# STAIRCASE PRESSURIZATION SYSTEM

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**Abstract -** *An Pressurized staircases are a significant piece of the Fire Safety Strategy of tall structures. Long departure times are repaid by making safe conditions inside departure staircases permitting considering the uprooting time inside those stairs as time where inhabitants can be viewed as sheltered. Regardless of whether a crisis generator is installed, the process of providing power to the fan should aim at the goal, that is, a potential fire would not impact it. It is best to plan the stair pressure frame by experienced fire safety engineers who can handle all development details. Remember that over-pressurized stairs can cause more damage than anything else.*

***Key Words***: *Pressurized stairs, generator, safety.*

## 1. INTRODUCTION

*In a multi flooring building, the stairs usually represent the only way out of the fire. Exit stairs must be smoke-free and to consolidate configuration includes that improves the speed of departure of the inhabitants. In an elevated structure, most building standards require the fire flights of stairs to be pressurized to keep smoke out. Consolidating the configuration involves improving the speed of departure for inhabitants. The fire flight of stairs in an elevated structure are mandated by most building regulations to be pressurized to keep smoke out. Pressurization of the flight of stairs meets a few needs*

*•Inhibition movement of smoke to flight of stairs, territories of shelter, deep openings, or comparative zones.*

*• Maintain an enduring climate in regions of asylum and methods for departure during the requisite clearing time.*

*•Facilitate the operation of fire and salvage by improving the perceptibility of structural firefighters.*

*•Protecting life and reducing property damage. The International Building Code (IBC) is commonly accepted in the United States, and three basic ways of supplying smoke shields are recognized:*

*1. Natural ventilated balconies with stairs*

*2. Stair ventilation mechanics.*

*3. The stair pressurization system is the most commonly preferred design choice due to the relative expense of similar mechanical systems and architectural space concerns related to the provision of external balconies and staircase vestibules. The smoke control systems are addressed in this course and the design issues associated with stairwell pressurisation systems are studied.*

### 1.1 MANAGEMENT OF SMOKE

A smoke-the-board system contains all independent strategies or mixing to control or impact smoke production.

The key idea about setting up a smoke management system is to ensure that the evacuation is faster than the spread of smoke / fire. The fire is generally constrained by methods for water pipes, fire hydrants and sprinklers, which ought to be essential for the boarding plan. A procedural fire disguise system will be utilized to restrict the pace of warmth expulsion and Control fire spread.

1. Compartmentation

Compartmentation involves the usage of fire-resistant obstructions to anticipate the spread of smoke to fire-free areas. Dividers, assignments, ground, walls, smoke dissuasive systems, smoking dampers and other fixed and mechanical barriers are used. The adequacy of seclusion is constrained by the extent to which borders regulate free flooding. Smoke control outline originators frequently consolidate segment systems with pressurization innovation.

2. Ventilation of exhaust

Smoke monitoring is better cultivated by exhaust ventilation in wide open-air areas with elevated rooftops, for example atria, malls, contour, air terminals etc. Assemble a lot of hot smoke in the room, where the techniques for a ventilation of managed smoke weakening are expelled out. Advantageous air under the smoke layer is also fundamental, provided the area without smoke.

3. Dilution

Attenuation technology can remove smoke in spaces far from the fire source. This technology provides air to the outside through the HVAC frame to reduce smoke. The use of this technology can ensure that there is enough gas and particulate accumulation in the compartment to allow smoke to penetrate from the continuous compartment. More importantly, after the fire is suppressed, the fire crisis management department can use the weakening strategy to exhaust the smoke. Smoke reduction is also called soot purification, exhaust or smoking. For example, you can use this method to remove smoke that has invaded a safe space (for example, leaving a passage or shelter). In addition, reducing the stuffiness helps to put out the smoke after putting out the fire.

4. Flow of air

The wind energy policy regulates smoke in places of obstructions with at least one major openings. It is used for monitoring smoke through open entrances, caves in subways, railways, and park roads. The strategy utilizes air speed crosswise over or between obstructions to control smoke development. One burden of the wind flow strategy is that it supplies expanding oxygen into the fire. In the internal structure, wind flow strategies must be used in the presence of alarming alarms. The technique of wind current is better introduced after fire conceal or in buildings with insufficient fuel.

