DESIGNING STAIR PRESSURIZATION SYSTEMS

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Introduction

Stairwell pressurization systems are still in their embryonic stages. In fact, there is not one accepted standard that provides complete design criteria. This paper is simply one fire protection engineer's experience in the design and testing of stair pressurization systems.

Reference Sources and Test Data

Basic information for the design of stair pressurization systems can be obtained from several reference sources which are included in the bibliography. However, some of those sources are significant enough to mention at this time. They include the many publications made available through the National Research Council of Canada, especially Measures for Fire Safety in High Buildings, Supplement No. 3 to the National Building Code of Canada, issued in 1973.

In 1972 tests were performed at the Henry Grady Hotel in Atlanta, GA to measure the effectiveness of various pressurization systems for both stairs and elevators utilizing full-scale fire testing in an existing hotel building which was to be torn down. These tests demonstrated that it was possible to pressurize stairways and elevators to make them resistive to smoke penetration under actual full-scale fire conditions.

About that same time, the Polytechnic Institute of Brooklyn performed pressurization tests of stairways in existing high-rise office buildings. These full-scale tests provided some insight into the design of stair pressurization systems and highlighted some of the potential problems in attempting to develop general design criteria. The results were published in “Report of Fire Tests Analysis, and Evaluation of Stair Pressurization and Exhaust

ABSTRACT

In the absence of established criteria for the design of stairway pressurization systems for medium and high-rise buildings, several methods are developed empirically from experience in the field are suggested. Formulas are derived for calculating airflow into stairwells from multiple injection points to overcome stack effect, wind velocity, pressure losses from friction and leakage, and over-pressurization created by fire conditions. Assumptions necessary for designing effective and economical systems are presented, as are the cautions to be exercised in field testing the designed system after installation.
in High-Rise Office Buildings" in September 1972. It was learned that most uncontrolled room fires very seldom exceed a static pressure increase of more than 0.10 in. of water column. Incidentally, this was later confirmed by tests performed at the National Bureau of Standards.

The National Bureau of Standards has also done some in-depth studies of stair pressurization systems and has several publications available. The Bureau has also performed some full-scale tests of stair pressurization systems utilizing cold smoke (better known as SF-6 which is a measurable gas with nondestructive qualities). The Bureau has investigated stair pressurization and has outlined many designs in their publication entitled "Stairwell Pressurization Systems" by Benjamin and Kline.

The Bureau has also developed a computer program for analysis of pressurized stairs documented in a report, "A Computer Program for Analysis of Pressurized Stairwells and Pressurized Elevator Shafts" by Kote, January 1981. The original intent of this program was to analyze various stairwell pressurization system designs. However, it is reasonable to assume that it can also be used as a design tool by inputting certain design assumptions into the program and analyzing them to see if they are effective.

Probably the most complete manual on smoke control and stair pressurization systems is Smoke Control in Fire Safety Design by Butcher and Parnell, published in 1979 and available through the NFPA.

Design Criteria

The National Research Council of Canada's Measures for Fire Safety in High Buildings, Measures F & G, pressurized Stairs and Elevator Shafts, provides adequate protection of building occupants in exiting high building in nonsprinklered situations when the stairs and elevator shafts are pressurized. A formula for calculating air flow into stairs for pressurization is: $Q = 15,000 + 200N_1$ for non-weather-stripped doors or $Q = 15,000 + 100N_1$ for weather-stripped doors where $N_1$ is the number of doors which are assumed to have a 2 ft. perimeter (equivalent to a 3 ft. by 6 ft.-8 in. door) and $Q$ is the total air flow in cfm. Other door sizes require a proportional change in the multiplying factor for $N_1$ depending on the actual perimeter. This formula assumes top injection with a vent to the exterior provided at the bottom of the stair shaft having an area not less than 20 sq. ft. conforming to the formula $A = 0.5N_1$ where $A$ is the number of square feet required for the vent which must be opened at the time the stair is pressurized.

This pressurization formula assumes leakage through the stair shaft walls and provides for additional leakage which will occur through crack areas around the stair door openings. It is an approximate formula based upon research and testing.

The pressure required for the air supplied using this formula must be at least that equal to the pressure differential at ground level caused by stack effect. See Figure 1. The Canadians consider stack effect to be more significant than the pressure increase which may result from a compartment fire which is generally less than 0.1 in. of water column. In order to provide a safety factor it should be assumed that the minimum pressure differential provided should be at least equal to 0.15 in. of water column.

