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APPEAL SUMMARY

Status: Decision Rendered

Appeal ID: 23413	**Project Address:** 1337 E Burnside St
Hearing Date: 2/5/20	**Appellant Name:** Joel Joiner
Case No.: B-009	**Appellant Phone:** 503-806-1421
Appeal Type: Building	**Plans Examiner/Inspector:** Joe Thornton, Ali Soheili, Chanel Horn
Project Type: commercial	**Stories:** 6 **Occupancy:** Commercial **Construction Type:** New
Building/Business Name: Broadstone Anthem	**Fire Sprinklers:** Yes - Various
Appeal Involves: other: Appeal to use 2019 OSSC	**LUR or Permit Application No.:** RFAM
Plan Submitted Option: pdf [File 1] [File 2]	**Proposed use:** Multi-Use Retail/Housing

APPEAL INFORMATION SHEET

Appeal item 1

Code Section	909.21.1 2014 OSSC
Requires	Elevator hoistways shall be pressurized to maintain a min positive pressure of 0.10 in. of water and max positive pressure of .25 in. water with respect to adjacent occupied space on all floors. this pressure shall be measured at the midpoint of each hoistway door, with all elevator cars at the flor of recall and all doors on floor of recall open and all other doors closed. the opening and closing of hoistway doors at each level must be demonstrated during the test. The supply air intake from an outside uncontaminated source located a minimum distance of 20 ft from any air exhaust system or outlet.
Code Modification or Alternate Requested	We would like to request the use of 909.20.1 2019 edition of OSSC in lieu of sec. 909.21.1 of 2014 OSSC.
Proposed Design	Design was changed during Rational Analysis modeling to include zero clearance doors in the basement/parking garage area to act as vestibule to counter stack effects in hoistway.
Reason for alternative	Section 909.20.1 has 4 exceptions included. exception 4 reads: "The minimum positive pressure of 0.10 in. water and Max of .25 in. water with respect to occupied floors are not required at the floor of recall with the doors open. The Rational Analysis model (report attached) depends on exception 4 to achieve code compliance.

APPEAL DECISION

Use of hoistway pressurization in lieu of enclosed elevator lobbies with omission of testing at floor of recall per 2015 IBC: Granted as proposed.
Note: Pressurization will be verified as part of plan review.
Also note, Subject to Oregon State Elevator inspector approval.

The Administrative Appeal Board finds that the information submitted by the appellant demonstrates that the approved modifications or alternate methods are consistent with the intent of the code; do not lessen health, safety, accessibility, life, fire safety or structural requirements; and that special conditions unique to this project make strict application of those code sections impractical.

Pursuant to City Code Chapter 24.10, you may appeal this decision to the Building Code Board of Appeal within 90 calendar days of the date this decision is published. For information on the appeals process, go to www.portlandoregon.gov/bds/appealsinfo, call (503) 823-7300 or come in to the Development Services Center.

JENSEN HUGHES

Advancing the Science of Safety

Request for Alternate Methods and Materials (RFAM)

BROADSTONE ANTHEM APARTMENTS

Section 909.21.1 Pressurization Requirements

Introduction:

The Broadstone Anthem Apartments is a mixed-use low-rise building with an underground parking garage, first floor retail, parking, and live work units, and five additional floors of housing over first floor. The building is provided with sprinkler protection. The building was designed under the 2014 Edition of the Oregon Structural Specialty Code (OSSC). The building contains two elevator shafts that are required to be pressurized and two non-pressurized exit enclosures.

Code Reference:

Section 909.21.1 of the 2014 Edition of the OSSC

Code Requirement:

Elevator hoistways shall be pressurized to maintain a minimum positive pressure of 0.10 inches of water (25 Pa) and a maximum positive pressure of 0.25 inches of water (67 Pa) with respect to adjacent occupied space on all floors. This pressure shall be measured at the midpoint of each hoistway door, with all elevator cars at the floor of recall and all hoistway doors on the floor of recall open and all other hoistway doors closed. The opening and closing of hoist-way doors at each level must be demonstrated during this test. The supply air intake shall be from an outside, uncontaminated source located a minimum distance of 20 feet (6096 mm) from any air exhaust system or outlet.

Code Intent:

In lieu of providing enclosed elevator lobbies, hoistway pressurization is permitted. Elevator hoistways are pressurized to keep smoke from entering shafts and spreading throughout a building. Requiring a minimum positive pressure of 0.10 inches of water column ensures that stack effect is overcome and the elevator shafts can be protected from smoke. The upper limits of positive pressure of 0.25 inches of water column are required to allow the doors to operate.

Request:

To use the provisions of Section 909.20.1 of the 2019 Edition of the OSSC in lieu of section 909.21.1 of the 2014 OSSC

Justification:

Section 909.21.1 of the 2014 Edition of the OSSC requires that the pressure differential be measured at all elevator hoistway doors simultaneously. The 2019 Edition of the OSSC is anticipated to be adopted by the end of 2019 and adds four exceptions to Section 909.20.1. The section and new exceptions read as follows:

Elevator hoistways shall be pressurized to maintain a minimum positive pressure of 0.10 inch of water (25 Pa) and a maximum positive pressure of 0.25 inch of water (67 Pa) with respect to adjacent occupied space on all floors. This pressure shall be measured at the midpoint of each hoistway door, with all elevator cars at the floor of recall and all hoistway doors on the floor of recall open and all other hoistway doors closed. The pressure differentials shall be measured between the hoistway and the adjacent elevator landing. The opening and closing of hoistway doors at each level must be demonstrated during this test. The supply air intake shall be from an outside, uncontaminated source located a minimum distance of 20 feet (6096 mm) from any air exhaust system or outlet.

Exceptions:

1. On floors containing only Group R occupancies, the pressure differential is permitted to be measured between the hoistway and a dwelling unit or sleeping unit.

2. Where an elevator opens into a lobby enclosed in accordance with Section 3007.6 or 3008.6, the pressure differential is permitted to be measured between the hoistway and the space immediately outside the door(s) from the floor to the enclosed lobby.

3. The pressure differential is permitted to be measured relative to the outdoor atmosphere on floors other than the following:

    3.1. The fire floor.

    3.2. The two floors immediately below the fire floor.

    3.3. The floor immediately above the fire floor.

4. The minimum positive pressure of 0.10 inch of water (25 Pa) and a maximum positive pressure of 0.25 inch of water (67 Pa) with respect to occupied floors are not required at the floor of recall with the doors open.

The building's stairwell pressurization model will utilize Exception 4 to achieve code compliance.

Summary: This request provides a level of protection and safety that is at least equivalent to that prescribed by the technical code requirements for the Broadstone Anthem Apartments. We respectfully request your approval.

Prepared by:

JENSEN HUGHES, INC.

November 19, 2019

Kevin E. Murphy
Consultant

Date

Reviewed by:

EXP.
12/31/2019

11/15/2019

November 19, 2019

Thomas V. Barnum, P.E.
Senior Fire Protection Engineer

Date

Reviewed by:

November 19, 2019

Authority Having Jurisdiction

Date

KEM/TVB:km/ba
1KEM19164/3.0RFAM & Amendments/2019-11-19- Broadstone Anthem RFAM OSSC Section 909

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ELEVATOR HOISTWAY PRESSURIZATION RATIONAL ANALYSIS REPORT BROADSTONE ANTHEM PORTLAND, OREGON

Prepared For
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Milwaukie, OR 97222

November 15, 2019
Revised December 30, 2019

Project #: 1KEM19164

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Appendices

1.0 Introduction

This report is intended to describe, in performance-based language, the approach to active smoke management features for the Broadstone Anthem project in Portland, Oregon. This report also describes the interaction of these systems in providing an overall coordinated fire protection package. The project is designed in accordance with the prescriptive and performance requirements for rational analysis described in Section 909.4 of the 2014 OSSC, as amended and adopted by the City of Portland.

The computer modeling program, CONTAMW 3.2, will be used to obtain final airflow estimates for the active smoke management systems and is detailed further in this report. Mechanical drawings dated December 15, 2017 were used to develop the CONTAMW model and this document.

1.1 APPLICABLE CODE SECTIONS

The 2014 OSSC is the applicable code for the Broadstone Anthem project. All code references in this report are to the 2014 OSSC unless otherwise noted. An Alternate Means and Methods Request to utilize the 2019 OSSC Section 909.20 has been submitted to the City of Portland. The following code section is applicable to the project:

+ 2019 OSSC Section 909.20 – Where elevator hoistway pressurization is provided in lieu of required enclosed elevator lobbies, the pressurization system shall comply with Section 909.20.1 through 909.20.11.

1.2 KEY REFERENCES

The Handbook of Smoke Control Engineering[1], by John H. Klote and James A. Milke, published jointly by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the Society of Fire Protection Engineers (SFPE) are used as a reference for relevant wind and pressurization calculations, for the Climatic Design Information, and to provide guidance where the intent of the Code is not clear. Data sources used in the preparation of this report also include the ASHRAE Climatic Design Conditions (ACDC) web site[2] and the Society of Fire Protection Engineers Handbook of Fire Protection Engineering (4th edition)[3].

