ASHRAE Guideline 16-2022R

Public Review Draft

Selecting Outdoor, Return, and Relief Dampers for Air-Side Economizer Systems

First Public Review (May 2025)

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a. interpretation of the contents of this Guideline,
b. participation in the next review of the Guideline,
c. offering constructive criticism for improving the Guideline, or
d. permission to reprint portions of the Guideline.

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NOTE

Approved addenda, errata, or interpretations for this guideline can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.

(This foreword is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

FOREWORD

Control damper selection and sizing are a critical first step in the design of a control system. The system designer should take care to make the correct damper selections. Improper selection and sizing may cause hunting; improper temperature, flow, and pressure control; and other operational difficulties.

The objective of this guideline is to address the application and sizing of outdoor, return, and relief dampers used to control

- *outdoor-air intake for economizer (free) cooling,*
- *minimum-ventilation outdoor airflow for indoor air quality, and*
- *building pressure.*

This guideline focuses on the three most common damper configurations for systems employing an air-side economizer:

a. Supply and return fan
b. Supply and relief fan
c. Supply fan with gravity (nonpowered) relief

These configurations have outdoor, return, and relief dampers. For other damper configurations, such as multiple return dampers within a system, the general information in this guideline is still beneficial.

The methods of control described in this guideline are not intended to indicate a control preference but to show how dampers typically operate in heating, ventilating, and air-conditioning systems that include an air-side economizer.

This guideline was prepared under the auspices of ASHRAE. It may be used, in whole or in part, by an association or government agency with due credit to ASHRAE. Adherence is strictly on a voluntary basis and merely in the interests of obtaining uniform guidelines throughout the industry. Changes in this 2022 revision of Guideline 16 include updated references.

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1. PURPOSE

This guideline provides the basis for selecting and sizing control dampers (outdoor, return, and relief) commonly found in constant-air-volume (CAV) and variable-air-volume (VAV) air-handling units (AHU) and systems with air-side economizers.

2. SCOPE

2.1 This guideline covers the application of mixed-air control dampers in AHUs and systems that incorporate air-side economizer systems for cooling.

2.2 This guideline addresses the selection of control dampers based on damper characteristics and damper pressure drop.

2.3 This guideline is not intended to cover dampers used elsewhere in heating, ventilating, and air-conditioning (HVAC) systems.

2.4 This guideline does not cover air mixing.

3. DEFINITIONS

3.1 Definitions of most terms used in this guideline can be found in *ASHRAE Terminology of Heating, Ventilation, Air Conditioning, & Refrigeration* [1].

3.2 Terms used in this guideline that are not found in *ASHRAE Terminology of Heating, Ventilation, Air Conditioning, & Refrigeration* or that are used differently are defined in this section.

maximum outdoor-air damper: a modulating damper or set of dampers used to control the outdoor airflow to the system in excess of minimum ventilation outdoor air for free cooling (air-side economizer). Also called economizer outdoor-air damper. May also serve to provide the minimum outside airflow control.

minimum outdoor-air damper: a two-position damper in parallel with the maximum outdoor-air damper to provide the minimum outdoor air required for ventilation.

FOREWORD

The 2025 edition of Guideline 16 updates normative references. This standard was prepared under the auspices of ASHRAE. It may be used, in whole or in part, by an association or government agency with due credit to ASHRAE. Adherence is strictly on a voluntary basis and merely in the interests of obtaining uniform guidelines throughout the industry.

path pressure drop: the pressure drop in the air path that is affected by the control damper.

relief air: building return air discharged by the AHU equipment to control building pressure when an HVAC system is operating in the economizer cycle.

ventilation air: the minimum amount of outdoor air required for the purpose of controlling air contaminant levels in buildings.

*α**-value:*** the ratio of path pressure drop, including fully open control damper pressure drop, to the pressure drop across the fully open damper at design flow.

4. SYSTEM ARRANGEMENTS

4.1 General

4.1.1 This guideline covers air-handling systems that include an air-side economizer. The most common variations are:

a. Arrangement 1 (Figure 1): HVAC system with a return fan
b. Arrangement 2 (Figure 2): HVAC system with a relief fan
c. Arrangement 3 (Figure 3): HVAC system with a gravity or motorized relief damper

4.1.2 Figures 1–3 show features and controls that are optional. For example, supply/return/relief fan motors are shown with variable-speed drives as the method of controlling fan capacity. Other methods of fan capacity control may be used. The figures shown are VAV systems. This guideline also applies to CAV systems.

4.1.3 The supply-air temperature sensor (T-1) normally controls dampers D-2 and D-3 so that one damper closes as the other opens (Figure 4). For Arrangements 2 and 3, sequencing the dampers (Figure 5) reduces energy costs in VAV systems by reducing pressure drop in the mixing mode. This has an impact on the way dampers are selected (see Section 4.3.3.4, second paragraph).

4.1.4 The required minimum outdoor-airflow rate must be delivered to the building regardless of the ambient conditions or the supply-airflow rate. The type of minimum outdoor-air control system has an impact on plenum pressure PL-2 and, therefore, an impact on sizing dampers. Three approaches to ensure minimum outdoor-airflow rate are as follows:

a. *Approach A—Injection fan with volume control (Figure 1).* The minimum outdoor air is drawn through the minimum outdoor-air damper (D-4) and injected into the mixed air plenum (PL-2). Volume control is required because of the pressure variations in both the mixed air plenum and outside the building. Volume control options include varying fan speed and modulating the outdoor-air damper (D-4). When varying injection fan speed is used for volume control, damper D-4 is a two-position damper for shutoff of outdoor air when the AHU is OFF. The modulating ventilation air damper option should be used when a relief fan or barometric relief is used, since the pressure in PL-2 will be considerably less than ambient with these designs, possibly causing excess outdoor air to be drawn in when the injection fan is at minimum speed. Outdoor-airflow rates are typically determined with either a flow sensor in the minimum outdoor air or a differential pressure sensor across minimum outdoor-air damper (D-4), provided the damper is two-position (differential pressure can be correlated to flow only for a fixed orifice). The economizer outdoor-air control damper (D-3) is closed except when it is used to maintain a mixed air temperature during the economizer mode of operation.
b. *Approach B—Modulating return-air damper (Figure 2).* Minimum outdoor air is drawn through a two-position minimum outdoor-air damper (D-4). However, rather than being injected into the mixed air plenum (PL-2) by an injection fan, air is drawn into the plenum by the supply fan. In this approach, to obtain the required minimum outdoor air, the return-air control damper (D-2) is modulated independently of the other control dampers. As in Approach A, the minimum outdoor-airflow rate is typically determined with either a flow sensor in the minimum outdoor airstream or a differential pressure sensor across the two-position minimum outdoor-air damper (D-4).
c. *Approach C—Modulating outdoor-air damper with no separate minimum outdoor-air damper (Figure 3).* This approach requires a means to measure outdoor airflow, such as (a) an outdoor-air control damper with an integral flow-measuring station, (b) an outdoor-air damper capable of being set to a repeatable minimum position (e.g., using a direct-coupled actuator) across which a pressure differential is measured and controlled, or (c) an airflow-measuring device capable of measuring the control signal at the minimum outdoor-airflow rate, which may be only 10% to 20% of the design airflow rate. Note that some flow-measuring stations must have high velocities so that a detectable control signal may be generated at minimum outdoor-airflow rates.

4.2 Return Fan System

4.2.1 System Description. Arrangement 1 systems (Figure 1) consist of a supply fan, return fan, control dampers, and appropriate coils.

4.2.2 Example Control Sequence†

4.2.2.1 Building Pressure Control. The relief air control damper (D-1) is used to maintain building pressurization by regulating the flow of relief air from the building. Building pressurization is used to reduce infiltration of unconditioned air and its adverse impact on local thermal loads. A portion of the minimum outdoor and economizer outdoor air leaves the building by exfiltration and general exhaust fans. The balance of the outdoor air leaves the building through the relief air control damper path. Building pressure sensor P-2 provides a direct acting control signal used in the control of the relief damper (D-1). The range of the sensor is generally ±0.1 in. wg (±25 Pa). Unless the building has zones that have different pressure requirements, only one differential pressure sensor is required. If the building has more than one relief damper, the sensor normally controls all dampers in parallel.

4.2.2.2 Return Fan Control. The capacity (speed) of the return fan is based upon a differential pressure sensor (P-3) to maintain the pressure in the plenum (PL-1) high enough to discharge the design relief air volume through the wide open exhaust/relief damper (D-1). The low-pressure port of sensor P-3 is referenced to the outdoor pressure on the same side of the building as the relief louver to compensate for wind effects. As the relief damper opens, the plenum pressure drops, and the return fan speed increases to maintain the setpoint of sensor P-3. The pressure in the return plenum will generally range from 0.1 to 0.3 in. wg (25 to 75 Pa). The setpoint of pressure sensor P-3 is determined by the balancing contractor to overcome the losses through the relief damper, the relief louver, the plenum, and associated ductwork (Path PL-1 to A).

4.2.2.3 See Section 4.1.4 for minimum outdoor-air control.

4.2.3 Damper Types and Sizing

4.2.3.1 Select the relief damper (D-1) first. An opposed-blade damper is recommended since it will have lower pressure drop than a smaller parallel-blade damper when selected for linear throttling characteristics, thus reducing the cost of operation. The damper selection is based upon the maximum design relief air (design primary air supply rate minus mechanical exhaust minus exfiltration and pressurization air). First determine the relief air path pressure drop without the relief damper (from PL-1 to atmosphere). For a linear response opposed-blade damper, the ratio between the pressure drop in the relief air path and the pressure drop through the open damper (α-value) should be 8 to 15 (see Section 5 and Figure 6). This means that the damper will have a wide-open pressure drop of 7% to 15% of the relief path pressure drop at design flow. The resulting wide-open damper face velocity will frequently be around 1000 to 1500 fpm (5 to 8 m/s). Once the damper is sized, the pressure in plenum PL-1 relative to ambient may be estimated—information that will be needed in the selection of the return damper.

