DEPT OF BLDGS 121324290 Job Number

ES279806166 Scan Code

NYC Buildings

CCD1: Construction Code Determination Form

Must be typewritten.

☑ Orient and affix BIS job number label here ☒

1 Location Information *Required for all requests on filed applications.*

House No(s) 501 Street Name WEST 30TH STREET

Borough MANHATTAN Block 702 Lot 50 BIN 1012456 CB No. 104

2 Applicant Information *Required for all requests on filed applications.*

Last Name GREENE First Name MICHAEL Middle Initial

Business Name KOHN PEDERSON FOX ASSOCIATES Business Telephone 212 237 3503

Business Address 11 WEST 42ND STREET Business Fax (212) 956-2526

City NEW YORK State NY Zip 10036 Mobile Telephone

E-Mail MTownsend@kpf.com License Number 018052

License Type ☒ P.E. ☐ R.A. **DOB PENS ID # (if available)**

3 Attendee Information *Required if different from Applicant in section 2 or no Applicant.*

Relationship to the property: ☒ Filing Representative ☐ Attorney ☐ Other:

Last Name BATISTA First Name ARELIS Middle Initial

Business Name THE RELATED COMPANIES Business Telephone (212) 801-3476

Business Address 60 COLUMBUS CIRCLE 19TH FLOOR Business Fax (212) 801-1048

City NEW YORK State NY Zip 10023 Mobile Telephone (646) 573-3391

E-Mail ARELIS.BATISTA@RELATED.COM License/Registration # (if P.E./R.A./Attorney)

DOB PENS ID # (if available) B04671

4 Nature of Request *Required for all requests. Only **one** request may be submitted per form.*

Note: Do not use this form for Zoning Resolution determination requests - use ZRD1 form

Determination request issued to: ☒ Borough Commissioner's Office ☒ Technical Affairs

Job associated with this request? ☐ Yes (provide job#/doc#/examiner name below) ☒ No

Job Number:________ Document Number:______ Examiner:________

Has this request been previously denied? ☐ Yes ***(attach all denied request form(s) and attachment(s))*** ☒ No

Indicate total number of pages submitted with this request, including attachments: ***(attachment may not be larger than 11" x 17")***

Construction Code (if applicable): ☐ 2008 Code ☐ 1968 Code ☐ Prior to 1968 Code

Indicate relevant code section(s), rule(s), etc:

Indicate all Buildings Department officials that you have previously reviewed this issue with (if any):

☐ Borough Commissioner ☐ Code & Zoning Specialist ☐ General Counsel's Office

☐ Deputy Borough Commissioner ☐ Chief Plan Examiner ☐ Other:

ADMINISTRATIVE USE ONLY

Reference #: Appointment date: Appointment time:

Appointment Scheduled With:

Comments:

Reviewed By: **Date** **Time:**

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Edwin Tang, RA
Executive Director,
NYC Development Hub
APPROVED WITH CONDITIONS
Control No. 20581
Date 2/27/13
Page 1 of 6

6/09

5 Description of Request (additional space is available on page 3)

This is a request for:

☐ Interpretation or clarification

☒ Variation of Building Code or Rules per § 28-103.3 (please state in detail the practical difficulty that is specific to this project, and provide the analysis as to equally safe alternative, as per NYC Charter Section 645(b)(2))

☐ Variation of Multiple Dwelling Law (MDL) § 277.16 for Article 7B Buildings (please state in detail the practical difficulty that is specific to this project and provide the analysis as to equally safe alternative, as per NYC Charter Section 645(b)(2))

Note: Variations of any other MDL provisions must be filed with the Board of Standards and Appeals (BSA) per MDL § 310.

Please itemize all attachments, including plans/sketches, submitted with this form. If this is based on a plan examiner objection, type in the applicable objection text exactly as it appears on the objection sheet.

The design of the smoke control system for the atrium of the Hudson Yards Tower C project was evaluated using a Computational Fluid Dynamics (CFD) model to evaluate the performance of the system including exhaust and makeup air quantities. The conditions in the atrium were reviewed for tenability during egress and the exhaust and supply quantities were adjusted to achieve passing results. The analysis was performed in lieu of calculating the supply and exhaust quantities using the smoke production calculations outlined in Section 909.8 of the Building Code. The CFD model calculates the movement of heat and smoke produced by the fire throughout the atrium. The conditions throughout the atrium were evaluated for visibility to a lighted object (i.e. exit sign), temperature, and carbon monoxide concentration.

Variation and Interpretation:

A Variation is proposed from Section 909.8 Exhaust Method of the Building Code to permit the use of more recent editions of the IBC (2006) to design the atrium smoke control system.

The 2008 NYC Building Code (based on the 2003 IBC) requires the exhaust rate to be determined based on the algebraic equations described in Section 909.8 for the calculation of the smoke production rate for a design fire. More recent edition of the IBC (2006, 2009, and 2012) have included significant changes to Section 909.8. Beginning with the 2006 IBC, the IBC now adopts NFPA 92B, Standard for Smoke Management Systems in Malls, Atria, and Large Spaces by reference in lieu of the previous requirements of Section 909.8. In accordance with 2006 IBC and NFPA 92, the design fire and smoke production rate may be evaluated using an engineering analysis.

The CFD required exhaust quantity is 275,000 cfm per NFPA 92B in lieu of the 1,600,000 cfm required by the algebraic equations in the 2008 NYC Building Code.

Atrium Description:

The Hudson Yards Tower C atrium connects Floor 6 though Floor 20 of the building. The occupied portions of Floor 6 through Floor 20 will be separated from the atrium by 2-hour fire resistance rated construction or glass protected by sprinklers as required by Building Code Section 404.5. However, each floor will have a balcony open to the atrium. Balconies are not considered "floors" open to the atrium as outlined in the IBC Commentary. However, the smoke control system must be designed to maintain tenability for such balconies during a fire condition.

Justification:

The algebraic equations of the Building Code are based on empirical data and the application of the empirical correlations is limited to the range of data used to develop the correlations. The equations are used to calculate the smoke production rate of a fire based on the heat release rate of the fire and the design smoke layer height above the fuel. The calculated smoke layer height is required to be six feet above the highest level open to the atrium, the Seventeenth Floor in the Tower C atrium.

Note: Buildings Department Determination will be issued on the CCD1 Response Form

ADMINISTRATIVE USE ONLY		
Reviewed By:	Date:	Time:

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Edwin Tang, RA
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NYC Development Hub

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Date 2/27/13
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6	**Description of Request** (use this section if additional space is required for description)

More recent editions of the IBC code have included significant changes to the Section 909.8 to address deficiencies in the equations provided in Section 909.8 and to incorporate more modern methods of smoke control system design. Beginning with the 2006 IBC, all recent editions of IBC now adopt NFPA 92B Standard for Smoke Management Systems in Malls, Atriums, and Large Spaces by reference in lieu of the previous requirements for Section 909.8. NFPA 92B permits state-of-the-art methods for designing smoke control systems, including Computational Fluid Dynamics (CFD). The CFD model is a three-dimensional domain that was created using the architectural model of the Tower C project. The CFD model allows for detailed studies of the smoke movement within the atrium and is capable of determining smoke production for a variety of fuel and building configurations. A CFD model solves hundreds of equations for discrete cells which the atrium is converted into. The architectural and mechanical elements of the Tower C atrium were broken into approximately 8.2 million cells for the analysis.

It is proposed to use the methods outlined in NFPA 92B, which includes a CFD model, in lieu of the algebraic equations based on the following:

- The latest editions of the IBC adopts NFPA 92B in lieu of the algebraic equations
- NFPA 92B outlines the most recent approaches in fire protection engineering for smoke management in atria

The 2008 NYC Building Code requires a minimum design fire size of 5,000 BTU/s unless a rational analysis is performed to justify a lower heat release rate. A rational analysis was performed including the analysis of potential combustibles within the boundaries of the atrium and the presence of fire protection systems. The peak heat release rate, based on fire test data, results from a 3.1 MW (approximately 3,000 BTU/s) couch fire. This approach is consistent with the requirements of NFPA 92B.

It is respectfully requested to provide a smoke control system with 275,000 cfm as outlined in the attached Atrium Smoke Control Analysis dated May 11, 2012.

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NYC Development Hub
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Control No. 20581
Date 2/27/13
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Note: Buildings Department Determination will be issued on the CCD1 Response Form

7	**Statements and Signature** *Required for all requests*

I hereby state that all of the above information is correct and complete to the best of my knowledge. Falsification of any statement is a misdemeanor and is punishable by a fine or imprisonment, or both. It is unlawful to give to a City employee, or for a City employee to accept, any benefit, monetary or otherwise, either as a gratuity for properly performing the job or in exchange for special consideration. Violation is punishable by imprisonment or fine, or both.

