emphasis on the minimum OA position.

Accuracy

The combination of poorly matched dampers and total hysteresis in the linkage and actuators can make stable control of mixed air temperature very hard to accomplish, even if advanced controllers are used.

If the minimum position of the OA damper is not controlled accurately, the minimum OA volume will be smaller or larger than the required value. A lower volume will result in a poor indoor air quality. A higher volume will result in wasteful high operating costs.

Pneumatic Actuators

Pneumatic actuators are still installed in older buildings; an understanding of their operation is essential. They have spring return function and operate with a very high hysteresis. This is inherent to the design. The pressure of the control signal acts on the diaphragm and produces a force, which pushes out the stem and compresses the spring until the forces are in balance. The position of the shaft will change in proportion to the air signal along the nominal signal to position curve. Refer to Figure 14.

To produce a net force at the output shaft, there must be an imbalance between the diaphragm and the spring. The force from the diaphragm must be stronger than the spring to produce a pushing force. The force from the diaphragm must be less than the spring force in order to produce a pulling force. This deviation between the position and the nominal signal/position curve is called “spring range shift”.

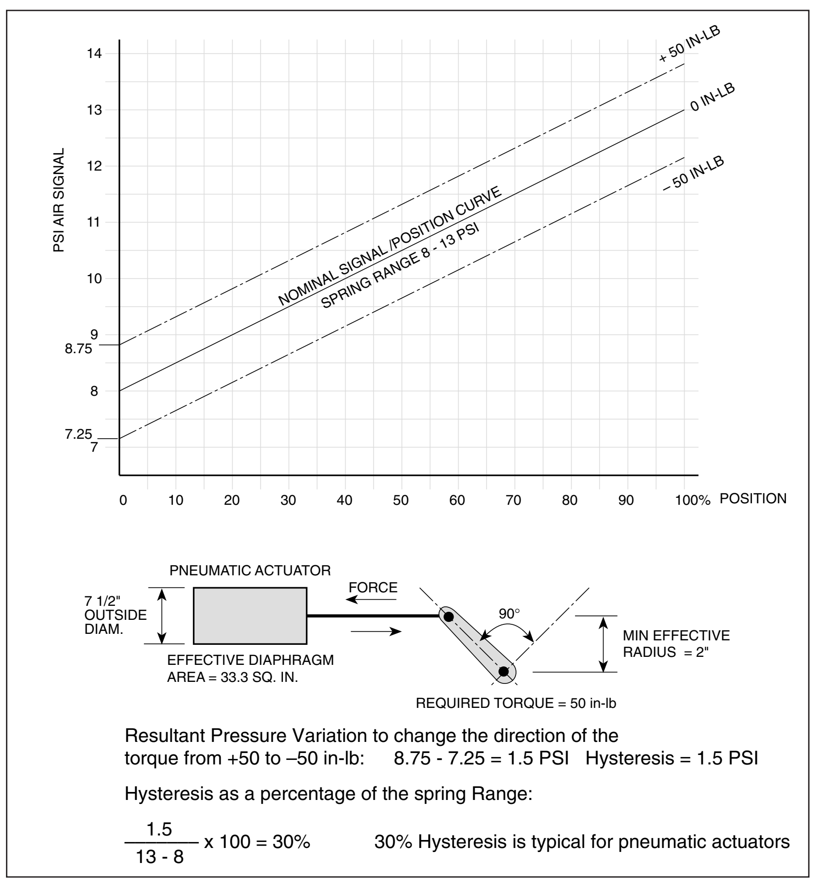


Figure 15. Typical Pneumatic Spring Range Shift and Hysteresis

Figure 15 shows a pneumatic actuator which is required to produce a clockwise (+) 50 in-lbs torque to open a damper, and a counterclockwise (-) 50 in-lbs torque to close it. The minimum effective radius of the linkage arm is 2". Which means that the pushing or pulling force of the actuator is +25 lb. or - 25 lb. (Torque/Effective radius = Force. 50/2 = 25 lb.)

The outside diameter of this actuator is 7½", which corresponds to an effective diaphragm (piston) area of approximately 33.3 sq. in.

When the signal pressure and the position are in balance, no net force is produced at the output shaft. This is represented by the "nominal signal/position" curve. To produce a 25 lb. force the signal pressure has to be higher or lower than the nominal signal/position curve.

The resultant pressure variation is 25 lb./33.3 sq. in. = 0.75 psi. To change from +50 in-lbs to -50 in-lbs torque, the total variation has to be 2 x 0.75 = 1.5 psi. This is 30% of the spring range of a typical pneumatic actuator (8 to 13 psi).

The hysteresis and spring range shift in an actual installation depends upon how generously the pneumatic actuator is sized, in comparison to the required torque. If the actuators are oversized, the hysteresis will be less. The recommendation of the pneumatic actuator manufacturer's is typically 1¼- 2 in-lbs for each square foot of damper area. This is less than adequate. The resulting hysteresis can be 12% or more. Refer to Figure 16.