4.2.3.2 Select the minimum outdoor-air damper (D-4) if one is used.

a. *Approach A (see Section 4.1.4, item a, and Figure 1).* If D-4 is modulating for capacity control, it should be selected using the procedure similar to that described above for relief damper D-1. If D-4 is two-position, it may be either parallel or opposed blade and may be the size of the ductwork.
b. *Approach B (see Section 4.1.4, item b, and Figure 2).* D-4 is two-position, so it may be either parallel or opposed blade. It should be sized for the minimum outdoor-airflow rate at the same face velocity as the economizer outdoor-air damper (D-3). If the minimum outdoor-airflow control is based on the differential pressure across this damper, the minimum available pressure transducer resolution available (typically 0 to 0.1 in. wg [0 to 25 Pa] for commercial-grade transducers) may dictate the damper size and pressure differential.

† Due to the potential for interaction between the building pressurization and return fan control loops, extra care must be taken in selecting the parameters that determine the dynamic response of the digital filters and feedback controllers. To prevent excessive control loop interaction, the closed loop response time of the building pressurization loop should not exceed one-fifth of the closed loop response time of the return fan control loop. This can be accomplished by decreasing the gain of the building pressurization controller. To prevent fluctuations in outdoor-air pressure attributed to wind gusts from exciting the control systems, digital filters should be configured to reject input spikes and/or provide a moving average of the building's differential pressure signal.

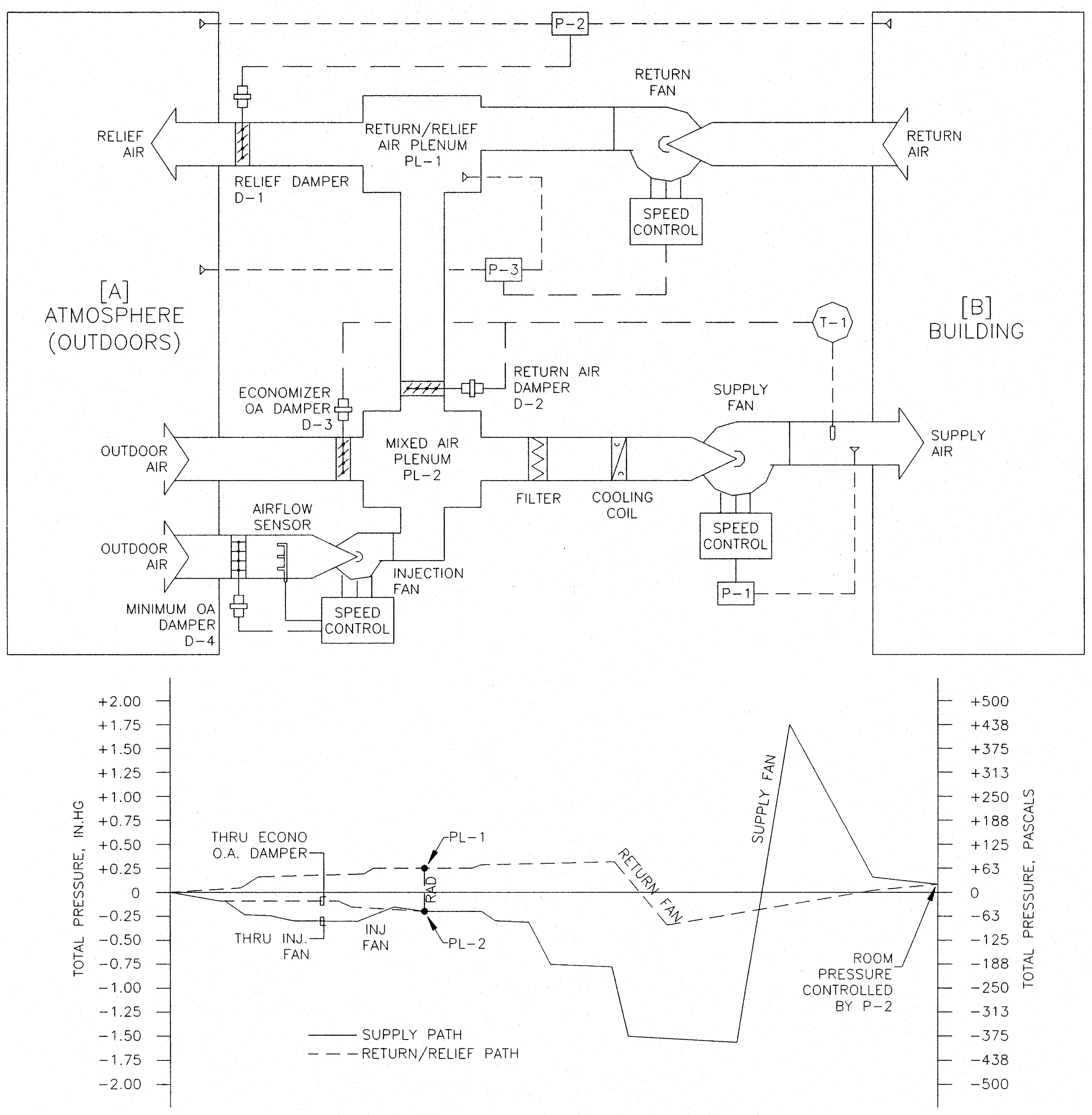

Figure 1 Arrangement 1: HVAC system with a return fan (with minimum outdoor-air control Approach A).

4.2.3.3 Select the economizer outdoor-air damper (D-3). Because of space limitations, this damper is often the same size as the outdoor intake louver. The size of this damper is not critical since it does not directly control outdoor airflow. The flow of outdoor air through this path (A to PL-2 and through the minimum outdoor-air damper if used) is always the difference between the supply airflow and the return airflow through path PL-1 to PL-2, and, therefore, the damper size and type have no effect on the amount of outdoor air. Dampers with a low pressure drop are generally used to minimize the cost of operating the supply fan. Because this damper does not control flow, either opposed-blade or parallel-blade action can be used.

4.2.3.4 Finally, select the return-air damper (D-2). The damper selection is based upon the maximum return-airflow rate, which is the difference between the design supply air and the minimum outdoor-airflow rate. The return-air damper should be selected so that the pressure drop from

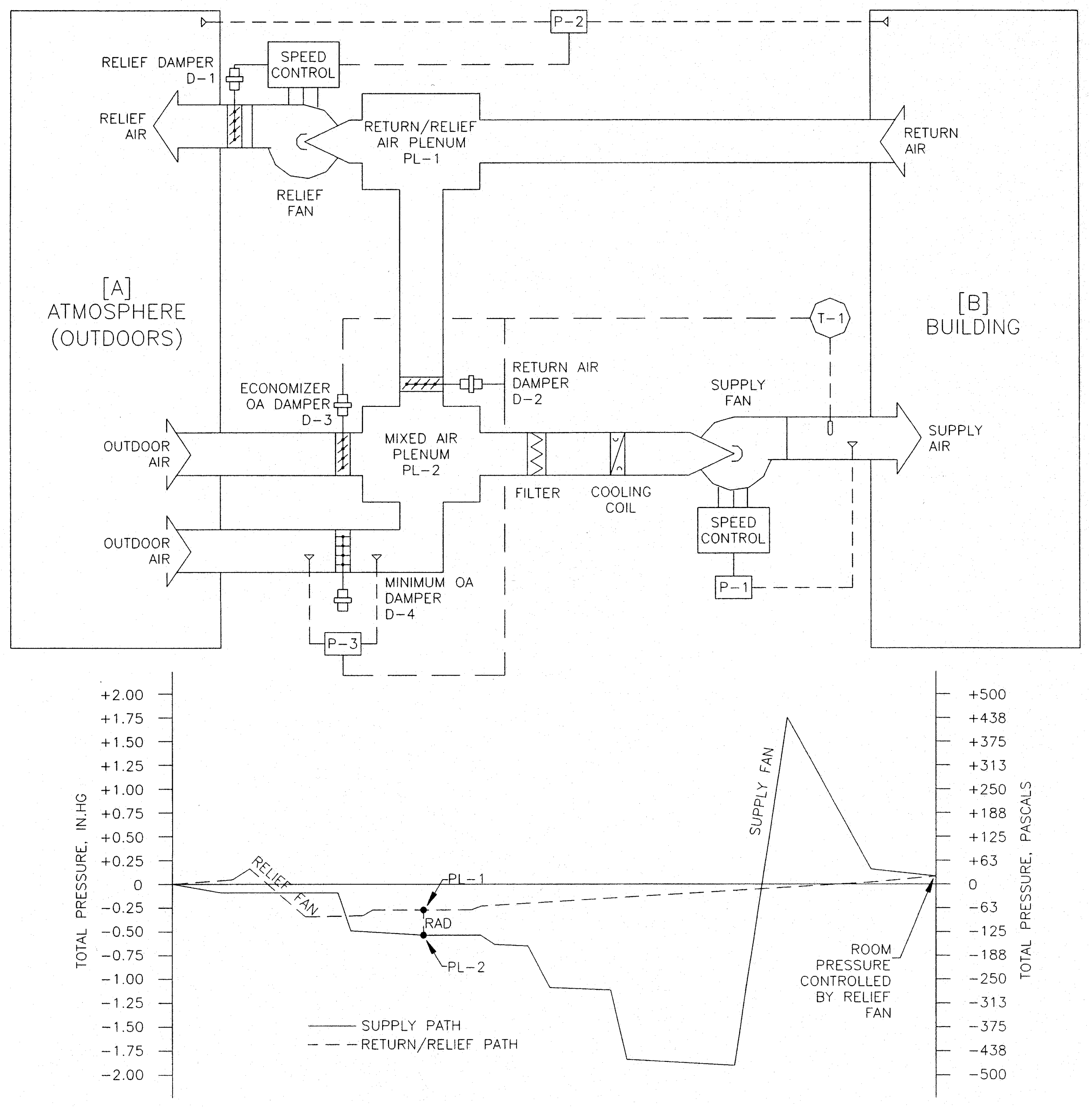

Figure 2 Arrangement 2: HVAC system with a relief fan (with minimum outdoor-air control Approach B).