Name (please print): MICHAEL GREENE, PE

Signature: [signature] Date: 5/23/12

REGISTERED ARCHITECT MICHAEL D. GREENE NO. 027052 STATE OF NEW YORK

P.E. / R.A. Seal *(apply seal, then sign and date over seal – not required for Attorneys on unified applications)*

ADMINISTRATIVE USE ONLY		
Reviewed By:	**Date:**	**Time:**

ZRD1/CCD1 Response Form

Location Information (To be completed by a Buildings Department official if applicable)

House No(s) 501 Street Name W 30 St

Borough Manhattan Block 702 Lot 50 BIN 1012456 Job No.

DETERMINATION (To be completed by a Buildings Department official)

Request has been:	☐ Approved	☐ Denied	☒ Approved with conditions
Follow-up appointment required?	☐ Yes	☐ No	

Primary Zoning Resolution or Code Section(s):

Other secondary Zoning Resolution or Code Section(s):

Comments:

The request for a variance from BC 909.8 for the exhaust method of the smoke control system in the subject atrium to use the IBC 2006 design standards in lieu thereof, as part of a computational fluid dynamics model to evaluate the performance of the smoke control system, is hereby approved, with concurrence from the Bureau of Fire Prevention, and subject to their conditions as indicated herein attached.

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Edwin Tang, RA
Executive Director,
NYC Development Hub
APPROVED WITH CONDITIONS
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Name of Authorized Reviewer (please print):

Title (please print):

Authorized Signature: Date: Time:

Issuers: write signature, date, and time on each page of the request forms; and attach this form .

Note: Determination will expire if construction document approval is not obtained within 12 months of issuance.

The City of New York

FIRE DEPARTMENT
9 MetroTech Center Brooklyn, N.Y. 11201-3857

TAMARA SAAKIAN P.E.
Director of Engineering and Technology Management
Bureau of Fire Prevention Room 3W-02

F.P.Index # 1301051
FPIMS # 33023193

February 7, 2013

REVIEWED BY
Edwin Tang, RA
Executive Director,
NYC Development Hub
APPROVED WITH CONDITIONS
Control No. 20581
Date 2/27/13
Page 5 of 6

Mr. Michael Greene, R.A.
Kohn Pedersen Fox Associates P.C.
11 West 42nd Street
New York, NY 10036

Re: Hudson Yards – Tower C
Variance application
Atrium smoke control

Dear Mr. Greene,

The project is a 59 story office building which includes floor openings connecting 15 stories, Floors 6 to Floor 20. The floor openings are designed as an atrium. A smoke control system is required in accordance with NYC Building Code 404.4

The Technology Management Unit is in receipt of documentation submitted in support of a variance application submitted to the Department of Buildings, in reference to Section 909.8 and 909.9 of the 2008 NYC Building Code for the proposed above referenced location. In lieu of section 909.8 and 909.9, a CFD analysis was conducted (Report "Atrium Smoke Control Analysis" dated May 11, 2012) to demonstrate that the smoke control system designed for the Hudson Yards Tower C atrium maintains a tenable environment for the evacuation of occupants from the atrium during a fire condition.

Three scenarios were looked at as mentioned in the report dated May 11, 2012. The design fire size is based on fire test data for a 3-cushion sofa fire (3.1 MW) that will burn out without activating the automatic sprinkler system in two of the three scenarios.

Based upon a review of the documentation submitted, which includes a computational fluid dynamics (CFD) fire model analysis report, CFD fire model input files and architectural plans, please be advised that the Fire Department has no objection to the Department of Buildings granting the above referenced variance application, subject to the following conditions:

1. Complete automatic sprinkler protection throughout the building.

2. Separation of the atrium and balconies from the remainder of the building on all floors by a two hour fire barrier walls and shutters, or equivalent atrium

separation, such as glazing protected by closely spaced sprinklers in accordance with NYC BC 404.5

3. Projected beam smoke detection at the ceiling of the atrium above Floor 20.

4. Spot-type smoke detection at each balcony open to the atrium.

5. A smoke control system capable of 275,000 cfm of smoke exhaust, while maintaining the following tenable conditions:

    a. Temperature less than 140 F
    b. Carbon monoxide concentration less than 1.200 ppm
    c. Visible distance greater than 25 feet.

6. Tenable conditions shall be maintained at least 6 feet above any walking surface that forms a portion of the required egress system within the smoke zone.

7. Mechanical make-up air supplied by the atrium, consisting of 100% outside air, at a rate of 248,000 cfm.

8. Activation of the smoke control system is by automatic sprinkler water flow in the atrium smoke zone, smoke detection in the atrium, or by manual controls at the fire command center. Portions of the HVAC system serving the atrium that are not used for smoke control will be shut down upon activation of the atrium smoke control system.

9. Emergency power for smoke control and fire alarm system components shall be in accordance with NYC Building Code 909.11

When responding to the Department regarding the subject matter, kindly refer to F.P.Index # 1301051A.and address all correspondence to Leo Subbarao, Administrative Project Manager/ Alexander Eng, P.E. Chemical Engineer who can be reached at 718 999 1517/ 718 999 1006.

REVIEWED BY
Edwin Tang, RA
Executive Director,
NYC Development Hub
APPROVED
WITH CONDITIONS
Control No. 20581
Date 2/27/13
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Very truly yours,

Tamara Saakian, P.E.

TS:LS:AE

C: Code Consultants Professional Engineers, P.C.
C: Related Companies

Hudson Yards - Tower C

New York, New York

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NYC Development Hub
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WITH CONDITIONS
Control No. 20581
Date 2/27/13
Page 47 page report

Atrium Smoke Control Analysis
Supplemental Report

September 6, 2012

The Fire Protection and Life Safety Experts

CODE CONSULTANTS
PROFESSIONAL ENGINEERS PC

Atrium Smoke Control Analysis
Supplemental Report

Hudson Yards – Tower C
New York, New York

Prepared For:

Related Companies
60 Columbus Circle
New York, NY 10023

Prepared by:

CODE CONSULTANTS PROFESSIONAL ENGINEERS, PC
215 West 40th Street, 15th Floor
New York, New York 10018
212-216-9596

CCI Project No. 110413.54.000

September 6, 2012

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Section I

I. Introduction and Scope

The Hudson Yards project consists of the construction of a platform over the existing Hudson Rail Yards bounded approximately by 10th Avenue and 12th Avenue between 30th Street and 33rd Street located in Manhattan, New York. Proposed construction above the platform includes more than 12 million square feet of office, residential, retail and cultural spaces and more than 12 acres of public open space.

Tower C, a portion of the Hudson Yards project, is a 59-story office building which will contain approximately 1.5 million gsf of office space. The design of the new office building includes floor openings connecting 15 stories, Floor 6 to Floor 20. The floor openings are being designed as an atrium.

Code Consultants Professional Engineers, PC (CCPE) has been retained by Related Companies to assist in designing the smoke control system for the atrium to meet the requirements of the 2008 New York City Building Code (NYCBC) based on the 2003 edition of the International Building Code (IBC). CCPE outlined a smoke control concept for the atrium and the building code requirements that have been addressed in the design of the atrium in the Atrium Smoke Control Analysis report dated May 11, 2012. The results of that analysis demonstrate that the proposed design meets or exceeds the intent of the prescriptive requirements and is supported by the requirements of more recent editions of the IBC.

This supplemental report has been provided to document analysis of two additional design fire scenarios, as requested by FDNY.

The results of the original CFD analysis, combined with the additional analysis, demonstrate that the smoke control system designed for the Hudson Yards Tower C atrium maintains a tenable environment for the evacuation of occupants from the atrium during a fire condition. Based on the results of the analysis documented in the Atrium Smoke Control Analysis report dated May 11, 2012 and this supplement, it is the professional opinion of Code Consultants Professional Engineers, PC that the fire protection and life safety concepts outlined in this analysis will provide a level of safety equal, if not superior, to that intended by the applicable codes.

Section II

II. Additional Design Fires

At the request of FDNY, two additional design fires have been analyzed. These design fires represent small fires that could occur in the space, reducing the amount of smoke and hot fire gases that are produced.

This supplemental report analyzes the following two design fires:

- A trash can fire on Floor 6 directly beneath the floor openings to the levels above that is not controlled by the automatic sprinkler system;

- A trash can fire on Floor 6 directly beneath the angled wall adjacent to the floor openings that is not controlled by the automatic sprinkler system;

These fire locations are the same as Design Fires 1 and 2 in the original report, and the locations are indicated in Figure 1 in the Graphics Appendix of that report. These fires are used to investigate whether the smoke control system is capable of providing tenable conditions not only during very large fires, but for very small fires as well.

The fire size of the trash can fires is based on fire test data included as Appendix A to this supplemental report. Fuel properties for upholstered furniture are used in this design fire scenario, as it would produce denser smoke than would be expected from the fuel loading of a trash can fire.