1.3 BUILDING DESCRIPTION

The project is located at 1337 East Burnside Street in Portland, Oregon. The Broadstone Anthem project will include the construction of a 7-story mixed used building, with one (1) level of underground parking and utility areas, one (1) ground floor level of parking with offices, shops, residential apartments, and five (5) additional levels of residential apartments and assembly areas. The building is not classified as a highrise facility and will not be provided with smokeproof enclosures. The garage areas are provided with automated exhaust systems, and the building is provided with general exhaust for residential use and commercial kitchen utilities. Make-up air is provided in the common residential corridors via two (2) separate shafts supplied by rooftop mounted units. The Broadstone Anthem building height for this project will be 78.75 feet to the highest point. The highest occupied level is Level 6 at approximately 56.5 feet above grade. The building is sprinklered throughout with an automatic sprinkler system. Two (2) stairways are provided that extend through all floors, and two (2) elevator banks are provided. The facility is not provided with elevator lobbies on any level. The basement level is provided with zero-clearance swing-doors, and will be provided with elevator hoistway pressurization systems that will independently serve each elevator shaft.

[1] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012.
[2] ASHRAE, ASHRAE Climatic Design Conditions 2009/2013/2017 [Online] Available: http://www.ashrae-meteo.info (2019).
[3] The SFPE Handbook of Fire Protection Engineering, 4th Edition. National Fire Protection Association. 2008. Quincy, MA.

2.0 Design Method

2.1 OVERVIEW

The elevator hoistway pressurization system at the Broadstone Anthem project consist of two (2) independent hoistway pressurization systems, one serving each elevator shaft. Elevator lobbies are not provided as a part of this project. Zero-clearance swing doors will be provided for each elevator shaft within the basement level, only.

An Alternate Means and Methods Request has been submitted to the City of Portland to allow the use of the currently adopted 2019 OSSC with regards to the elevator hoistway pressurization system. The design goal of the elevator hoistway pressurization system is to prevent smoke from migrating into the elevator hoistways and progressing into floors above the fire floor. To meet this goal, the elevator hoistways are pressurized to maintain a positive pressure within those hoistways with respect to the building interior.

The building levels and the interior building partitions are passively protected and are not provided with an active smoke control system. The following sections describe the major features of the smoke control system.

2.2 MAXIMUM DOOR OPENING FORCE

Section 1008.1.3 requires a fire door to release when subjected to a 15-pound force, the door to be set into motion when subjected to a 30-pound force, and the door to swing to full-open when subjected to a 15-pound force. When the elevator hoistway pressurization system is operating, the 30-pound door opening force will be used as the maximum door opening force appropriate for the stairway doors.

This pressure value corresponding to door opening force will vary based upon the door closer force, the door width, and the door height. For the purposes of the CONTAMW model, a 30-pound opening force value resulted in a maximum allowable pressure differential of 0.445 inches w.g. for a 3-foot wide by 6-foot 8-inch tall door. This maximum pressure differential value can vary widely based upon the door width or height and field conditions. The door size assumed at the exit stairways is based on the design development drawings provided to Jensen Hughes.

The determination of the force required to open a door is calculated below, using equation 9-1 from Section 909.6.2 (the same equation can be found in the Handbook of Smoke Control Engineering[4]).

Where: F = Total door-opening force (lbf)

F_R = Force to overcome the door closer (lbf)

W = Door width (ft)

A = Door area (ft^2)

ΔP = Pressure difference across the door (in. H2O)

d = Distance from the doorknob to the knob side of the door (ft)

K_d = Coefficient (5.20)

$$\Delta P = 2*(W-d)*(F-F_r) / (K_d WA)$$

For a 3-foot wide by 6-foot 8-inch tall door, the maximum allowable pressure differential is calculated as:

ΔP = Design pressure, calculated below

[4] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012.

W	=	Door width = 3 feet
d	=	Distance from doorknob to the knob side of the door (ft) = 0.25
F	=	Total door opening force = 30 lbs.
F_r	=	Force required to overcome closing device = 5 lbs.
K_d	=	Coefficient = 5.2
A	=	Door area (3'X6'8") = 19.8 ft^2

Therefore:

ΔP = 2(W-d) (F- Fr)/(KWA)=2*(3-.25)(30-5)/(5.2*3*19.8) =

0.445 inches w.c.

The maximum door opening force must be field verified during special inspection and commissioning of the elevator hoistway pressurization systems. The maximum pressure differential is driven by the maximum door opening force permitted for the exit stairway doors, which is a 30-pound force per Section 1008.1.3. Power-assisted door operators will be required where excessive door opening forces are encountered in the field. Based on the modeling and configuration of doors, Jensen Hughes does not foresee a need to provide power-assisted doors as no fire door in the facility achieved a pressure differential in excess of 0.445 inches w.c.

The elevator hoistway shafts are required to be separated from the remainder of the building by 2-hour fire rated construction. The elevator hoistway doors are required to have a 90-minute fire protection rating.

Jensen Hughes recommends that variable frequency drives be provided for all fans serving the hoistway pressurization systems as this will aid in the commissioning of the system.

2.3 LEAKAGE PATHS

Section 909.5 lists the maximum allowable leakage area permitted for various building assemblies. The CONTAMW model utilizes average leakage areas identified in the Handbook of Smoke Control Engineering as previously referenced, which have a lower leakage rate than the maximum leakage rates permitted by Section 909.5. The design assumes the following leakage factors:

Walls:

Exterior	A/A_w = 0.0072-in^2/ft^2
Exit Enclosure	A/A_w = 0.016-in^2/ft^2
Elevator Shaft and Other Shafts	A/A_w = 0.120-in^2/ft^2
Interior Partitions	A/A_w = 0.144-in^2/ft^2
Floors	A/A_F = 0.0075-in^2/ft^2
Roofs	A/A_F = 0.000795-in^2/ft^2
Interior Doors (.25-inch gap)	A/A_F = 0.244 ft^2 of leakage per door
Exterior Doors (.25-inch gap)	A/A_F = 0.079 ft^2 of leakage per door
Closed Elevator Doors (3.5 feet wide)	A/A_F = 0.68 ft^2 of leakage per door
Open Elevator Doors (3.5 feet wide)	A/A_F = 6 ft^2 of leakage per door

Where:

A = Total leakage area, ft^2

A_F = Unit floor or roof area, ft^2

A_w = Unit wall area of barrier, ft^2

2.4 ELEVATOR HOISTWAY PRESSURIZATION AIRFLOW

The computer model, CONTAMW 3.2 was used for the purposes of modeling the airflow in the building and providing estimates for the elevator hoistway pressurization systems. The elevator hoistway pressurization fan capacities have been determined assuming all doors in each elevator hoistway are, with the basement excluded for use of zero-clearance swing doors:

- Closed on all floors.
- Closed on all floors, first level open (Primary Recall).
- Closed on all floors, basement level open (Secondary Recall).

Consideration was given to Temperature Effects, Stack Effect, and Wind Effects to verify that the hoistways will not be under or over-pressurized such that the required pressure differentials are not met and that doors to the hoistway enclosure will operate properly. An analysis was performed for winter and summer conditions, both of which included wind effects.

It is the project team's design intent for the normal HVAC system to shut-down upon manual and automatic activation of the elevator hoistway pressurization system as part of the sequence of operations. Shut-down of HVAC is not initiated at the smoke control panel but is programmed to occur upon activation of the elevator hoistway pressurization system. The garage exhaust systems were modeled as running at full capacity during all fire scenarios.

As CONTAMW provides estimates, final adjustments to the elevator hoistway pressurization system will be made in the field, as required, to ensure that acceptable pressure differentials are achieved. The fan sizing estimates were based on the CONTAMW modeling, which uses an average of the barrier leakages allowed by Section 909.5 and from the Handbook of Smoke Control Engineering[5]. Based upon these factors, Jensen Hughes recommends that variable frequency drives be provided for all fans serving the elevator hoistway pressurization system as this will aid in the commissioning of the system.

To account for the unknown field construction leakage rates, the hoistway fan sizes typically include a safety factor of approximately 10-percent. At the client's request, the maximum fan capacity has been used with no increased factor of safety. Based on the results of the CONTAMW model, Primary Recall will be to the ground floor, and Secondary Recall will be to the Basement Level.

Primary recall will require venting of the hoistway to achieve the required pressure differentials, with approximately 1.6 square-feet of venting in elevator hoistway 1 and 2.1 square-feet of vent area in elevator hoistway 2. Secondary recall and non-recall scenarios will not require ventilation to achieve the required pressure differentials. Additional relief venting to the exterior of the building from Level 1 and Level 2 is not required.

Table 1 - Elevator Hoistway Pressurization – No Recall - Injection Rates and Location

Injection Location	Pressurization Rate Per Injection Point (cfm)		
	EF-2 (1)	EF-2 (2)	Total
	Elevator 1	Elevator 2	
Roof	10,000	10,000	
Total cfm			20,000

[5] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012.

