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EMERGENCY STAIRWELL VENTILATION

A detailed appraisal of Brown & Root's emergency stairwell ventilation system.

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THERE's probably no heating, ventilating, air-conditioning engineer in the commercial building field who hasn't been made aware, in at least the past several years, of the increasing stringency of federal, state and local fire codes. This has been brought about, not necessarily by a larger number of high rise fires, but by the same growing public and governmental concern for individual and group safety that has created offspring such as OSHA. However, this is not to say that there has not been, in the recent past, a number of high rise disasters that would make any concerned HVAC engineer toss a bit at night. If one should have a sense of complacency, he or she should read a new novel by Thomas Scortia and Frank Robinson entitled *The Glass Inferno* or view its motion picture counterpart, *Towering Inferno*. More than ever, these works emphasize the age old "Murphy's Law" that, while referring to mechanical systems, implies that if anything can go wrong, it will!

It is, however, to the credit of the discipline that its engineers have been generally far ahead of the codes, in most respects, concerning public safety. In fact, most recent local level codes are wisely based on the general practice and recommendations of the cities' consultants. It's my opinion that the more recent code revisions involving fire safety, which have taken place in the larger U.S. cities, are indeed a fine reflection on those city building departments.

I would like to touch on one such update through the use of an example. The revision concerns emergency stairwell ventilation . . . the example is Brown and Root's new Engineering Southwest building in Houston, Texas.

THE BUILDING

The structure is a thirteen level office use building with twelve floors above grade and is rectangularly shaped 110 by 275 ft. Each floor's fire loading was kept intentionally low, with the only unusual space uses being a basement reproduction room, a second floor computer complex and a penthouse radio room.

The centrally located elevator bank contains six high speed passenger lifts and is located adjacent to the center stairwell, which is one of three, the remaining two being located internally at opposite ends of the building. In order to discourage short trip monopolization of the elevators and encourage some exercise for normally desk-ridden personnel, the doors from each floor into the center stairwell are held open against their closers by magnetic holders while the other stairwell doors remain in the normally closed position when not in use.

Before going into the specifics of the stairwell ventilation system, let me touch briefly on the fire containment system as a whole. The mainstay of the system is a network of smoke and heat detectors activating directly a 24-hour monitored panel. Backing up this feature, the building is completely sprinklered and has fire department standpipe connections at each stairwell on each floor. The city water main, in turn, is reinforced by a 250,000 gal fire water storage tank fitted with a secondary diesel powered pump should a primary electrical pumping system malfunction occur.

THE CODE

In considering the safest means of personnel egress in a fire and smoke situation, the HVAC engineers looked for the best possible method of providing ventilation and smoke protection in the three hour structurally rated stairwells.

The following are excerpts from the City of Houston code governing the protection of any one stairwell for this class structure:

"**Stairshaft Air Movement System.** *The stairshaft shall be provided with mechanical supply and exhaust air. There shall be a minimum of 2500 cfm discharge at the top of the shaft. The supply shall be sufficient to provide a minimum of .05 in. of water column with respect to atmospheric pressure with all doors closed and a minimum of .10 in. water column difference between the stairshaft and the vestibule.*

"**Vestibule Ventilation.** *The vestibule shall be provided with not less than one air change per minute and the exhaust shall be 150% of the supply. Supply air shall enter and exhaust air shall discharge from the vestibule through separate, tightly constructed ducts used only for that purpose. Supply air shall enter the vestibule within 6 in. of the floor level. The top of the exhaust register shall be located at the top of the smoke trap, but no more than 6 inches down from the top of the trap and shall be entirely within the smoke trap area. Doors, when in the open position, shall not obstruct duct openings. Duct openings may be provided with controlling dampers, if needed, to meet the design requirements, but are not otherwise required."*

The south stairwell was chosen to become the main pressurized escape route due to its opening into a relatively uncongested area, most likely remote to the projected position of mobile fire fighting equipment.

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Because under Brown and Root HVAC standards, the entire building would normally be pressurized to .05 in. water column static pressure to prevent outside air infiltration to conditioned spaces, a rigid interpretation of the Code required static pressures (relative to true atmosphere) of .10 in. water column in the stairshaft and a negative .05 in. water column in each vestibule. This results from the interpretation that where the Code refers to atmosphere, it is assuming that the building proper is at atmospheric pressure.

Since the structure would be pressurized, a mentioned above, it was determined then to produce a .05 in. water column difference between the stairshaft and the building proper when the central air handling system is operating, thereby actually producing .10 in. water column in the stairshaft relative to true atmosphere. This provides for a positive pressure differential between the stairshaft and the rest of the building should the central air handling unit for that half floor fail to deactivate (as designed) in the fire situation.

On the other hand, in the case of negative pressure requirements in the vestibules, the assumption had to be made that the central air handling unit would go off line as required, leaving the main floors at true atmospheric pressure. Therefore, the vestibule system was designed to produce a negative .05 in. water column relative to true atmosphere, producing then a static pressure difference of .15 in water column between the stairshaft and the vestibule, while the Code required literally only a minimum of .10 in. water column difference.