Typical upholstered furniture consists of various materials including wood and foam. Since the density of the foam is low, foam is a fraction of the weight of the furniture. The fuel properties for upholstered furniture have been modeled based on the furniture being 50% foam and 50% wood by weight as summarized in the following table:

Fuel	Heat of Combustion (kJ/g)	Soot Yield (g/g)	CO Yield (g/g)
Wood	20	0.015	0.0045
Polyurethane (flexible foams)	28.8	0.1875	0.028
Upholstered furniture (50% wood & 50% polyurethane)	24.4	0.1	0.016

The fuel properties for wood and polyurethane foams listed above are based on the fuel properties recorded in the SFPE Handbook of Fire Protection Engineering, 3rd Edition (Appendix D).

Section III

III. Fire Modeling Results

The fire modeling analysis was used to determine the conditions in the Hudson Yards Tower C atrium during each of the two design fire scenarios. The fire modeling results are presented primarily using graphical floor plans of Floor 17 of the building, which is the highest level of exit access open to the atrium. The smoke detector activation times were calculated as part of the CFD analysis and are provided in the results outlined below.

A. Design Fire 1: Trash Can Fire Centered Below Atrium Floor Openings

Figure 1 below shows the heat release rate of this design fire:

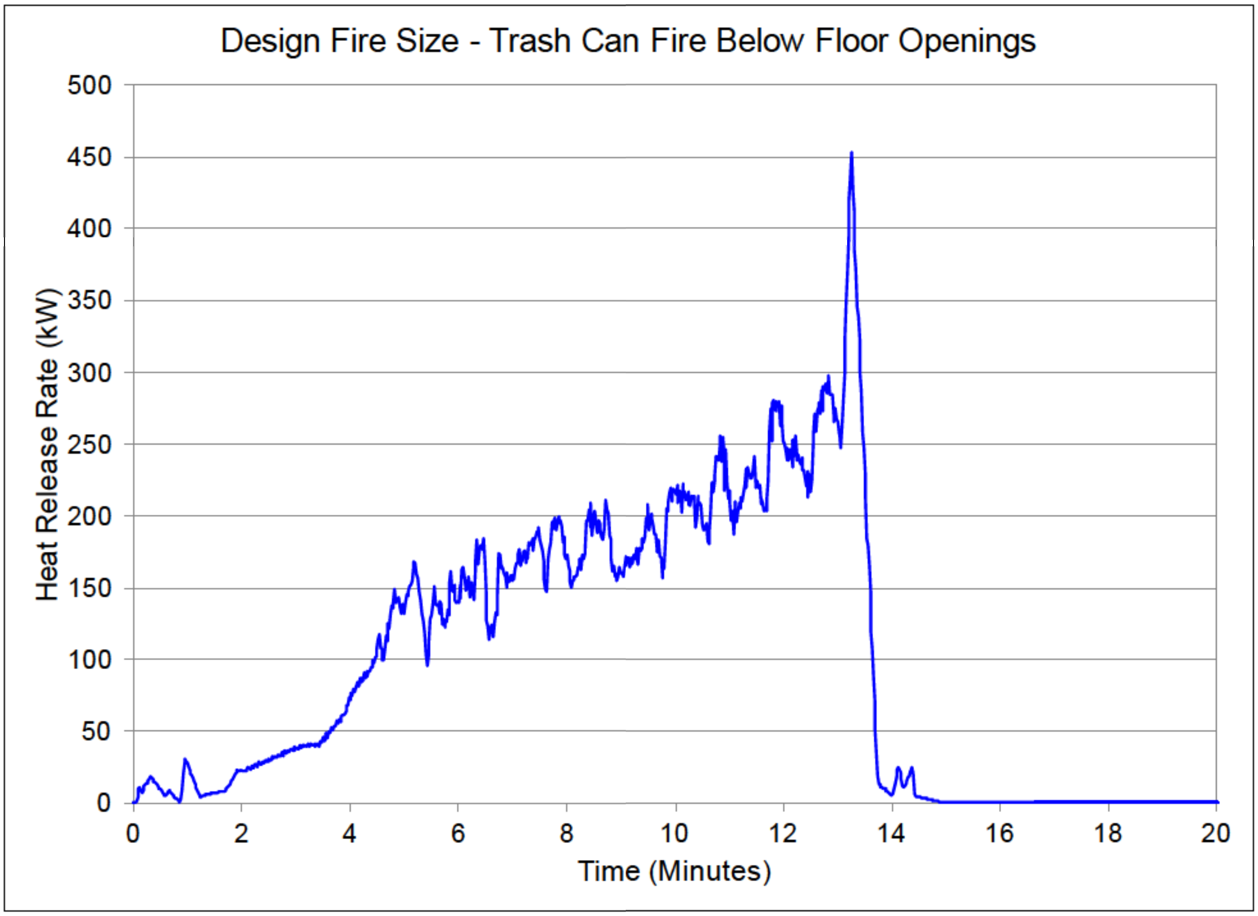

Figure 1: Design Fire Size of the Trash Can Fire below Floor Openings.

During this fire scenario, the smoke control system with an exhaust rate of 275,000 cfm at the top of the atrium is activated upon the activation of a projected-beam smoke detector in the atrium. Projected-beam detector activation occurs approximately 211 seconds after ignition. The results of this scenario are summarized in the table below:

Life Safety Criteria	Maximum Value
Visible distance	Greater than 25 feet
Carbon monoxide concentration	4 ppm
Temperature	75°F

Figures 2, 3, and 4 show the temperature, carbon monoxide concentration, and visibility, respectively, at six feet above Floor 17. The snapshots are taken at the time of maximum smoke spread (14 minutes) and at 20 minutes.

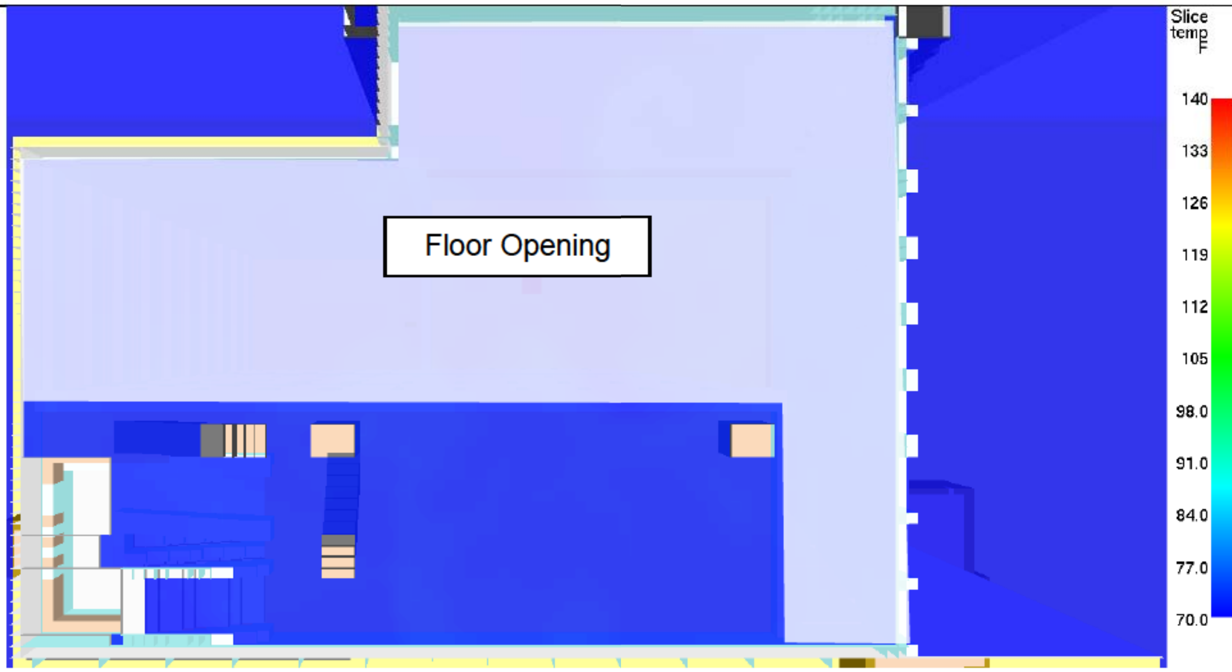

Figure 2a: Maximum Smoke Spread (14:00)

