MINNESOTA MULTI-PURPOSE STADIUM
MINNEAPOLIS, MINNESOTA

BUILDING CODE NARRATIVE
100% Construction Documents (2014-05-02)

FSC, INC.
9225 Indian Creek Parkway
Overland Park, KS 66210
913.722.3473

Author: Ali Alaman, P.E. aalaman@fsc-inc.com

Jerry Bachar, C.B.O. jbachar@fsc-inc.com

Michael Koop, P.E. mkoop@fsc-inc.com

Jasmine Kaplan. C.P.E. jbrand@fsc-inc.com

SUMMARY

This narrative documents the applicable Building Code requirements and alternate design approaches.

Table of Contents

1. Authorities Having Jurisdiction:

- The City of Minneapolis, Minnesota (all disciplines except electrical), and
- The State of Minnesota (electrical discipline)

2. Applicable Codes: (http://www.dli.mn.gov/PDF/sbc_dates.pdf)

The applicable codes are incorporated under the 2007 Minnesota State Building Code (an amended 2006 IBC). Please see Appendices A and B for all the codes adopted by the State.

The State Building Code (SBC) will be herein referred to unless noted otherwise.

Meeting Minutes
Please see Appendix C for minutes of meetings on May 1, 2013 and July 22, 2013.

3. Code Approaches

3.1 Occupancy Classifications

West doors are closed

- A-4: Arena - indoor sports viewing.

Other occupancies in the building include

- B: Administrative offices
- B: assembly rooms with less than 50 occupants (Section 303.1, Exceptions 1 and 3), i.e., individual suites
- M: Team Store
- A-2: Non game day banquets and receptions
- A-3: Non game day meeting and conferencing and lounges
- Note – Holding rooms for more than 5 people are classified as an I-3 occupancy; and as an R-3 if the occupant load is 5 or less.
- Daycare (for any age, by other than a relative and for less than 24 hours): I-4
- Incidental Use (section 508.2): storage, parking garage (includes Dock)

3.2 Allowable Height and Area

Mixed Use Approach	Nonseparated Mixed Use
Type of Construction	I-A
Allowable Height	Unlimited
Actual Height	Measured as the vertical distance between the average exterior grade to the average height of the highest roof
Allowable Number of Stories	Unlimited
Actual Number of stories	(see table below)
Allowable Area per story	Unlimited
Actual Area per story (largest footprint)	460,000 sf
Allowable Area Total building	Unlimited
Actual Area Total building	1,776,000 sf

Story as defined by the SBC	Name of story on plans
Basement	Event Level
Basement	Executive Suite Level
1	Lower Club Level
2	Main Concourse
3	Upper Club
4	Upper Suite
5	Upper Concourse
5 Mezzanine	Mechanical Mezzanine

3.3 High-Rise

When enclosed (an A-4 occupancy) the stadium is a high rise building (SBC Section 403). See Item 19 of this report.

<u>NOTE:</u> Per telephone conversation with the city on April 16, 2014, the Fire Department stated that the lowest level of fire department vehicle access will be considered the field.

3.4 Smoke Protected Assembly Seating- Specialized Egress Provisions

As defined by section 1002.1 of the SBC:

> **SMOKE-PROTECTED ASSEMBLY SEATING.** Seating served by *means of egress* that is not subject to smoke accumulation within or under a structure.

The table below shows which levels are smoke protected. Accordingly, the specialized egress provisions of section 1028.6.3 apply.

Smoke control by natural and mechanical ventilation are permitted by SBC 909.1 and NFPA 92B section 4.3.1.

Smoke Protected by Natural Ventilation – the space has openness that allows smoke to naturally ventilate into the large volume of the dome. In this fashion, smoke does not build down and impede the egress path.

Smoke Protected by Mechanical Ventilation - To address conditions where the size of a space may not be large enough to contain the smoke safely away from the occupants while they exit but is still an assembly related space where smoke protected exit factors are desired to be used, mechanical smoke control approaches have been recognized by the building code. These approaches usually involve mechanical extraction of smoke from the space.