5. Pressurization systems

This technology uses the restricted distinction of obstacles to control the generation of smoke. The pressure frame mainly introduces stairwells, deep holes, Refuge, and numerous exit paths. The border's high-pressure side is the sanctuary or vacation route. Smoke emerges from the side with low intensity. The air from the side of high pressure to the side of the bottom pressure (by the expansion slit and the opening in the entrance) counteracts the smoke penetration. The technique to direct the flue gas from the low-pressure side to the outside will ensure that there is no weight for gas production.

### 1.2 MOVEMENT OF SMOKE

The structure can be regarded as the progress of space, each space is distributed with a specific weight, and the air between them develops from a high strain area to a low weight area. While by and by, it is workable for compel angles to exist in huge vertical spaces, for example, stairwells, the critical weight contrasts can for the most part be considered as happening over the significant partitions of the structure, for example entryways, windows, dividers and floors. The distinction in weight decides if it will stream by any means, and how much and how rapidly it will stream. Enormous weight contrasts produce huge streams. The chief components liable for the weight contrasts and, subsequently, the smoke development is:

1. Temperature difference between indoor and outdoor air (chimney impact)

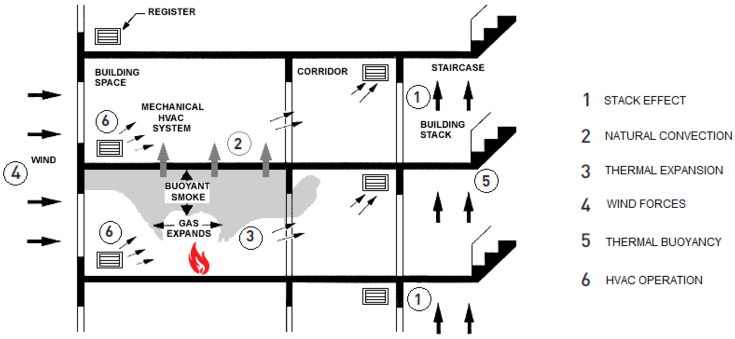
2. Common convection

3. Warm extension

4. Wind powers

5. Lightness of burning gases

6. Air conditioning activity




FACTORS AFFECTING THE MOVEMENT OF SMOKE

The air movement generated by mechanical ventilation will cause the pressure difference inside the building to be the same as natural forces and superimposed. By designing HVAC system which supplies air at a high rate. HVAC system is becoming now a days more and more popular for buildings. The main advantages of HVAC system limits infiltration of air which caused by winds and stack effects. Improved HVAC equipment can be linked to fire and smoke systems to overcome smoke control duties.

## 2. RESESRCH GAP

Simon lay, et.al [1] Paper deals with the reason behind the censorious for some of the professionals regarding pressurization system in apartments, hospitals, buildings, etc. in terms of controlling the smoke. What are the difficulties faced by the professionals while designing and fitting the systems has also been discussed, further various measures has been taken in order to get rid of these challenges for the creator.

G.T. Tamura, et.al [2] Paper described a brief description and a quick review on the study of coding required among with the clearance used by staircase and also about the different arrangements in pressurized systems. Different types of tests has been escorted in the research laboratory of Canada such as fire tests as well as non-fire testing. The measurement in the differences of pressure at the door exit to be calculated.

Busra Hepguzel, et.al [3] The author presented the concept of staircase pressurized model, where she took a model of high-storey building which she conducted through a field test. The objective of the research is to analyze the effect of existence of a non-pressurized vestibule. The author considered two model system where in first model closing of door of each floor and in second model some of the door for the floor is open to analyze FPL system effectively. She concluded with the advancement of FPL which improves the functioning of well maintained system of pressure in a tall building.

Mark Patrick, et.al [4] analyzed that stairwell plays a very important role for maintaining pressure differences in a high-storey buildings. In order to maintain a stable environment overall in buildings gives flexibility for the pressurized system to exert high thrust in shaft to maintain gases and smoke in a uniform manner towards the door exit. But during an emergency a proposal has given that atleast one door to be open during a chaos. With some additional method he research the different size required for development of pressurized system.