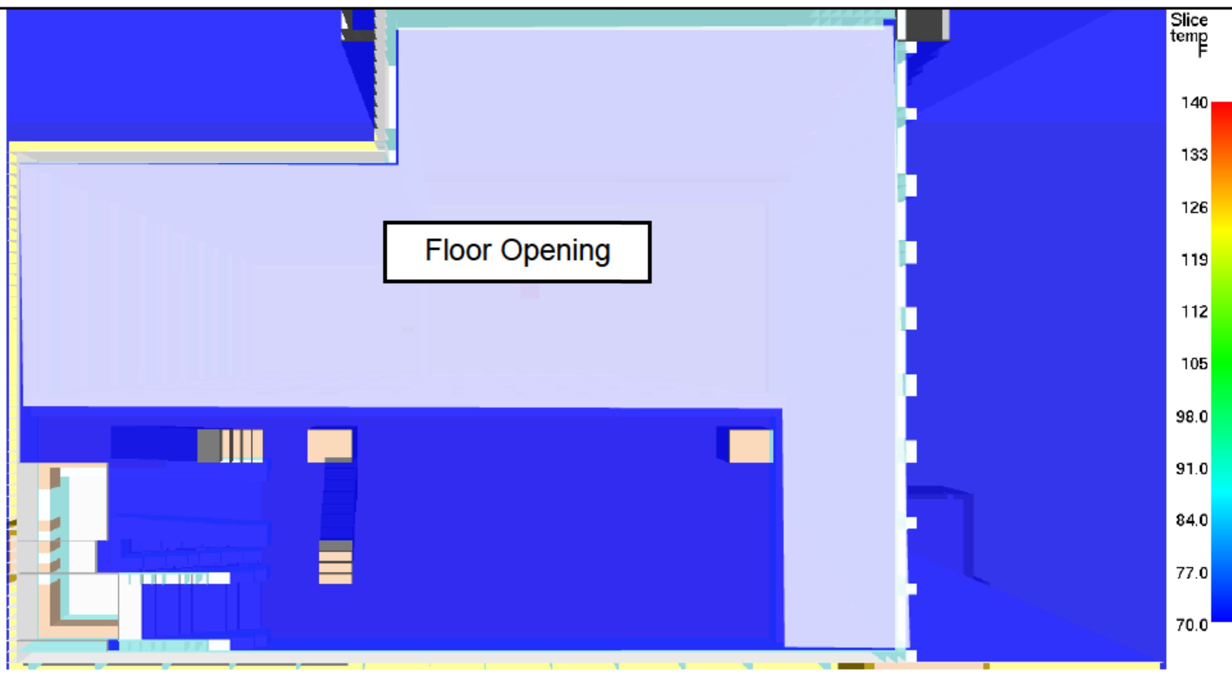

Figure 2b: 20:00

Figure 2: Temperature 6 Feet above Floor 17
Design Fire 1: Trash Can Fire under Floor Openings

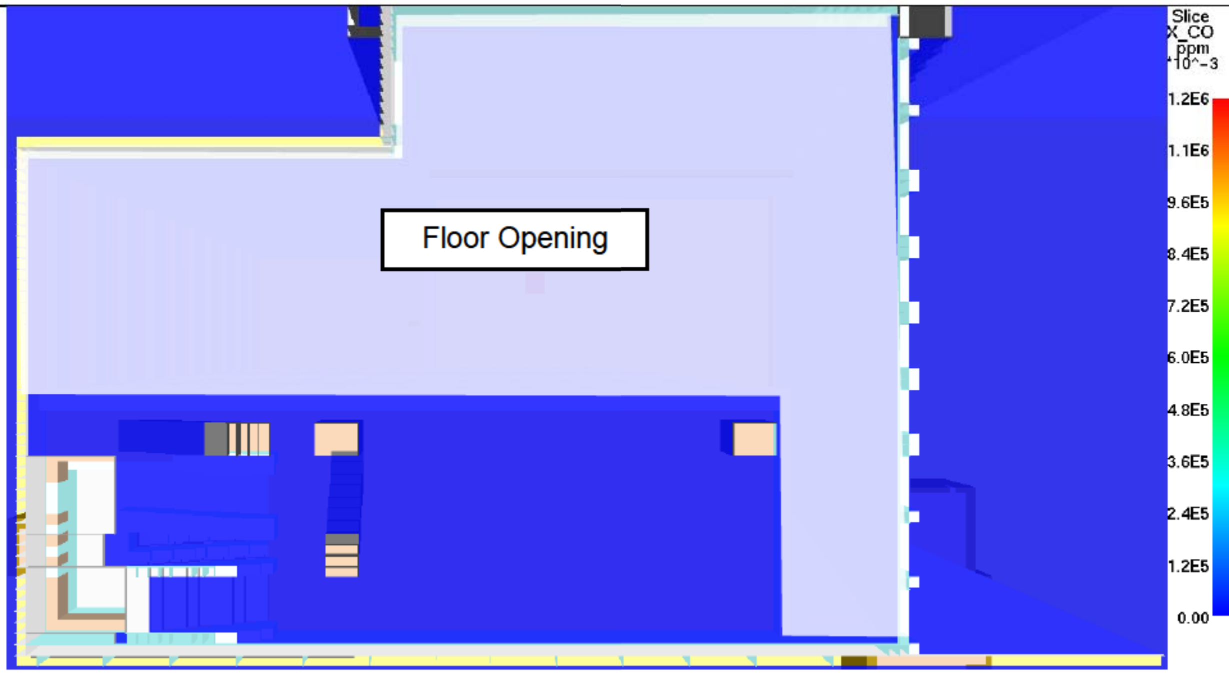

Figure 3a: Maximum Smoke Spread (14:00)

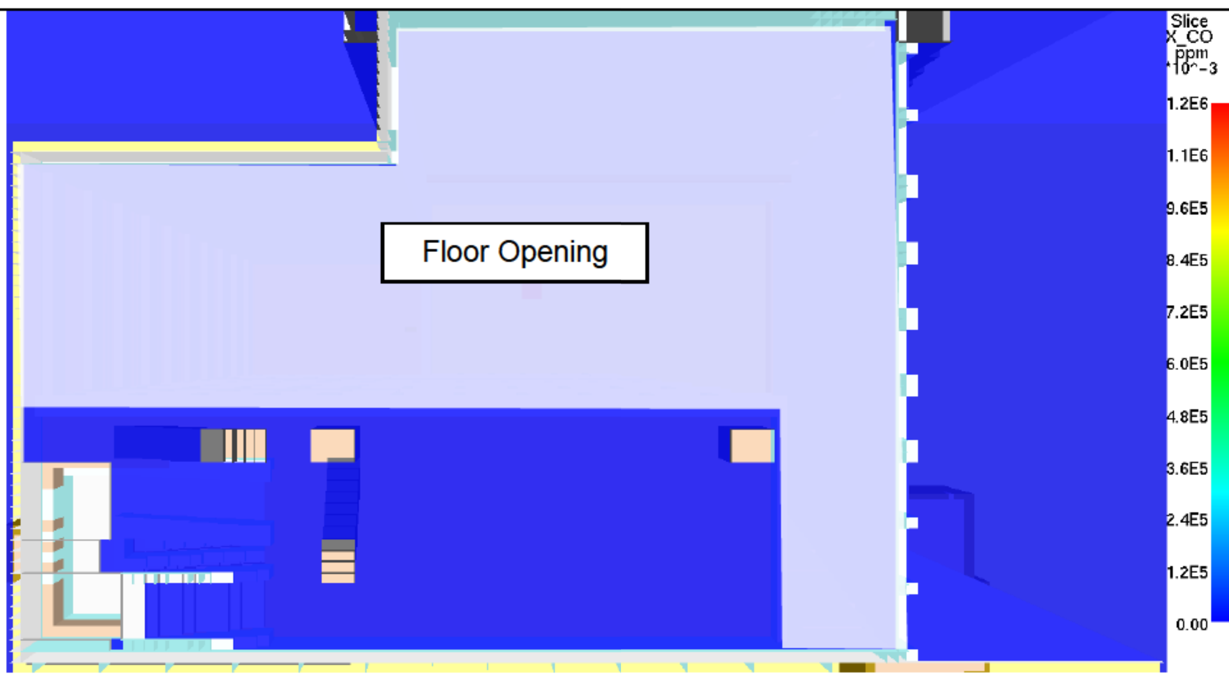

Figure 3b: 20:00

Figure 3: CO Concentration 6 Feet above Floor 17
Design Fire 1 Trash Can Fire under Floor Openings