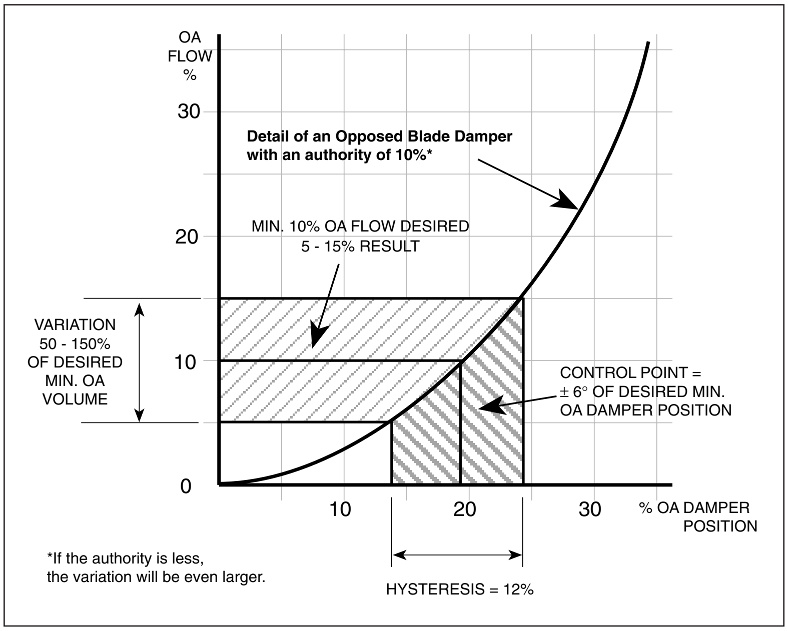


Figure 16. Results of Hysteresis on Minimum OA Air Flow

Positioner

The accuracy of pneumatic actuators is considerably improved if they are provided with positioning relays ("positioner"). A positioner compares the actual position of the actuator with the control signal, and changes the pressure to the diaphragm until the actuator assumes a position that corresponds to the control signal. This reduces the hysteresis to about ¼ psi, or 2½ - 5%, depending upon the operating range. However, frequent recalibration is needed to maintain the accuracy.

The additional cost of the positioner, and its adjustment, must not be forgotten when comparisons are made between pneumatic and electric actuators.

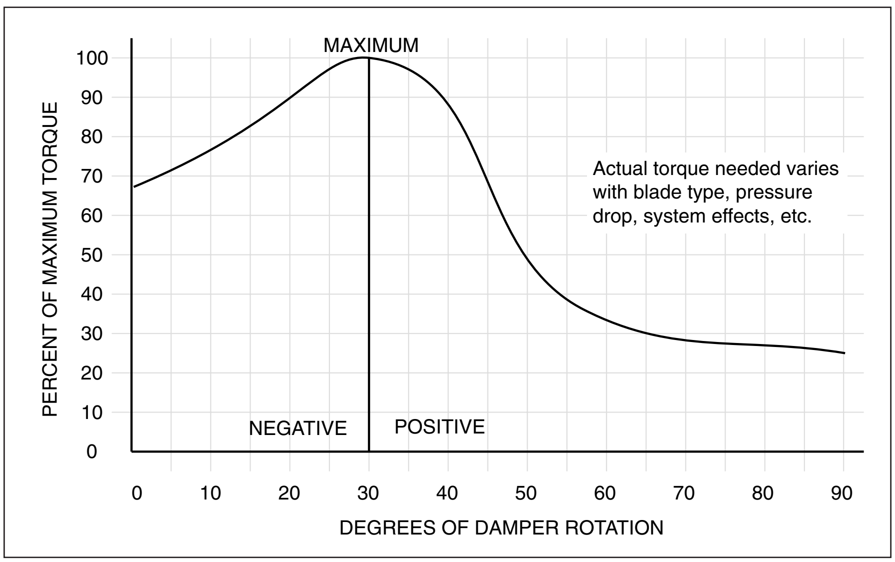


Figure 17. Typical Torque Requirement

Torque

The torque required to operate a damper depends upon the size, type, quality and condition of the damper. It is also dependent upon the differential pressure and air flow. Contrary to popular belief, the maximum required torque is not always at the closed position. Typically, the maximum torque requirement is found at about 30% open position. Refer to Figure 17.

Linkage

The actuator is connected to the damper via a linkage, which has a couple of ball joints, pivots and other elements that have some play. The slack in the linkage can easily cause a 1 - 3% hysteresis, when the stress changes from a pulling force to a pushing force. This effect requires the actuator to move about 1 - 3% before the damper begins to move. The amount of hysteresis depends upon the condition of the linkage and how well it has been adjusted. If the linkage is improperly adjusted and the joints are worn, the hysteresis can actually be larger than 5%.

Electronic Actuators

Electronic proportional actuators require both a power source, usually 24 VAC, and a control signal, usually 2 to 10 VDC or 4 to 20 mA. Their operation can be compared to a pneumatic actuator with a positive positioner. However, unlike its pneumatic counterpart, the electronic actuator requires no field calibration and usually no field maintenance. The position feedback is more precise than a pneumatic device because of a repeatable, geared, interface between the actual actuator position and its feedback monitoring system. The feedback signal is also usually available as an output from the actuator to either monitor the actuator position or as signal for part of a control sequence. Refer to Figure 18 and Figure 19.