The Elevator Hoistway Pressurization system will be required to operate at the following rates or be provided with hoistway relief to achieve the following input CFM to each shaft for each scenario, based on the CONTAMW model, as follows:

- No recall
  - Elevator 1 – 6,500 CFM
  - Elevator 2 – 6,500 CFM
- Primary recall
  - Elevator 1 – 10,000 CFM
  - Elevator 2 – 9,000 CFM
- Secondary recall
  - Elevator 1 – 10,000 CFM
  - Elevator 2 – 10,000 CFM

3.0 *Rational Analysis*

Section 909.4 requires that systems or methods of construction used for smoke control be based on a rational analysis in accordance with well-established principles of engineering. At a minimum, the analysis must address the following:

+ Stack effect (909.4.1)
+ Temperature effects of fire (909.4.2)
+ Wind effects (909.4.3)
+ HVAC system effects (909.4.4)
+ Climatic effects (909.4.5)
+ Duration of operation (909.4.6)

The following sections of this report address the above listed items:

3.1 STACK EFFECT

3.1.1 Code Requirements

Section 909.4.1 requires the elevator hoistway pressurization system to be designed such that the maximum probable normal or reverse stack effect will not adversely interfere with the system's capabilities. In determining the maximum probable stack effect, altitude, elevation, weather history, and interior temperatures must be taken into consideration.

3.1.2 About the Stack Effect

The stack effect becomes more pronounced as the height of the space of interest increases and as the temperature differential between the space of interest and the exterior becomes greater. For shafts, where stack effect would be most pronounced, the warmer air will rise to the top of the shaft. This creates a greater positive air pressure at the top of the shaft, while simultaneously resulting in a lower pressure at the bottom of the shaft, where less air is present.

Typically, equal but opposite pressure differentials exist above and below the neutral plane of any space, which usually occurs at the midpoint of that space. It is important to note that pressure differentials arising from the stack effect in spaces having minimal height are negligible. Examples of such spaces are typical floors (less than approximately thirty feet) or similar spaces. Figure 1 depicts the pressure differentials that would arise as a result of the stack effect during the winter. The thicker continuous directional line represents how smoke generated on a lower floor might move to upper levels via shafts as a result of the pressures created through normal stack effect. Reverse stack effect, typically encountered during warmer weather (summer), would have the opposite effect of that shown in Figure 1 below.

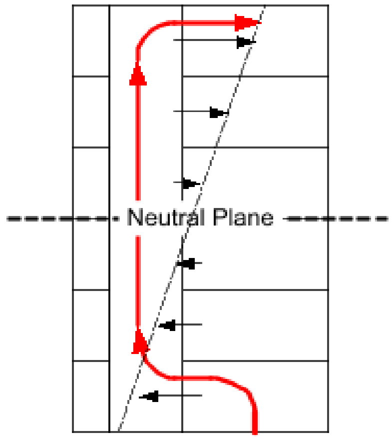

Figure 1 - Stack Effect in Typical Winter Conditions

3.1.3 Modeling the Stack Effect.

Equations that can be used to calculate the stack effect in shafts within a building are presented in Chapter 3 of the ASHRAE text *Handbook of Smoke Control Engineering* (Equations 3.33, 3.34). The equations work well for simple geometries including low-rise buildings and shell buildings where the number of compartments, and therefore the number of flow paths, between the shaft and the exterior of the building are limited.[6] Under those circumstances, the equations can be calculated by hand or by entering them into a spreadsheet. However, as the number of compartments between the shaft and the exterior of the building increase or the number of floor levels increase, the equations become proportionally more complex to work with.

$$\Delta P_{so} = (\rho_o - \rho_s) g z \qquad (1)$$

Equation (1) can be simplified if the ideal gas law, $P_{atm} = \rho R T$ is applied. Substituting for density, we arrive at the following:

$$\Delta P = \frac{g P_{atm}}{R} \left(\frac{1}{T_o} - \frac{1}{T_i} \right) z \qquad (2),\ 3.33$$

Assuming standard atmospheric pressure, Equation (2) may be further simplified:

$$\Delta P = K_s \left(\frac{1}{T_o} - \frac{1}{T_i} \right) z \qquad (3),\ 3.34$$

Where:

ΔP = Pressure differential (in. water gage)

[6] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012 (p. 131).

ΔP_{so} = Pressure differential from shaft to outside (in. water gage)

g = Gravitational acceleration = 32.2 ft/s^2

K_s = Coefficient (7.64)

ρ_o = Density of air outside the shaft

ρ_s = Density of air inside the shaft

R = Gas constant of air = 5.97 (ft-lb)/(slug- °R)

T_o = Temperature of air outside the shaft (°R)

T_s = Temperature of air inside the shaft (°R)

Z = Distance from the neutral plane (ft)

Alternatively, the computer model CONTAMW models these effects directly using ambient and interior building temperatures, wind data, altitude, and elevation inputs. The Law of Conservation of Mass in combination with Bernoulli's fluid flow approximation are used to determine flow rates and pressures across flow nodes between modeled sub-zones. Stack effect differentials from top to bottom of each floor are assumed to be negligible. Stack effect in vertical shafts is directly calculated by CONTAMW using the equations referenced above. Local temperature data taken from the Handbook of Smoke Control Engineering[7] and ACDC website for Portland, Oregon at the Portland International Airport weather station will be used as input into CONTAMW. The extreme peak temperature will be taken as 91.2° F for summer and 23.9° F for winter.

It is assumed that elevator hoistway pressurization air is untreated. As such, the elevator hoistway temperatures are calculated as follows[8]:

$$T_S = T_O + n(T_b - T_O)$$

T_b = Temperature of air inside the building is 68 ° F (20° C)

T_s = Temperature of air inside the shaft

T_o = Temperature of air outside the shaft

n = dimensionless heat transfer factor (range from 0.05 to 0.15, suggested value of 0.15 is conservative per the *Handbook of Smoke Control Engineering*)

[7] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012 (Ch. 2, Table 2.1).

[8] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012 (Ch. 10, Equation 10.1).

The following input values will be used in the winter model to represent normal stack effect with specific height reference to Stair A through Stair E as well as the elevator hoistway shafts:

T_b = Temperature of air inside the building is 68 ° F (20 °C)

T_o = Temperature of air outside the shaft is 23.9 °F (-4.5 °C)

T_s = Temperature of air inside the shaft is 30.5 °F (-0.83 °C)

To represent the impact of reverse stack effect on smoke movement, the following values were used within the model for a summer scenario:

T_b = Temperature of air inside the building is 68 ° F (22.2 °C)

T_o = Temperature of air outside the shaft is 91.2°F (32.9 °C)

T_s = Temperature of air inside the shaft is 87.7 °F (31.3 °C)

The garage areas are ventilated by garage exhaust systems, it is assumed that the garage temperature is the same as the exterior temperature during a fire event. Refer to CONTAMW User's Manual published by the National Institute of Standards and Technology (NISTIR 7251) for additional documentation on modeling the stack effect.

3.2 TEMPERATURE EFFECTS OF FIRE

3.2.1 Code Requirements

Section 909.4.2 of the 2014 OSSC requires that the buoyancy and expansion caused by the design fire be addressed. Both empirical and theoretical approaches may be taken in this endeavor. It is the OSSC's intent that the designer examines the potential impact of likely severe design fires on the particular fire protection systems and passive barrier systems present in a building. Based upon the analysis, logical steps can then be taken to reduce the probability of smoke migration from the zone of fire origin to surrounding smoke zones.

3.2.2 Theoretical Effects of Buoyancy

According to the principles of smoke control design and documented in the ASHRAE text Handbook of Smoke Control Engineering, buoyancy forces of heated gases are a direct result of the density differential between the heated and unheated or relatively unheated gases within a space. Given this fact, Equation 3.33 in Chapter 3 of the ASHRAE text[9] can also be applied to calculate the pressure differential between a room or a series of rooms open to one another and surrounding spaces outside the space of fire origin.

The data in

Table 2 shows that the heated gases within the space will be cooled by sprinklers to a temperature below 350ºF, application of the above equations demonstrates that pressure differentials approximately in the range of 0.05 to 0.15-inches water gauge can be anticipated. It is worth noting that for sprinkler-controlled fires, smoke temperatures of 165ºF (the activating temperature of the sprinkler) are considered realistic per 2009 edition of NFPA 92 and even that value is considered

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[9] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012 (p. 129).

conservative once the sprinkler system is activated[10]. In either case, the larger the space, the greater the heat losses to the surroundings as the hot gas layer is diluted, and hence the smaller the pressure gradient. Table 2 lists a variety of pressure gradients for rooms and fires of varying sizes, as well as corresponding pressure gradients that would be anticipated.

Table 2 - Effects of Buoyancy on Pressure Gradient[11]

Buoyancy Effects of Combustion Gases – Gas Temperature at Ceiling (°F)	Pressure Differential (inches water gauge) (Assumes Room Temperature of 68°F)
1600°F (uncontrolled)	0.06 (assumes 5.6 ft. above neutral plane)
1290°F (uncontrolled)	0.12 (assumes 30 ft. above neutral plane)
350°F (sprinkler controlled)	0.08 (assumes 30 ft. above neutral plane)
350°F (sprinkler controlled)	0.03 (assumes 10 ft. above neutral plane)
165°F (sprinkler controlled)	0.02 (assumes 10 ft. above neutral plane)
165°F (sprinkler controlled)	0.05 (assumes 30 ft. above neutral plane)

It is evident from the data in

Table 2 that spaces with low ceiling heights and sprinkler-controlled fires generate very small pressure gradients in the area of fire origin as a result of buoyancy. Based on this data, it was decided that buoyancy effects will not have a significant impact on the modeling performed for the building because the analysis assumes that the maximum temperatures within the fire compartment will be less than 350°F based on a fully sprinklered building and ceiling heights of approximately 10 feet. The pressurization systems will be designed to produce a minimum pressure differential of 0.10 inches water gauge, which will be greater than the maximum expected buoyancy induced pressure gradients within the room of fire origin.