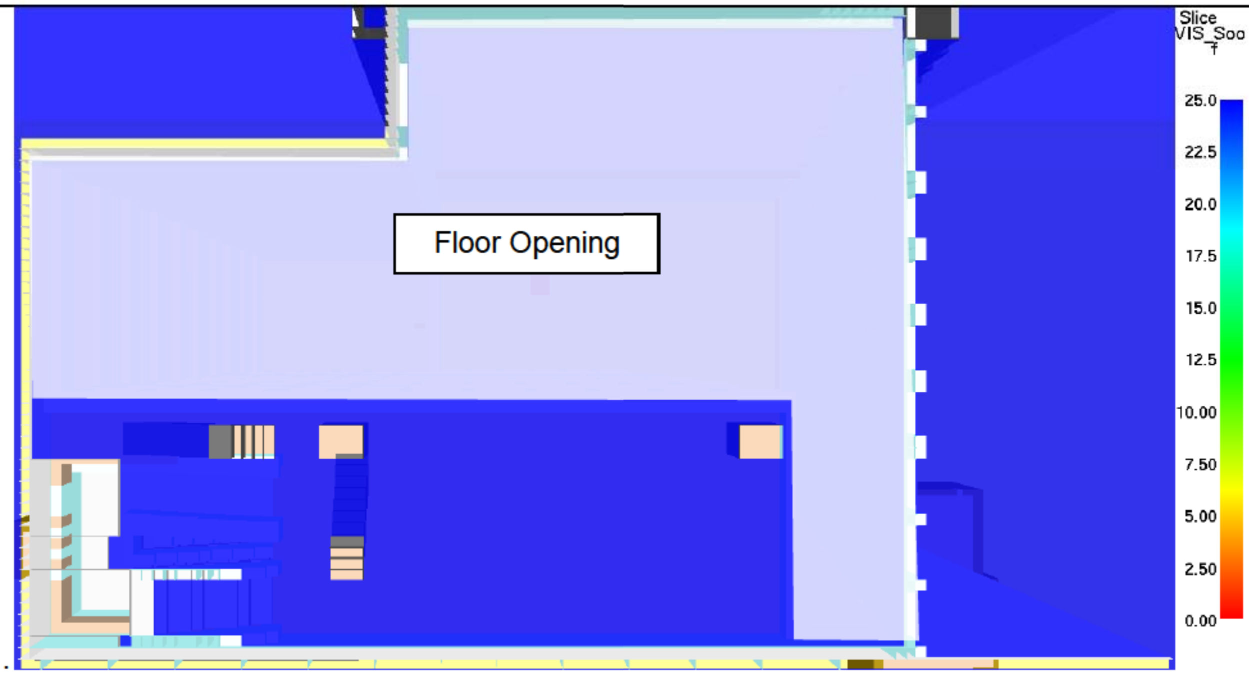

Figure 4a: Maximum Smoke Spread (14:00)

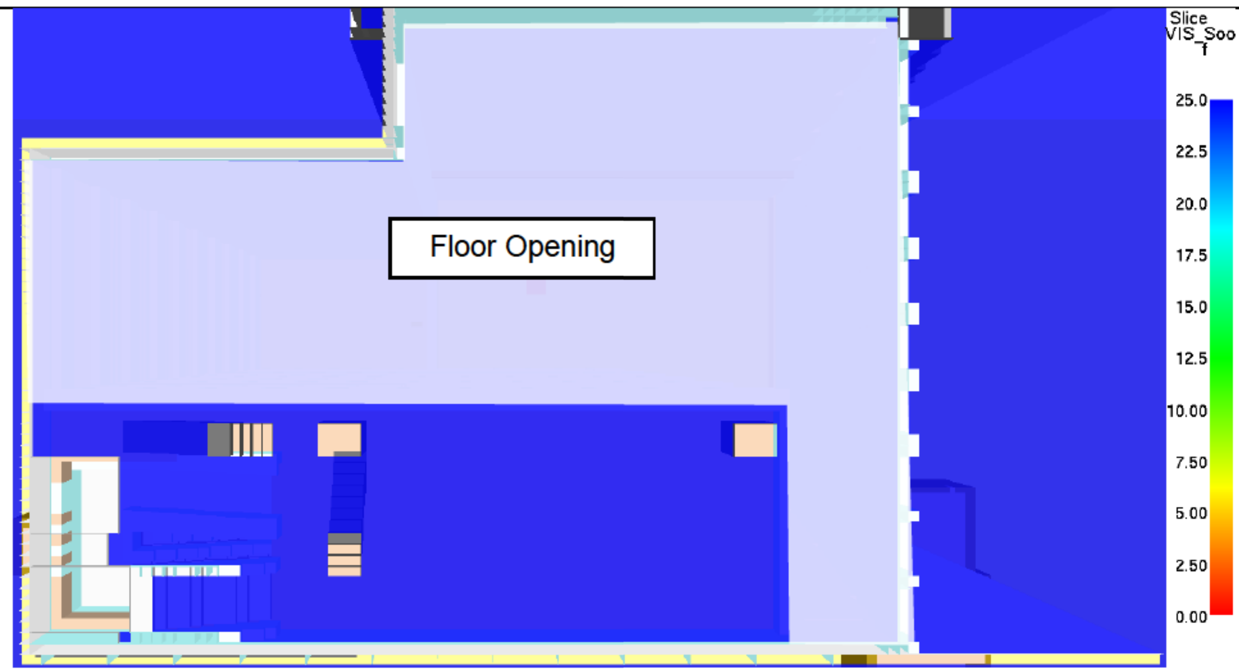

Figure 4b: 20:00

Figure 4: Visibility 6 Feet above Floor 17
Design Fire 1: Trash Can Fire under Floor Openings

Figures 2, 3, and 4 show that the smoke control system maintains tenable conditions in the atrium during this fire scenario. Carbon monoxide, visibility, and temperature levels all remain near ambient conditions.

Figure 5, below, shows the visibility in a vertical section through the atrium to evaluate the impact of smoke stratification.

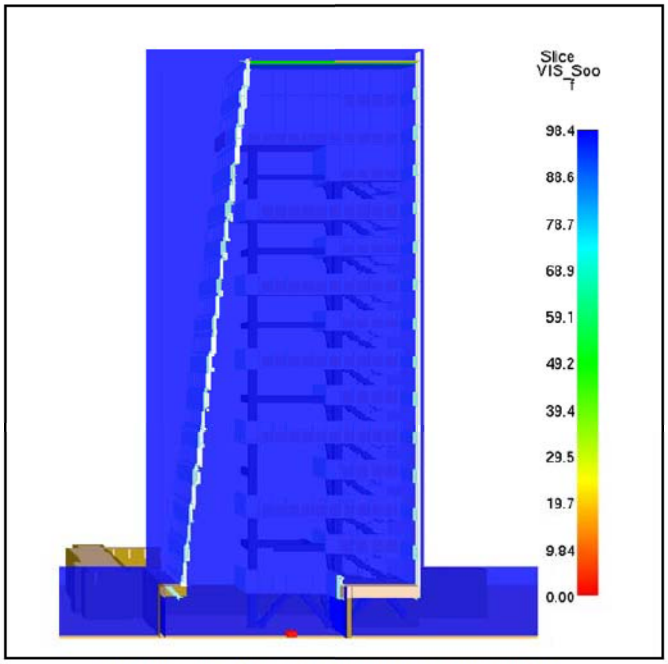

Figure 5: Visibility Section at 14:00
Design Fire 1: Trash Can Fire under Floor Openings

Figure 6, below, shows the temperature in a vertical section through the atrium.

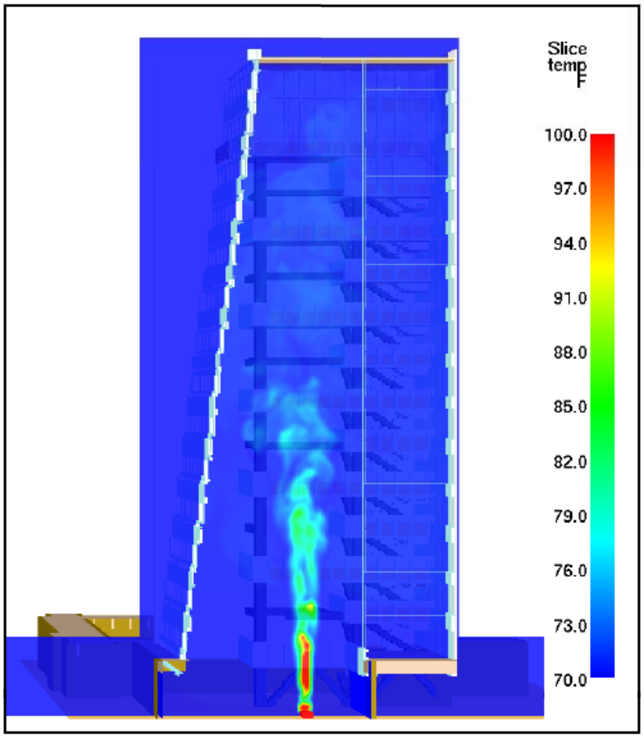

Figure 6: Temperature Section at 4:30
Design Fire 1: Trash Can Fire under Floor Openings

The results in Figures 5 and 6 show that smoke from the fire is diluted by the smoke control system and that airflow from the smoke control system eliminates stratification.

Based on the results presented above, the proposed smoke control system with an exhaust rate of 275,000 cfm is capable of maintaining tenable conditions for egress during this design fire condition.

B. Design Fire 2: Trash Can Fire on Floor 6 adjacent to Sloped Wall

In this fire scenario, the trash can fire is located on Floor 6 adjacent to the sloped wall. Figure 7, below, shows the heat release rate of this design fire.