Care must also be taken so that overpressurization does not occur to the point that the doors into the stairs cannot be opened without excessive force. Summer conditions are especially critical since stack effect may actually be reversed, causing a change in the pressures within the stair shaft. Furthermore, the upper floors may be over pressurized, especially in very high buildings, due to the stack action wherein the pressure is positive in the stair above the neutral plane as opposed to negative below the neutral plane. However, if the stair is pressurized with
Available total Pressure Vs Building Height

FIGURE 1
outside air, the stack action should be overcome relatively quickly and should not be a significant effect once the stair temperature is equalized to the outside air temperature. The provision of multiple injection points may also help alleviate the over-pressurization problem.

Both the 1981 BOCA Basic Building Code and the 1979 Standard Building Code require a minimum pressure of 0.15 in. of water column to be maintained within a pressurized stair in a sprinklered building. The 1982 Uniform Building Code requires a minimum pressure of 0.25 in. of water column with all doors closed. The Uniform Building Code is the only code that mentions any criteria relating to doors being opened or closed.

In all cases, the building codes require some means of relieving air within the stairs at the top (which assumes bottom injection). The BOCA Basic Building Code requires a damper relief opening capable of discharging 2,500 cfm so as to prevent pressures in the stair from exceeding 0.35 in. of water column. The Standard Building Code specifies a similar requirement at the top of the stair but limits the maximum pressure to 0.50 in. of water column. The 1982 Uniform Building Code specifies a barometrically operated damper at the top of the stair capable of discharging a minimum of 2,500 cfm with no maximum pressure limit within the stair enclosure.

In reviewing the design criteria in the national model building codes it appears that there is no consistent agreement on how to design a stair pressurization system. It is left up to the designer, who is generally a mechanical engineer, (in conjunction with a fire protection engineer it is hoped), to develop his own criteria. The ultimate truth, of course, occurs when field testing is performed. For many designers this is an unacceptable level of risk which has to be assumed because if the pressurization cannot be achieved, then it may be necessary to completely redesign the stair pressur-

ization system at a time when the owner is trying to occupy the building. Not only does this generally mean additional costs in construction but also delays in occupancy that become costs assumed by the owner and which may be passed on to the designer.

In Smoke Control in Fire Safety Design, the authors have developed formulas that take into account the leakage which will occur around the doors opening into the stair as well as the excess air needed based upon the number of doors that can be expected to be opened intermittently during evacuation of the building. These formulas are:

\[
Q_1 = 17.9A_1^{1/2}N_1 \text{ Leakage (cfm)}
\]

\[
Q_2 = 150A_2N_2 \text{ Extra air for open doors (cfm)}
\]

\[
P = KN_3 (Q/4005A_3N_4)^2 \text{ Pressure loss (in. H}_2\text{O)}
\]

\[
Q = Q_1 + Q_2 \text{ Total pressurization air (cfm)}
\]

\[
A_4 = Q_2/8 \text{ Area of relief vent (sq. in.)}
\]

\[
A_1 = \text{leakage (crack) area around the openings into the stairs (in sq. in.)}
\]

\[
A_2 = \text{area of the typical stair door (in sq. ft.)}
\]

\[
N_1 = \text{number of doors opening into the stair}
\]

\[
N_2 = \text{number of stair doors open during exiting}
\]

\[
P = \text{pressure differential between the stair and the inside of the building (in in. of water column)}
\]

\[
Q_1 = \text{quantity of air to accommodate door leakage (in cfm)}
\]

\[
Q_2 = \text{extra quantity of air needed when}
\]
stair doors are open during exiting (in cfm).

Because extra air may be injected into the stair enclosure at times when all doors are closed, it may be necessary to provide a relief vent to avoid overpressurizing the stair. The relief vent area can be calculated using the formula \( A = \frac{Q}{28} \) where \( A \) is the area of relief vent in square inches. This relief vent can be barometrically operated so as to maintain a minimum pressure within the stair.

The above formulas assume that the stairs are supplied at multiple injection points serving not more than three stories each. Thus any friction loss due to air distribution within the enclosure is minimal and is not considered when calculating the pressure at which the air needs to be supplied. Furthermore, a 25 percent safety factor is recommended to allow for other leakage. No leakage through the stair shaft walls has been taken into consideration which may not be significant except in very tall buildings. Therefore, this additional safety factor may also compensate to a certain degree for that assumption.