Irwin A. Benjamin, et.al [5] The researcher examined that the design of staircase pressurized model has not been acceptable for a competitive demand in american market. He planned to develop two different design to meet the cutting age technology for a staircased model. For this model he developed the idea of more than one injection system. The paper always focussed on the future design to meet the demand requirements for the future generation. In one or more than one injection system he advanced with the different cases of the injection model.

Francis C.W. Fung, et.al [6] researched that the efficiency of staircase system can be improved with the experimental and simulation analysis of model. In this paper, a quantitative experimental method has been developed to understand the movement by general physical law which is related directly with the fine fibres. The experiment is conducted in a tall building having 12 floors of a prototype construction. In this experimental analysis the level of different weather conditions is taken into factors with different level of approach.

Jose Torero, et.al [7] Paper gives the importance of pressurized staircase system for the safety planning in a muti storey buildings. The mechanism through which the stairs are provided safety by providing the difference in pressure across the floor to make sure that the smoke could not be able to enter. The system has been developed based on bernoulli theory of difference in pressure with respect to imperical constants. The censor has been set up for each storey of the building to examine the direct flow of pressure.

Richard P. Thornberry et.al [8] The author published the report to account the safety measures through a fire problems in a multi-storey buildings. He much focussed on the design and implementation of staircase pressurized system with consideration of different material factors in it. In this paper he explained the experimental and practical measures in the design and testing experience with respect to pressurized system. He ensure that staircase are designed in order to minimise the leakage.

## 3. DESIGN AND METHODOLOGY

### 3.1 Mechanical

1. Smoke control equipment (IBC necessities)

• Fan (IBC 909.10.1)

• Air duct (IBC 909.10.2)

• Dampers (IBC 716.3 and 716.5.5)

2. Staircase booster fan:

One kind. IBC records the high and low standards of the physical structure to determine when a stairwell booster fan frame is needed.

b. More than two fans should be pressurized, and structures above 7 floors should be evaluated. One fan is at the peak of the staircase and the other is at the foot of the staircase.

c. The fan has a variable volume through a VFD and retains a positive static load in each stairwell. The weight differential of the staircase to the region will not surpass the most extraordinary opening power selected for the new NFPA 92A form.

3. Move pressure mechanisms must work by administering other ventilation systems of structure naturally [IBC Section 909.20.6].

4. Step pressurization devices and ventilation work shall be orchestrated by NFPA 101 7.2.3.9.2

5. Both equipment required for pressure frameworks, like fans, tubing, modified dampers and equity dampers, would be sufficient, appropriate for its needs, for the potential introductive temperatures, as seen by the sound appraisal and grasped by the official fire code.

•Smoke Damper-ANSI/UL 555S, Smoke Damper Standard

• Smoke control framework ANSI/UL 864 norm for control unit

• Material-NFPA 90A.

### 3.2 Electrical and Controls

1. Power and control equipment (IBC fundamental)

• Power framework (IBC 909.11)

• Detection and control system (IBC 909.12)

• Firefighter Control Panel (IBC 909.16)

2. Electrical assist associations with willing be coordinated according to NFPA 70. The crisis fortification force inconvenience of the crisis generator must contribute to it and must operate within 60 seconds [IBC 403.10.2].

3. A fire war room that agrees to Section 911.1 of IBC will be given in the zone attested by close by fire fighters.1. Force and control hardware (IBC essential)

- Power system (IBC 909.11)
- Detection and control framework (IBC 909.12)
- Firefighter Control Panel (IBC 909.16)

4. A fire war room that consents to Section 911.1 of IBC will be given in the zone affirmed by nearby firemen. One kind. Crisis sound/alarm communication frame unit.

b. Local firefighter communication team.

c. Fire location and warning frame alarm unit.

d. Floor area of the elevator and activity annunciator.

e. Valve sprinkler and display board for water flow.

f. The crisis generator supervises gadgets, starts manually and moves the essentials.

g. Always open the control of the staircase entrance.

h. A phone for local firefighters to control access to the phone frame of the general population.

i. Mark fire siphon status.

j. Status flags and air trade monitors utilizing the system.

k. The IBC Segment 909.16 firefighter control panel is used for the smoke control frame.

l. Pointers for crisis power and standby regulation.

Schematic structure drawing, showing a general floor plan, and designating the structure centre, departure method, fire insurance frame, fire extinguishing device and arrival of local firefighters.

m. Worksheet.

o. Open location framework, different areas of this code are clearly required.