PL-1 to PL-2 is equal to the differential pressure available between the two plenums. The pressure in PL-1 relative to ambient pressure is equal to the pressure drop from PL-1 through the relief air damper and louver to the outdoors (see Section 4.2.3.1). The pressure in PL-2 will depend on the minimum outdoor-air approach:

a. *Approach A (see Section 4.1.4, item a, and Figure 1).* With an injection fan, the pressure in PL-2 should be slightly lower than ambient (e.g., 0.05 to 0.10 in. wg [10 to 25 Pa]). (The system could operate at a positive pressure when in the minimum outdoor-air mode, presuming the injection fan is so sized. However, the plenum must have a negative pressure for operation when the economizer outdoor air damper (D-3) is open.)

b. *Approach B (see Section 4.1.4, item b, and Figure 2).* The pressure in PL-2 is equal to the pressure drop at the minimum outdoor-airflow rate from the outdoors through the minimum outdoor-air damper to PL-2.

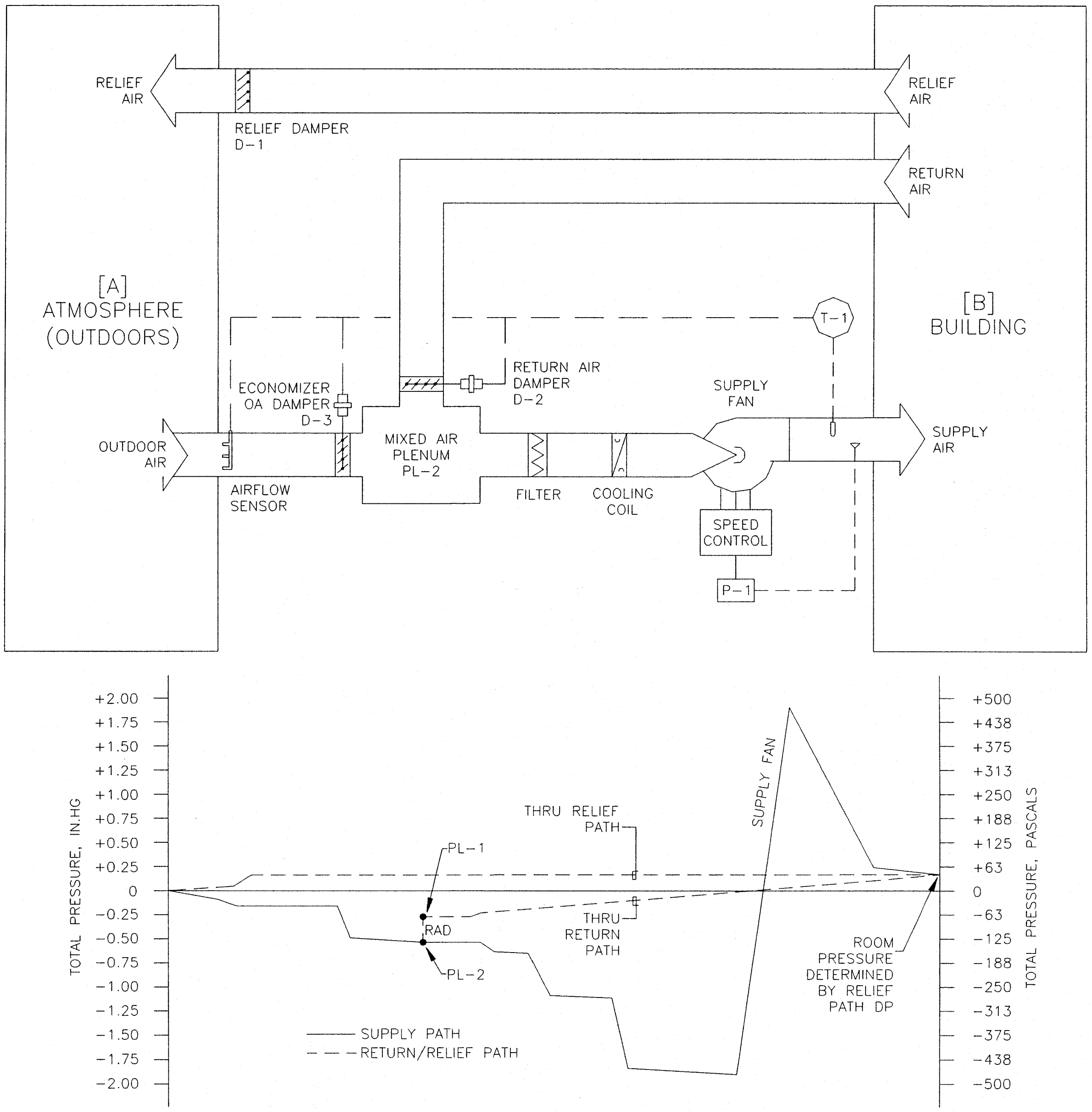

Figure 3 Arrangement 3: HVAC system with a gravity or motorized relief damper (with minimum outdoor-air control Approach C).

c. *Approach C (see Section 4.1.4, item c, and Figure 3).* The pressure in PL-2 is equal to the pressure drop at the minimum outdoor-airflow rate from the outdoors through the outdoor-air damper to PL-2 when the damper is at minimum position. The minimum position is up to the designer, but it should be well below full open so that the damper can open further when the supply fan airflow rate is low and the pressure in PL-2 approaches ambient pressure.

Note that when calculating the pressure drop from PL-1 to PL-2, take care to keep the signs correct: the pressure in PL-1 will be positive relative to ambient, while the pressure in PL-2 will be negative. For instance, the pressure in PL-1 may be 0.2 in. wg (50 Pa), while the pressure in PL-2 may be –0.1 in. wg (–25 Pa), so the pressure drop is 0.2 – (–0.1) = 0.3 in. wg. (50 – [–25] = 75 Pa).

A parallel-blade damper is usually recommended because the α-value for the damper will be small (the damper will account for most of the pressure drop between PL-1 and PL-2). At low α-values, a parallel-blade damper will provide a more linear response.

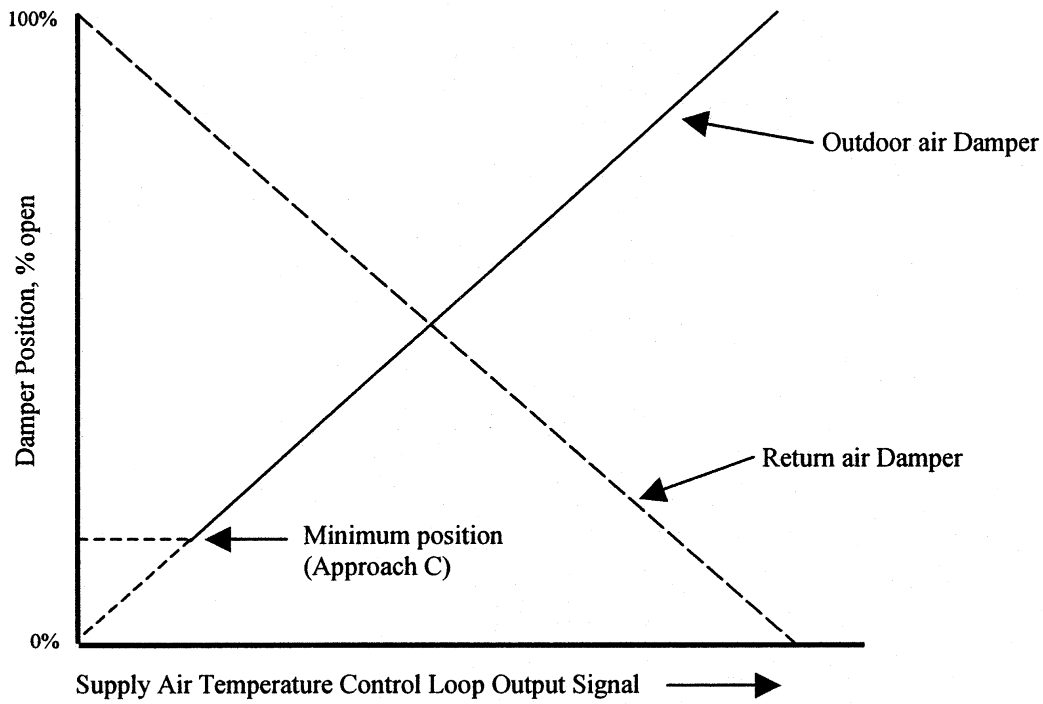

Figure 4 Overlapping damper control.

