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| YORK® | **Return Fan and Exhaust Fan Economizers and Building Pressurization** | |
| **APPLICATION GUIDE** | Supersedes: Nothing | Form 100.00-AG3 (104) |

## OUTSIDE AIR

One of the primary functions of a packaged rooftop unit (RTU) or air-handling unit (AHU) is to provide a prescribed amount of outside air (OSA) to the conditioned space to comply with the ventilation requirements of ASHRAE Standard 62. When weather conditions are favorable, an economizer cycle can be used to increase the amount of outside air introduced into the system to offset mechanical cooling energy.

If unaccounted for, the additional outside air of the economizer cycle will increase the pressure level of the conditioned space to unacceptable levels. An exhaust provision in the AHU or RTU prevents the pressure in the space from increasing to unacceptable levels.

## ECONOMIZER OPTIONS

There are three primary types of economizer systems available to control building pressurization by exhausting excess air from the space: barometric relief dampers, powered exhaust fans, or powered return fans. An accurate analysis of these systems is required to determine which is best for a given application.

### Barometric Relief Dampers

A barometric relief economizer consists of an economizer section with a gravity relief damper in the return air plenum as shown in Figure 1. As the unit approaches 100% OA operation the return air damper closes and the building pressure begins to increase. Subsequently, the pressure in the return air plenum increases. When the space pressure is greater than the return air pressure drop and outdoor atmospheric pressure, the gravity relief air damper opens and provides the required exhaust operation.

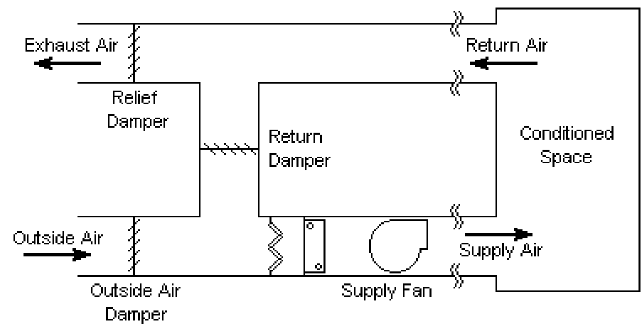


**Figure 1.** Barometric Relief Economizer

### Exhaust Fans

An exhaust fan economizer consists of an additional fan mounted in the AHU or rooftop economizer section (see Figure 2). This fan discharges air to the exhaust duct, or in the case of a rooftop unit, directly outdoors. By monitoring space pressure, the exhaust fan is used to balance the amount of air exhausted from the space with the amount of outside air introduced to the system. The exhaust fan modulates from full capacity, when the unit is in 100% outside air operation to “off” when the unit is in minimum outside air mode.

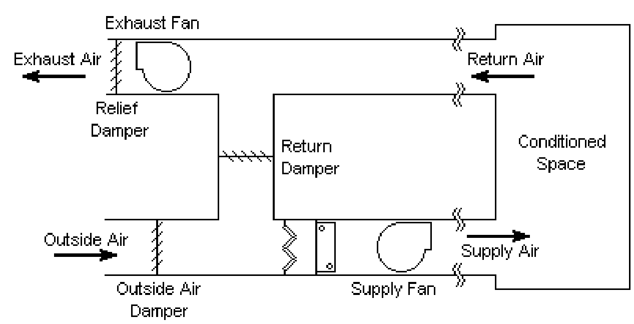


**Figure 2.** Exhaust Fan Economizer

The exhaust fan economizer option requires that the supply fan be selected to handle the greater of the following static pressure requirements:

1) 100% outside air operation - this includes the static losses of the outside air ductwork, OSA damper, filters, coils and other AHU internal losses, plus the supply duct static pressure loss.

2) 100% return air operation - this includes the return air ductwork, RA damper, filters, coils and other AHU internal losses, plus the supply duct static pressure loss.