4. Crisis control must be accessible to the corresponding individual within 10 seconds (IBC 403.11.1):

a. Crisis voice / alert mail frameworks

b. Frameworks of alarm

c. Programmed systems for fire positioning

d. Vehicle lift illumination

e. Getaway course lighting

f. Leave sign brightening

5. A crisis voice/caution correspondence framework, which is likewise permitted to fill in as an open location framework, will be introduced as per IBC 907.2.12.and 403.6.

6. The voice alarm edge must deliver a preordained alert to the area where the admonition starts or is issued by smoke alarms, sprinklers, water streaming systems or manual notifications. The message must communicate details and headings to the occupants. [BWI 907.2.12.2].

7. The local social opportunity of the two-way correspondence structure of fire fighters must run between the central control station and any lift, the elevator, the stairway and the corridor. A phone station or jack is provided in every fire siphon room in structures fitted with fire siphons. [IBC 403.7 and 907.2.12.3].

**3.3 Calculation –**

Q (cfm) = $0.827 \times A \times dP^{1/2}$

Q1 = $0.827 \times A \times 50^{1/2}$

Width of Door = 1.2m

Height of Door = 2.4m

Crack Length = 5mm

Effective leakage area, A = (1.2m+2.4m) x 2 x 1 x 5mm

= 3.6m x 2 x 1 x .005m

= 0.036 sq. m

Q1 = 0.827 x 0.036 x 7.07

Q1 = 0.21 $m^3/s$

(1m = 3.28ft

$1m^3 = 35.28ft^3$

$1m^3/s$ = (35.28/1/60) CFM

= 35.28 x 60 CFM

$1m^3/s$ = 2118.8 CFM)

Q1 = 0.21 x 2118.8 x 6 floors

Q1 = 2676 CFM

Door opening in the fire floor = 1.2m x 2.4m = 2.88 m$^2$ = 31.0 sq.ft

Air loss to the fire door at 125 fpm

Q2 = AV x N

Q2 = 31.0 x 125 x 1 floors

Q2 = 3875.0 CFM

Grand total Q(cfm) = Q1 + Q2

= 2676.0 + 3875.0 cfm

= 6551 cfm

10% Safety- 7200 CFM

Hence, it is proposed to go with 1200 X 6NOS SUPPLY FAN

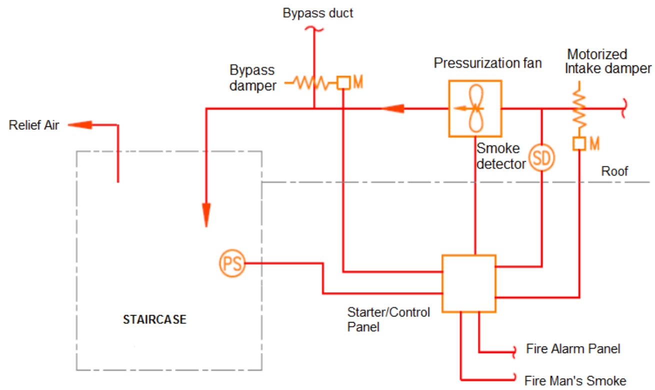
| STAIRWELL PRESSURISTION DUCT QUANTITY | | | | | | | |
|---|---|---|---|---|---|---|---|
| S.NO | SIZE(mm) | length(m) | SIZE(m) | Area(SQM) | Safety factor(10%) | Total material(SQ.M) | Gauge |
| 2 | 1100x450 | 7 | 1.5 | 21 | 2.1 | 23.100 | 22 |
| 3 | 1100X350 | 6 | 1.45 | 17.4 | 1.74 | 19.140 | 22 |
| 4 | 1100X250 | 6 | 1.35 | 16.2 | 1.62 | 17.820 | 22 |
| | | | | | | | |
| | | | TOTAL DUCT QUANTITY | | | 60.060 | |

| GRILLE QUANTITY | | | | |
|---|---|---|---|---|
| S.NO | SIZE(MM) | NUMBER | TYPE | REMARKS |
| 1 | 800x400 | 6 | LINEAR | OUTER SIZE ACCORDING TO STANDARD |
| | | | | |

Area = (length x size) x 2.