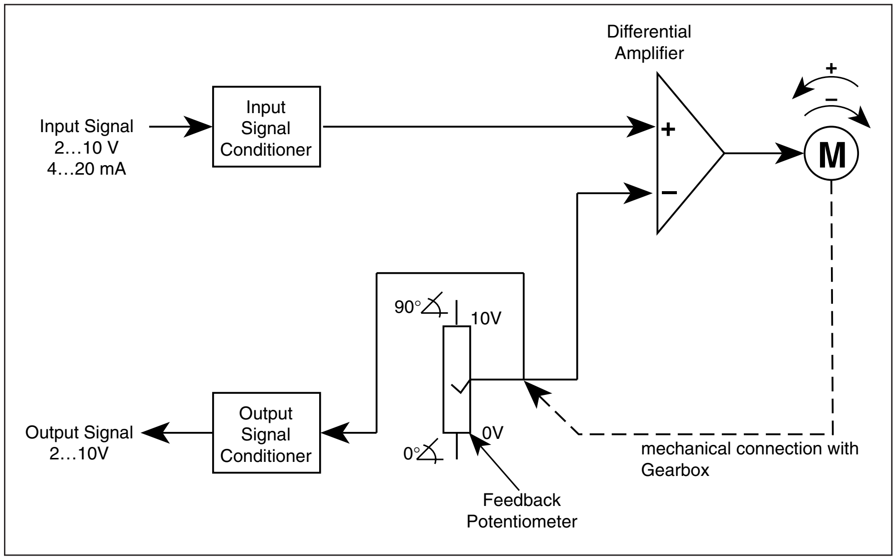


Figure 18. Actuator Positioning Circuit

Figure 18 shows a typical potentiometer circuit used to measure feedback. In this case, the signal from the potentiometer is fed into a differential amplifier along with the input signal. The differential amplifier looks at the difference between the input and feedback signal. It then gives a signal to move the actuator clockwise or counterclockwise until the feedback signal matches the input signal. Figure 19 shows another method which uses microprocessor technology. In this case, a microprocessor communicates to an application specific integrated circuit (ASIC). The ASIC both controls and monitors a brushless DC motor. By monitoring the digital pulses generated at the brushless DC motor, the exact position of the actuator can be determined by the microprocessor. The microprocessor also allows for special control criteria to be used in either operational characteristics or input signal processing.

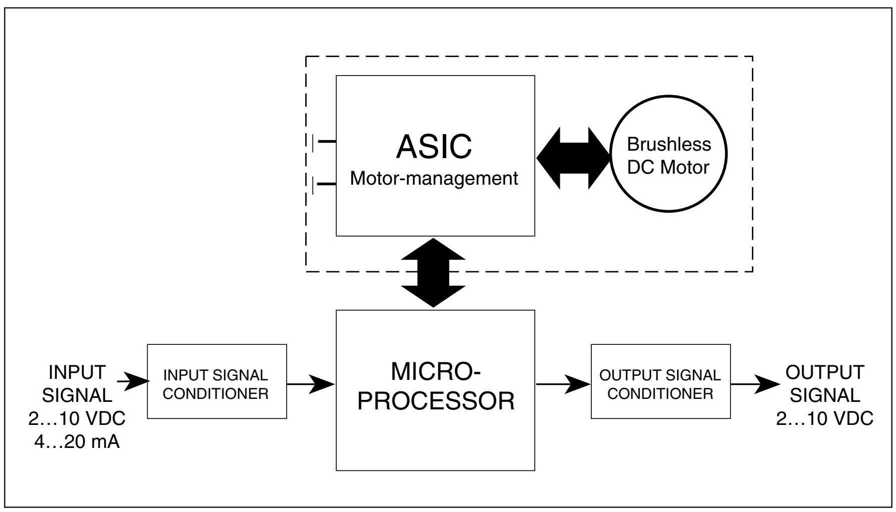


Figure 19. ASIC Circuit

Crank Arm Type

Legacy oil immersed gear train and electrohydraulic actuators typically have a small hysteresis of about 1%. These actuators are mounted to dampers in a similar manner as a pneumatic actuator, by the use of a linkage. This, as in the case of pneumatics, adds 1% to 3% of hysteresis to the system and care must be taken in its setup. Electrohydraulic actuators are not gear type actuators; they work similarly to a pneumatic actuator by building up pressure against a spring. Because they work against a spring they are subject to spring range shift.

Direct Coupled

Direct coupled actuators, just as the crank arm type, have a hysteresis of about 1%. However, this style of actuator does not require the use of a linkage. Because of this, the additional hysteresis of a linkage is not present. Without a linkage between the actuator and damper, the damper position can be controlled more accurately and the actuator torque is transmitted more efficiently to the damper. Also, the installation time is dramatically reduced. Table 1 provides a comparison of several actuator/damper combinations and their relative accuracy; direct coupled actuators are by far the most accurate.

	Pneumatic without Positioner	Pneumatic with Positioner	Electronic with Linkage	Belimo Direct Coupled
Actuator	12%[a]	2½-5%[b]	1%	1%
Linkage	1-3%	1-3%	1-3%	None
E/P Transducer	2%	2%	None	None
Total	15-17%	5½-10%	2-4%	1%

[a] 30% if undersized [b] Before calibration drift

Table 1. Actuator Damper Positioning Accuracy

An exploded view of a typical Belimo direct coupled actuator mounting method is shown in Figure 20. It is easy to see just how simple and straightforward this mounting method is. Direct coupled mounting greatly reduces installation time and lowers installation costs because fewer parts are needed.

The difference between direct coupled mounting and mounting using linkage is illustrated in Figure 21. Notice that the use of linkage often requires mounting the actuator on an independently located mounting bracket. The linkage itself generally consists of at least two crank arms connected by an operating rod attached to the crank arms with ball joints. Linkage systems can become quite complex and a number of geometrical issues must be addressed that can effect torque and response times. Refer to Belimo's Mounting Methods Guide for more information about damper linkages.