3.2.3 Theoretical Effects of expansion

Smoke movement can also be caused by expansion from the energy released by a fire.[12] The degree to which expansion occurs and how the smoke migrates to adjacent spaces primarily depends on (1) sprinkler activation and (2) the nature and quantity of leakage paths between the room of fire origin and the adjacent spaces. The ratio of the volumetric flows (into and out of the room of fire origin) is expressed as a ratio of absolute temperatures as shown in Equation 3.28 of Chapter 3 of the ASHRAE text Handbook of Smoke Control Engineering.

Calculations using the above referenced equation demonstrate that for an unsprinklered fire having hot gas temperatures of approximately 2200°F, the hot gases produced by the fire will expand to approximately five times their original volume.[13] In comparison, for a sprinkler-controlled fire having gas temperatures of approximately 350°F, the gases will expand to approximately 1.5 times their original volume (assuming that the temperature of the air into the fire compartment is 68°F). As steps are taken to reduce the temperature of the gas layer (i.e., by providing sprinklers that will discharge and control, or even extinguish the fire) and the fact that there may be open doors, the effects of expansion on smoke migration are reduced

[10] NFPA 92, *Standard for Smoke Control Systems*, National Fire Protection Association, Quincy, MA, 2015. Section A5.2.1.
[11] The SFPE Handbook of Fire Protection Engineering, 4th Edition. National Fire Protection Association. 2008. Quincy, MA. Page 4-369.
[12] The SFPE Handbook of Fire Protection Engineering, 4th Edition. National Fire Protection Association. 2008. Quincy, MA. Page 4-370.
[13] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012 (p. 126).

significantly. For these reasons, it was decided that the modeling performed for this analysis did not need to consider expansion effects.

3.3 WIND EFFECTS

3.3.1 Code requirements

Section 909.4.3 requires the elevator hoistway pressurization system design to consider the adverse effects of wind. The design should address the effects of wind pressures generated on the windward and leeward sides of the building, especially where leakage paths between the exterior and the interior of the building would be expected to be significant in area. Additionally, the placement of intake and relief vents for elevator hoistway pressurization systems should consider the impact of wind, the possibility of reintroducing smoke into the mechanical systems of the building being protected, the possibility of impacting the fan status indication at the smoke control panel, and the possibility of overcoming the opposing pressures associated with high wind speeds at the point of relief from the building.

3.3.2 Theoretical Effects of Wind Pressure

Air infiltration through the exterior walls of a building can have a significant impact on the effectiveness of the building's elevator hoistway pressurization system. One of the driving forces for air infiltration is external wind pressure, which is dependent on wind speed, wind direction, building configuration, building height and local terrain effects. Figure 2 on this page shows typical wind profiles for the windward and leeward sides of a building. The wind pressures depicted in Figure 2 can be calculated using Equations 3.35 and 3.36 in Chapter 3 of the previously referenced ASHRAE text *Handbook of Smoke Control Engineering.*

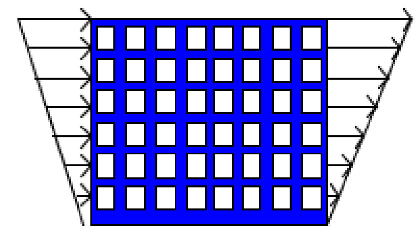

Figure 2 – Wind Pressures as a Function of Building Height

Variables that must be assigned values when applying Equation 3.36 include outside air density and a dimensionless pressure coefficient (C_w). The value for wind velocity at the upwind wall, U_H, is calculated using Equation 3.35 and requires values for wind velocity at a reference elevation (U_o), the reference elevation (z_o), the elevation at which the wind velocity (U_H) is to be calculated (z), and a dimensionless wind exponent (a) that is dependent on terrain conditions upwind of the building.

CONTAMW 3.2 is used to model wind pressure effects on the elevator hoistway pressurization system by providing ambient exterior temperatures, wind data, altitude, and elevation inputs. In addition to the ability to physically model the wind pressures as a function of height and direction, the model allows the user to input varying wind speed values and terrain profiles, thus accounting in part for the presence of other buildings or similar obstructions to wind that may be around the design area of interest.

The computer model CONTAMW accounts for local terrain conditions by calculating a wind pressure modifier. The calculations performed by CONTAMW are dependent on two constants that are provided by the user, namely the Local Terrain Constant and the Velocity Profile Exponent. Typical values for these constants for various terrain regions are documented in the *CONTAMW 3.2 User Manual*[14]. The terrain regions in the user manual are intended to correspond with the terrain categories described in the ASHRAE text *Handbook of Smoke Control Engineering*.[15] Interpolation between values is considered acceptable when the actual terrain conditions are somewhere in between those described in the definitions.

The value for C_w in Equation 3.36 of Chapter 3 of the *Handbook of Smoke Control Engineering* will vary from building to building as the value is reliant on the shape and height of the building. For each building, the value of C_w varies according to the angle of the wind with respect to the building, except where the building design closely resembles a square.

It should be noted that the wind profile is independent of the true magnetic direction that any given wall may be facing. Instead, the profile is arranged so that a wind direction of 0 degrees for a given building face represents the condition where the wind is approaching the wall at a right angle (i.e., 0 degrees = north wind on a north facing wall). This allows all exterior walls of the building to be represented by a single wind profile.

3.3.3 Other Wind Conditions

The impact of wind on the building elevator hoistway pressurization system is highly dependent on the layout and nature of openings in the building. Depending on whether the fire is on the windward or leeward side of the building, the pressure caused by wind may either facilitate the spread of smoke or could prevent smoke from moving out of the area of fire origin. Table 3 below lists a range of steady state, wind-induced pressures derived from Equation 3.36 of Chapter 3 of the ASHRAE text *Handbook of Smoke Control Engineering.*

Table 3 - Wind-Induced Pressures on a Building

Wind Velocity (Assumes ρ_o = 0.075 lb/ft^3, C_w = 0.7)	Wind-Induced Pressure From Equation 3.36 (inches w.g.)
5 mph	0.01
10 mph	0.03
25 mph	0.21
50 mph	0.85

The presence of fixed windows and doors in the exterior wall of a building usually results in minimal air leakage from the exterior of the building to the interior, which limits the impact of wind-induced pressures on the elevator hoistway pressurization system. In contrast, the presence of operable windows/doors or open-to-air openings is of greater concern. Where such conditions exist, it may be necessary to upgrade the level of passive protection to compensate for the

[14] Dols, W. Stuart, Walton, George W., *CONTAMW User Guide and Program Documentation*, National Institute of Standards and Technology, Gaithersburg, MD, NISTIR 7251, February 14, 2013 (p. 139).

[15] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012 (p. 132-133).

anomalous behavior of the wind through these openings. Jensen Hughes recommends that door sweeps be installed on the smokeproof enclosure doors and on the exterior discharge doors. Proper adjustment of these door sweeps would minimize air leakage and help to maintain the required pressure differentials.

3.3.4 Wind Data

Prevailing wind direction data was researched on the Ashrae Meteo (Ashrae-Meteo.info) web site[16] along with the *Handbook of Smoke Control Engineering*[17] design conditions for Portland, Oregon and was evaluated for use as input into CONTAMW to determine the adverse effects of wind. This data recorded at the Portland International Airport weather station is considered to be representative of conditions in Portland for the purposes of the modeling presented in this document. From this data, it can be seen that the prevailing wind direction is typically 120° from 0° North in winter and 310° from 0° North in the summer.

The CONTAMW model will utilize a 23.8 mph wind speed, which is the Extreme Wind Speed value that corresponds with a 1 percent cumulative frequency of occurrence, as reported on the Ashrae Meteo (Ashrae-Meteo.info) web site and in the *Handbook of Smoke Control Engineering*[18]. System sensitivity to wind direction is also be evaluated, mainly oriented around the prevailing wind direction, which is input in the model to be from 120° from 0° North in the winter and from 310° from 0° North in the summer.

3.4 HVAC SYSTEM EFFECTS

3.4.1 Code Requirements

Pursuant to Section 909.4.4, the effect of the Heating Ventilation and Air Conditioning (HVAC) systems on the transport of smoke and fire must be considered. The system must be designed to prevent the transport of fire products through the use of combination smoke/fire dampers and automatic shutdown of HVAC equipment.

3.4.2 Forced Ventilation System Actions

Combination smoke/fire dampers will be shown on the design drawings provided by the mechanical engineer where necessary. The normal HVAC equipment does not serve the elevator hoistways. This analysis assumes that the effects of a fire in the building will not transport smoke or fire into the elevator hoistways through the HVAC equipment. Additionally, the HVAC equipment will be required to have fire and/or smoke dampers as required by Section 716 and smoke detection where required by Section 907. Appendix A contains a conceptual sequence of operation for the smoke control system with indications of smoke control and HVAC actions during a fire event.

Building HVAC operations will be shut-down upon manual and automatic activation of the elevator hoistway pressurization systems as identified in the conceptual smoke control matrix in Appendix A.