The exhaust fan is sized to handle 100% of the return air pressure drop, which consists of the return duct, exh duct and relief damper when the unit is in full econom mode. The exhaust fan can be either a propeller fan or a centrifugal fan. Propeller fans move a large volume of air at low static pressure, but for applications with higher exhaust fan pressure drops, a centrifugal fan is the better choice.

**Return Fans**

A return fan economizer also consists of an additional fan mounted in the AHU or RTU. The key differences between this and the exhaust fan economizer are that the return fan discharges into the economizer and runs *continuously* in order to balance the amount of air supplied to and removed from the space.

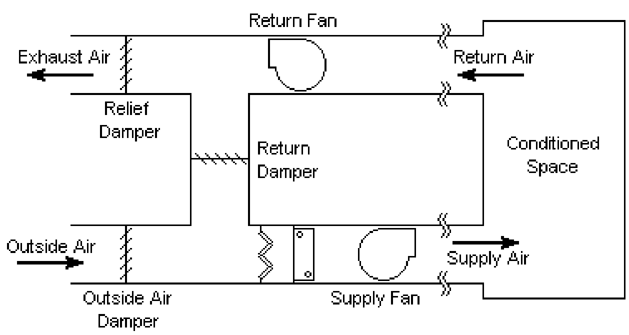


**Figure 3.** Return Fan Economizer

Fan selection for the return fan economizer application is similar to that of the exhaust fan economizer. The exception is that the return fan, not the supply fan, handles the static pressure of the return air ductwork. The supply fan is selected for 100% outside air operation; this includes the static losses of the OSA ductwork, OSA damper, filters, coils and other AHU internal losses, plus the supply duct static pressure loss.

The return fan is then designed to meet the static pressure requirements of 100% exhaust air operation; this includes the return duct, exhaust duct and exhaust damper. The return fan will operate continuously in conjunction with the supply fan to balance the amount of air supplied to and exhausted from the space.

## SELECTING A SYSTEM

After gaining an understanding of the three economizer types, one must consider the advantages and disadvantages of each to determine the best system for a given application.

**Cost Considerations**

It is apparent from the above selection guidelines that important differences in both first cost and operating costs exist among the three systems. The barometric relief air economizer features the lowest first cost and lowest operating cost because it does not require a second fan; however this system is also the most limited in its application.

Of the remaining two systems, the exhaust fan economizer typically has a lower first cost and lower operating cost than a return fan system. Although two fans are required in either case, the exhaust fan is typically designed for a lower static pressure and consequently requires a smaller motor than a return fan. The exhaust fan also operates less frequently than the return fan, which may reduce operating costs.

The return fan economizer design often has a higher first cost and higher operating cost than the exhaust fan economizer design because the fan and motor may be larger and must run continuously to maintain building pressurization. This is especially true in buildings that do not require ventilation air during occupied times.

It is important to remember, however, that exhaust fan economizer systems are not always less expensive than return fan economizers. In a unit with an exhaust fan economizer the supply fan has to over come the return air pressure drop, which may require a larger supply fan and supply fan motor than a comparable return fan system. Therefore, individual systems must be evaluated to determine the most efficient first cost option.

**Energy Considerations**

<u>Barometric Relief Economizer</u>

Barometric relief economizers use the least energy of the three systems due to the lack of a powered economizer fan. However, there are still energy considerations associated with this type of system. ASHRAE Standard 90.1-2001, the *Energy Standard for Buildings Except Low-Rise Residential Buildings* includes requirements for economizer dampers, including those used in barometric relief economizers.

ASHRAE 90.1-2001 allows gravity (non-motorized, barometric) dampers on buildings that are less than three stories tall above ground level and for buildings of any height provided that they are located in climates that have fewer than 2700 Heating Degree Days of 65°F (2700 HDD65). This is because the high pressures caused by stack effect in tall buildings can push barometric dampers open. In cold climates, the infiltration of unconditioned air can increase energy costs during the heating season.