It is also possible to mount a direct coupled actuator separately, and connect it to the damper via a linkage. About 20% of installations require this, but it should be used only if it is completely impossible to mount the actuator directly. The Belimo mounting instructions for linkages must be followed. If it is an old installation, replace the old ball joints with new ones that have the least possible play. It is important that the hysteresis be as small as possible.

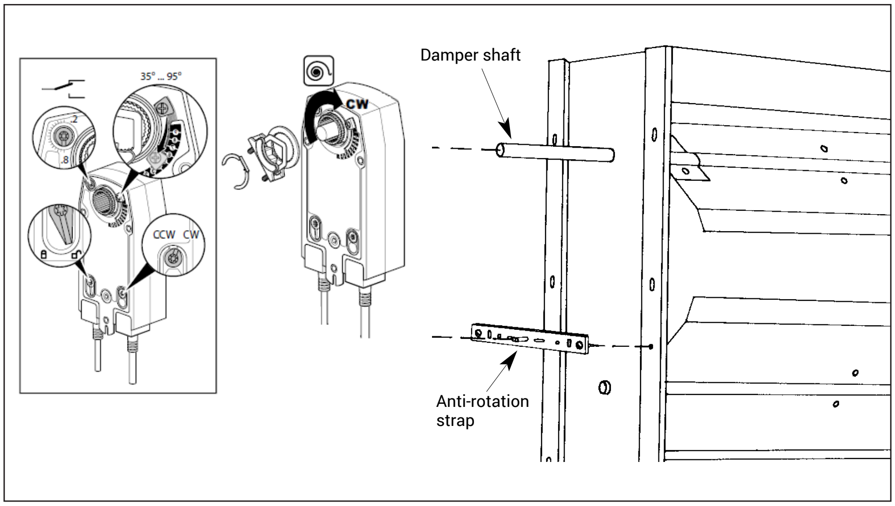


Figure 20. Direct Couple Mounting

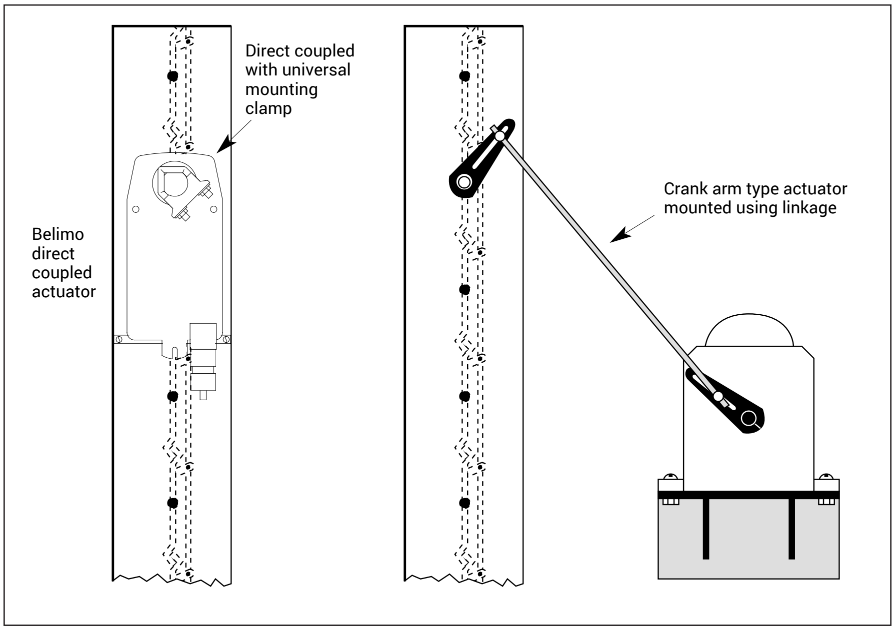


Figure 21. Direct Couple Mounting vs. Crank Arm Type

Optimizing Economizer Systems

Sizing of Dampers

The installed characteristics are determined by the authority of each damper. By sizing each damper correctly, the installed characteristics of the dampers can be chosen in such a way that they complement each other.

Examples of dampers that are poorly matched are illustrated in Figure 22 and Figure 23. In Figure 22 the OA and RA dampers are of opposed blade type, and have high authorities. The result is that the total air flow (MA) will not be constant. For example, when the dampers are in the mid position, the total flow will be much less than normal. In Figure 23 the dampers are of parallel type and have a very small (2%) authority. When the dampers are in the mid position the flow is much larger than normal.

Dampers that have been selected and sized so their installed characteristics complement each other is illustrated in Figure 24. The OA damper has opposed blades, and the RA damper has parallel blades. Both have an authority of 15%. As illustrated, the total flow (MA) remains rather constant regardless of the mixing ratio. As long as the variation in the total flow (MA) is less than 15%, the dampers can be regarded as well matched. Of course, each damper has to be sized with respect to the air flow and the available differential pressure. The OA damper should always be sized for a larger flow than the EA damper. The differential pressure across the RA damper is larger than across the EA damper, so the RA damper will be the smallest.

It is important to remember that there must be a slightly negative pressure at point A, in order for the outside air to enter the building. The pressure at point B has to be slightly positive in order for the exhaust to leave the building.

Very often the dampers are selected based upon the available duct size, with little concern for how well they are matched. In many installations, the OA damper is installed next to the weather louver, and therefore has to be the same size to keep the velocity through the louver below 500 FPM to avoid snow and rain entering. This results in a very small damper authority and this makes the sizing of the RA damper very important and demanding.