Level	Smoke Protected / Not Smoke Protected
Field	Smoke Protected by Natural Ventilation
Southeast Field Vomitory and Truck Dock	Vomitory: Smoke Protected by Natural Ventilation Truck Dock: Smoke Protected by Mechanical Ventilation
Field Level Sideline Club	Smoke Protected by Mechanical Ventilation
Field Level South Major Loop Corridor	Smoke Protected by Mechanical Ventilation
Event Level Other Indoor	Not Smoke Protected
South Red Zone Lounges	Smoke Protected by Mechanical Ventilation
Executive Suites Lounge	Smoke Protected by Mechanical Ventilation
Lower Club Level North	Smoke Protected by Mechanical Ventilation
Lower Club Level South	Smoke Protected by Mechanical Ventilation
North Red Zone Lounge	Smoke Protected by Mechanical Ventilation
Main Concourse	Smoke Protected by Natural Ventilation. In addition, mechanical ventilation along sidelines
Lower Seating Bowl	Smoke Protected by Natural Ventilation
Upper Club Level – north	Smoke Protected
Upper Club Level – south	Smoke Protected
Upper Suite Level – north	Smoke Protected
Upper Suite Level - south	Not Smoke Protected
Upper Concourse	Smoke Protected by Natural Ventilation
Mechanical Mezzanine	Smoke Protected by Natural Ventilation
Upper Seating Bowl	Smoke Protected by Natural Ventilation

NOTE: Occupants in smoke-protected seating areas will be in a smoke-protected environment throughout their exit access path.

3.5 Mechanical Smoke Control (see also meeting minutes from 7-22-2013)

As a result of using the smoke protected provisions, natural ventilation and/or mechanical smoke control is required and will be provided in the affected areas.

Please refer to Appendix D - *Smoke Control Report.* Please also refer to the SP (Smoke-Protected) drawings which graphically show the areas listed in the table above.

Post-Fire Smoke Exhaust System: Required by natural or mechanical ventilation at a rate of 3 air changes per hour (SBC Section 913).

5.3.1 Make-up air Doors: The design utilizes exterior doors to provide make-up air for the mechanical smoke exhaust fans. The design intends for fans to activate based upon a signal that confirms said doors are no longer on the closed position. NFPA 92B does not address whether exhaust fans are to operate based upon confirmation of whether make-up air doors are confirmed as "not closed" or whether they are "fully open". FSC recommends the latter because it is better and safer for occupants for the smoke exhaust system to activate with a partially open door rather than not operate at all with a partially open door.

5.3.2 Testing without Smoke Bombs:
Section 909.18.8.1 of the State Building Code requires component testing.

Smoke bombs are not required by the State Building Code, the IBC nor NFPA 92B as per the following excerpts.

NFPA 92B

Smoke bomb tests do not provide the heat, buoyancy, and entrainment of a real fire and are not useful in evaluating the real performance of the system. A system designed in accordance with this document and capable of providing the intended smoke management might not pass smoke bomb tests. Conversely, it is possible for a system that is incapable of providing the intended smoke management to pass smoke bomb tests. Because of the impracticality of conducting real fire tests, the acceptance tests described in this document are directed to those aspects of smoke management systems that can be verified.

ICC Guide to Smoke Control in the 2006 IBC

Real smoke and artificial smoke must not be used for acceptance testing of smoke control systems with the exception of tracer testing. Artificial smoke can be produced by smoke bombs or other kinds of smoke generators, and it almost always lacks the buoyancy of smoke from the design fire. Smoke control systems do not perform as intended when subjected to such artificial smoke. Testing with smoke can only be realistic when the fire is the design fire, and this typically has unacceptable risks to life and property. If artificial smoke is heated to the temperature of the design smoke, the danger to life and property is the same as that from the design fire. Acceptance testing is required by Section 909.18 of the IBC which is discussed in this chapter.

3.6 Escalator Floor Openings

Escalators that are not part of the means of egress connect various levels.

North Side: Escalators connect the main concourse to the Upper Club level and will be regulated per SBC 707.2, Exception 2.1 (as such, they are regarded by the SBC as equivalent to shafts). Wall or an 18 inch draft curtain with closely spaces sprinklers are required at the floor opening. These floor openings are not regulated as atria.