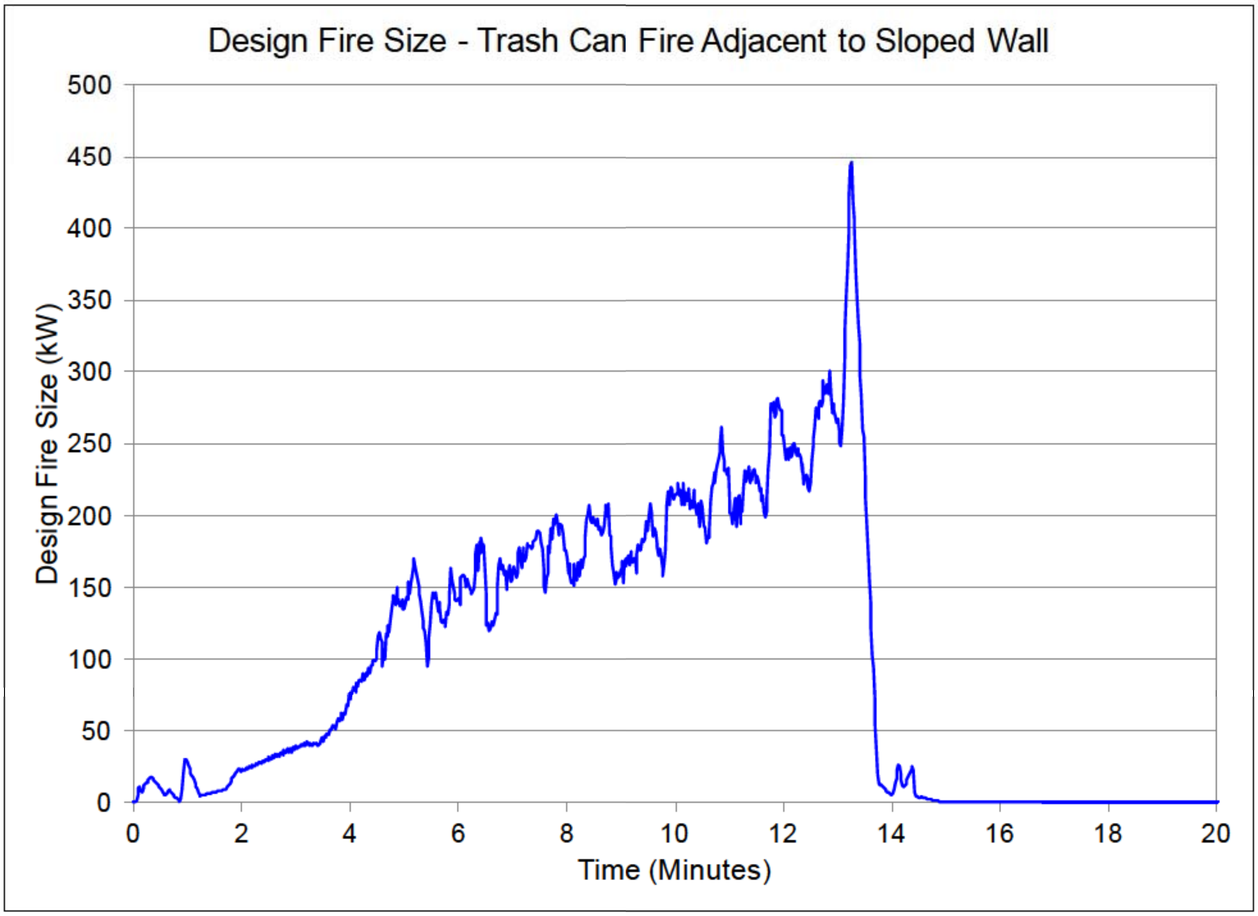

Figure 7: Size of the Trash Can Design Fire on Floor 6 Adjacent to Sloped Wall

During this fire scenario, the smoke control system with an exhaust rate of 275,000 cfm is activated by projected beam detector at the ceiling above Floor 20. The smoke detector is expected to activate 162 seconds after the start of the fire. The results of this scenario are summarized in the table below:

Life Safety Criteria	Maximum Value
Visible distance	Greater than 25 feet
Carbon monoxide concentration	3 ppm
Temperature	75°F

Figures 8, 9, and 10 show the temperature, carbon monoxide concentration, and visibility, respectively, at six feet above Floor 17. The snapshots are taken at the time of maximum smoke spread (14 minutes) and at 20 minutes.

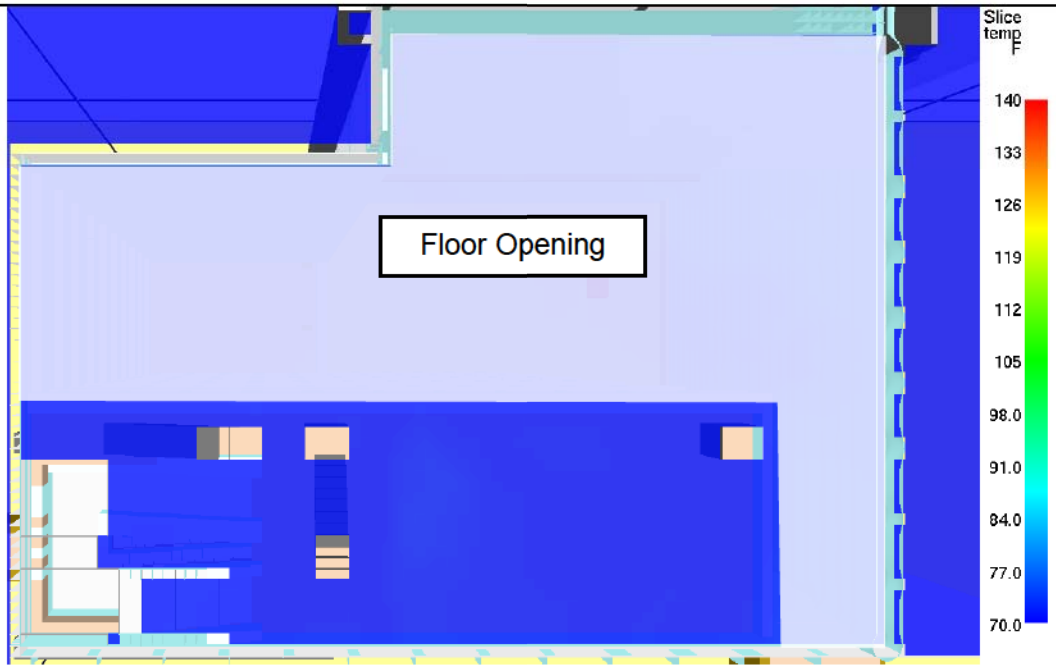

Figure 8a: Maximum Smoke Spread (14:00)

Figure 8b: 20:00

Figure 8: Temperature 6 Feet above Floor 17
Design Fire 2: Trash Can Fire adjacent to Sloped Wall

Figure 9a: Maximum Smoke Spread (14:00)

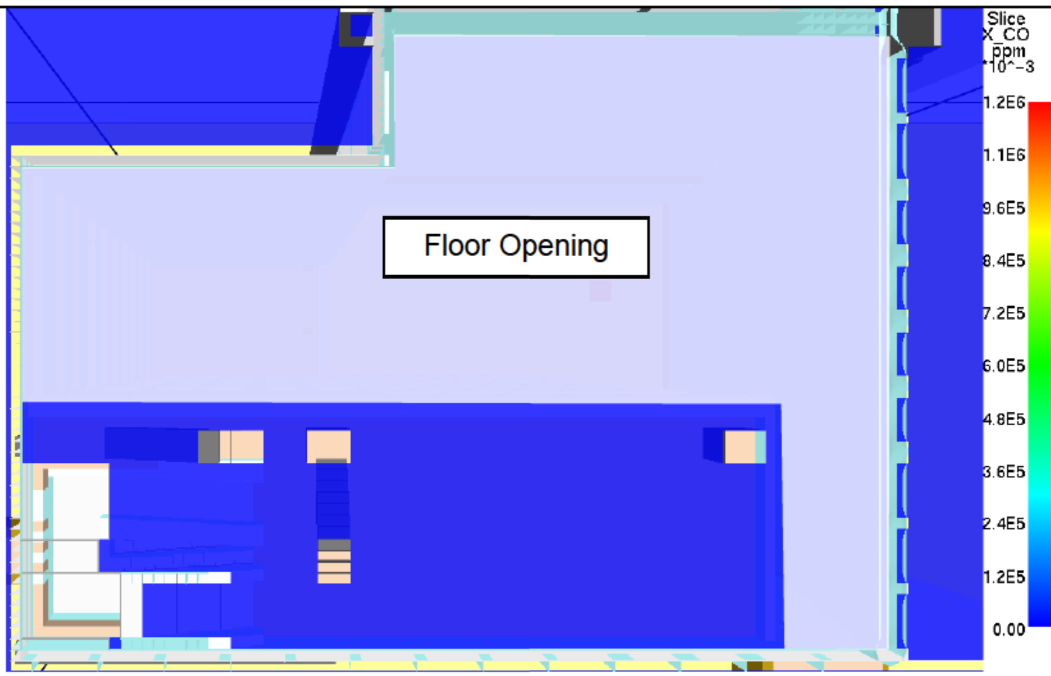

Figure 9b: 20:00

Figure 9: CO Concentration 6 Feet above Floor 17
Design Fire 2: Trash Can Fire adjacent to Sloped Wall

Figure 10a: Maximum Smoke Spread (14:00)

Figure 10b: 20:00

Figure 10: Visibility 6 Feet above Floor 17
Design Fire 2: Trash Can Fire adjacent to Sloped Wall

Figures 8, 9, and 10 show that the smoke control system maintains tenable conditions in the atrium during this fire scenario. Carbon monoxide, temperature and visibility levels remain near ambient conditions.