The extra air flow is based upon providing a minimum velocity through an open stair door of 150 ft. per minute. Tests have shown that this will prevent "cold" smoke from entering a stairway under most conditions. The Canadians recommend a minimum velocity of 200 ft. per minute.

**Formula Derivation**

The obvious way to assess a stair pressurization system is to examine the mass air flow rate into and out of the stair shaft and provide for adequate air to compensate for any leakage. This air can be provided at a reasonable pressure that will overcome the effects due to stack effect, wind velocity, over-pressure created by fire conditions, and pressure losses due to the distribution of the pressurization air. However, it is often difficult to assess all the leakage paths within a stair enclosure.

One can start with the mass air flow rate equation which reads as follows: \( Q = \frac{KAX^{1/2}P^{1/2}60(2G)^{1/2}}{} \). This formula will determine the quantity of air required to supply the leakage that may occur around doors. It does not take into consideration potential leakage which may occur through the shaft walls. For concrete and gypsum wall-board stair enclosures this leakage should be relatively insignificant except in possibly very tall buildings. However, for concrete block construction not covered with plaster or dry wall, the leakage can become significant even in medium height buildings.

For the above formula:

\[ Q = \text{total mass air flow rate (in lb. per min)}. \]

\[ K = \text{orifice coefficient for the cracks around the door which is assumed to be 0.9}. \]

\[ A = \text{leakage area (in sq. ft.)}. \]

\[ X = \text{density of air (in lb. per cu. ft.) at standard temperature and pressure = 0.075}. \]

\[ P = \text{pressure differential between the stair and the inside of the building (in lb. per sq.ft.)}. \]

\[ G = \text{gravitational constant = 32.2 ft. per sec. squared}. \]

When all the factors are incorporated into the above equation and appropriate conversions made so that \( Q \) represents cfm, then we arrive at the formula suggested by Butcher and Parnell which is \( Q_1 = 17.9A_1^{1/2}N_1 \).

Since there is air loss when doors are opened intermittently during exiting, we must also incorporate the formula for calculating the minimum velocity through an open door to prevent smoke from migrating.
into the stair because of the subsequent drop of pressure. This is based on the formula \( Q_2 = 150A_2N_2 \).

Remembering that these formulas are based upon providing injection points at every three stories in a building, it becomes necessary in buildings where this is not so, to compensate for pressure losses in the distribution of air from a remote source.

In order to make the formula accommodate injection points serving more than three stories, it is necessary to take into consideration pressure losses in the stair due to the distribution of air through the stair especially when several stair doors may be open during the exiting process.

The Canadians have developed a formula for calculating the pressure loss which occurs in such a condition. Tamura developed a coefficient for determining the pressure loss factor in a stair based upon the formula \( K = P/NV_H \) where:

- \( K \) = pressure loss factor.
- \( P \) = pressure loss (in in. of water column).
- \( N \) = number of floors.
- \( V_H \) = velocity head (in in. of water column).

Measuring values for two existing building conditions: one using a conventional air shaft with a switch-back stair and the other using a scissors stair shaft, it was determined empirically that \( K \) was equal to 59 for the conventional stair shaft and 45 for the scissors stair shaft.

Based on the above information I have derived a formula for determining the total air quantity required to maintain adequate air flows and a formula for determining the minimum design pressure of the air at the injection point. Additional calculations must be made for friction loss through the discharge grilles, the fan itself, and the distribution system from the point where it is introduced into the stair back to the fan source. These additional pressure losses can be readily calculated by any mechanical engineer utilizing simple friction loss formulas or friction loss tables in design handbooks, depending upon the duct size, length and other factors.

The total quantity of air supplied is \( Q = Q_1 + Q_2 \) in cfm and the pressure required to be supplied at the injection points into the stairs is \( P = P_1 + 0.15 \) in in. of water column.

\[
Q_1 = 17.9A_1p^{1/2}N_1
\]
\[
Q_2 = 150A_2N_2 \text{ and } P_1
\]
\[
Q_3 = KN_3(Q/4005A_3N_4)^2 + 0.15
\]

where:

- \( N_1 \) = number of doors opening into the stair.
- \( N_2 \) = number of doors open during exiting.
- \( N_3 \) = number of floors served by a single injection point.
- \( N_4 \) = number of injection points.
- \( A_1 \) = leakage (crack) area around each stair door. (in sq. in.).
- \( A_2 \) = area of exit stair door (in sq. ft.).
- \( A_3 \) = cross sectional area of the stair (in sq. ft.).
- \( K \) = 59 for switch-back stair.
- = 45 for a scissors stair.
- \( Q \) = total quantity of air for stair pressurization (in cfm).
- \( P \) = total pressure differential at each injection point (in in. of water column).
Since we don’t know what the pressure will be in the stair, it is necessary to substitute the equation for $P_1$ into the overall equation for $Q$ and solve for $Q$. The quadratic equation which results is:

$$Q^2[2 \times 10^{-5}KN_3(A_1N_3/A_3)^2 - 1] + 300A_2N_2Q + 48(A_1N_1)^2 - 2.25 \times 10^4(A_2N_2)^2 = 0.$$ 

The numbers determined from a given building are substituted into this formula reduced to a simple quadratic formula of the form $aQ^2 + bQ + c = 0$. Utilizing the quadratic solution:

$$Q = \frac{-b \pm (b^2 - 4ac)^{1/2}}{2a}.$$ 

Obviously there are two solutions for $Q$ but only one will be realistic. It is very easy to deduce which is the correct solution for $Q$ by approximating the required flow. As a check I often utilize the Canadian formula where $Q = 15,000 + 200N_1$. This formula is usually fairly accurate for building more than 15 stories in height.

The above derived formula will provide a conservative estimate of the required air flow for stair pressurization in buildings up to 35 stories or so in height. Beyond that height it may be inaccurate because of the significant area of the stair shaft walls which must be taken into consideration for potential leakage.

Once the total air quantity is determined, then the total pressure required at each injection point can be calculated utilizing the formula $P = P_1 + 0.15$ were $P = KN_3(Q/4005A_3N_4)^2$.

Because there is the potential for over-pressurization when no doors or fewer doors than that calculated are open at any given moment, pressure control can be accomplished in one of several ways. One method is to provide the relief vent indicated earlier. Its area can be calculated by $A = Q_2/8$ which provides the required vent area in square inches. This vent can be barometrically operated and set at a minimum 0.15 in. water column. It should open directly to the exterior to relieve over-pressurization which may occur. It may be necessary to distribute these vents throughout the stair enclosure in a very tall building depending upon the number of injection points and the distance from the injection points to the vent.

Another method which may be effective is to utilize a fan with a relatively flat supply curve so that at any given flow rate the discharge pressure is approximately the same. However, this type of fan may not be effective where the distance to the injection point is significantly long, i.e., greater than 10 stories, since generally speaking these fans do not have much "push power".

Another more expensive way utilizes a series of static pressure sensors that modulate supply dampers at multiple injection points to control the quantity of air flow based upon the measured pressure differential within the stair in comparison to the adjacent occupied space. This method relies heavily on mechanical, electrical and pneumatic subsystems which are more susceptible to failure especially when they are not operated on a regular basis.

The simplest way to prevent significant over-pressurization is to provide multiple injection points; in effect, an injection point at every floor level. This provides for relatively even distribution when the network is sized so that the pressure and velocity of the air discharged at any point is approximately equal. This can be accomplished by controlling the size of the duct as well as the area of the discharge outlets.

**Calculation**

Before calculations can be undertaken a reasonable assumption must be made as to the number of stair doors that can be ex-
pected to be open during a fire emergency. In most high-rise buildings the general rule is that a staged evacuation to remote floor will occur only on the fire floor, the floor directly above, and the floor directly below. Therefore, it can be assumed that at any given time four doors may be opened simultaneously.

Some designers have suggested that, in addition, the door at the bottom of the stair should also be included since some people may decide to leave the building. In my opinion, it is not necessary since the door is only opened intermittently. Especially in tall buildings when someone has reached the discharge door, all exit activity has probably been completed so that the discharge door would only be open when other stair doors would already be closed.

One can see from the formula for \( Q_2 \) that a typical 3 ft. by 6 ft., 8 in. door will require approximately 3,000 cfm to achieve a 150 ft. per minute air flow through the door when it is completely open. Thus, the number of doors open becomes critical in the design considerations for stair pressurization.