South Side: The escalator from the Event Level to the Upper Club Level will be enclosed in a 2 hour shaft. Other escalator openings will utilize SBC 707.2, Exception 2.1. These floor openings are not regulated as atria.

East and West Sides: Escalators are open to the bowl volume and part of the A-5 occupancy.

3.7 Floor Joints

The floor joints at the slab perimeter and expansion joints will be 2-hour but 0-hour when located within 10 feet of a nearby floor opening (SBC 713.1).

3.8 Sprinkler System (Alternate Design Approach)

Sprinklers are required by Sections 903.2.1.4, 903.2.1.5, 403.2 and 1025.6.2.3. Sprinklers will be provided throughout with the following exemptions.

Sprinklers may be omitted at the roof of the stadium except within 50 feet of the upper bowl seating per city approval.

By following the above, the stadium is sprinklered where required and where effective and will be regulated as a sprinklered building in accordance with Section 903.1.1 of the SBC.

Standpipes
Required in all exit stairs (enclosed and unenclosed). Additional hose connections may be required by the Fire Department.

3.9 Fire Extinguisher Locations (Alternate Design Approach)

Due to tampering and vandalism issues, it is not desirable (and may not be safe) to provide fire extinguishers in public areas. Else, will be provided as required by the State Fire Code Section 906.1(1), Exception and in concessions, back-of-house and constantly attended spaces. Please see Part 20 of this report. This alternate has been approved by the city.

3.10 Fire Alarm System

The building will be provided with a manual fire alarm system as required by Section 907.2.1.

a. Positive Alarm Sequence (Investigation Delay): Positive alarm sequence (per NFPA 72 Section 6.9.4) for up to a 3 minute investigation delay may be utilized, if approved by the AHJ. This is approved by the city

b. Presignal Feature: Permitted by SBC Section 907.7 and NFPA-72 Section 6.8.1.2, if approved by the AHJ.

c. Required Smoke Detection: Elevator recall, duct detection.

d. Pull Stations: Due to tampering and vandalism issues, it is not desirable (and may not be safe) to provide pull stations in public areas. In addition, pull stations may be deleted (except at the Fire Alarm Panel) as permitted by Section 907.2.1, Exception, because the building is regulated as a sprinklered building. Submitted as an Alternate Design Approach.

3.11 Voice Alarm in the Bowl and Concourses (Alternate Design Approach)

Section 907.2.1.1 requires a voice communication system to transmit prerecorded and live messages to the spectators. **This issue is very important in large crowd safety. At issue is providing clear, intelligible and audible messages to the bowl and concourse occupants. The typical Fire Alarm Voice Communication speakers are not designed for large area coverage or to overcome high ambient crowd noise levels typical of sports venues.**

For this stadium it is proposed that the PA system will be interfaced with the fire alarm system. It will be provided with emergency power. Prerecorded and live (from the Fire Command Room) emergency voice messages can be transmitted.

The sound system will augment the voice evacuation system for the stadium. We would expect the sound system in the bowl to be the primary method for delivery an emergency message to the fans in the seating bowl. Additional speakers in the "back of house" can either be muted to allow the fire alarm devices to be used or the sound system speakers can be used to also deliver the emergency message.

While all of the sound system electronics are UL listed, the overall system does not comply with NFPA 72 requirements for fire alarm systems. Other municipalities and NFPA 101 *The Life Safety Code* (2012 ed., sections 12.3.4.3.6 and 9.6.3.9.2), have allowed the sound system to function in this manner, as long as the sound system is connected to an emergency power system. This alternate has been approved by the city.

3.12 Text Messages in the Bowl

Text messages (with back-up power) shall be provided where public address is utilized and in the same capacity; prerecorded or real time as specified in SBC Section 1108.2.6.2.