Figure 11, below, shows the visibility in a vertical section through the atrium to evaluate the impact of smoke stratification.

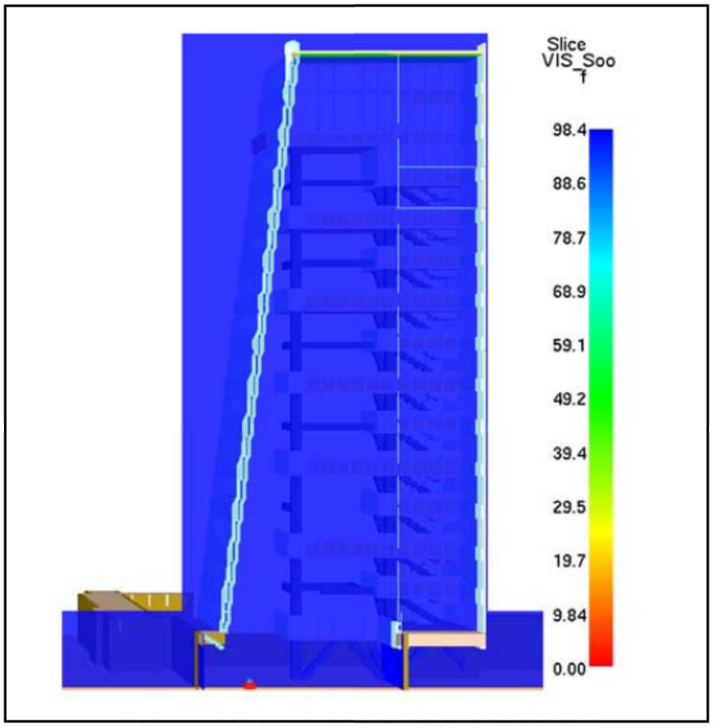

Figure 11: Visibility Section at 14:00
Design Fire 2: Trash Can Fire adjacent to Sloped Wall

Figure 12, below, shows the temperature in a vertical section through the atrium.

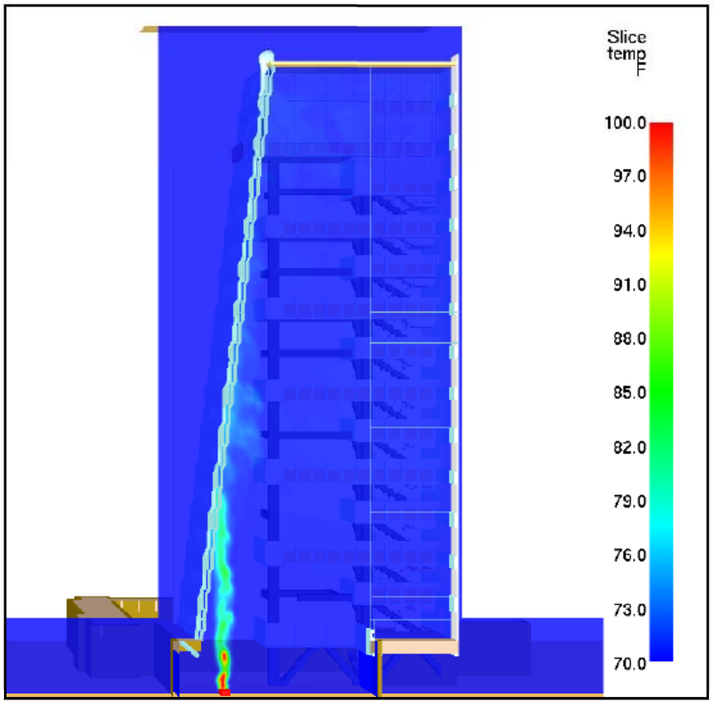

Figure 12: Temperature Section at 3:40
Design Fire 2: Trash Can Fire adjacent to Sloped Wall

The results in Figures 11 and 12 show that smoke from the fire is diluted by the smoke control system and that airflow from the smoke control system eliminates stratification.

Based on the results presented above, the proposed smoke control system with an exhaust rate of 275,000 cfm is capable of maintaining tenable conditions for egress this design fire condition.

C. Summary

The results of the analysis show that the proposed smoke control system design will provide the following fire protection and life safety benefits:

- Maintains temperature below 75°F at 6 feet above the highest walking surface open to the atrium.
- Maintains the carbon monoxide concentration near ambient conditions at 6 feet above the highest walking surface open to the atrium.
- Maintains visibility of more than 25 feet at 6 feet above the highest walking surface open to the atrium.

- Exhausts smoke and other fire gases from the building to allow for safe egress through the atrium during a fire condition.

Section IV

IV. Summary

The new Hudson Yards Tower C building will include an atrium that connects Floor 6 through Floor 20 of the building. Mechanical smoke control will be provided for the atrium to meet the requirements of Section 404.1 of the NYCBC. The smoke control system has been designed using a Computational Fluid Dynamics (CFD) fire model to ensure that the complicated air and smoke flow patterns during a fire in the atrium are properly analyzed. Additional design fires have been analyzed in this report at the request of FDNY.

Based on the design fires specified in the Atrium Smoke Control Analysis report dated May 11, 2012, as well as in this Supplemental Analysis, the smoke control system will provide a tenable environment within the atrium as required by Section 909 of the NYCBC. The smoke control system has been designed to maintain tenable conditions for egress during a large fire condition involving padded furnishings, as well as during a small fire such as a trash can.

The results of the analysis demonstrate that tenable conditions will be maintained within the atrium using the proposed smoke control system. It is the professional opinion of Code Consultants Professional Engineers, P.C. that the smoke control concepts presented in this report will provide a level of fire protection and life safety that is equal to, if not superior to, that intended by the New York City Building and Fire Codes.

Appendix A

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
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REPORT OF TEST
FR 4018

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Heat Release Rate Tests of Plastic Trash Containers

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Abstract

Two experiments were conducted to characterize the potential hazard from ignition of nominal 136 L (30 gal) trash containers made from high-density polyethylene (HDPE) and loaded with cellulosic debris. Heat release rate was measured as a function of time from ignition using a furniture–scale oxygen consumption calorimeter. In addition, total heat flux was measured at a location approximately 1 m from the trash container centerline. The two trash containers were observed to burn in a different manner due to the way the containers melted. In the first test, the container opened up from the top down and had a peak heat release rate of approximately 300 kW. In the second case, the trash container melted and opened from the midpoint in the container down. This resulted in a container that tended to close up into itself instead of opening up and thus, yielded a peak heat release rate of approximately 150 kW. Heat release rate and heat flux time histories and photographs are presented for both experiments.

Key Words:
fire data; fire models; fire tests; heat release rate; heat flux

Introduction

Measurement of the rate at which a burning item releases heat is a critical parameter in fire protection engineering. The heat release rate can be used in the characterization of the hazard represented by a given fuel package. Heat release rate can provide information on fire size and fire growth rate. When used as input to a computer fire model, the heat release rate can be used to estimate available egress time and determine alarm and suppression system activation time. Heat flux measurements can be used to estimate potential for ignition of adjacent fuel items.

NIST has received requests from state fire marshals and representatives of the Bureau of Alcohol, Tobacco and Firearms (ATF) for estimates on the burning rate of a "typical 30 gallon, plastic trash can filled with construction debris". This report is limited to a single type of trash container with a single fuel load. One replicate experiment was conducted.

Experimental Configuration

The experiments were conducted under the furniture calorimeter hood in the NIST Large Fire Research Facility. This hood is square, 3 m by 3 m and slopes upward at a 45° angle to a 0.5 m diameter duct. During a fire test, data from various sensors is acquired using a computer-based data acquisition system. The fire test data is recorded for further data reduction and interpretation after the test. Data acquisition and reduction in the Large Fire Research Facility are accomplished using in-house developed computer software [1].

Using the principle of oxygen consumption, it is possible to calculate the heat release rate of burning materials when the products of combustion are collected in an exhaust hood. Parker [2, 3] presents several sets of equations for calculating heat release rate using oxygen consumption. The appropriateness of each set of equations depends on the combustion products being measured. A paper by Janssens [4] proposes a form of the equations for calculating heat release rate specifically for full-scale fire test applications.

Heat release rate is determined in the NIST Large Fire Research Facility using the equations [4] together with data obtained from instruments in the exhaust hood. The measured heat release rate for the furniture calorimeter in the heat release rate range of the experiments has been shown to be within 20 percent of the actual value [5]. Stroup, et al. [5] contains details concerning the calculation of heat release rate and its implementation in the Large Fire Research Facility.