Non-motorized dampers are also acceptable on ventilation systems serving unconditioned spaces, and in systems with a design outside air intake or exhaust capacity of 300 cfm or less. All other ventilation systems must be equipped with motorized dampers.

ASHRAE also sets limits on the leakage rates of dampers in Standard 90.1. Table 1 lists the acceptable maximum leakage rates for motorized and non-motorized dampers depending on the jobsite climate. These requirements apply to exhaust air, outside air and return air dampers.

| Climate | Maximum Damper Leakage at 1.0 in- w.c. cfm per $ft^2$ of damper area | |
|---|---|---|
| | Motorized | Non-Motorized |
| HDD65>7200 or CDD50>7200 | 4 | Not allowed |
| HDD65<2701 and CDD50<3601 | 20 | 20[a] |
| All others | 10 | 20[a] |

Notes:
[a] Dampers smaller than 24 in. in either dimension may have leakage of 40 cfm/$ft^2$.

**Table 1.** Maximum Damper Leakage
(Source: ASHRAE Standard 90.1-2001)

<u>Exhaust Fan Economizer</u>

Exhaust fan economizers generally have a lower annual energy cost than return fan economizers because return fans must operate continuously while the exhaust fans only operate as needed to prevent building over pressurization. ASHRAE recognized this fact and built a credit into the Standard 90.1 Fan Power Limitation (FPL) formula for systems that use exhaust fans in lieu of return fans.

The FPL is defined as the "ratio of the fan system power to the supply fan airflow rate (main fan) of each HVAC system at design conditions." In other words, the <u>nameplate</u> horsepower of each fan in the system, that operates when the system is at design conditions, is added together and the result is divided by the design airflow rate of the supply fan. The result is compared to the values in Table 2.

| Supply Air Volume | Allowable Nameplate Motor Power | |
|---|---|---|
| | Constant Volume | Variable Volume |
| <20,000 cfm | 1.2 hp/1000 cfm | 1.7 hp/1000 cfm |
| ≥20,000 cfm | 1.1 hp/1000 cfm | 1.5hp/1000 cfm |

**Table 2.** Fan Power Limitation
(Source: ASHRAE Standard 90.1-2001)

The values in Table 2 can be modified (increased) based on several factors. Since a return fan operates throughout the year, the return fan motor must *always* be included in the fan system power calculation. However, an exhaust fan may not need to operate during design cooling or design heating conditions when the unit is likely to be in minimum outdoor air mode. If this is the case, the exhaust fan motor horsepower does not have to be included in the calculation, which makes the FPL much easier to meet. If the exhaust fan operates during design conditions, a credit is available to account for the fact that the exhaust fan still does not operate as frequently as the return fan. The formula for this credit is given in Equation 1.

**Eq. 1** Relief fan credit (hp) = $F_R \times [1-(CFM_{RF}/CFM_n)]$

Where: $F_R$ = nameplate rating of the relief fan (hp)
$CFM_{RF}$ = relief fan airflow at clg. design condition
$CFM_n$ = supply fan airflow at clg. design condition

Additional FPL credits are available for systems that include energy recovery devices, systems that require filtration with an initial (clean) air pressure drop greater than 1.0 in-w.c. and systems that are designed with a differential of more than 20°F between the supply air temperature at design conditions and the design room temperature. For more information on the ASHRAE Standard 90.1 fan power limitation, see York International Forms 102.20-MG2 and 50.05-TD1.

### Design Considerations

First cost, operating cost and energy efficiency are important considerations, but foremost the system must be designed to operate properly. System pressure is usually the determining factor in what type of economizer system is selected.

<u>Barometric Relief Economizer Selection</u>

Suitability of a barometric relief economizer is the easiest to determine. Building static pressure must generally be maintained at not more than 0.1 in-w.c. above atmospheric pressure.[1] Higher internal pressures may make doors difficult to open or close, which could compromise security or violate the Americans with Disabilities Act.