## 4. CONTROL SYSTEM

The initiation of the flight of stairs smoke control happens on the alert sign gave by any contraption, includes water sprinkler switch, heat monitor, smoke caution and manual siphoning station (pull box). Most flight of stairs smoke control outlines work along these lines, with little consideration paid to the wellspring of the alert sign. The IBC territory 903.3.1.1 requires extensive procedural control to react rapidly and precisely to the smoke control structure. The following describes the general activity sequence of the stairwell pressurization frame:




1. Any alert in any zone of the structure will initiate the smoke control mode.

2. The frame opens the mechanized damper in real time to report, and the damper actuator sends a signal to the booster fan to make it run.

3. The weight sensor presented in the flight of stairs will control the back damper to keep up a predictable 50Pa load in the flight of stairs.

4. At the air inlet a smoke detector (SD) is introduced. If smoke is found, the booster fan in the stairwell must be turned off.

5. The fan should be manually stopped and wired.

## 5. STAIRWELL PRESSURIZATION ACCEPTANCE TEST

The test of the stairwell pressurized frame should follow the following conditions:

• The number and area of entrance channels remain open.

• Known external weight conditions.

•Maximum allowable entrance tension.

### 5.1. General states of testing

Before completing the pressure control structure, a test should be performed to check the representation of the pressure frame. It is especially important to install and close the correct entry channels and windows before estimating the wind flow and weight comparison. The vent holes leading to the shaft and the leeward side of the structure should be opened to help pressurize. The test should not be conducted at turns exceeding 11 mph (5 m/s) because, the adverse effects of the wind on the boost are difficult to allow. For each explicit code, the stack impact may be compensated.

Pre-utilitarian agenda things incorporate, however not restricted to, the accompanying:

1. Introduce the fan frame and damper (if applicable) according to the contract record and the instructions of manufacturer's installation.

2. The point-to-point inspection of the control frame has been completed to ensure that all fans and damper information/yield focus points are effectively wired.

3. The typical power, if any, brings a crisis to each fan and damper, which are gathered under the appropriate voltage.

4. All fan frames have been adjusted according to the agreement report. 5. Introduce and use all safety and interlocking devices according to the contract archives, especially the fan status and high-pressure mode.

## 5.2. Grouping of activity

The assignment gathering of a solitary flight of stairs pressurization casing will fluctuate dependent on the application and plan (uncorrected or revised). The segment dampers open on practically all edges (if pertinent), and When a sign happens, the reinforcement fan will usually open.

To test the best movement (uncompensated and remedied) of the flight of stairs pressurized outline, kindly enact a planning banner, and play the relating message:

1. Assurance all division dampers are open (if applicable), and fans turn on flexibly.

2. With all entrances closed, measure and record the weight difference of each stairwell entrance. The estimated pressure difference should exceed the value required by the specification. Pay attention to the effects of the stack; wind speed and heading; and open-air temperature may affect the estimated weight and frame balance.

3. Assess and record the power due to begin an entry using a spring scale. Hold the entrance open and measure the difference in weight over each stairway. Estimated having opened power of the entry should not exceed code, while the cross-sectional pressure over residual entries should meet and exceed code.

4. Open the number of each entrance from the top, estimate and record the power required to open each entrance separately, and the weight difference of the remaining stairwell entrances. The estimated inlet opening power should not exceed the specification, and the lateral pressure difference at the remaining inlet should meet or exceed the prerequisites of the specification.

5. With every necessary entryway open, decide the bearing of wind stream over every entryway opening. Check that wind streams from the stairwell to the consumed space.

6. For reimbursed structures, seek after unclear procedures from portrayed above anyway with one-of-a-kind affirmations rules. At the end of the day, the arranged flight of stairs pressure set point ought to be kept up all through the trial, and the reaction time determined by the control must be verified. The response period of the pressurized control cycle should not decrease the nature of temporary limitations below the value the code requires.

## 5.3. Activities and Maintenance Manual

The action and support manual will give preconditions to guarantee the right action of the system for a mind-blowing duration cycle. [NFPA 92-12:7.3] The undertaking and backing manual will incorporate the accompanying:

1. The system utilized in the essential planning of the structure resembles purposely demonstrating the structure during arrangement.