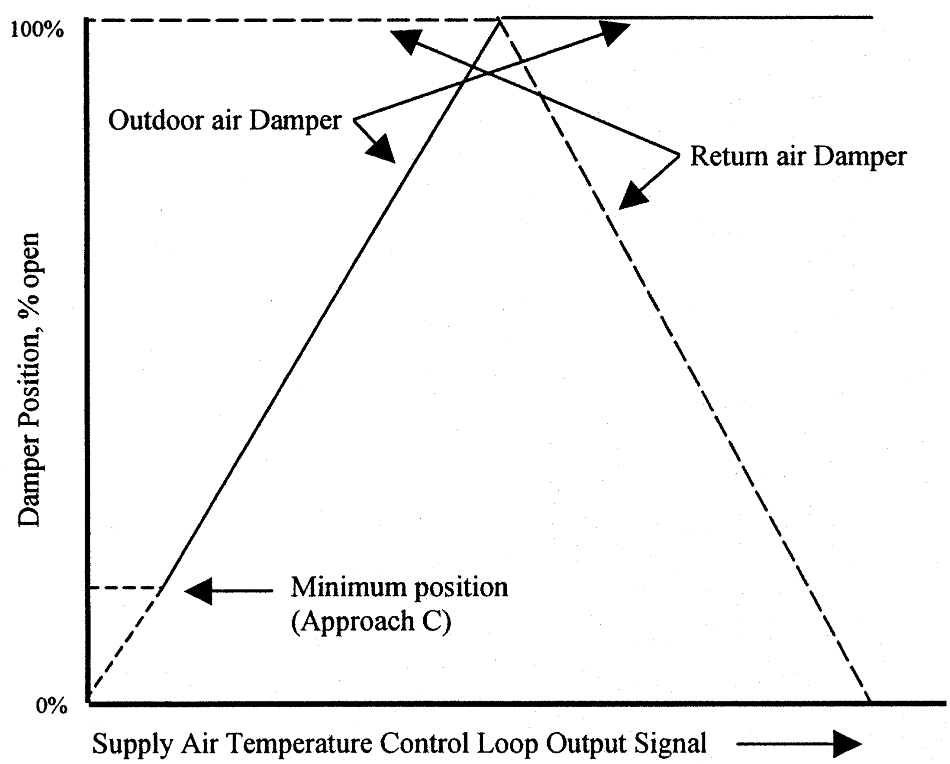

Figure 5 Sequenced damper control.

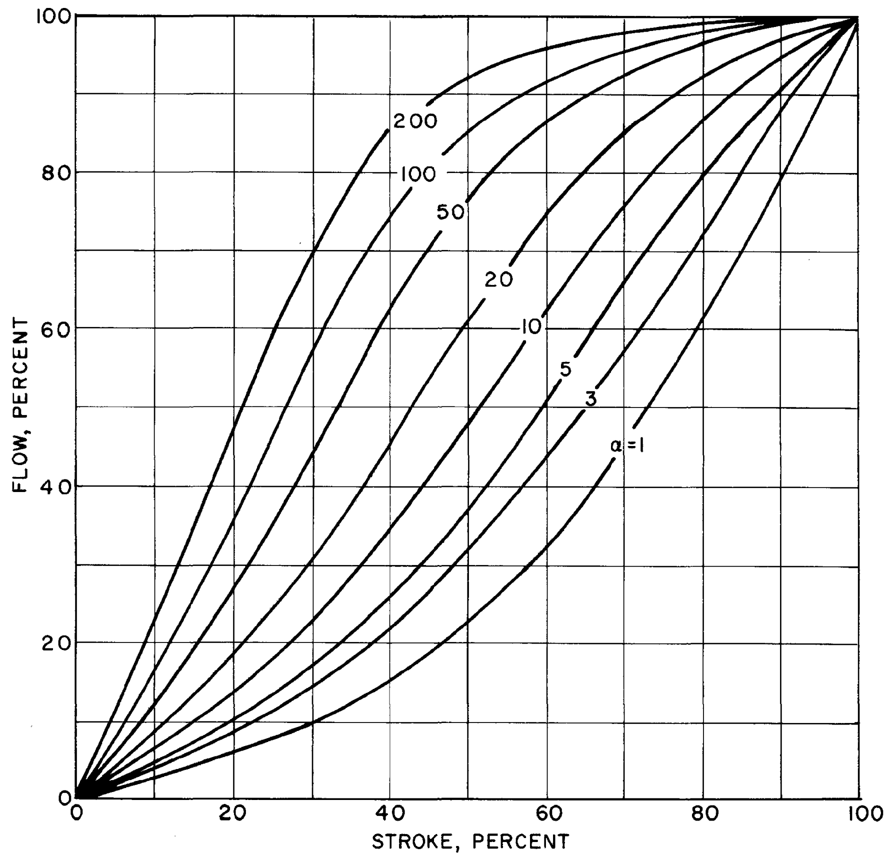

Figure 6 Installed opposed-blade damper characteristic curves.[3,6]

4.3 Relief Fan System

4.3.1 System Description. Arrangement 2 systems (Figure 2) consist of a supply fan, relief fan, control dampers, and appropriate coils.

4.3.2 Example Control Sequence

4.3.2.1 Building Pressure Control. The building pressure, sensed by differential pressure sensor P-2, controls the speed of a relief fan. As the building pressure rises, the speed of the relief air fan increases and, as the pressure drops, speed decreases. The high-pressure port of P-2 senses indoor pressure and the low-pressure port senses outdoor pressure. The range of the sensor is generally ±0.1 in. wg (±25 Pa). Unless the building has zones that have different pressure requirements, only one differential pressure sensor is required. If more than one relief fan is in the building, the sensor normally controls the speed of all fans in parallel.

4.3.2.2 See Section 4.1.4 for minimum outdoor-air control.

4.3.3 Damper Types and Sizing

4.3.3.1 First, size the relief air damper (D-1). This damper is typically a two-position damper interlocked to the fan (or a gravity backdraft damper) with relief fan volume control such as a variable speed drive, variable pitch blades (axial fan), inlet vanes (centrifugal fan), and/or fan staging. As such, it should be selected for low pressure drop to minimize fan energy and may be either parallel or opposed blade. If damper D-1 is used for volume control (discharge damper), size it as instructed in Section 4.2.3.1.

4.3.3.2 Select the minimum outdoor-air damper (D-4)—if one is used—as instructed in Section 4.2.3.2.

4.3.3.3 The economizer outdoor-air damper (D-3) should be selected for low pressure drop to minimize the cost of operating the supply fan. Damper face velocities from 400 to 1500 fpm (2 to 8 m/s) at design flow are typical. Very often, because of space limitations, this damper is the same size as the outdoor intake louver. See Section 4.3.3.4 for recommended damper blade action (opposed or parallel).

4.3.3.4 Finally, select the return damper (D-2). Return-air damper sizing is based upon the maximum return-airflow rate, which is the difference between the design primary supply air and the minimum required outdoor-airflow rate. With a relief fan, the pressure in PL-2 must be below the pressure in PL-1. The pressure in PL-1 is pressure drop from the space to PL-1 minus any positive pressure being maintained in the space relative to ambient to counter infiltration. This will usually be more negative than PL-2 has to be for any of the three minimum outdoor-air approaches described in Section 4.1.4. Therefore, the pressure drop between PL-1 and PL-2 (including damper D-2) should be as low as possible to minimize the negative pressure in PL-2 and minimize supply fan energy. Damper face velocities from 800 to 1500 fpm (4 to 8 m/s) at design flow are typical.

Where outdoor-air and return-air dampers are controlled so that one opens when the other closes (Figure 4), both outdoor-air and return-air dampers should be parallel-blade dampers. Tests show that a relatively constant pressure drop across the return air and outdoor-air paths throughout the economizer cycle can be achieved by using parallel-blade dampers (see Section 5.2). Where outdoor-air and return-air dampers are sequenced (see Figure 5), either parallel or opposed action may be used.

4.4 Relief Damper System

4.4.1 System Description. Arrangement 3 systems (Figure 3) consist of a supply fan, relief air damper, control dampers, and appropriate coils. The relief system is not fan-powered and relies on building pressurization to cause excess outdoor air to relieve to atmosphere.

4.4.2 Example Control Sequence. The building pressure is controlled by the relief damper (D-1). The damper may be a gravity-type counter-balanced backdraft damper or a motorized damper. As the building pressure rises, the relief damper (D-1) opens. The building pressure will be the same as the pressure loss through the relief damper and the relief air path (Path B-A).

4.4.3 Damper Types and Sizing

4.4.3.1 The relief damper (D-1) and entire relief path (Path B-A) must be sized large enough to prevent overpressurization of the building (a pressure high enough to cause doors to whistle or stand open) when the system is in maximum outdoor-air mode. For most buildings, the maximum pressure is in the range of 0.05 to 0.1 in. wg (10 to 25 Pa). The relief damper pressure drop includes the pressure required to open the damper when gravity dampers are used.

4.4.3.2 Select the economizer outdoor-air damper (D-3) as instructed in Section 4.3.3.3.

4.4.3.3 Select the return-air damper (D-2) as instructed in Section 4.3.3.4.

4.4.3.4 Select the minimum outdoor-air damper (D-4), if one is used, as instructed in Section 4.2.3.2.

5. DAMPER SELECTION RATIONALE

5.1 Arrangement 1 (Figure 1). The relief damper (D-1) is generally the duct or relief louver size. In this case, the α-value is high (5 to 10 range). In order to achieve a linear response, it is necessary to use an opposed-blade damper (Figure 6). A linear response is desirable for improved control stability.