THE GENERAL SYSTEM

As the roof remained the only physically reasonable location for stairwell ventilation equipment, consideration had to be given to minimizing the number and size of supply and exhaust duct risers. The obviously simple method of locating supply air equipment at ground level and exhaust equipment at roof level was impractical due to the prevailing layout and physical situation of the building.

It was also desirable to utilize the equipment under normal as well as emergency operating conditions . . . both from the standpoint of economy and maintenance. As the main HVAC system consisted of a dual-duct, medium velocity, chilled water arrangement, with only two central station air handlers per floor, it was decided to use weatherproof, package type equipment to both condition the stairwell and provide the necessary outside air pressurization.

In considering the simplest means to the end, it was first proposed to provide only two air movers for the subject stairwell; that is, to supply pressurizing outside air to the stairshaft, allow that same air to exhaust through barometric dampers into each vestibule, where it would be captured at ceiling level by the mechanical exhaust system. This design was discarded primarily due to the specter of both balancing the system originally and maintaining that balance. It was also considered that, even though the wall common to the stairshaft and vestibules was not a firewall, it afforded some protection was compromised by the presence of the barometric damper openings.

The decision was then arrived at to make the stairshaft and vestibule systems two separate entities. This would allow the use of a packaged chilled/hot water rooftop unit to both condition the stairshaft during normal operation and pressurize it in the emergency situation.

It was deemed practical then, to place the vestibules into a straight emergency ventilation situation with no conditioned air being supplied during normal operation. Some might argue the practicality of conditioning a stairwell, especially one that will experience large amounts of conditioned air infiltration due to door activity. On the other hand, the benefits of being able to bring the stairshaft back to comfort conditions after weekly emergency tests and offset accurately the lighting and odor loads were definite considerations in this case.

The schematic in Fig. 1 indicates the general configuration and function of the system in the emergency situation.

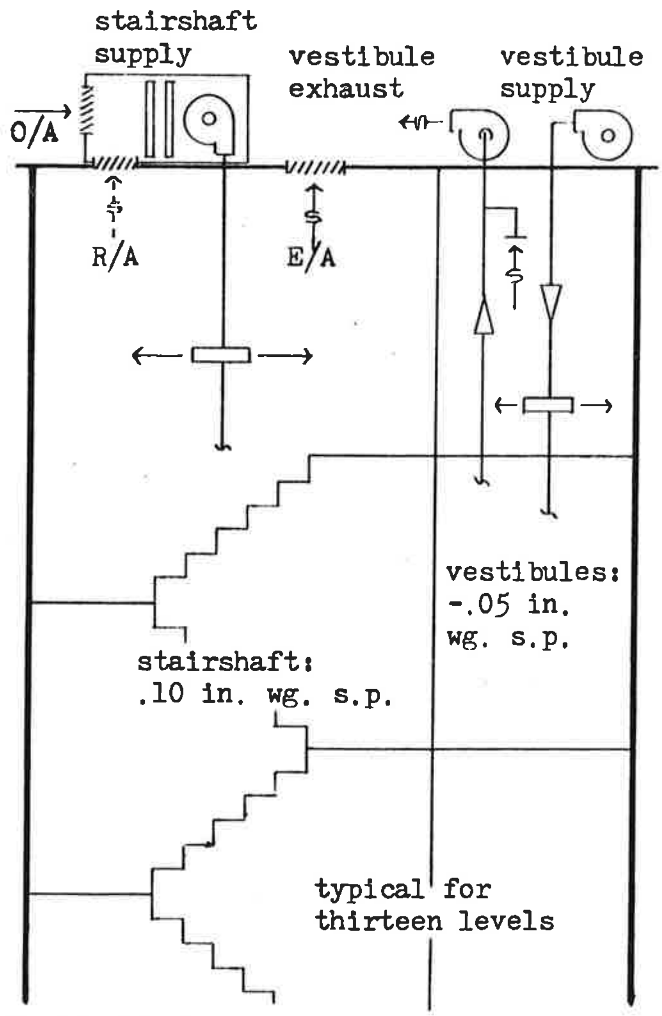

Fig. 1. Stairwell schematic

THE STAIRSHAFT SYSTEM

Left with this general arrangement, a rooftop package was chosen with a non-overloading fan sized to maintain in the stairshaft, a positive static pressure of .10 in. water column with respect to atmosphere. The fan selection was based on two parameters. First, that it be able to maintain the specified static pressure with all doors in the closed position. In addition, the designers felt it necessary to supply enough air to the stairshaft so as to maintain a minimum velocity of 100 ft per minute through any single open stairshaft/vestibule door. Fortunately, this additional requirement fell within the minimum stairshaft exhaust air quantity prescribed by the City Code and within the minimum supply air quantity necessary to maintain pressurization against the stairshaft crack and masonry wall leakages (with all doors closed).