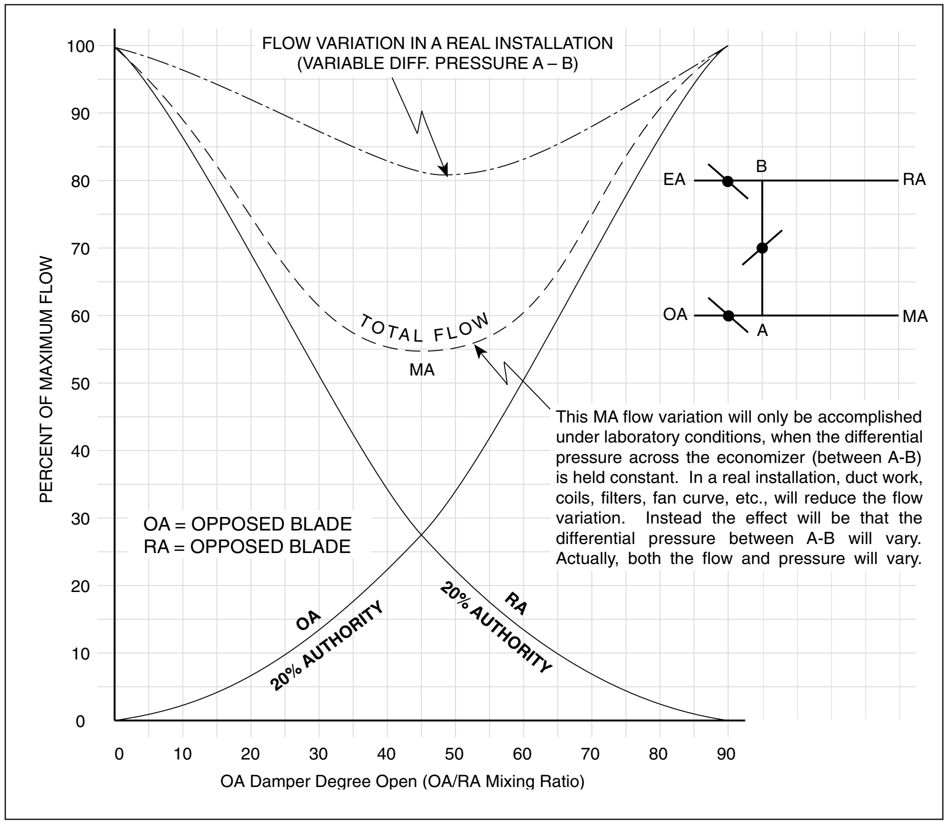


Figure 22. Example of Poorly Matched Dampers

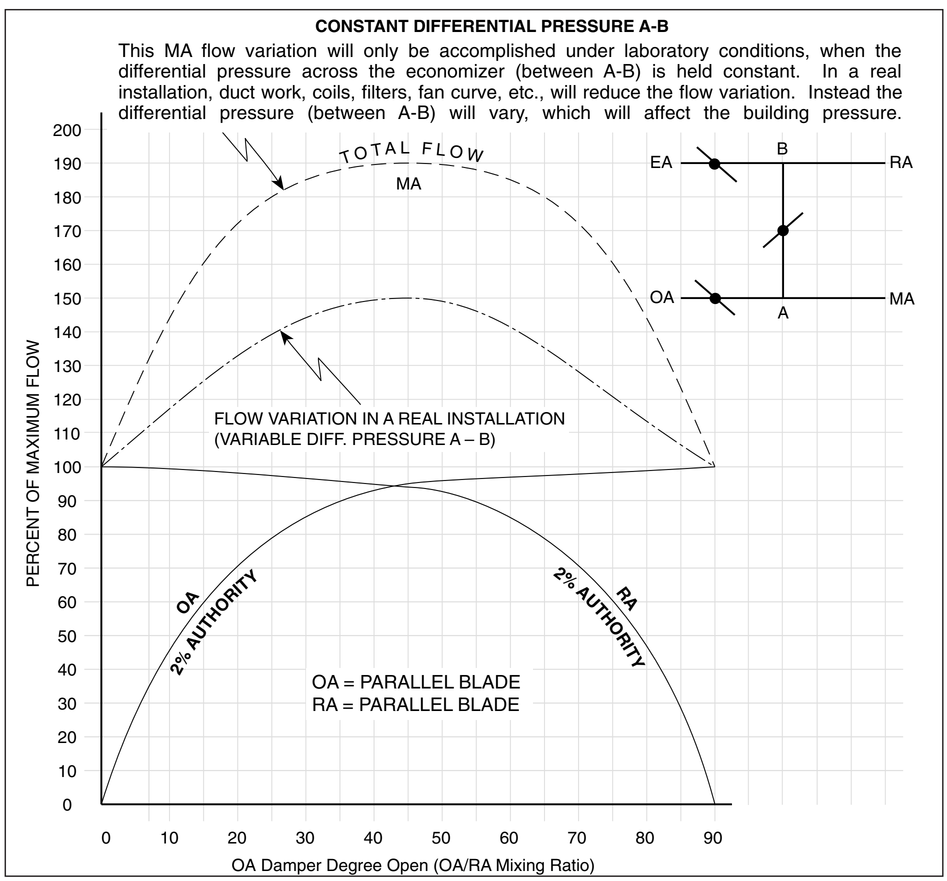


Figure 23. Example of Poorly Matched Dampers

Linearization

The installed flow characteristics of a damper at different authorities is very non-linear at the bottom and top part of the curve. However, between about 10% and 80% flow, the characteristics are rather linear for curves with authorities between 1% to 50%. Refer to Figure 6 and Figure 7.