The return-air damper (D-2) is selected to drop the positive pressure that occurs in PL-1 down to the negative pressure in PL-2. The damper should usually be parallel blade (Figure 7) to provide a more linear response since its α-value will usually be low (1 to 2 range).

The economizer outdoor-air damper (D-3) should be sized for a low pressure drop. See Section 4.2.3.2 for details.

5.2 Arrangement 2 (Figure 2) and Arrangement 3 (Figure 3). The return-air damper (D-2) and the economizer outdoor-air damper (D-3) are selected to be parallel-blade dampers so that there is little or no change in pressure drop across the mixing box when the dampers change position, assuming the dampers are controlled so that one opens when the other closes (overlapping damper control). Using opposed-blade dampers causes a large increase in the pressure drop across the assembly at part load (e.g., 50% open to each path). Using parallel-blade dampers will therefore reduce energy usage for VAV systems and prevent a reduction in airflow from occurring in CAV systems. It will also minimize the effect that the change in damper position will have on the other pressure-sensitive control loops (such as supply duct pressure control and pressure-independent terminals) and minimize the system instability caused by pressure changes in the system and by control loop interaction.

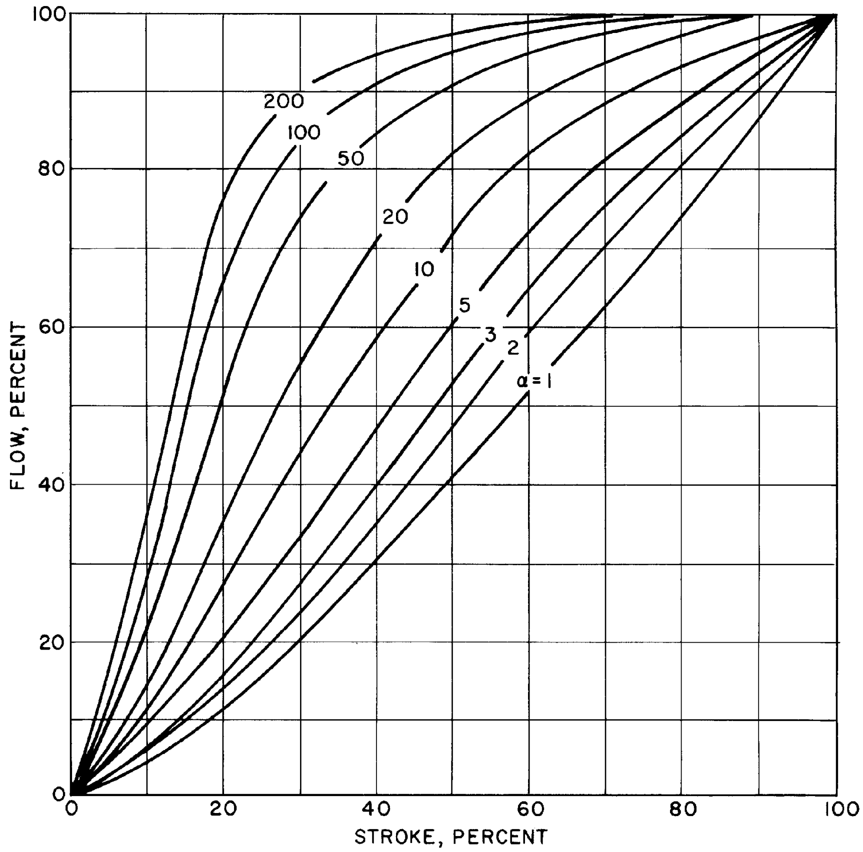

Figure 7 Installed parallel-blade damper characteristic curves.[4,6]

Tests conducted in an airflow chamber (Figures 8, 9, and 10) built in compliance with AMCA Standard 500[2] show that a relatively constant pressure drop across the mixing box (PL-2) can be achieved by using parallel-blade dampers (Figures 11, 12, and 13).

These tests were conducted with

- the dampers 90 degrees apart in the mixing box,
- the airstreams off the dampers opposing to facilitate mixing, and
- the external resistance the same through the outdoor-air path (A to PL-2 through D-3) at design flow as it is through the return-air path (B to PL-2 through D-2) at design flow.

Three tests were run with external resistances of 0.28 in. wg (70 Pa) (Figure 11), 0.38 in. wg (95 Pa) (Figure 12), and 0.50 in. wg (125 Pa) (Figure 13). The differential pressure on the vertical axis is the negative pressure in the mixing box and includes the drop across the dampers.

6. REFERENCES

1. *ASHRAE Terminology of Heating, Ventilation, Air-Conditioning, & Refrigeration, 2nd ed.*, 1991. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta.
2. *AMCA Standard 500-D-2018, Laboratory Methods of Testing Dampers for Rating*. Air Movement and Control Association International, Arlington Heights, Ill.
3. 2021 ~~2017~~ *ASHRAE Handbook—Fundamentals*, Chapter 7, Figure 13, p. 7.7.
4. 2021 ~~2005~~ *ASHRAE Handbook—Fundamentals*, Chapter 15, Figure 13, p. 15.6.
5. Van Becelaere, Robert, 1998. "Mixing Box Damper Testing," *ASHRAE Transactions* 104(2), p. 1226.
6. Brown, E.J., and J.R. Fellows. 1957. "Pressure Losses and Flow Characteristics of Multiple-Leaf Dampers." *ASHRAE Journal*, August 1957, p. 119.

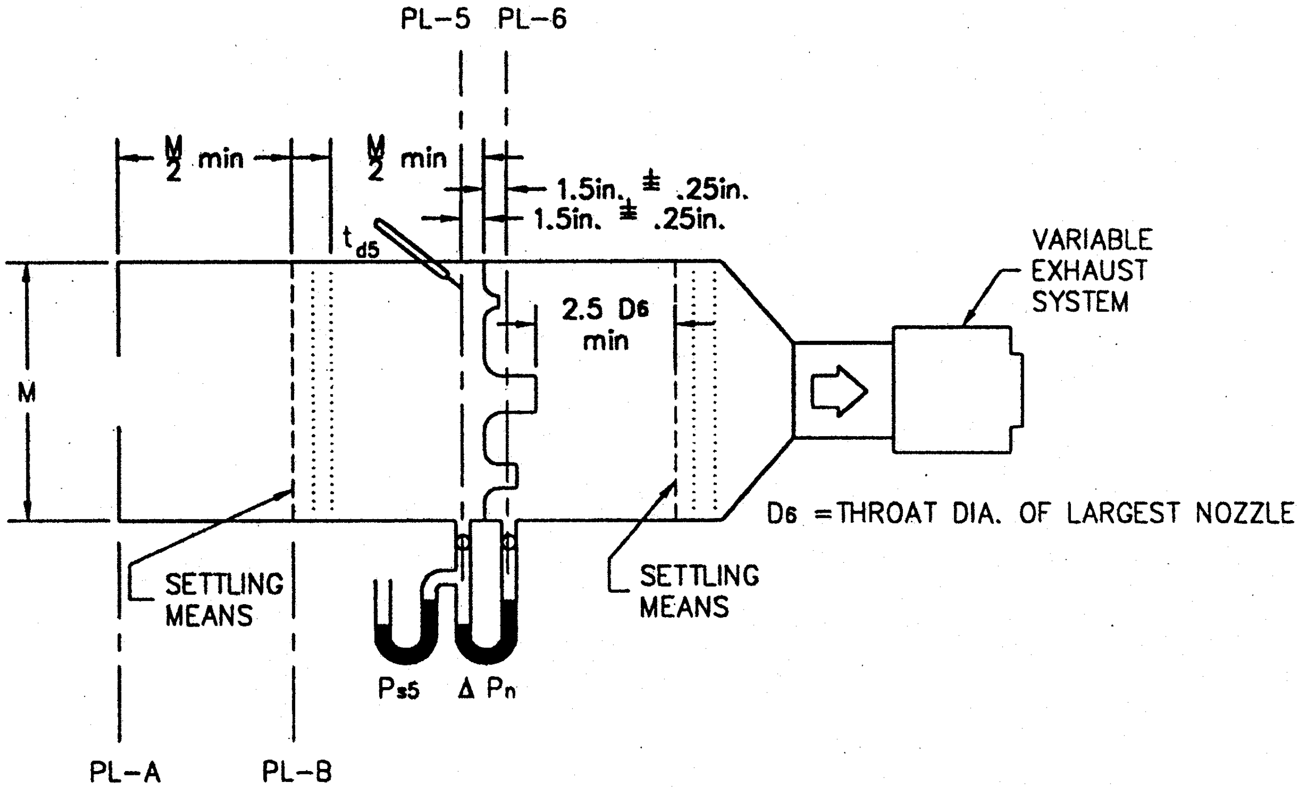

Figure 8 Airflow measurement test setup for Figures 9 and 10.

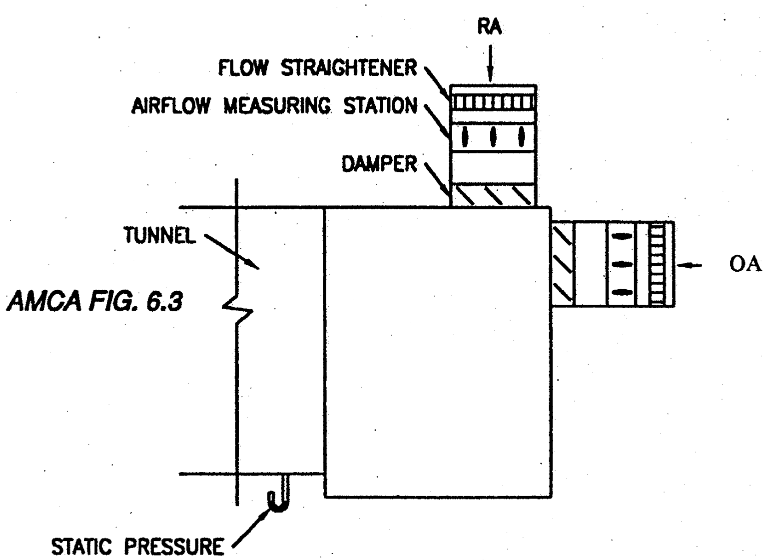

Figure 9 Parallel-blade damper in a test setup with opposing airflow.