Pressurization air is supplied midway between alternate landings and the supply air grilles are provided with opposed blade dampers for balancing purposes. This arrangement provides for an equalized supply situation which would, in the even of smoke and heat penetration of the stairshaft, distribute fresh air at thirteen levels rather than only at one ground line. This reduces tendency toward a stratifying concentration of smoke and hot gases at the top and cooler fresh air toward the bottom of the stairshaft. This is not to indicate however, that large amounts of fresh air should ever

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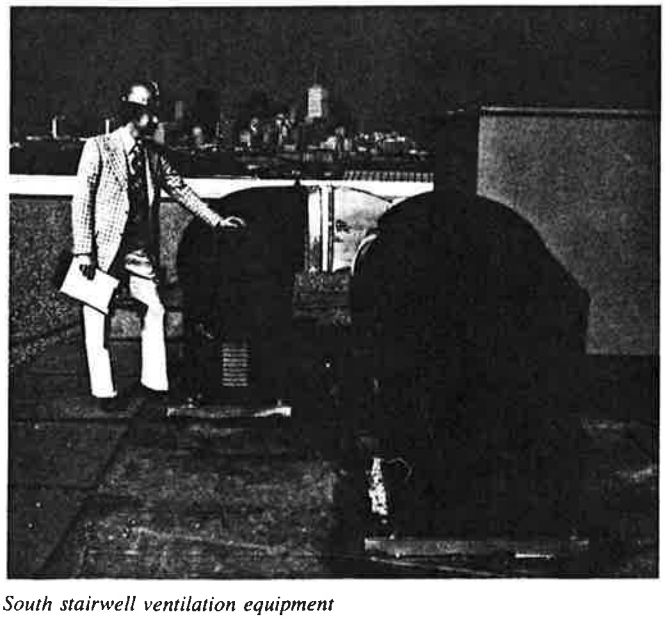
be dumped, in an unbalanced situation, part-way up a stairshaft as this outside air, especially under winter conditions, can conceivably create an entrapment which holds the effects of combustion in the lower stairshaft, making total egress possible.

Under normal operation, conditioned air is supplied via the rooftop package in a 95% to 5% return air to outside air ratio, passing through a chilled water coil and a hot water coil located in the pre-heat position. Upon activation of any single smoke or heat detector, the return air damper closes, while the interlocked outside air damper assumes the fully open position.

When full pressurization has been reached, an adjustable, counter-balanced, barometric damper, set in the roof slab, over the center of the stairshaft, relieves the exhaust air. It should be noted here, that an extreme safety factor in the stairshaft pressurization system could result in dangerously large forces acting aginst the vestibule/stairshaft doors, as these doors are required by Code to open in the direction of egress, which is against the forces of pressurization. In this case, the typical 3 ft by 7 ft steel door will experience a total force (acting through the door center) of 16.4 lbs under the pressurizing differential of .15 in. water column. When an automatic door closer is added, the total force experienced at the knob should not exceed 25 lbs.



South stairwell ventilation equipment

THE VESTIBULE SYSTEM

Vestibule ventilation was developed around the use of an exhaust and a supply air vent set. Both fans were again specified as non-overloading, arrangements. Supply fan, ductwork and accessories were sized to simply deliver air at minimum grille face velocity to each vestibule floor level. Once again, opposed blade dampers were incorporated at the wall grilles to assure air delivery to the lower levels.

The exhaust fan and attendant duct system were sized to remove 150% of the supply with three doors open or, as the fan was actually chosen, remove the equivalent amount of supply air while drawing a negative pressure on the vestibule.

As the stairshaft system fan was electrically interlocked to the smoke/heat detection system, the vestibule system was interlocked to the stairshaft fan to achieve simultaneous activation of the entire stairwell system, which is, in its entirety, switched to emergency power should the permanent electrical system be interrupted.

In essence then, an individual fleeing a smoke/fire situation enters the vestibule experiencing a negative pressure in relation to the main floor area he or she just left. Any smoke or gas entering the vestibule during the door opening and closing process is trapped above the breathing line and exhausted on the rising air flow in the vestibule. Upon opening the stairshaft door, the individual should encounter a draft of clean, outside air rushing from the stairshaft to the vestibule, absolutely preventing any smoke penetration of the stairshaft.

Even though the prevailing City Code required that only one of the three building stairwells be pressurized, Brown and Root's engineers felt it essential for complete safety to pressurize also the north stairwell, thereby providing pressurized escape routes at both ends of the structure.

As time progresses, we will unfortunately see just how good today's pressurization systems really are. Let's hope that we can develop the use of this extremely effective tool as rapidly as possible. □□

ACKNOWLEDGEMENTS

1. Photography by MARCELLINO, Houston, Texas.
2. Correale, William H., Paul R. DeCicco and Robert J. Cresci, "Stair Pressurization for Fire Protection," *The Military Engineer*. September — October, 1973.
3. Anonymous, *The City of Houston Building Code*, Vol. 1, Modified Uniform Building Code, 1970 Edition, Dept. of Public Works and Engineering.