Pressure losses in the return air path and through the relief damper add to the space pressure in this type of system. As such, the barometric relief economizer is best suited for low return pressure applications such as single story buildings with no return air ductwork, and exhaust requirements of less than 25% of the total supply airflow.

Counterbalances can adjust the pressure at which relief dampers open, and in some cases actuators are used to control the dampers during the economizer cycle. Regardless of system design, the supply fan must handle the full system pressure of a barometric relief economizer.

Exhaust Fan Economizer Selection

An exhaust fan economizer is capable of handling a higher return path air pressure drop than a barometric relief economizer while maintaining reasonable space pressurization, but care must still be used in the design of the system.

Consider the "Poor Design" arrangement shown in Figure 4. In full economizer mode, the supply fan delivers 100% outside air. As the unit goes into mixed air mode, the return air damper begins to open and the outside air damper modulates shut. Normally the supply fan draws return air into the mixing plenum, however due to the more negative pressure in the return plenum, outside air begins to flow through the return damper instead. This short-circuiting of air causes the building pressure to rise as the exhaust fan draws air from the low-pressure mixing plenum instead of the building. The outside air damper continues to close because the economizer control device sees no change in temperature or enthalpy until return air is drawn into the mixing plenum.

Eventually the outside air damper closes enough to create a greater negative pressure in the mixing plenum than in the return plenum, and return air begins to flow through the return damper in the correct direction. Now the negative pressure in the mixing box is –1.3 in-w.c. and the inlet pressure of the supply fan is approximately –2.3 in-w.c., which is much higher than the –1.2 in-w.c. pressure drop for which it was designed. The high air velocities in the mixing plenum may cause stratification if air blenders are not used.

Return air static pressure losses should still be minimized for an exhaust air economizer. As shown in the "Good Design" arrangement in Figure 4, the return plenum pressure drop should be designed to be less negative than the mixed air plenum during full economizer operation. Such a design allows the supply fan to overcome the pressure drop of the return plenum without using excess power. The lower air velocities in the mixed air plenum also facilitate air mixing.

Due to fairly straightforward controls, exhaust fan economizers are well suited for variable air volume applications. In VAV applications, the capacity of the exhaust fan is typically controlled through a VFD connected to a differential pressure sensor in the space. Care must be taken when locating the differential pressure sensors. Indoor pressure sensors should be located away from exterior doors and elevator shafts to prevent signal fluctuations that could result in fan instability. Likewise, outdoor sensors should be located or protected to prevent exposure to wind, which also causes signal fluctuations.

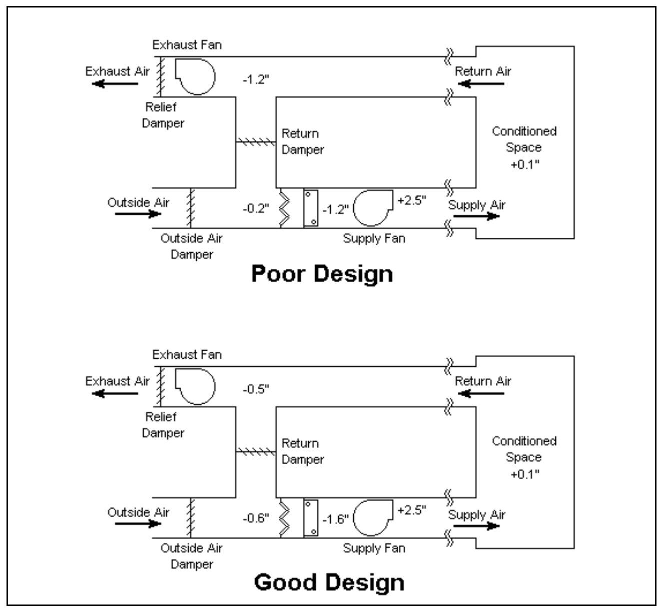


**Figure 4.** Exhaust Fan Pressures

[1] Mold remediation specialists believe that buildings in cold, dry climates should be maintained under a slightly negative pressurize if conditioned air is warmer and more humid than the ambient air.