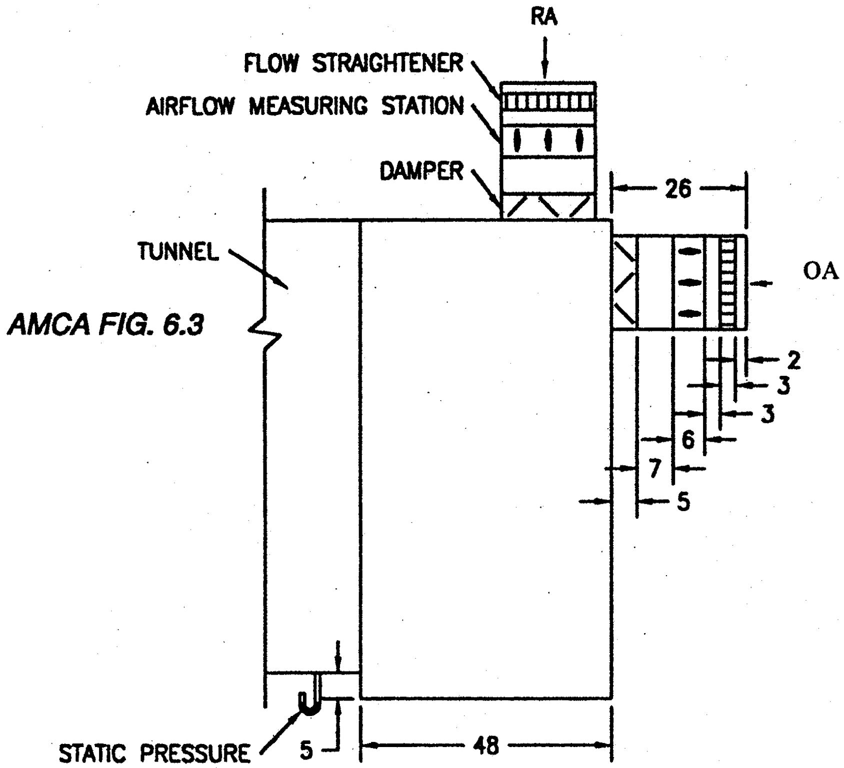

Figure 10 Opposed-blade damper test setup.

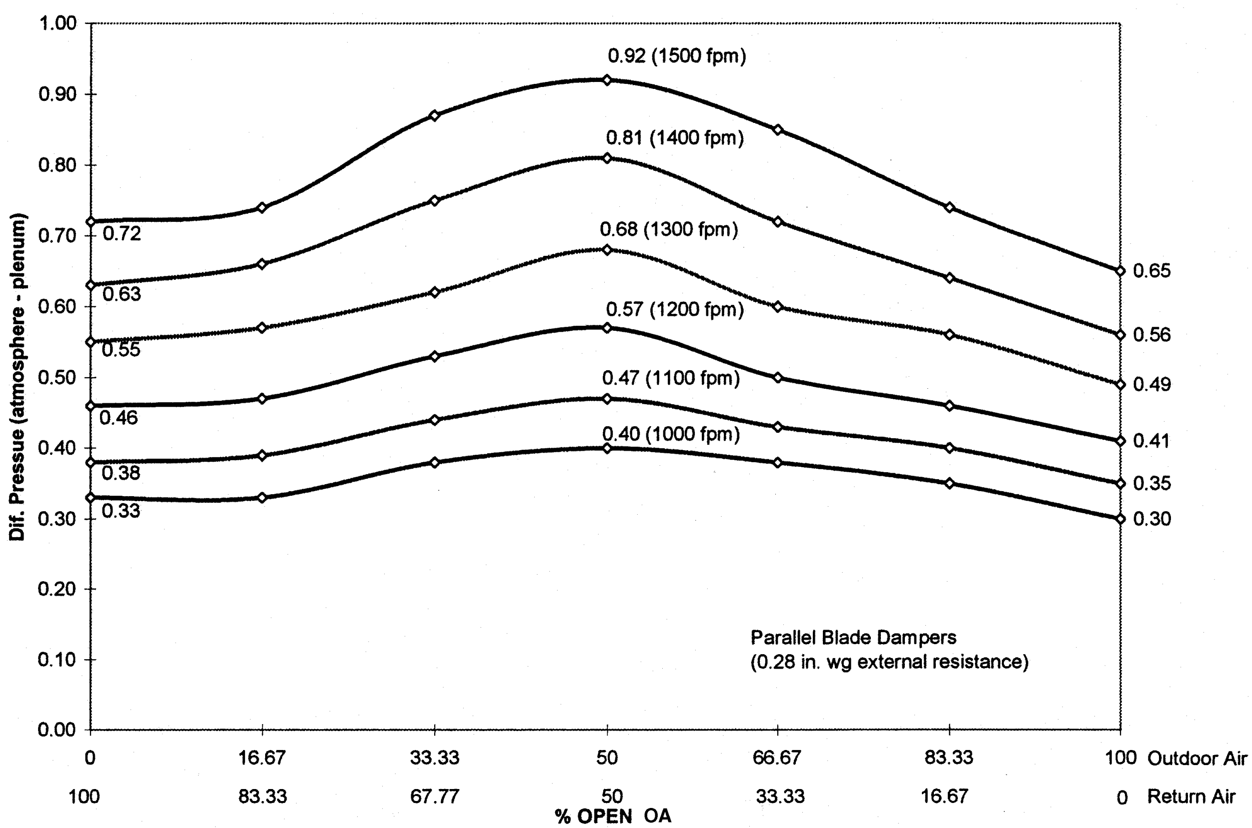

Figure 11 Performance of parallel-blade dampers in return-air and outdoor-air paths at 0.28 in. wg external pressure.[5] To convert pressure loss in in. wg to Pa, multiply by 250.

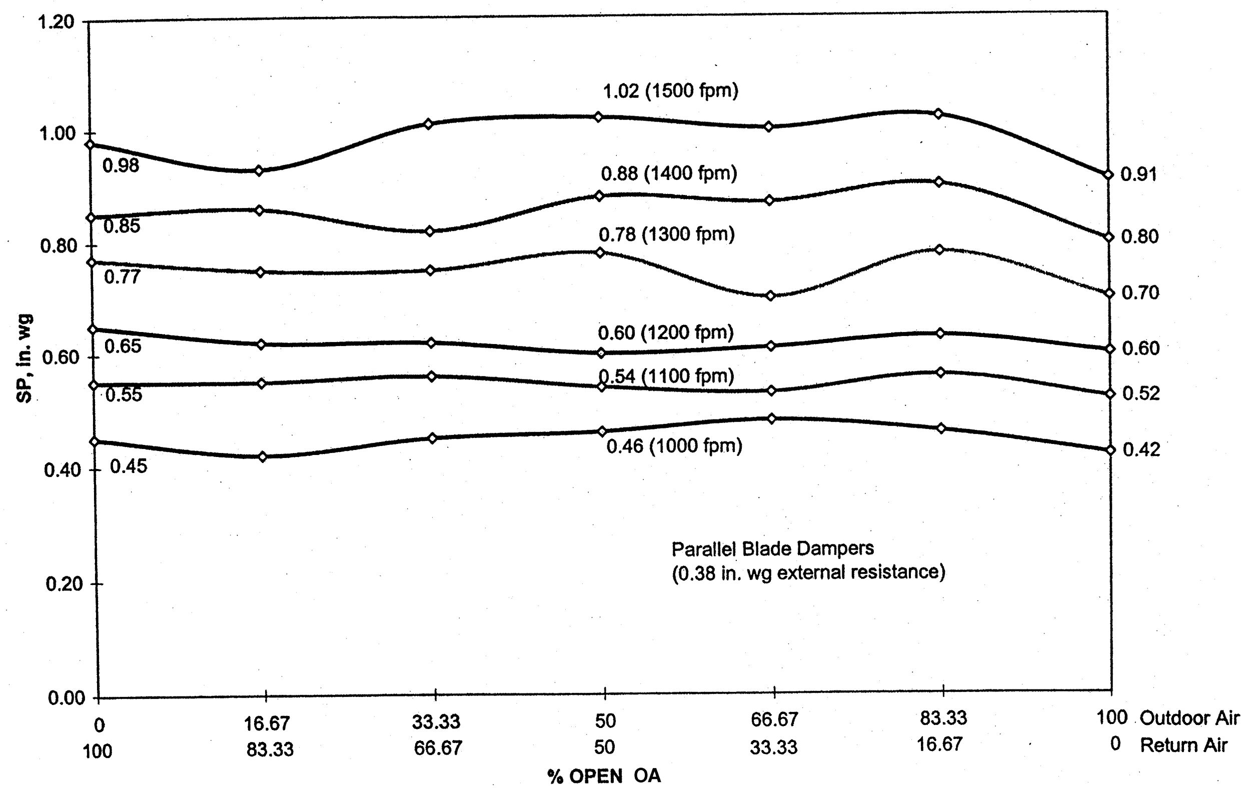

Figure 12 Performance of parallel-blade dampers in return-air and outdoor-air paths at 0.38 in. wg external pressure.[5] To convert pressure loss in in. wg to Pa, multiply by 250.