Most dampers are oversized, so there is no need to open them fully, in order to get the desired maximum flow. For example, if we limit the maximum opening of a damper to 80% flow, the non-linear top portion can be eliminated.

Outside air dampers must provide a specified minimum OA volume. Therefore, they must not be modulated below a certain minimum position. This is fortunate, because it eliminates the lower non-linear portion of the curve. From minimum to maximum flow the damper now operates in the linear portion of the characteristic curve.

The throttling range will be very small for an opposed blade damper with a 1% authority curve operated by a direct coupled actuator with 2-10 V control signal. To open the damper to a 20% position (minimum flow), the control signal is 2.8 V. To open the damper to an 80% flow, the control signal is 5.2 V. Only a 2.4 V change in the control signal is required to throttle the damper from minimum to maximum flow. Because only a small portion of the operating range is utilized for this application, the resulting MA temperature can be erratic if the control loop is not correctly tuned. Refer to Figure 25.

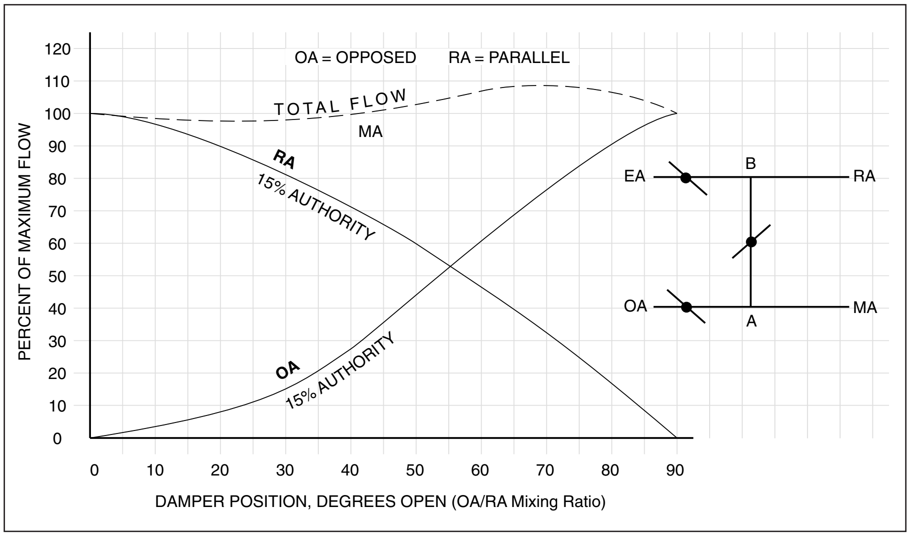


Figure 24. Example of Properly Match Dampers

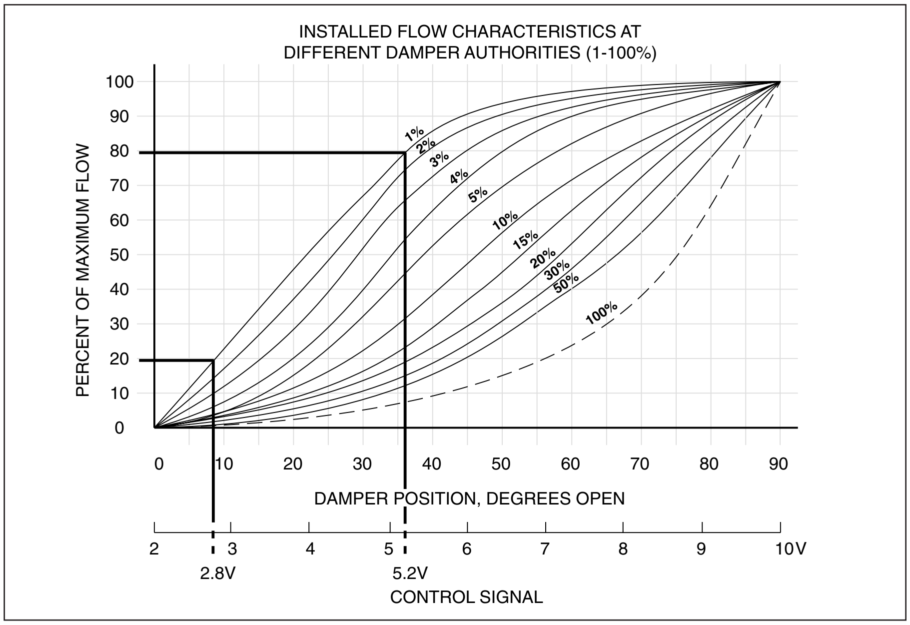


Figure 25. Installed Opposed Blade Damper Flow Characteristics

Travel Adapted (MFT Actuators)

Belimo offers MFT damper actuators that can improve the throttling performance described above in Figure 25. First adjust the actuators end stop to match the desired maximum flow, and then initiate the adaption routine. The adaption routine will scale the 2-10 VDC control signal over the mechanical rotation of 0° to 36°. For non-spring return actuators (GM / AM / NM / LM) press the manual override button once, for spring return actuators (AF, NF, LF, and TF) click the CW/CCW switch twice. When adaptation is initiated, the actuator will drive one full cycle to its mechanical end stops. Upon completion of this cycle, the actuators working range (input, feedback and running time) will be adapted to the actual mechanical angle of rotation. Finally, determine the control signal required to achieve 20% flow as described above in the section titled "Ventilation Minimum Position."