3.5 CLIMATIC EFFECTS

Section 909.4.5 indicates that the design should consider the effects of high and low temperatures on the system, property, and occupants of the building in question. Local temperature data taken from the Ashrae Meteo (Ashrae-Meteo.info) web site and the *Handbook of Smoke Control Engineering*[19] for Portland, Oregon at the Portland International Airport weather station indicates that moderate hot and cold temperatures are to be expected in Portland. Upper and lower boundary temperature data of **91.2° F and 23.9° F** will be used as inputs to CONTAMW to predict climatic temperature effects on the stack effect and associated pressure calculations.

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[16] ASHRAE, ASHRAE Climatic Design Conditions 2009/2013/2017 [Online] Available: http://www.ashrae-meteo.info (2019).
[17] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012.
[18] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012.
[19] Klote, J.H., Milke, J.A., *Handbook of Smoke Control Engineering*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA, 2012.

The elevator hoistway pressurization equipment should be shielded from extreme environmental conditions like direct sun exposure, heat, wind, snow, rain, and dust. The location of the pressurization fan inlets should be located such that they will not be blocked by accumulation of snow.

3.6 DURATION OF OPERATION

Section 909.4.6 requires that all portions of active or passive smoke control systems be capable of continuous operation for not less than 20 minutes or 1.5 times the calculated egress time, whichever is greater. The elevator hoistway pressurization system will be designed for continued operation for at least 20 minutes or 1.5 times the calculated egress time, whichever is greater.

4.0 Mechanical Elevator Hoistway Pressurization System Activation

Controls for each zone of the elevator hoistway pressurization system will be provided at an approved location at the Firefighter's Smoke Control Panel. For a more detailed account of component responses, please refer to the Conceptual Fire Alarm and Smoke Control Sequence of Operation matrix provided for reference in Appendix A.

Upon any sprinkler waterflow, public area smoke detector, or manual fire alarm box activation, the elevator hoistway pressurization system will activate. All required dampers shall configure for elevator hoistway pressurization as identified in the conceptual functional matrix in Appendix A.

5.0 System Implementation Requirements

This section is not intended to summarize all requirements listed in Section 909 but is intended to highlight those areas of design where some care is required to ensure that the system design is adequately coordinated, according to the requirements presented in Section 909.21.1 through Section 909.21.11. All requirements in Section 909 will nonetheless apply as applicable.

All components shall be listed and installed using a methodology appropriate to ensure the prescribed survivability as follows:

+ Equipment including fans ducts and dampers in accordance with 909.10, 909.21;
+ Primary and secondary power systems in accordance with 909.11, 909.21.5;
+ Detection and control systems in accordance with 909.12, 909.21.6;
+ Marking and Identification in accordance with 909.21.8;
+ Control Diagrams in accordance with 909.21.9;
+ Fire-fighter's smoke control panel in accordance with 909.21.10;
+ System Response Time in accordance with 909.21.11;
+ Acceptance Testing in accordance with 909.21.7.

5.1 EQUIPMENT REQUIREMENTS

All equipment including, but not limited to, fans, ducts, and any dampers, shall be suitable for their intended use and must be listed for the probable temperatures for which these components may be exposed in accordance with 909.10 and 909.21. Proper listings for this equipment should be obtained and submitted with the design or submitted during the Construction Phase prior to installation.

As determined by the CONTAMW model, Primary Recall will be to the ground level, and Secondary Recall will be to the basement level.

5.1.1 Ducts

Ducts installed as part of an elevator hoistway pressurization system will be protected with the same fire-resistance rating as required for the elevator shaft enclosure as required by Section 909.21.3.

5.1.2 Duct Smoke Detectors

Section 909.21.4.2 requires fans serving as part of an elevator hoistway pressurization system be provided with smoke detectors that will automatically shut down the fan system when smoke is detected within the system. Fans that are part of an elevator hoistway pressurization system will be provided with the capacity to initiate a manual run command from the Fire Command Center's Firefighter's Smoke Control Panel to override the smoke detector shutdown of the fan. Initiation of an elevator hoistway pressurization fan smoke detector will annunciate a supervisory signal at the FACP.

5.1.3 Fans

Section 909.21.4.1 requires that when located within the building, fans serving an elevator hoistway pressurization system be protected with the same fire-resistance rating required for the elevator hoistway being served.

Section 909.21.4.3 requires that a separate fan system be provided for each elevator hoistway. Jensen Hughes recommends variable frequency controlled direct drive fans.

5.1.4 Dampers

Dampers that are part of the elevator hoistway pressurization system must be monitored to verify proper position (open and/or close). Fire and/or smoke dampers shall be provided as required by Section 716. Regardless of the purpose for which they are installed within a smoke control system, automatic dampers must be listed and conform to the requirements of approved, recognized standards.

Automatic dampers, regardless of the purpose for which they are installed within the smoke control system, will be listed and conform to the requirements of approved, recognized standards in accordance with Section 909.10.4. Smoke dampers and combination fire/smoke dampers will be listed and labeled in accordance with ANSI/UL 555S and 2009 NFPA 92A, Section 6.3.

5.2 POWER SYSTEMS

Primary and secondary (emergency) power is required for the elevator hoistway pressurization system in accordance with and 909.21.5. Standby power is required to be provided from the same source as other required emergency systems for the building. Transfer to full standby power must be automatic and is required to occur within 60 seconds of failure of primary power. Where elements of the elevator hoistway pressurization system rely on volatile memories or similar must be supplied with uninterruptable power sources of sufficient duration to span 15-minute primary power interruption. The System must be capable of withstanding power outages. A power surge protector, conditioners, suppressors, or other approved means shall protect elements of the smoke control system that are susceptible to power surges.

The standby power source and its transfer switches is required to be separate from the normal power transformers and switch gears and ventilated directly to and from the exterior. The separate room is required to be enclosed with no less than 1-hour fire barriers constructed in accordance with Section 707 or horizontal assemblies constructed in accordance with Section 711, or both.

5.2.1 Emergency Generator

The emergency generator(s) must supply power to the following systems. Those that are underlined are considered essential to the elevator hoistway pressurization system.

1. Exit signs and exit illumination.
2. Elevator car lighting.
3. <u>Fire alarm and supervisory systems</u>.
4. <u>Fire detection and supervisory systems</u>.
5. <u>Sprinkler alarm and supervisory systems</u>.
6. All required communications and public-address systems.
7. <u>Elevator door systems.</u>
8. Lighting circuits for designated response point, security, generator and main switch gear room, and fire pump room.

9. Elevator Hoistway Pressurization equipment including panels and controls.

5.3 DETECTION AND CONTROL SYSTEMS

All detection and control systems must be supervised in accordance with Section 909.12. Positive confirmation of actuation, testing, manual override, device mechanisms, and the presence of power downstream of all disconnects shall be provided.

Elevator hoistway pressurization systems require provisions for verification to confirm the fans used for elevator hoistway pressurization are operating. Fans are required to be monitored typically with differential pressure sensors or load sensing current transformers to verify air flow. Sail type airflow switches are not recommended. Co-locating the current transformers with the variable frequency drives can reduce the fire alarm installation requirements. Differential pressure sensors must be located at the fan location with pressure taps at the supply and outlet of the fan. The presence of power downstream of all disconnects can be monitored using a sensor or disconnect switch position sensor. Variable frequency drives should be monitored as well to confirm they are powered and functioning properly. Dampers should be monitored using end switches and should be wired individually or in series (not less than two circuits should be used – one circuit for supply dampers and one circuit for exhaust dampers as required) or one signaling line circuit with modules indicating actual damper position.

The elevator hoistway pressurization system supervision should be indicated at the Firefighter's Smoke Control Panel.

5.4 CONTROL AIR TUBING

Control air tubing (e.g. pneumatics to operate components), if used, is to comply with the installation and testing criteria of OSSC Section 909.13.

5.5 MARKING AND IDENTIFCATION

The detection and control systems must be clearly marked at all junctions, accesses, and terminations. This marking must be approved for its use by the fire and/or building officials in accordance with Section 909.21.8.

5.6 CONTROL DIAGRAMS

Identical control diagrams that depict the devices in the system identifying their location and functions shall be current and kept within the building in a location agreed upon by the jurisdiction, along with file copies for the Building and Fire Departments in accordance with Section 909.21.9.

5.7 FIREFIGHTER'S SMOKE CONTROL PANEL

The Firefighter's Smoke Control Panel (FSCP) is required in an approved location adjacent to the Fire Alarm Control Unit for manual control and override of automatic control for the mechanical elevator hoistway pressurization system in accordance with Section 909.21.10. This panel should be designed such that it graphically depicts the layout of fans, major ducts, and dampers within the building that are part of the smoke control system. A clear indication of the direction of airflow should be provided on the graphical display. A legend and status indicators should be provided for all smoke control equipment by LED indicators as follows:

- GREEN: Fans, dampers and other operating equipment in their **ON** or **OPEN** status;
- RED: Fans, dampers and other operating equipment in their **OFF** or **CLOSED** status;
- YELLOW/AMBER: Fans, dampers and other operating equipment in a **FAULT** status;
- WHITE: Fans, dampers and other operating equipment in their **NORMAL** status.

A lamp-test push button or other self-restoring means must be provided to test the FSCP. Fault status should be identified by pulsing the indicator lamp. The graphical layout of the FSCP should be submitted to the Fire Department prior to acceptance and installation.