3.13 Code Approaches Based on Large Bowl Volume

Please see 3.35 of this report for a list of alternate design approaches some of which are based on the large bowl volume

3.14 Field Use (e.g., concert, Final Four, wrestling events, etc.)
The occupant load will be limited to 9,128 occupants.

a. Egress Scheme: Field occupants exit up the lower bowl aisles to exits on the Executive Suite level on the south side, the Lower Club level on the north side and up both end zone aisles to the Main Concourse. Portable egress stairs are needed for field occupants to access to the lower bowl aisles. Field occupants also egress via the southeast field vomitory to the 15 foot wide ramp. See 3.17(b).

b. Travel Distance: Actual travel distances are in the 450 foot range. Please see 3.35 of this report for a list of alternate design approaches.

c. Portable toilets are required when the field is occupied for a concert or similar event.

3.15 Elevator Lobbies or Hoistway Pressurization

As permitted by SBC section 707.14.1, exception 6, all hoistways will be pressurized in lieu of providing elevator lobbies.

3.16 Exit Stair and Ramp Enclosure Pressurization (Sections 403.13 and 909.20.5).

a. Exit stair and ramp enclosure pressurization is required where stairs or ramps serve levels more than 75 feet above the lowest level of fire department vehicular access. Per telephone conversation with the city on April 16, 2014, the Fire Department stated that the lowest level of fire department vehicle access will be considered the field. With the exception of Stair 10 which is open to the bowl, all stairs enclosures and (per same phone call with the city) the enclosed east ramp from the upper concourse to the main concourse will be pressurized.

b. Exit stair enclosure pressurization is required where stairs serve levels more than 30 feet below the level of exit discharge. For pedestrian ramp at dock, see 3.17.b.

c. <u>Scissor Stairs</u> Several of the stair enclosures are constructed as interlocking stairs (i.e., 2 intertwined stairs in one enclosure). These are permitted to be considered as one exit.

3.17 Ramp

a. See 3.16.a.

b. See 3.16.b. Below the main concourse the ramp is provided with a 2-hour separation. The ramp is used as an exit and is entered at the dock. The dock will be provided with a mechanical smoke exhaust system designed to keep the smoke layer above the header of the ramp opening. This is done so that smoke is prevented from entering into the egress ramp. Accordingly, the ramp will be a smoke proof enclosure meeting the intent of SBC 909.20.4 which is to prevent smoke from entering the enclosure. Per telephone conversation with the city on April 16, 2014, the city stated that the ramp will be required to be pressurized per SBC section 909.20.4.4.

3.18 Pedestrian Walkway

<u>Separation</u>
One of the options below will be selected regarding the separation requirements for Pedestrian Walkways in Section 3104.5

The pedestrian walkway and connected garage are sprinklered. A glass separation protected by sprinklers is permitted in accordance with Section 3104.5, Exception 1..

Travel distance within the walkway is limited as follows:

- Without sprinkler protection in the walkway = 200 feet
- With sprinkler protection in the walkway = 250 feet

3.19 Main Exit

Provided on the Main Concourse. Multiple main exits are provided on other levels (Section 1025.3, Exception).

3.20 Barrier at Egress Ramp and Stairs

Where stairs and ramps continue down through the building past the level of exit discharge, an approved barrier is required in compliance with Section 1020.1.5.

3.21 Lapendaries

Required to be class A or meet NFPA 701.

3.22 Exit Signs (see also meeting minutes from 7-22-2013)

Exit signs on bowl side of vomitories are not required (Section 1011.1, Exception 5).

However, the city is requiring the following (per denial --of travel distance alternate, dated 4/16/2014)

of the exit signs in the public areas. In public areas of the facility, where exit signs are required, use larger (New York City standard - 8" tall letters, 1" minimum stroke) exit signs.

3.23 Omission of Areas of Refuge (Alternate Design Approach)

The State Building Code (section 1007.3 and 1007.4) prescribes areas of refuge as components of the accessible means of egress system for the disabled.

Per approved alternate, areas of refuge are not required; however, 2-way communication at elevator lobbies is required.

3.24 Pyrotechnics

In accordance with NFPA 101, *The Life Safety Code*, use of pyrotechnics in indoor facilities is permitted by obtaining a special permit from the AHJ and required to meet NFPA 1126.

In accordance with NFPA 101, *The Life Safety Code,* Section 12.7.3 reproduced below.