It is common practice to mechanically link the OA and RA dampers. This will save the expense of one actuator. Unfortunately, there are a couple of serious disadvantages associated with this. The most obvious problem is that the linkage will add a hysteresis to the operation of the RA damper. An even more serious problem is that the dampers have to be selected very carefully, so they are well matched. Otherwise the mixing ratio will not be controlled in a linear way, the total flow will not be constant and the pressure will vary. Examples of poorly matched dampers are illustrated in Figure 22 and Figure 23; and Figure 24 illustrates an example of correctly matched dampers.

By adapting the MFT actuator travel to the required maximum flow, the operation of the dampers can be modified so a more linear portion of the dampers are used. This also allows poorly sized dampers to be operated so they can more accurately complement each other. The full range of the control signal is utilized, and there will be a linear relationship between the OA/RA mixing ratio and the control signal. Also, the pressure in the mixing plenum will be constant.

As illustrated in Figure 26, each of the dampers has its own actuator, so they can be operated independently of each other.

It is possible to duplicate the function of the travel adapted MFT actuators with the software of a DDC system. This is acceptable, but it is not necessarily a cost saving, because the analog voltage values associated with the maximum flow must be programmed for each actuator, rather than using a single 2-10 VDC control signal. Another problem is that the fine tuning of the adapted MFT travel should be done in conjunction with the balancing, and it is hard for the balancing contractor to access the DDC controller.

Choice of Dampers

In order to avoid air stratification one option is to use a parallel blade damper mounted in the RA section to cause the RA and OA airflow to mix. The OA and EA dampers are both opposed blade dampers that complement each other and offer good throttling characteristics. Refer to Figure 27.

Because in many installations, the OA damper has the same size as the weather louver, it will be oversized in comparison to the flow, which results in a low authority. Opposed blade dampers have characteristics that can control small air flows more accurately than parallel blade dampers. For example: in order to supply a 20% flow, an opposed blade damper, with an authority of 1%, has to open to an 8° position, while a parallel blade damper, with the same authority, should open to a 2.5° position. Refer to Figure 28 and Figure 29. If the total hysteresis in the actuator and linkage is just 5°, the parallel blade damper may supply anything from 0% to 46% minimum OA volume (0° to 7.5° damper position). The positioning of an opposed blade damper is not quite as critical. A 5° error will result in an 8% to 30% deviation from the desired OA volume (3° to 13° damper position), so the opposed blade damper is a better choice when the OA damper is oversized and has a small authority.

The travel adapted MFT actuator allows the dampers to operate in such a way that they complement each other. This is done by limiting the damper movement to the linear portion only, and it makes the task of sizing