In accordance with Section 909.21.10, the FSCP is required to have the highest priority of any control point within the building and provide control capability over the complete elevator hoistway pressurization system within the building as follows:

On/Auto/Off. Control over each individual piece of operating elevator hoistway pressurization equipment that can also be controlled from other sources within the building.

Open/Auto/Close. Control over all individual dampers or groups of dampers as approved by the Fire Department relating to elevator hoistway pressurization that are also controlled from other sources within the building.

On/Off or Open/Close. Control over the elevator hoistway pressurization system and other critical equipment associated with fire or smoke emergency that can only be controlled from the FSCP.

The FSCP must have the following control actions and priorities:

1. **ON/OFF or OPEN/CLOSE** control actions must have the highest priority of any control point in the building. No automatic or manual control from a control point other than the FSCP shall contradict the control action. When automatic means are provided to interrupt normal, non-emergency equipment operation or to produce a specific result to safeguard the building or equipment such as duct smoke detectors, this must be capable of being overridden by the FSCP. The last control action as indicated by each FSCP switch position must prevail. In all cases, control actions must not require the elevator hoistway pressurization system to assume more than one configuration at any one time.
2. Only the **AUTO** position of the three-position fire-fighter's control panel switch is permitted to allow automatic or manual control action from other control points in the building. The **AUTO** position must be the **NORMAL**, non-emergency building control position. Where the panel is in the **AUTO** position, the actual status of the device must be indicated by the status indicator on the FSCP. When an automatic signal requires an emergency condition, the **NORMAL** position must become the emergency condition for that device or group of devices within the zone. In all cases, control actions must not require more than one configuration of the elevator hoistway pressurization system at any one time.

Any modulating dampers or variable speed fans shall display their proper operation through positive feedback of appropriate position sensors in the field.

5.8 RESPONSE TIME

Activation of the elevator hoistway pressurization system must be initiated immediately after receipt of the appropriate automatic or manual activation command in accordance with Section 909.21.11. The components must be activated in the sequence necessary to prevent physical damage of the equipment. The FSCP response time must have the same response time for automatic or manual elevator hoistway pressurization system action from any building control point. The total response time, including the time necessary for detection, shutdown or operating equipment and elevator hoistway pressurization system startup, shall allow for the full operating mode to be achieved before the conditions in the zone or space exceed the design smoke condition.

The specific system response time for each component is not specified in the OSCC; however, 2009 NFPA 92A provides the following response time requirements[20], which are based on UUKL requirements:

1. Initiation of elevator hoistway pressurization via automatic or manual activation: 10 seconds
2. Fan operation at the desired state: 60 seconds
3. Completion of damper travel: 75 seconds
4. Firefighter's smoke control panel indication of field device status after operation: 15 seconds

[20] 2009 NFPA 92A, _Standard for Smoke-Control Systems Utilizing Barriers and Pressure Differences_, National Fire Protection Association, Quincy, MA, 2015. Section 6.4.3.6.3.

The total response time should not exceed 75 seconds, in accordance with standard practice. However, the mechanical engineer of record will need to determine the minimum system response time that can be provided while safely transitioning related mechanical equipment to the elevator hoistway pressurization configuration.

5.9 ACCEPTANCE TESTING

Prior to commissioning the smoke control system, detailed smoke control system testing scenarios should be developed by either a Special Inspector or the design team in accordance with Section 909.18. The testing criteria should be reviewed by the City of Portland to ensure that the methods of testing are acceptable. General testing criteria for this building will be included in the Appendix of the final report. Testing will include activation of the elevator hoistway pressurization system by devices identified in the sequence of operation.

Three (3) copies of a document describing testing procedures of all active fire protection systems should be submitted to the City of Portland for review and comment prior to final testing. The preparation of these test scenarios should be prepared by and coordinated through the respective Contractor and Engineer.

5.9.1 Special Inspector

The elevator hoistway pressurization system shall be tested by a Special Inspector required per Section 909.21.7 and deemed appropriate by the City of Portland. The Special Inspector is recommended to be retained to verify compliance with Section 909 prior to issuance of a mechanical permit. The Special Inspection team for elevator hoistway pressurization shall have expertise in fire protection engineering, mechanical engineering, and certification as air balancing.

5.10 PROTECTION OF CONTROL WIRING FOR ELEVATOR HOISTWAY PRESSURIZATION SYSTEMS

Section 909.21.4.1 requires fan systems, when located within the building, be provided with the same fire-resistance rating required for the elevator shaft enclosure. As such, equipment, control and power wiring, and ductwork associated with the elevator hoistway pressurization system is to be separated from building interior spaces by being either enclosed in 2-hour construction; encased in 2-inches of concrete; or by the installation of listed 2-hour rated cables.

The primary and emergency power for the elevator hoistway pressurization systems must be provided with 2-hour protection from the point it leaves the transfer switch location to the elevator hoistway pressurization equipment. Where the pressurization equipment is located on the roof, the 2-hour protection is permitted to terminate at the roof surface.

5.11 PERIODIC OPERATION AND MAINTENANCE

All active fire protection systems and devices are required to be regularly tested in accordance with applicable codes and standards by qualified individuals acceptable to the local AHJ. Records of all maintenance and testing must be retained on site and presented to the local AHJ and its representatives upon request.

6.0 Conclusion

The above report constitutes the elevator hoistway pressurization system rational analysis. This report is intended to support the elevator hoistway pressurization methodology proposed for the Broadstone Anthem project in Portland, OR.

Based on the results of the computer modeling completed by Jensen Hughes, the preliminary system volumetric flow rates as outlined in this report were found to be satisfactory for the performance of the system and are considered capable of meeting the minimum pressure differentials as required by the 2014 OSSC for provision of elevator hoistway pressurization.

This report provides an outline in performance-based language the goals and requirements for provision of a code compliant elevator hoistway pressurization system; however, the elevator hoistway pressurization system design and implementation shall be the responsibility of the Mechanical Engineer of Record for the project and the mechanical contractor.

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A. Appendix A

A.1. CONCEPTUAL ELEVATOR HOISTWAY PRESSURIZATION AND FIRE ALARM SEQUENCE OF OPERATION

→Response ↓ Initiating Device	Elevator Hoistway Pressurization Activation	Shutdown Fan and / or Close Dampers associated with Building HVAC	Close Doors on Hold-Opens
AREA DETECTORS			
Building Residential Corridor Smoke Detectors	■	■	■
Elevator Lobby Smoke Detectors[2]	■	■	■
DUCT DETECTORS			
Supply Fans Not Part of Elevator Hoistway Pressurization System		■[1]	
Pressurization Fans		■[1]	
WATERFLOW			
Any Floor Level	■	■	■
MANUAL			
Manual Fire Alarm Box in Fire Command	■	■	■
Manual Controls at Firefighter's Control Panel[2]	■	■	■

1. Only shut down associated fan. Manual override to be provided at the smoke control panel for the elevator hoistway pressurization fans.
2. Detectors on Level 1 recall elevators to P1, all others recall elevators to Level 1.

B. Appendix B

B.1. CONTAMW RESULTS

BROADSTONE ANTHEM BUILDING		
Summer – Elevator Hoistway Pressurization Effect – No Recall – (inches H2O)		
Level	**Elevator 1**	**Elevator 2**
6	0.176	0.174
5	0.171	0.169
4	0.168	0.166
3	0.170	0.168
2	0.195	0.193
1	0.224	0.205
P1	-	-

BROADSTONE ANTHEM BUILDING		
Summer – Elevator Hoistway Pressurization Effect – Primary Recall – (inches H2O)		
Level	**Elevator 1**	**Elevator 2**
6	0.215	0.230
5	0.209	0.224
4	0.221	0.206
3	0.206	0.221
2	0.222	0.238
1	-	-
P1	-	-

BROADSTONE ANTHEM BUILDING		
Summer – Elevator Hoistway Pressurization Effect – Secondary Recall – (inches H2O)		
Level	**Elevator 1**	**Elevator 2**
6	0.162	0.175
5	0.156	0.170
4	0.159	0.165
3	0.163	0.160
2	0.161	0.158
1	0.215	0.208
P1	-	-

BROADSTONE ANTHEM BUILDING		
Winter – Elevator Hoistway Pressurization Effect – No Recall – (inches H2O)		
Level	**Elevator 1**	**Elevator 2**
6	0.120	0.120
5	0.129	0.130
4	0.140	0.140
3	0.152	0.153
2	0.179	0.180
1	0.216	0.193
P1	-	-

BROADSTONE ANTHEM BUILDING		
Winter – Elevator Hoistway Pressurization Effect – Primary Recall – (inches H2O)		
Level	**Elevator 1**	**Elevator 2**
6	0.154	0.173
5	0.163	0.183
4	0.174	0.193
3	0.186	0.205
2	0.209	0.229
1	-	-
P1	-	-

BROADSTONE ANTHEM BUILDING		
Winter – Elevator Hoistway Pressurization Effect – Secondary Recall – (inches H2O)		
Level	**Elevator 1**	**Elevator 2**
6	0.106	0.106
5	0.177	0.117
4	0.128	0.128
3	0.139	0.139
2	0.152	0.151
1	0.180	0.179
P1	-	-

C. Appendix C

C.1. CONTAMW MODELING ENVIRONMENT

An airflow modeling tool CONTAMW developed by the National Institute of Standards and Technology (NIST) was used to calculate the minimum fan supply capacities required for elevator hoistway pressurization of the Broadstone Anthem project.