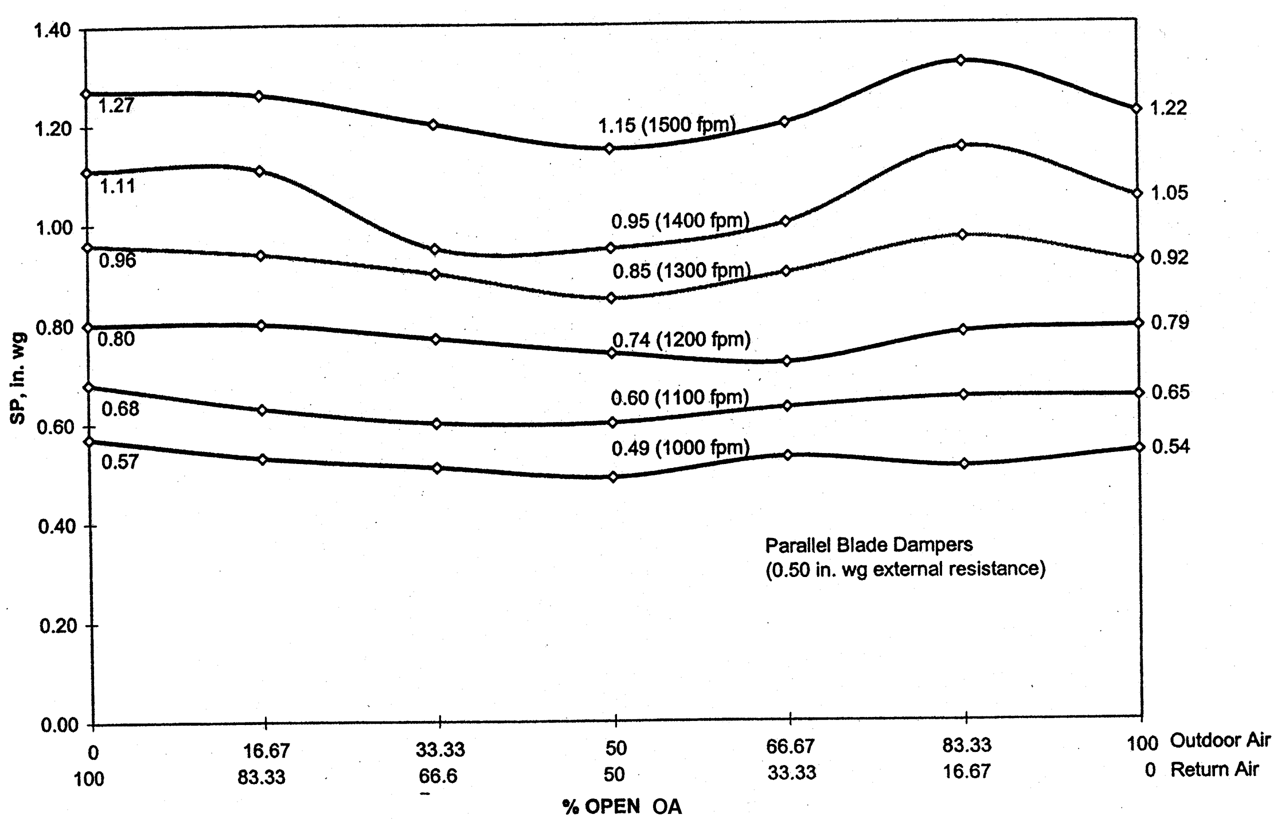

Figure 13 Performance of parallel-blade dampers in return-air and outdoor-air paths at 0.50 in. wg external pressure.[5] To convert pressure loss in in. wg to Pa, multiply by 250.

(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE APPENDIX A
INSTALLATION OF DAMPERS

Multisection dampers (generally dampers over 4 feet wide and 8 feet high) should have each section supported on all four sides or as recommended by the manufacturer. Damper sections with frames bolted together without any additional structural support will rack and bind when operated. The sections must all be in the same plane and must be secured with all frames square and free of twist. All frame and support members should be installed with fasteners that do not interfere with the blade operation. Joints between damper frames and structural members should be caulked to minimize leakage.

Multisection dampers can be linked to a common jackshaft to ensure that all blades on all sections operate in parallel. The jack shaft should have at least one support bearing for each damper section plus one, to keep the shaft from deflecting and binding the linkage. The jackshaft, bearings, and all necessary hardware shall be installed in accordance with the damper manufacturer's recommendations. For multisection outdoor-air dampers, using a concealed linkage and separate actuators for each section in lieu of jackshafts can improve the operation and longevity of the system.

Where outdoor and return dampers are intended to be operated so that one opens when the other closes (see Figure 4), they should be linked to the same shaft where possible. This ensures positive positioning through full stroke and minimizes the possibility of both dampers closing simultaneously. Physically linking the dampers is not possible when dampers are to be sequenced (see Figure 5) or when the return-air damper is used for minimum outdoor-air control (see Section 4.1.4, item b).

(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE APPENDIX B
SENSING BUILDING PRESSURES

Maintaining a constant indoor building pressure is often difficult because of the many variables, such as stack effect, wind velocity and direction, infiltration, and exfiltration. In most instances, the design engineer will have to select the most critical area and use this area to sense building pressure. Other areas of the building may have pressures higher or lower, but maintaining a constant pressure in these areas is normally not as critical.

Generally, the building pressure will be sensed from one location. Trying to average building pressures from several locations is rarely satisfactory.

In buildings requiring multiple pressure zones, each zone should be sealed so that air cannot migrate from the higher pressure zones to the lower pressure zones through common passages, such as corridors, stairwells, elevator shafts, or exhaust and return ducts. Where several air handlers serve a common space or spaces connected by common passages, all relief systems should be controlled using a single controller and control signal. This will prevent hunting (e.g., two relief systems going back and forth, where one is at 100% exhaust and the other at 0%, then vice versa).

The indoor port of the differential pressure sensor should be located well away from doors to the outside and elevators (due to piston effect). A common location is to terminate the indoor port of the sensor behind a temperature sensor cover. The outdoor port of the sensor is usually located on the same side of the building and at the same elevation as the indoor pressure port, and it should be protected from wind. Several manufacturers offer wind baffles for this purpose. Even following these guidelines, pressures will fluctuate due to wind gusts and doors opening. To ensure a stable signal and stable control, the signal should be time-averaged or dampened.

A positive building pressure of 0.05 to 0.10 in. wg (10 to 25 Pa) is generally maintained. This will generate an exfiltration velocity of approximately 8 mph (700 fpm) (3.5 m/s) to 10 mph (1000 fpm) (4.5 m/s) through an open door or other building opening.

Unless access to the building is through revolving doors or through an airlock vestibule, there may be times when it will not be possible to maintain the desired building pressure. A 20 mph (9 m/s) wind gust develops a velocity pressure of almost 0.2 in. wg (50 Pa), high enough to overcome the positive building pressure and allow outdoor air to infiltrate the building.

(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE APPENDIX C
EXAMPLE PROBLEM

This example shows how to apply this guideline to the air-handling system with return fan shown in Figure C-1 to determine the size and blade action for the relief air damper (D-1), return-air damper (D-2), economizer outdoor-air damper (D-3), and two-position minimum ventilation outdoor-air damper (D-4). Minimum outdoor airflow is controlled by Approach C (see Section 4.1.4, item c), using a differential pressure sensor with the setpoint correlated to minimum outdoor airflow through the damper. The design airflow rates are as follows:

Supply air: 40,000 cfm (19,000 L/s)

Return air: 38,000 cfm (18,000 L/s) (2,000 cfm [1,000 L/s] for space pressurization)

Minimum outdoor air: 10,000 cfm (5,000 L/s)

Following the procedures of Section 4.2.3:

a. Select the relief damper (D-1. The damper must be selected for the maximum relief air—in this case, 38,000 cfm (18,000 L/s). First calculate the pressure drop without the relief damper. Assuming as an initial guess that the velocity across the relief damper is the same as the return-air duct (1500 fpm [7.6 m/s]), the pressure drop is calculated as follows:

Fitting Number	Fitting Description	Data Source[C-1]	Velocity fpm (m/s)	Pressure Drop in. wg (Pa)
1b1	Tee, diverting	CR3-6	1500/1500 (7.6/7.6)	0.16 (40)
2	Duct	—	1500 (7.6)	0
4	Transition	SR4-2	1500/475 (7.6/2.4)	0.09 (22)
5	Louver with screen	Manufacturer	475 (2.4)	0.10 (25)
Total				0.35 (87)

b. According to Section 4.2.3.1, the relief damper should be opposed blade and have a wide open pressure drop equal to about 7% to 15% of the remainder of the relief air path, or 0.025 in. wg (6 Pa) to 0.05 in. wg (12 Pa). According to manufacturer's data for an airfoil type low-leakage damper at 1500 fpm (7.6 m/s), the pressure drop in a ducted installation is about 0.05 in. wg (12 Pa), which is in the desired range. Hence, the initial assumption of 1500 fpm (7.6 m/s) was reasonable. Had the pressure drop been outside the desired range, the duct and damper section size would be increased somewhat and the calculations repeated.

c. Select the minimum outdoor-air damper (D-4). This damper is one section of the outdoor-air damper shown in Figure C-1, the other section being the economizer outdoor-air damper. In this case, the damper is used as a fixed orifice for minimum outdoor-airflow control. The lowest range commercial differential pressure sensor is 0 to 0.1 in. wg (0 to 25 Pa), so the minimum pressure drop across the wide-open damper should be no less than 0.05 in. wg (12 Pa) for good controllability. According to manufacturer's data for a large airfoil type low-leakage damper, 1500 fpm (7.6 m/s) is required to achieve a 0.05 in. wg (12 Pa) pressure drop. Given the design duct height of 120 in. (3050 mm), the damper should be 8 in. × 120 in. (200 × 3050 mm). The damper action may be parallel blade or opposed blade.

d. Select the economizer outdoor-air damper D-3. Because the damper has no impact on airflow, it may be either opposed blade or parallel blade, and sizing is not critical. In this case, the overall outdoor-air damper is sized the same as the louver, 120 in. × 120 in. (3050 × 3050 mm). The minimum outdoor-air damper D-4 uses up 8 in. (200 mm), leaving 112 in. × 120 in. (2850 × 3050 mm) for damper D-3.

e. Select the return-air damper (D-2). The damper is sized for 30,000 cfm (14,000 L/s), which is equal to the design supply-air rate (40,000 cfm [19,000 L/s]) minus the minimum outdoor-air rate (10,000 cfm [5000 L/s]). The return-air damper should be selected so that the pressure drop across the path from PL-1 to PL-2 is equal to the pressure available between the two plenums.