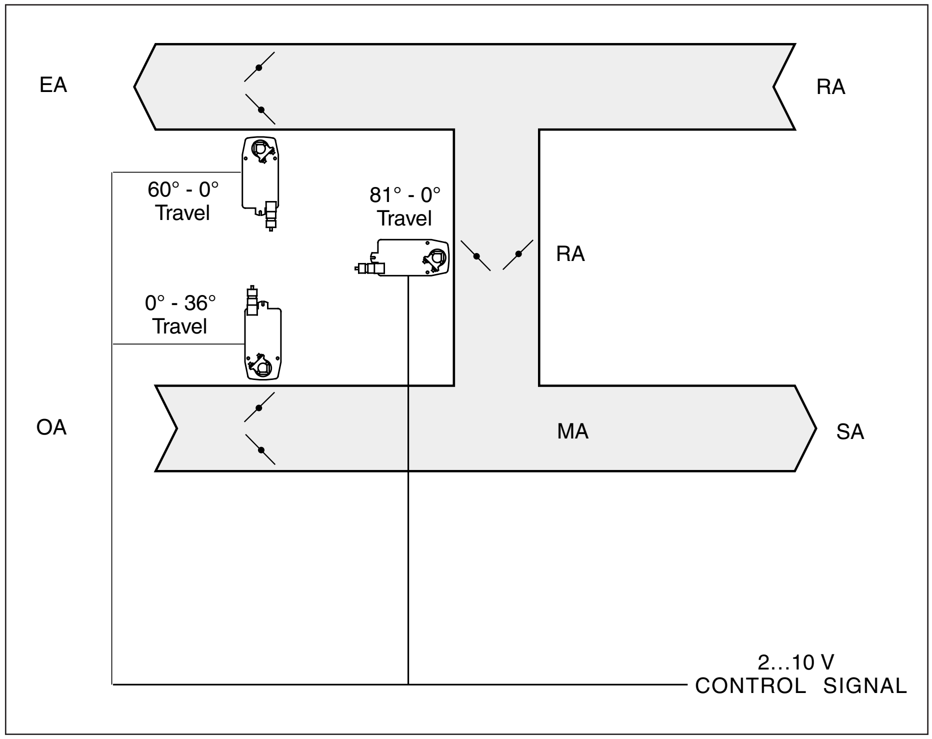


Figure 26. MFT Travel Adaption for Each Damper

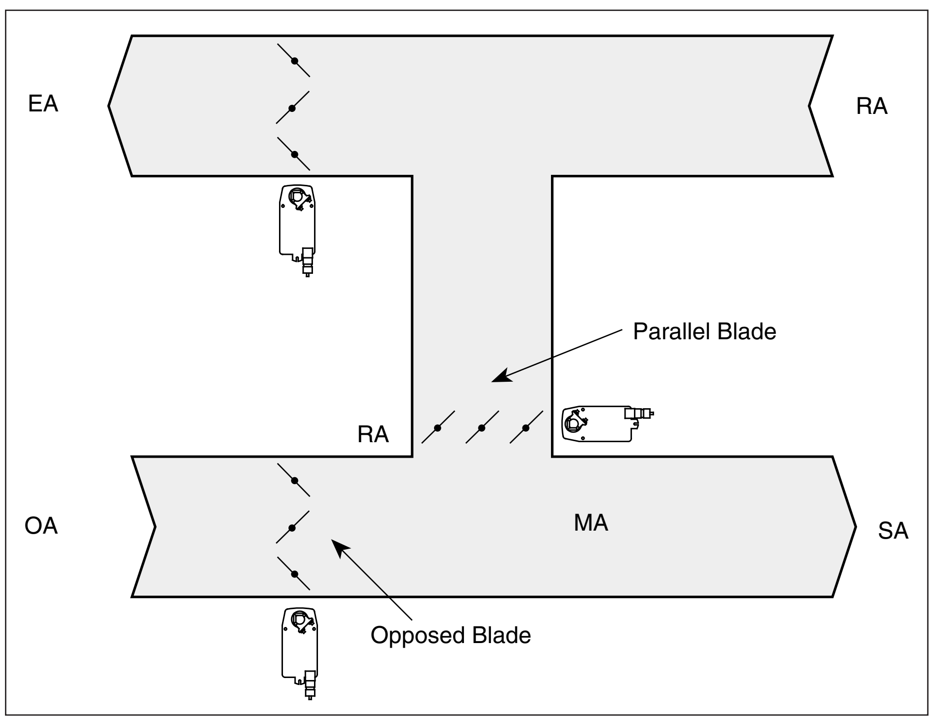


Figure 27. Combination of Parallel and Opposed Blade Dampers

the dampers less critical. However, this does not mean that it no longer matters how the dampers are sized. If the dampers are correctly sized, adapted MFT travel only needs modest adjustment, and a large portion of the damper movement can be utilized. However, if the dampers are poorly matched, a larger correction has to be used, and only a small portion of the damper movement can be used. Travel adapted MFT actuators will allow a great latitude when sizing the dampers, and even if the dampers are poorly matched, the function will be improved. However, the best result is achieved if the dampers are not excessively oversized.

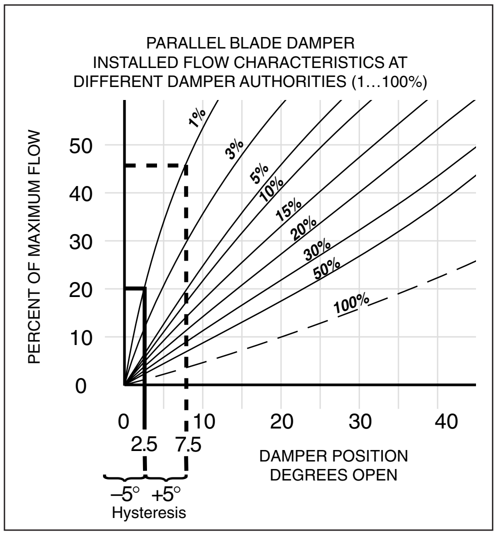


Figure 28. Parallel Blade Damper Authority

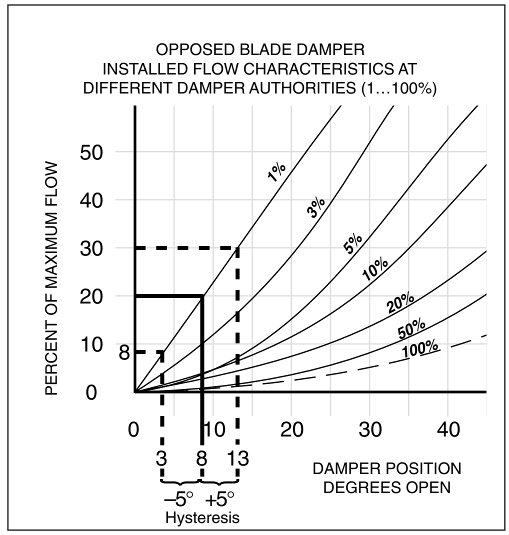


Figure 29. Opposed Blade Damper Authority

Summary

This guide has introduced a number of concepts. The importance of sizing and matching the dampers have been explained with respect to the authority and control. Refer to the damper manufacturers tables, charts, and instructions for final calculation and sizing of the dampers.

Modernization of Old Installations

When an old installation is modernized with a DDC system, it can be tempting to keep the old actuators if they still are working. This is always a very unfortunate decision, because of the poor accuracy provided by the legacy actuators. The full benefits of the DDC system will not be realized because the dampers cannot be controlled accurately.

Most old installations have problematic damper control. They would see increased efficiency and reduced costs if the old actuators were replaced with direct coupled MFT actuators with recommissioning of the OA airflow is performed.

Direct Coupled Actuators with MFT

Electronic direct coupled actuators offer a tremendous advantage because they are very accurate, and can position the dampers with the smallest possible hysteresis. If used in conjunction with the travel adapted MFT actuators, the dampers can be operated at a much superior level of control than would otherwise be possible.

Travel adapted MFT actuators offer the following advantages:

- Sizing of the dampers is simplified because the dampers need not be perfectly matched.
- Mixed air temperature control is improved.
- Total flow will remain constant regardless of the mixing ratio.
- Pressure in the mixing plenum will remain constant.
- Travel adapted MFT actuators require a simple end stop adjustment before the adaption routine is initiated. Flow measurements and adjustments are achieved at the same location.

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