Experiments

Two experiments were conducted to help characterize the potential hazard from ignition of nominal 136 L (30 gal) trash containers made from high density polyethylene (HDPE) and loaded with cellulosic debris. Each trash container was approximately 515 mm (20.25 in) in diameter and 700 mm (27.5 in) tall. The trash container alone had a mass of 3.6 kg (8 lbs). Each trash container had 10 kg (22 lbs) of debris "typical" of a construction site. The debris consisted of cut pieces of "2 X 4" lumber, sawdust, cardboard, paper, and cups, food wrappers and paper bags from a fast food restaurant. Similar sets of debris were prepared for each trash container. No further details of the fuel load were recorded. A photograph of a trash container loaded for testing is shown in Figure 1. Note the total heat flux gauge located at the back side of the container. The trash containers were placed on a 12 mm thick piece of gypsum board to protect the floor of the test facility.

Each experiment was conducted with the container centered under the exhaust hood. The total heat flux was measured with water-cooled Gardon type transducers. The total heat flux gauge was located 0.81 m above the floor with its face 1.07 m from the trash container centerline. Based on manufacturer's data, the standard uncertainty for the heat flux measurements is estimated at ±3 % [6].

An open flame was applied to the contents of the trash container using a propane torch. The trash was lit approximately half-way down the container and next to a side of the trash container. The torch was held in place for approximately 5 s. Once a small amount of debris was ignited, the torch was removed.

Results

The heat release rate curves obtained as a function of time from ignition for each of the two fire tests are shown in Figure 2. The heat release rate from Trash Container 1 grew to a maximum of approximately 300 kW prior to being suppressed at approximately 800 s. The final spike in heat release rate is due to the disturbance of the fire at the beginning of the suppression process.

The heat release rate from Trash Container 2 tracked the development of the fire in Trash Container 1 for the first three minutes after ignition. Then the heat release rates diverge with Trash Container 2 only reaching a peak of approximately 150 kW.

The total heat flux measurements for each test are given in Figure 3. The trends of the heat release rate curves are similar in the heat flux time histories of each test. Trash Container 1 has a peak heat flux of approximately 5 kW/m^2 while Trash Container 2 peaks at less than 2 kW/m^2.

Photographs of the fire development in Trash Container 1 are shown in Figures 4 through 9. The photographs show the fire growing from a small amount of trash burning in the container (Figure 4) to the fire involving the container (Figure 5). The container melts and opens up allowing more air to reach the fuel and increasing the fire size (Figure 6). The container continues to melt and burn (Figure 7) until the fuel package becomes a debris pile surrounded by a burning pool of molten plastic (Figure 8). Figure 9 shows the remains of the trash container and its contents after suppression at 800 s.

Figures 10 through 15 show photographs representing stages of the fire development for Trash Container 2. The photographs show the fire beginning in a manner similar to Trash Container 1 (Figure 10). Then a hole opens up in the side of Trash Container 2, near the point of ignition (Figure 11). This occurred with only a small portion of the debris burning. As a result, the burning near the opening intensified and caused burning debris to drop lower in the container, prior to a large amount of the debris igniting near the top of the trash can (Figure 12). From Figure 13, it can be seen that Trash Container 2 has closed in on itself, limiting air entrainment to the fuel inside the container and hence reducing the heat release rate. The trash container slowly melts away exposing more fuel surface area to the air, however the flames never grow significantly larger (Figure 14). The last photograph (Figure 15) shows the remains of Trash Container 2 burning just prior to being extinguished just after 900 s.

Summary

The two trash containers were observed to burn in a different manner due to the way the containers melted. In the first test, the container opened up from the top down and had a peak heat release rate of approximately 300 kW. In the second test, the trash container melted and opened from the midpoint in the container down. This resulted in a container that tended to close into itself instead of open up and yielded a peak heat release rate of approximately 150 kW.

While these two experiments provide some insight into the heat release rate and heat flux from the trash containers and debris described above, fire development is dependent on many factors, including: material (fuel) properties, material geometry, containment and ventilation to name a few. In these experiments, a change in how the container melted resulted in a significant difference in heat release rate.

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Figure 1. Loaded Trash Container prior to ignition.

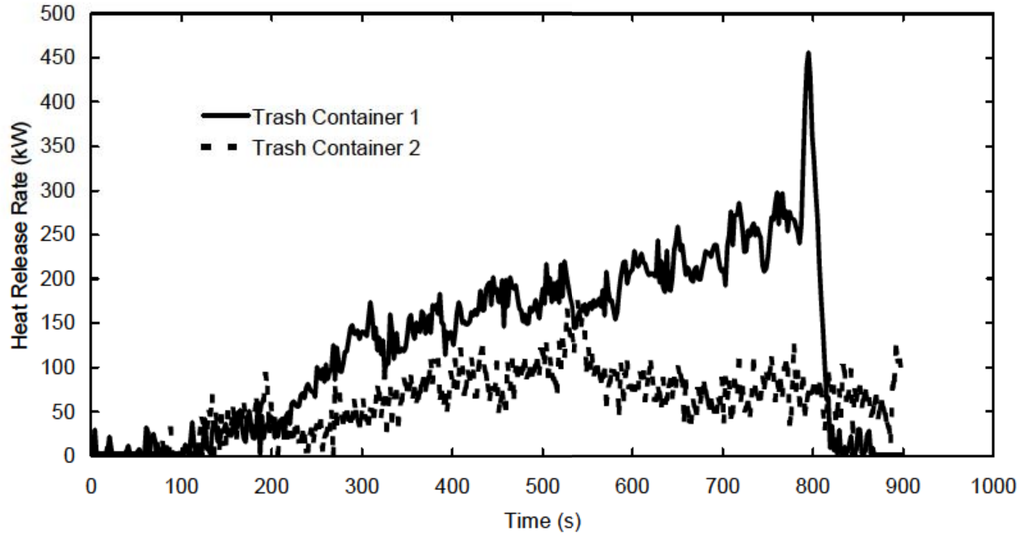

Figure 2. Graph of Heat Release Rate versus Time for Trash Containers 1 and 2.

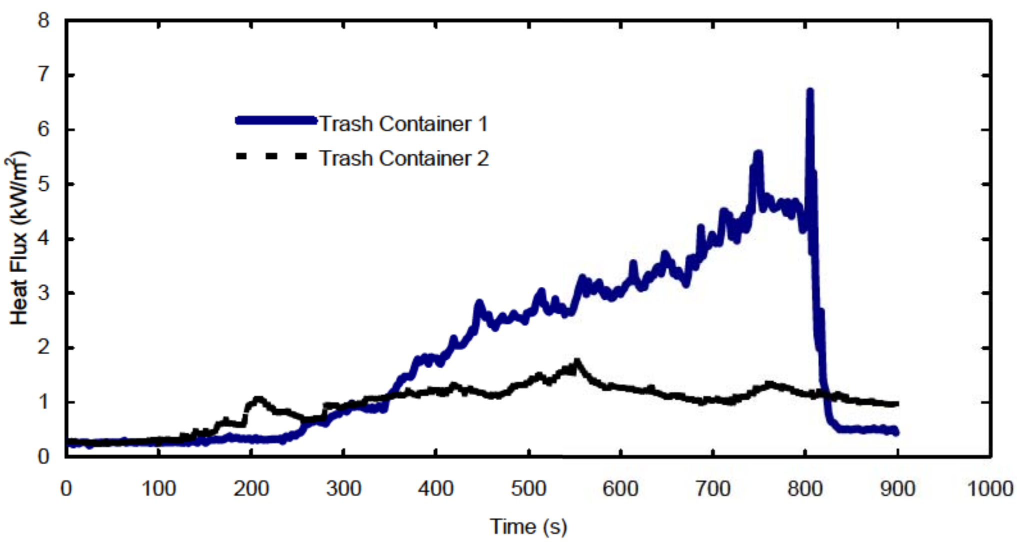

Figure 3. Graph of Total Heat Flux versus Time for Trash Containers 1 and 2.

Figure 4. Fire developing in Trash Container 1.

Figure 5. Trash Container 1 melting and allowing more ventilation for the burning fuel it contains.

Figure 6. Fire continues to grow in Trash Container 1.

Figure 7. Upper portion of container melts and collapses.

Figure 8. Molten plastic burning around debris pile.

Figure 9. Remains of Trash Container 1 after test.

Figure 10. Trash Container 2 just after ignition.

Figure 11. A hole opens in the side of Trash Container 2 near the point of ignition.

Figure 12. Fire continues to develop in the lower portion of container.

Figure 13. Trash Container 2 collapses in on itself, obstructing ventilation and limiting fire growth.

Figure 14. Trash Container 2 melts and opens exposing burning debris pile.

Figure 15. Remains of Trash Container 2 just prior to suppression at 900 s.