12.7.3 Open Flame Devices and Pyrotechnics. No open flame devices or pyrotechnic devices shall be used in any assembly occupancy, unless otherwise permitted by the following:

(1) Pyrotechnic special effect devices shall be permitted to be used on stages before proximate audiences for ceremonial or religious purposes, as part of a demonstration in exhibits, or as part of a performance, provided that both of the following criteria are met:

(a) Precautions satisfactory to the authority having jurisdiction are taken to prevent ignition of any combustible material.

(b) Use of the pyrotechnic device complies with NFPA 1126, *Standard for the Use of Pyrotechnics Before a Proximate Audience.*

3.25 Storage of Hazardous Materials

There will be no indoor fueling. There will be no indoor storage of fertilizer. Any control areas will be constructed of 1-hour fire barrier walls with a 45 minute door, and a 1-hour ceiling. Placards in accordance with NFPA 704 will be used.

3.26 Grandstands (Alternate Design Approach)

The grandstand tiered seating will be constructed of precast concrete two- or three-row planks. The SBC does not specifically regulate grandstands whereas NFPA-101, *The Life Safety Code,* does. Consistent with the Life Safety Code requirements (Table 12.1.6, footnote 'e'), the design provides precast concrete planks thick enough to yield a one hour fire rating with non fire rated joints. The structural frame (i.e., the primary columns and girders) will be 3 hour fire resistive. Please see 3.35 of this report for a list of alternate design approaches. This alternate has been approved.

3.27 Omission of fire resistance of roof trusses above the highest row or two (Alternate Design Approach)

SBC Table 602 footnote 'c' permits the omission of fire proofing when roof structural members are located 20 feet or more above the floor below. Else 1.5 hour fire proofing is required. There are 2 locations where the roof trusses are within 16 to 20 feet of the highest row or two. Fire proofing is not being provided above the highest two rows due to the limited amount of combustibles and the low temperatures they yield. Please see 3.35 of this report for a list of alternate design approaches. This alternate has been approved.

3.28 Omission of fire proofing at specific perimeter steel columns (Alternate Design Approach)

SBC Table 601 prescribes a 3 hour fire resistance rating for columns. A number of columns have been accepted by the city as being fire proofed up to 20 feet only, then no fire proofing up to the Upper Concourse. The city also accepted the west columns which are 30 inches round and concrete filled as well as north and south columns within vestibules which may remain non fire proofed.

3.29 Roof material (ETFE)

a. Hard deck on North roof.
b. ETFE on the South roof (ETFE is the acronym for Ethylene-Tetrafluoro Ethylene) Copolymer, which is a fluorocarbon based material. It's a durable, adaptable and transparent plastic related to Teflon). Used at the following facilities:
   - Basel Stadium, Switzerland, 2001
   - Art Center College of Design, South Campus, Pasadena, CA, 2004
   - Allianz-Arena, Munich, Germany, 2005
   - Duisberg Meiderich Theater, Germany, 2005
   - Beijing Natinal Aquatics Center, China, 2007
   - Beijing National Stadium, China, 2007
   - LeMay Museum, Tacoma, WA, 2009
   - Earthpark, Pella, IA, 2010
c. **Permitted by SBC section 2609.4 for up to 60% (proposed 42%) of the roof area in a sprinklered building.**

The cut sheet states **"The presence of fluorine makes this material self-extinguishing".**

Test	Classification	Notes
ASTM D 1929 (MSBC section 2606.4)	Self ignition temperature of 914°F (650°F or higher required)	
ASTM D 635 (MSBC section 2606.4)	CC1 burning extent of 1 inch or less	Specimen is horizontal. Flame applied for 30 seconds
NFPA 701	Pass	Specimen is vertical. Flame applied for 40 seconds
ASTM E 84 (MSBC section 2606.4)	Smoke Developed Index is 115 (450 or less required)	Specimen is horizontal. Flame applied for 600 seconds
ASTM E 84 (MSBC section 2606.4)	Flame Spread Index is 5 (no prescribed minimum)	Specimen is horizontal. Flame applied for 600 seconds

3.30 Fire Command Center

A fire command center in accordance with Section 911 is required. Please see part 19 of this report for room requirements.