CONTAMW modeling tool is a multi-zone indoor air quality and ventilation analysis computer program that incorporates necessary fluid mechanics equations to help solve varying physical and mechanical conditions in different portions of a building.

Currently, CONTAMW is extensively used worldwide for elevator hoistway pressurization system design.

Nomenclature

Elevator Hoistway 1, Elevator Hoistway 2 (Active elevator hoistway pressurization zones, supply)

Passive Smoke Zones

Figure 1: Basement Level

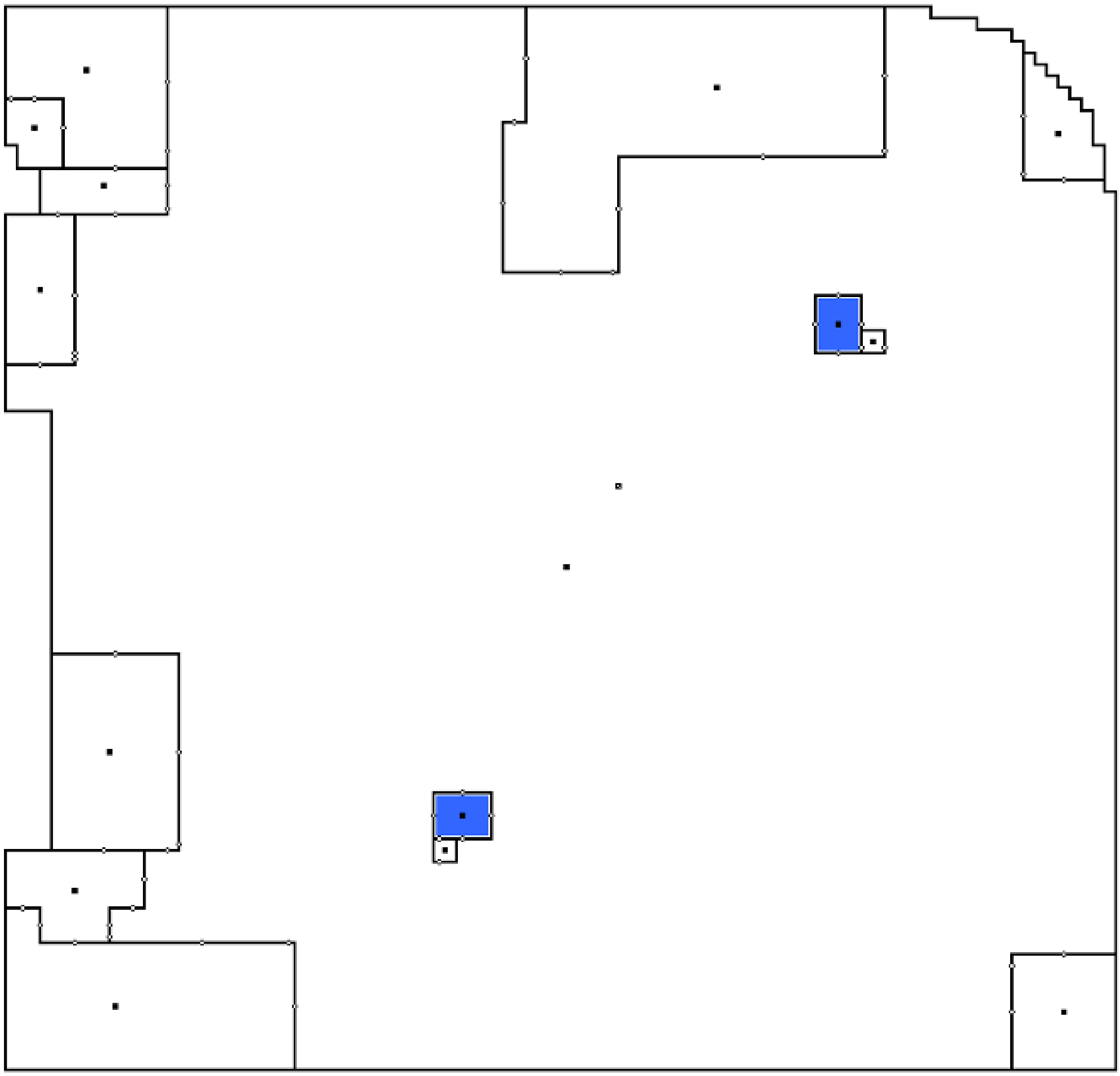

Figure 2: Ground Level

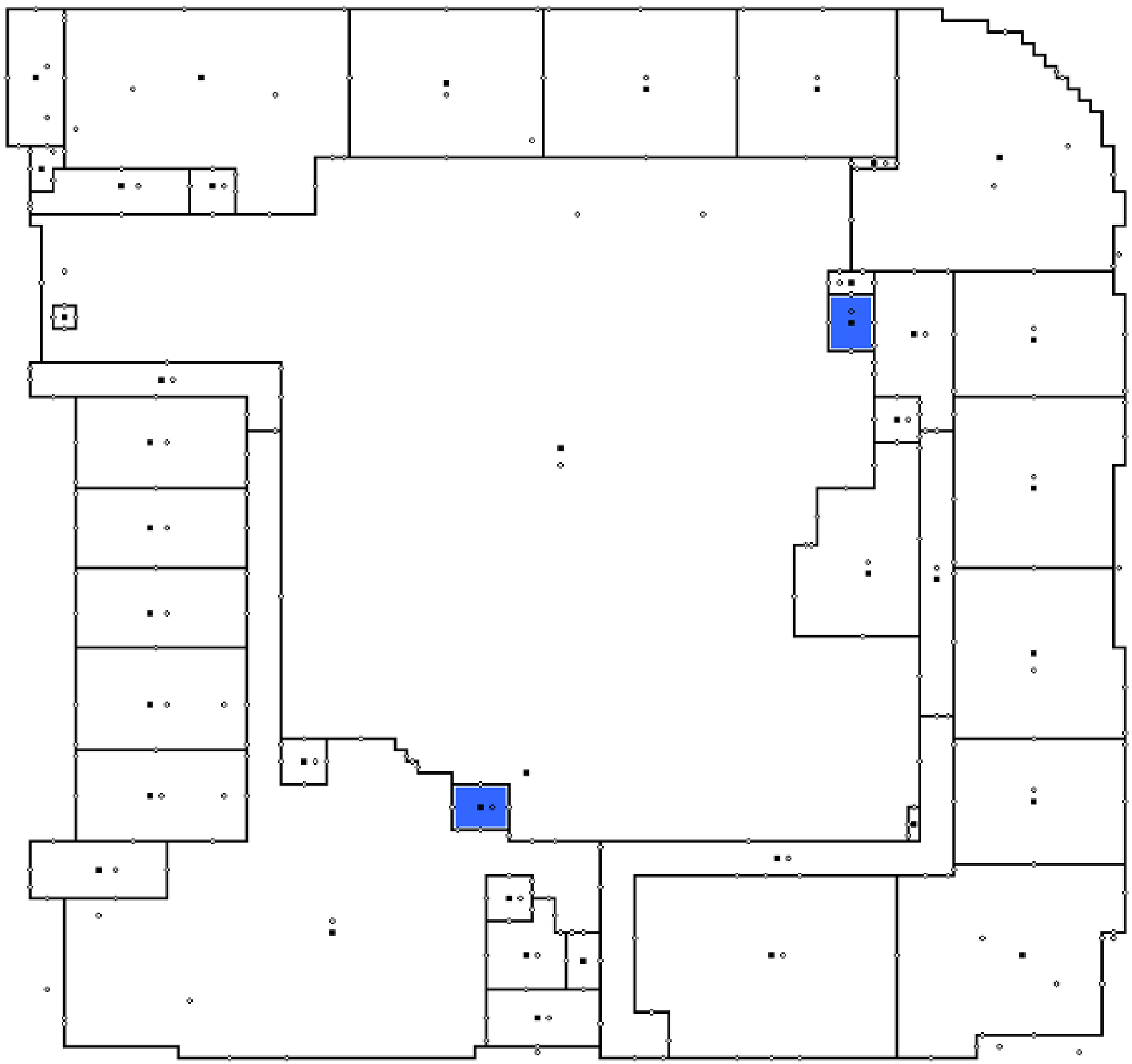

Figure 3: Second Level

Figure 4: Third Level

Figure 5: Fourth Level

Figure 6: Fifth Level

Figure 7: Sixth Level

Figure 8: Roof Level

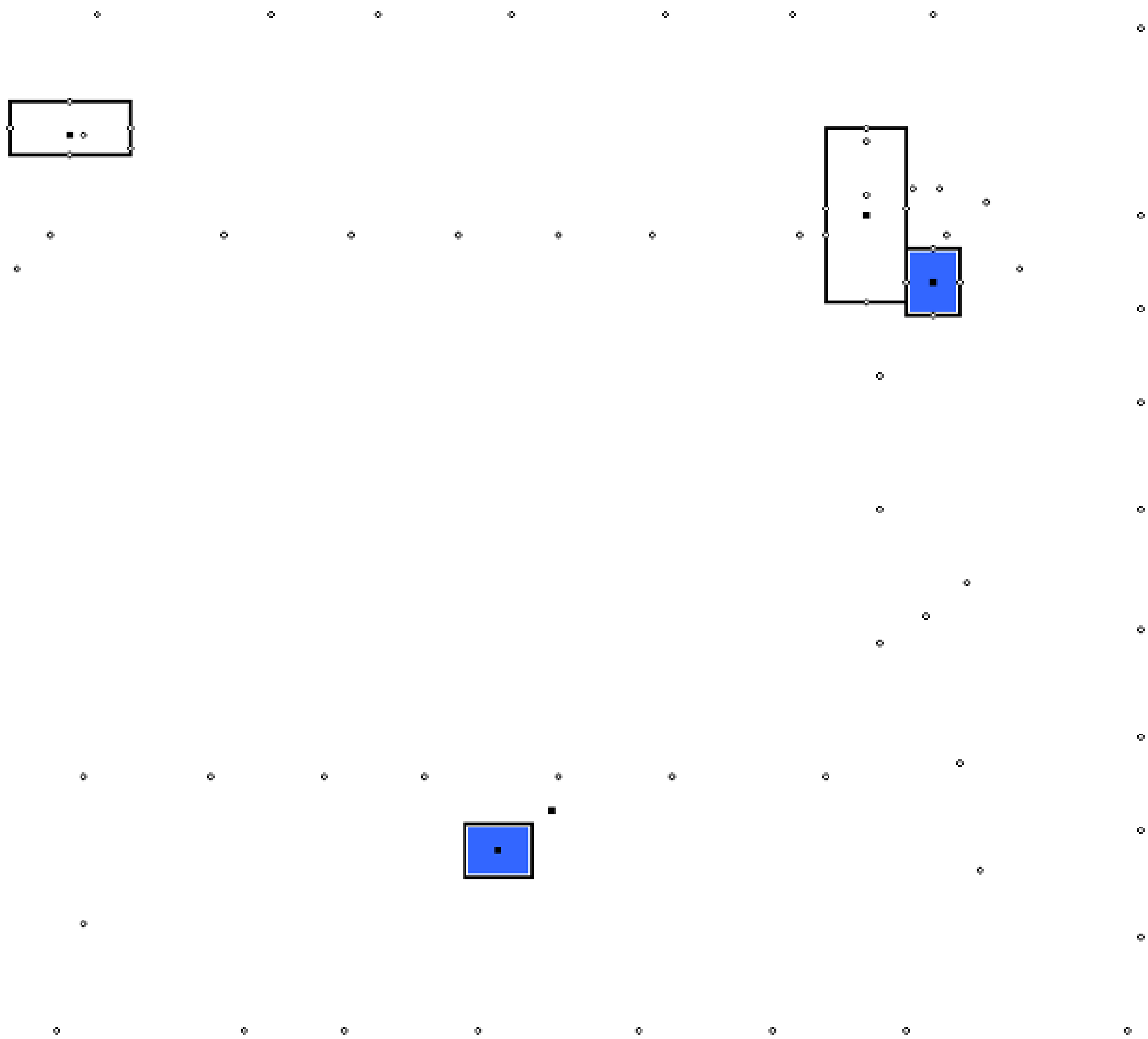

Figure 9: Overrun Level

D.Appendix D

D.1. TESTING CRITERIA

TESTING AND MAINTENANCE OVERVIEW – SPECIAL INSPECTION

Prior to commissioning the elevator hoistway pressurization system, detailed elevator hoistway pressurization system testing scenarios should be developed by either the special inspector or design team. The testing criteria should be reviewed by the City of Portland to ensure that the methods of testing are acceptable.

BACKGROUND INFORMATION

Three copies of a document describing testing procedures of all active fire protection systems should be submitted to the City of Portland for review and comment prior to final testing.

All testing and inspection for elevator hoistway pressurization systems will comply with the codes presently adopted by the City of Portland. The following sections highlight major inspection and testing requirements for the project.

CONTROL DIAGRAMS

Three copies of the elevator hoistway pressurization control diagrams should be submitted to the City of Portland prior to beginning testing of control equipment.

VISUAL INSPECTIONS

The following represents inspection requirements that will be fulfilled by either the City of Portland or the Special Inspector. It does not represent the Special Inspection Testing Program and has been provided for coordination purposes only. These testing criteria may be used to develop the final special inspection program.

Automatic Dampers.

Verify that automatic dampers installed within elevator hoistway pressurization systems are listed and conform to the requirements of approved recognized standards.

Control Diagrams.

Verify location of all fire alarm initiating devices indicated on control diagrams. Verify the location of all output devices (dampers, fans, controls/actuators, conductors, junction points) are installed according to the approved control diagrams. Verify that fire alarm initiating devices which activate elevator hoistway pressurization equipment are properly zoned in accordance with the respective elevator hoistway pressurization zone. This includes automatic sprinkler systems. Early phase testing and inspection of duct leakage, smoke/fire damper visual, freedom of movement, and continuity test/inspection will be permitted without approved control diagrams.

Marking and Verification.

Verify that the equipment, detection and control systems are clearly marked at all junctions, accesses, and terminations. Junction boxes, cover plates, and conduit couplings may be color coded as an acceptable means of infrastructure identification.

TESTING PROCEDURES
Control Action and Priorities.

(1) Verify that the FSCP has priority over other building systems (e.g., energy management control systems, building management system, automatic temperature control) when the elevator hoistway pressurization system is active.

(2) Verify that the FSCP functions in accordance with the design intent.

(3) Verify that doors, fans, and dampers are configured properly and that the appropriate status indication light is lit on the FSCP.

Controls.

(1) Verify that each hoistway has been put into operation by the actuation of one automatic initiation device. Verify that each additional device within the zone (this includes sprinkler zones) has been verified to cause the same sequence, but the operation of fan motors may be bypassed after the first few positive trials to prevent damage.

(2) Verify positive confirmation of actuation, testing and manual override.

(3) Verify control sequences throughout the system, including verification of manual override from the FSCP.