Return Fan Economizer Selection

A return fan economizer system is best suited for constant volume applications and systems with higher return path static pressures as shown in Figure 5. Volume control can be difficult in VAV systems that use a return fan and this can lead to undesirable swings in space pressurization.

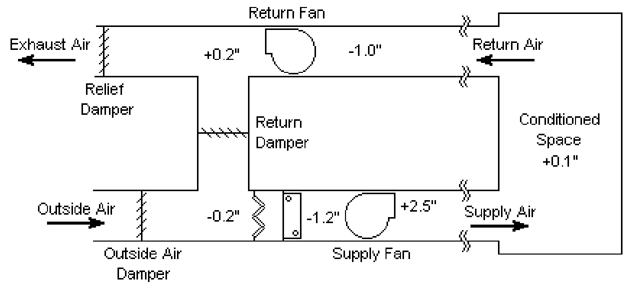


**Figure 5.** Typical Return Fan Pressures

## Room Pressure Considerations

Room pressurization depends on factors such as building construction, duct pressure losses, and outdoor wind velocity. For most cases, outdoor wind effects are minimal and can be ignored. To minimize duct losses, the supply and return ducts should be designed to handle the maximum supply and return air cfm respectively.

Two conditions determine when the return airflow is at the maximum:

1) The system is in minimum OA operation (full RA requirement) and

2) The space is at maximum allowable pressure.

Figure 6 shows an example of a system during minimum OA operation: In this example the supply system requires 6000 cfm with 10% minimum OA (600 cfm). Therefore the return air duct must handle 5,400 cfm.

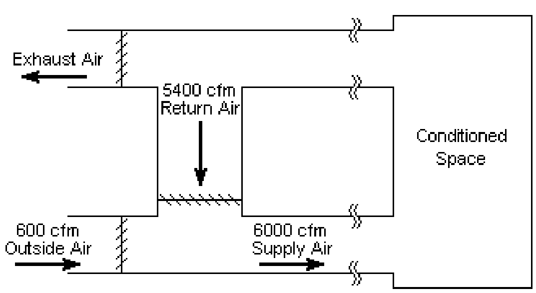


**Figure 6.** Return Fan Airflow

This example does not consider exfiltration or other exhaust sources, both of which must be accounted for to maintain an acceptable space pressure. A certain portion of the supply air entering the space leaks through openings in the walls, and around doors, windows, etc. This exfiltration depends on the space static pressure and the building construction. Figure 7 shows how exfiltration varies according to space pressure and building construction.

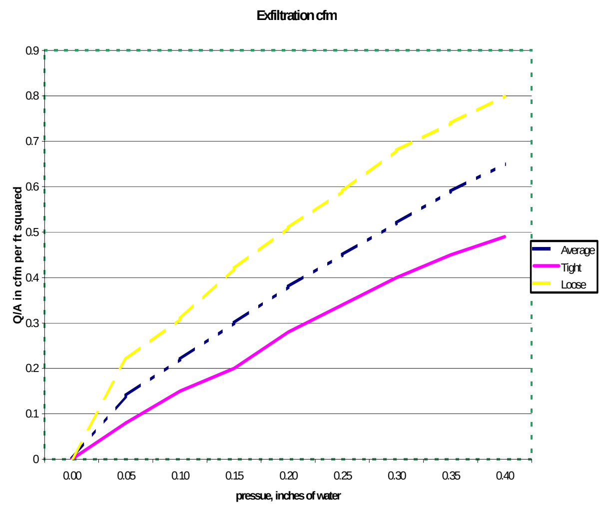


**Figure 7.** Building Envelope Exfiltration

(Source: ASHRAE Cooling & Heating Load Calculation Manual)

If the building in the previous example is of average quality construction, and the wall area of the space is 3000 $ft^2$, Figure 7 shows that at 0.1 in-w.c. pressure, the exfiltration per square foot of wall area (Q/A) is .22 cfm per $ft^2$. Therefore the space exfiltration is 0.22 x 3000 = 660 cfm.