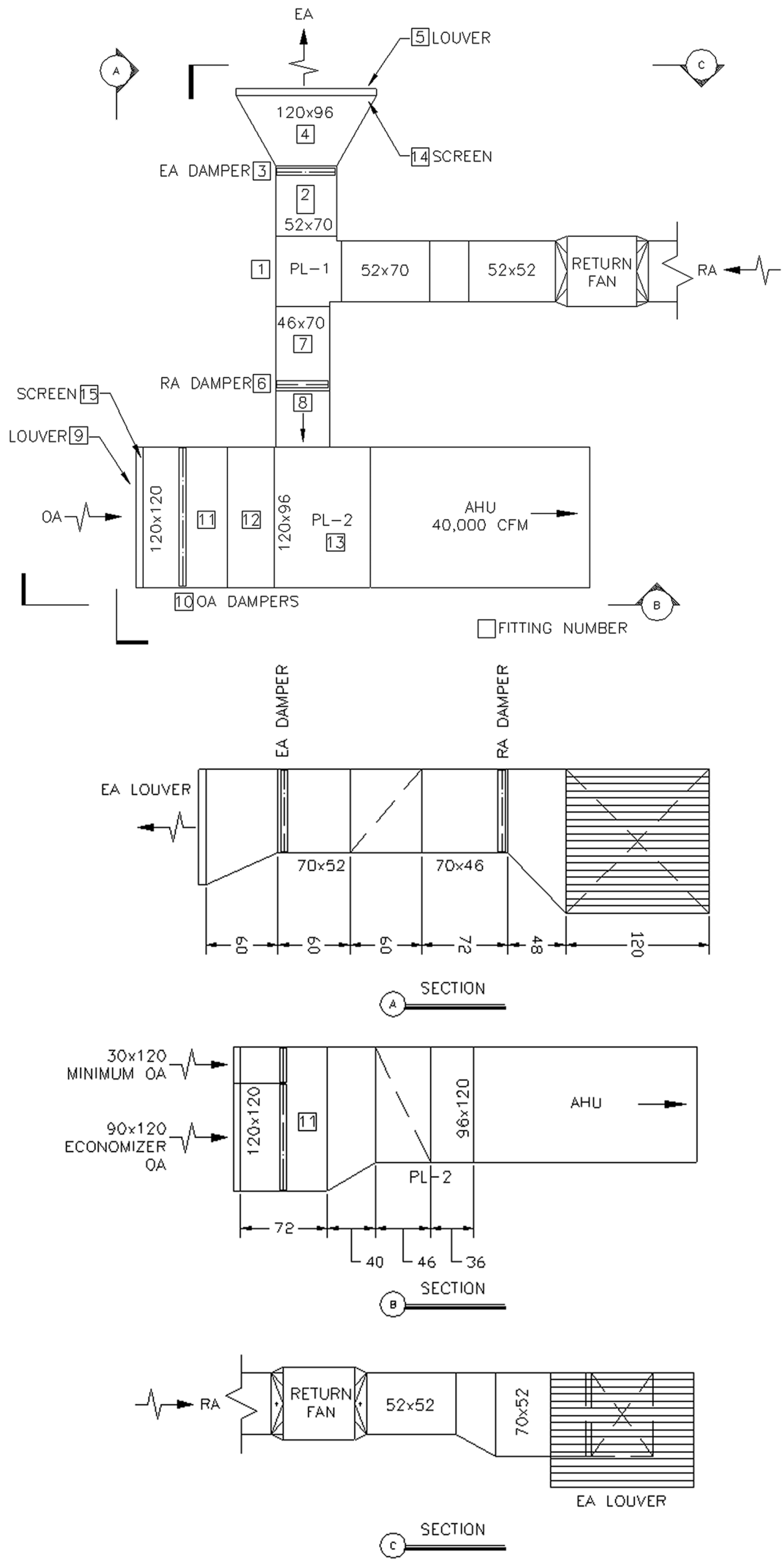

Figure C-1 Schematic of example problem.

First calculate the pressure of PL-1 relative to ambient. The airflow rate will be equal to the return-air rate (38,000 cfm [18,000 L/s]) minus the rate through the return-air damper of 30,000 cfm [14,000 L/s], or 8000 cfm [4000 L/s].

Fitting Number	**Fitting Description**	**Data Source[C-1]**	**Velocity fpm (m/s)**	**Pressure Drop in. wg (Pa)**
1b1	Tee, diverting	CR3-6	1500/315 (7.6/1.6)	0.15 (38)
2	Duct	—	315 (1.6)	0
4	Transition	SR4-2	315/100 (7.6/0.5)	0.01 (2)
5	Louver with screen	Manufacturer	100 (0.5)	0
Total				0.16 (40)

Next find the pressure in PL-2 at the minimum outdoor-airflow rate relative to ambient. Only D-4 is open under these conditions; economizer damper D-3 is closed.

Fitting Number	**Fitting Description**	**Data Source[C-1]**	**Velocity fpm (m/s)**	**Pressure Drop in. wg (Pa)**
9	Louver with screen	Manufacturer	100 (0.5)	0
10a	Transition into minimum outdoor-air damper	SR4-2	100/1500 (0.5/7.6)	0.05 (12)
10	Minimum outdoor-air damper	Manufacturer	1500 (7.6)	0.05 (12)
11	Duct	–	100 (0.5/0.6)	0
12	Transition	SR4-1	100/125 (0.5/0.6)	0
13s	Tee, converging			0.01 (2)
Total				0.11 (27)

PL-2 is negative with respect to ambient while PL-1 is positive. So the difference between the two is 0.16 in. wg – (–0.11 in. wg) or 0.27 in. wg (68 Pa). The return-air damper and duct are then selected for the same pressure drop. Iteration is required to find that a velocity of 1340 fpm (6.8 m/s) is required to create the desired pressure drop from PL-1 to PL-2 at 30,000 cfm (14,000 L/s).

Fitting Number	**Fitting Description**	**Data Source[C-1]**	**Velocity fpm (m/s)**	**Pressure Drop in. wg (Pa)**
1b2	Tee, diverting	SR5-15	1500/1500 (7.6/7.6)	0.14 (35)
6	Return-air damper	Manufacturer	1340 (6.8)	0.04 (10)
7	Duct	–	1340 (6.8)	0
8	Transition	CR11-1	1340/980 (6.8/5.0)	0.01 (2_
13b	Tee, converging			0.08 (20)
Total				0.27 (68)

The damper α-value is 0.27/0.04 = 7. In this case, either a parallel-blade or an opposed-blade damper will provide a reasonably linear response.

REFERENCES

[C-1] ASHRAE. ASHRAE Duct Fitting Database, 2016. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE APPENDIX D
BIBLIOGRAPHY

Alley, R.L. 1988. "Selecting and Sizing Outside and Return Air Dampers for VAV Economizer Systems," *ASHRAE Transactions*, V. 94, Pt. 1.

AMCA. 2009. Air Movement and Control Association International, Arlington Heights, IL. *Damper Application Manual*, Publication 502-06 (R2009).

Avery, G. 1995. "Building Pressure Controls to Comply with the Americans with Disabilities Act and ASHRAE Standard 62-1989." *ASHRAE Transactions*, V. 101, Pt. 2.

Avery, G. 1996. "Selecting and Controlling Economizer Dampers," *Heating/Piping/Air Conditioning*, August 1996.

Haines, R.W., and D.C. Hittle. 1993. *Control Systems for Heating, Ventilating, and Air Conditioning, 5th ed*. New York: Chapman & Hall. pp. 99-100.

Honeywell Damper Sizing Manual 77-0078.

Kettler, J.F. 1995. "Minimum Ventilation Control for VAV Systems: Fan Tracking vs. Workable Solutions," *ASHRAE Transactions*, V. 101, Pt. 2.

Robinson, K.D. 1997. "Static Air Mixer Fundamentals," *Heating/Piping/Air Conditioning*, August 1997.

Solberg, D., D. Dougan, and L. Damiano. 1990. "Measurement for the Control of Fresh Air Intake," *ASHRAE Journal*, January 1990.

Taylor, S.T. 2000. "Comparing Economizer Relief Systems," *ASHRAE Journal*, September 2000.

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