2. Need of testing and audit of structure and system parts and fundamental reiteration of testing (see NFPA 92, Chapter 8).

3. The fundamental arranging presumptions utilized in the structure and the structure and its utilization limitations showing up in the structure suspicions and requirements.

4. Smoke control system inspiration [NFPA 92-12:7.3.1].

5. Both proprietors and ward specialists will be issued a copy of the movement and backup manual. [NFPA 92-12: 7.3.2].

6. The structure proprietor is accountable for all system checks and monitors any abnormal test and assist according to the movement and maintenance manual. [NFPA 92-12: 7.3.3].

7. The proprietor of the structure is liable for continuously restricting the usage of the room and for restriction of the assignment and backing manual. [NFPA 92-12: 7.3.4]. Inside the framework, test archives and proprietor guides and guidance should be recorded.

## 6. CONCLUSIONS

The dominating methods for improving the earth in skyscraper stair fenced in areas are to ensure the stairs utilizing stair pressurization frameworks. Stair pressurization frameworks must be appropriately intended to abstain from making unfavorable conditions to leaving, for example, unsuitably high entryway opening powers because of stack impact. The firm quality of the power supply that drives the fan during the crisis should be carefully studied. No matter what measures are taken, they should not interfere with the power consumption of the booster fan. Regardless of whether a crisis generator is installed, the process of providing power to the fan should aim at the goal, that is, a potential fire would not impact it. It is best to plan the stair pressure frame by experienced fire safety engineers who can handle all development details. Remember that over-pressurized stairs can cause more damage than anything else.

**7. REFERENCES**

1. Simon Lay, Pressurization systems do not work & present a risk to life safety.In: Elsevier Science Limited,2013.

2. G.T.Tamura, Wang Y, Gao F (2004) Tests of stairwell pressurization systems for smoke control in a high-rise building. ASHRAE Trans 110:185–193.

3. Busra Hepguzel, Chung KC (1999) Evaluation of smoke exhaustion performance of a vestibule within tall buildings in Taiwan. Int J Eng Perform Based Fire Codes 1:71–80 3.

4. Mark Patrick, Kim JY, Shin HJ, Ahn CS, Kim JS, Joo SH (2014) Development of the separate airsupply type of pressurization smoke control system for the stairwells of high-rise buildings in Korea. Open J Fluid Dyn 4:251–262. doi:10.4236/ojfd.2014.43019.

5. Irwin A. Benjamin, INFPA (2012) NFPA 92 Standard for smoke control systems. National Fire Protection Association, Massachusetts.

6. Francis C.W. Fung, BSI (2005) BS EN 12101-6:2005 Smoke and heat control systems—Part 6: specification for pressure differential systems—Kits. CEN, Brussels.

7. Jose Torero, BSI (1998) BS 5588-4:1998 Fire precautions in the design, construction and use of buildings—Part 4: code of practice for smoke control using pressure differentials. BSI.

8. Richard P.Thornberry, TU¨YAK (2012) Turkey's regulation on fire protection regulation on fire protection of buildings. Turkish Fire Protection and Education Foundation, Istanbul.

9. De Cicco PR, Cresci RJ, Correale WH (1972) Report of fire tests, analyses and evaluation of stair pressurization and exhaust in high-rise office buildings. Polytechnic Institute of Brooklyn Center for Urban Environmental Studies, Baywood Publishing Company.

10. Shaw CY, Tamura GT (1976) Design of a stairshaft pressurization system for tall buildings. ASHRAE J 18(2):29–33.

11. Tamura GT (1989) Stair pressurization systems for smoke control: design considerations. ASHRAE Trans 95(2):184–192.

12. Tamura GT (1991) Determination of critical air velocities to prevent smoke backflow at a star door opening on the fire floor. ASHRAE Trans 97(2):627–633.

13. Tamura GT (1974) Experimental studies on pressurized escape routes. ASHRAE Trans 80(2):224–237.

14. Tamura GT, Shaw CY (1976) Air leakage data for the design of elevator and stair shaft pressurization systems. ASHRAE Trans 82(2):179–190.

15. Tamura GT, Shaw CY (1978) Experimental studies of mechanical venting for smoke control in tall office buildings. ASHRAE Trans 84(1):54–71.