Several factors need to be considered in determining the number of injection points. If injection points are provided so that not more than three floor levels are served, then over-pressurization will be minimized since there will be minimal friction loss. Thus, the only pressure to be concerned with would be the minimum pressure required to overcome the stack effect. Generally speaking even in buildings as high as 400 ft. the pressure created by stack effect under severe winter conditions will be less then 0.8 in. of water column. The force required to open a stair door exclusive of closer force can be calculated from the formula \( f = 2.6P_a \) where:

\[
F = \text{the force (in lb.) at the door edge opposite the hinge for a standard 3 ft. door.}
\]

\[
P = \text{the pressure difference between the stair and the occupied space (in. of water column).}
\]

\[
A_2 = \text{the area of the door (in sq. ft.).}
\]

At 0.8 in. of water column the force to overcome the pressurization would be equal to approximately 42 lb. for a standard 3 ft. by 6 ft., 8 in. door. Adding 10 lb. to overcome the closer force, the total force to open the door would be approximately 52 lb. This is a reasonable upper limit so that the vast majority of occupants can open the door without great difficulty. In fact, the 1981 BOCA Basic Building Code specifies that the maximum force to open a door may not exceed 50 lb.

Thus, where multiple injection points are provided serving not more than three stories each, over-pressurization is not a major consideration. However, from a cost-effective point of view, multiple injection points serving three stories or less may not be the best method for a particular building. In such cases a trial and error method may be necessary for calculating the required quantities of air and the pressure differences created using different numbers of injection points.

In many cases it is desirable to provide injection points on floors where mechanical equipment is located since exterior openings are available to supply the stair pressurization system. This certainly should be a consideration in order to minimize the duct work necessary at least in a vertical supply distribution network. If mechanical rooms are provided to serve not more than 10-15 stories, it may be feasible to inject air directly into the stair at these levels and eliminate the need for any vertical distribution duct.

This poses another problem in regard to where supply air intakes are located. The Canadians recommend top injection to counteract the stack effect and to utilize gravity to assist in the distribution of air especially under winter conditions.
NOTES:
1. THESE FORCES DO NOT INCLUDE THE FORCES REQUIRED TO OVERCOME THE DOOR CLOSER.

2. THIS GRAPH IS FOR DOORS 7 FEET HIGH.

FIGURE 2
Some express the concern that since smoke rises, it may be picked up by intake points above grade level. In my opinion, this is an extremely remote possibility because of the dilution that will occur especially if any wind is blowing.

Such remote possibilities can be accommodated by providing a smoke detector in the supply air intake which can close the intake damper when quantities of smoke have been detected. Of course, in such a case the stair pressurization would be lost at least on a partial basis. Serious consideration needs to be given to this issue.

Some local jurisdictions are requiring that injection not be permitted more than 50 ft. above grade. However, in the case of an inversion or a very humid or rainy day this may not be any more effective when a fire occurs on a lower level and the smoke is trapped near the ground.

In determining the location of the air injection, the prevailing winds need to be considered with the intake points preferably being located up wind. Such openings as toilet and kitchen exhaust outlets, smoke control exhaust discharges, and elevator vents all need to be considered in conjunction with the prevailing winds based on their proximity to the intake point.

Another item to consider is whether or not to gasket the doors opening into the stair. Gasketing can certainly minimize the leakage area but eventually will require maintenance. Not until recently have gasketing materials been made available for fire doors without jeopardizing the fire resistive rating of the assembly. In conjunction with gasketing it is necessary to determine the leakage areas around the door. I often assume a 1/8 in. crack along the two sides and the top of the door and then assume the maximum undercut permitted for a fire door of 3/4 in. This may be conservative but allows for error in design and also accommodates wear and tear that may occur.

To minimize leakage at the bottom of the stair doors it may be possible to utilize automatically operated drop sills. Gasketing and drop sills can add significantly to the installation costs. It may be more cost effective to oversize the stair pressurization fans and supply duct work to accommodate the additional leakage that may occur.

Over-pressurization can be controlled by several different methods. The method of pressure relief may have an impact on the design and sizing of the stair pressurization fans.

Assume a 24-story office building that has two mechanical rooms: one on the 12th floor and one on the roof. The typical floor-to-floor height is 12 ft., 6 in. so the total building height is 300 ft. Assume there are two exit stairs with dimensions of 8 ft. by 15 ft. The typical stair door is 3 ft. by 6 ft., 8 in. Assume a 1/8 in. crack around the door and a 3/4 in. undercut. Assume further that four stair doors may be opened at any time during the exiting process. Also assume that the minimum outside air temperature will be -20°F and that the average indoor temperature 70°F.