Bathroom and/or kitchen exhaust fans must also be accounted for. Assuming 300 cfm of loss from these sources brings the total loss to 660 cfm + 300 cfm = 960 cfm. Therefore, as Figure 8 shows, in order to maintain 0.1 in-w.c. space pressure, 5,040 cfm of air must be returned to the unit.

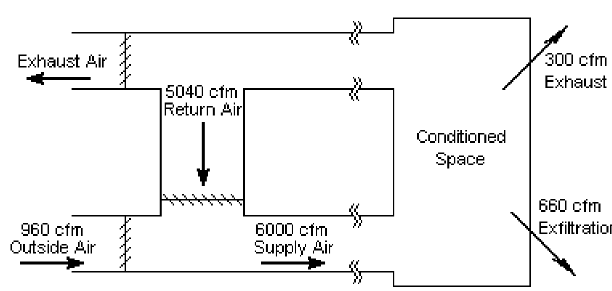


**Figure 8.** Return Fan Airflow with Space Losses

These calculations have given the values for return air required for minimum ventilation (5,400 cfm), and return air required to maintain space pressure of 0.1 in-w.c. (5,040 cfm). The return duct should be sized for the larger of these two values: 5,400 cfm.

If the local exhaust sources are shut off, the return air volume would increase by 300 cfm to 5,340 cfm and the outside air volume would decrease to 660 cfm to maintain proper space pressurization. If the return duct were sized to handle only 5,040 cfm, the additional pressure drop would increase fan motor power consumption and may result in acoustically objectionable duct rumble.

## SUMMARY

Selecting and designing the proper economizer is not difficult once one understands the features and limitations of each type. Barometric relief damper systems are the least expensive, and most limited of exhaust air systems and should only be used in small HVAC systems with return air pressure drops ≤ 0.10 in-w.c.

Exhaust fan systems typically have lower first costs and lower operating costs than return fan systems and can be used at return air pressures up to about 0.80 in-w.c. Return fan systems should be used when return duct pressures rise to 1.00 in-w.c. or higher. Control complexity is greater for VAV systems with return fans than VAV systems with exhaust fans.

Another consideration is that energy consumption is often increased when using a return fan economizer relative to the other economizer types. The continuous operation of the return fan and the poor static efficiency of a centrifugal fan operating at the low static pressure difference common in the return path often lead to an overall increase in annual energy consumption. However, it should be noted that, if properly designed, all three economizer types will comply with ASHRAE Standard 90.1-2001.

| Economizer Type | Advantages | Disadvantages | Other Considerations |
|---|---|---|---|
| **Barometric Relief** | • Lowest first cost.<br>• Lowest maintenance cost. | • Only applicable on small buildings with little or no return ductwork.<br>• Can result in building overpressurization. | • Applicable on systems with return air pressure drop ≤ 0.10 in-w.c.<br>• A damper actuator can reduce likelihood of overpressurization. |
| **Exhaust Fan** | • Lower first cost and operating cost than return fan economizer.<br>• Better suited to VAV systems than a return fan economizer. | • Supply fan must be sized to handle return air pressure drop.<br>• Return air pressure drop capability lower than return fan economizer. | • Limit return air pressure drop to ≤ 1.0 in-w.c.<br>• Propeller exhaust fans suitable for applications with very low return air pressure drops. |
| **Return Fan** | • Able to accommodate higher return air pressure drop than exhaust fan economizer. | • Higher first cost and operating cost than exhaust fan economizer.<br>• More difficult to control in VAV applications than exhaust fan economizers. | • Suitable for systems with return air static pressures greater than 1.0 in-w.c. |

## REFERENCES


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