(4) Simulation of standby power conditions and verification of elevator hoistway pressurization system operations from the FSCP.

Dampers/Doors.

Verify that dampers and smoke doors have been tested for function in their installed condition. Door opening force shall also be tested and verified to not exceed 30-pounds per Section 1008.1.3.

Detection Devices.

Smoke or fire detectors which are a part of an elevator hoistway pressurization system will be tested in accordance with NFPA 72 by the installing contractor(s) in their final condition. Field verification for compliance with all aspects of OSSC 909 will be performed by the Special Inspector. When testing duct type smoke detectors, both minimum and maximum airflow is required.

Ducts.

Perform/verify that ducts which are part of an elevator hoistway pressurization system have been traversed using generally accepted practices to determine actual air quantities.

Fans.

(1) Verify that motors driving fans do not operate beyond their name plate horsepower (kilowatts) as determined from measurement of actual current draw or kW meter.

(2) Examine fans for correct rotation. Verify measurements of voltage, amperage, revolutions per minute and belt tension have been made.

(3) Verify proper operation of air flow sensors.

Inlets and Outlets.

Perform/verify inlets and outlets have been read using generally accepted practices to determine air quantities and submitted with final report.

Pressurized Elevator Hoistways.

(1) Perform/verify that the upper portion of such enclosures have been provided with controlled relief vent capable of discharging air to achieve the required pressure differentials during testing of primary recall.

(2) Perform/verify that at least 0.10-inch minimum water gage and 0.25-inch maximum water gage relative to the hoistway door is achieved on every floor except where hoistway doors are open during all recall scenarios.

Response Times. Perform/verify control and actuation response times. Response time is measured from the time the equipment being tested is actually commanded to operate or shut down, as required. Protection of equipment through time delays or staging of start commands, as permitted by Code is allowed. Please refer to the OSSC for requirements.

Verify that the FSCP response time is the same for automatic and manual elevator hoistway pressurization action initiated from any other building control point.

Standby Power. Verify that full standby power is automatic within 60 seconds of primary power failure.

RECORDING TESTS AND FAILED TESTS OR INSPECTIONS

The Special Inspector will document specific tests and/or inspections and place them in the final report. The Special Inspector will advise City of Portland of the proposed inspection and testing scheduling. The Special Inspector shall provide the appropriate documentation to the Building Official in the event that a failing test or inspection has not been corrected by the Contractor. Should the Contractor not correct the areas failing the test or inspections, a correction notice will be given to the appropriate parties.

Contractor. A copy of this notice should be provided to the Building Owner. Re-testing or inspection shall be rescheduled as soon as possible.

FINAL INSPECTION REPORTS

Reports shall be in compliance with OSSC Section 909.20.7. A complete report of testing shall be prepared by the special inspector or special inspection agency. The report shall include identification of all devices by manufacturer, nameplate data, design values, measured values and identification tag or mark. The report shall be reviewed by the responsible designer, and when satisfied that the design intent has been achieved, the responsible designer will affix the designer's signature, seal, and date to the report.

A copy of the final report shall be filed with the Fire Department, Building Department and an identical copy maintained in a designated location.

The above-mentioned report will also have the signature of the approved inspector. The flow and pressure testing professional will also sign and affix their agency stamp.

PERIODIC OPERATION AND MAINTENANCE

All active fire protection systems and devices should be regularly tested in accordance with applicable codes and standards by qualified individuals acceptable to City of Portland. Records of all maintenance and testing should be retained on site and presented to the City and its representatives upon request.