First we need to calculate all the variables that will be inputted into the quadratic equation previously cited:

\[ A_1 = \text{cracked area} = 51.5 \text{ sq. in.} \]
\[ A_2 = \text{area of the typical stair door} = 20 \text{ sq. ft.} \]
\[ A_3 = \text{cross sectional area of the stair} = 120 \text{ sq. ft.} \]
\[ N_1 = \text{number of doors into the stair} = 25 \text{ (which includes one door to the roof).} \]
\[ N_2 = \text{number of doors opened during exiting} = 4 \text{ for this project.} \]
\[ N_3 = \text{number of floors served by a single injection point. Assume three injection points: one associated with each mechanical equipment room location and one at the first floor. Two injection points would probably be too excessive since 12 stories would then have to be served by a single injection point.} \]

\[ N_4 = \text{number of injection points} = 3. \]

\[ K = 59 \text{ for a switch-back stair.} \]

Substituting into the formula and solving for \( Q \) we find that the total pressurization air required for a single stair is 24,000 cfm. This would be distributed among the three fans so each fan would be sized for approximately 8,000 cfm.

Now let's determine the pressure required at the discharge point. Substituting into the formula we find that \( P_1 = 0.13 \text{ in. water column} \) and that \( P = 0.28 \text{ in. water column at the point of injection into the stair.} \) Therefore, we should provide three separate fans each sized at 8,000 cfm at approximately 0.3 in. of water column assuming the fans discharge without any significant duct work. We may need to add in some more static head to accommodate the pressure loss across the fan and across the discharge grills. These can be calculated and added into the static pressure required for the discharge at the fan capacity of 8,000 cfm.

To see if this will cause excessive pressures resulting in excessive force to open the stair doors, use the formula \( F = 2.6PA_2 \), where:

\[ P = \text{Pressure differential in stair (in in. of water column)} \]

\[ A_2 = \text{area of stair door (sq. ft.)} \]

\[ F = \text{force to open at door knob (lb.)} \]

Substituting into the formula we find that the force created by the pressure differential at the worst case condition is approximately 15 lb. Adding 10 lb. to overcome closer force, we see that approximately 25 lb. is required to open the stair doors. This appears to be reasonable.

Now let's compare our calculations with the Canadian formula. Substituting into their formula where \( Q = 15,000 = 200N_1 \) since we have assumed that the doors are not gasketed, we find that the total flow required is 20,000 cfm. From Figure 1, we find that for a 300 ft. high building at a 20°F outside air temperature the static pressure from the stack effect is approximately 0.45 in. of water column. Therefore, we need to provide a stair pressurization system capable of supplying a total of 20,000 cfm at a pressure of 0.45 in. of water column. This compares very favorably with our earlier calculation.

Problems and Pitfalls

Some of the key factors to be taken into consideration in any design of a stair pressurization system are:

1. Whether of not to provide top or bottom injection.
2. The maximum number of stories (floors) which a single injection point will serve.
3. The need for multiple injection points, especially in very tall buildings.
4. Strategic location of air intakes to avoid smoke contamination from other sources.
5. Assuming the proper number of doors that will be open during the exiting process.
6. Gasketing the stairway doors.
7. The method for preventing overpressurization.
It is important that any method to relieve the stair pressure should not be by mechanical means since negative pressure differential can be created which could induce air movement into the stair from adjacent spaces in the proximity of the stair door openings. In other words, exhaust should not be accomplished by powered exhaust fans but rather through barometrically controlled dampers or by means other than inducing exhaust air movement mechanically.

Testing takes considerable effort to make sure that accurate results are obtained. The tester should:

1. Make sure all doors are operating properly and are in the appropriate positions during the test.

2. Use a magnehelic gage to measure pressure differential between the stairway and adjacent space.

3. Check the operating sequence of the smoke control system with the pressurization system to make sure the latter is activated at the proper moment.

4. Verify that the correct fans were installed.

5. Check to see that barometric relief dampers operate at designed pressures.

6. Make sure stairways are sealed to minimize air leakage.

If an inadequate quantity of air is being supplied, replace the fan pulley with a larger size to increase the fan speed if a belt-driven fan is utilized. In general, that is more economical than replacing the fan unit when the additional air required is not significantly greater than originally designed and the pressure differentials are reasonably obtainable.
BIBLIOGRAPHY


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