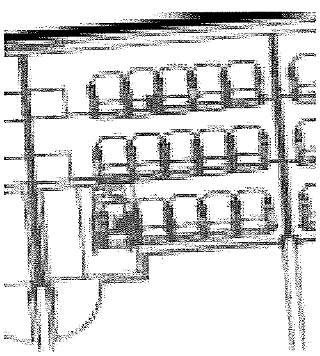
3.31 Elevators (Alternate Design Approach)

Alternate Means of Suspension.
Unlike Europe and much of the US, the State of Minnesota has not yet approved the use of anything else except ropes for hoisting (as opposed to belts which are used in many of the modern systems recently designed). System designs have moved on leaps and bounds. Per conversation with the Lead Inspector for the City, Mr. Bill Renke and the Elevator Advisory Group (consultant on this project), a couple of months ago, Mr. Renke expressed a willingness to review and was confident that any of the city's concerns would be addressed. Although there is currently a system being installed in the City this issue is being addressed on a case-by-case basis. This alternate has been approved.

3.32 Drinking Fountains (Alternate Design Approach)

Drinking fountains are required by SBC chapter 29 at the rate of 1 per 1,000 occupants. Accordingly 65 are required. A minimum of 50% of the required number is to be provided.

3.33 Stepped Aisles in Suites (Alternate Design Approach)



The diagram to the right shows the outdoor portion of a typical suite. The two front rows exit via a 23 inch wide stepped aisle.

Although SBC section 1025.9.1(2) prescribes a 36 inch wide stepped aisle we feel this design meets the intent of the code because of the very low population served.

As a point of comparison, a 48 inch wide aisle can serve up to 800 occupants. In other words, each half being 23 inches, can serve up to 400 occupants. In this instance, the 23 inch aisle serves 10 to 12 occupants. Accordingly, it is well within the egress time envisioned by the code. This alternate has been approved.

3.34 Fire Protection of Super Truss by Sprinklers (Alternate Design Approach)

The 4 inclined columns are to be protected by a deluge system up to 30 feet above the Upper Concourse. Please refer to the submitted Alternate Design Approach. This alternate has been approved.

3.35 List of Alternate Design Approaches (BELOW IS A SUMMARY. PLEASE REFER TO ACTUAL APPROVAL DOCUMENTATION)

	Alternate Design Approaches	FIS: Minneapolis Fire Inspection Services CCS: Minneapolis Construction Code Services	
		Written Response Date	**Status**
1	Omission of bowl sprinklers above the field and seats	2-12-2014 by CCS	Approved with conditions. Please refer to actual approval documentation.
2	Omission of fire extinguishers in public areas	10-9-2013 by FIS	Approved
3	Use of the PA system for fire alarm purposes in the bowl and concourses	2-12-2014 by CCS	Approved
4	Omission of Areas of refuge		Approved
5	Omission of fire resistance of roof trusses above the highest row or two	11-06-2013 By CCS	Approved
6	Omission of fire proofing at specific perimeter steel columns	1-29-2014 by CCS	Approved with conditions. Please refer to actual approval documentation.
7	Elevators: Means of suspension	10-25-2013 by CCS	Approved
8	Drinking Fountains (free water cups will be given at the concession stands)	10-25-2013 by CCS	50% reduction in required number of drinking fountains is acceptable
9	Stepped aisle width within suites' tiered seating	10-25-2013 by CCS	Approved
10	Fire Rating of Grandstands	11-13-2013 by CCS	Approved
11	Fire Protection of Super Truss by Sprinklers	2-12-2014 by CCS	Approved with conditions. Please refer to actual approval documentation.
12	Ramp from Event Level to discharge as smoke proof enclosure	3-14-2014 by CCS (denied)	Ramp required to be pressurized per SBC section 909.20.4.4, per telephone conversation with the city on April 16, 2014.
13	Dead-Ends at escalator landings	2-19-2014 by CCS	Approved
14	Overhead doors in the means of egress	3-14-2014 by CCS	Approved
15	Glass guards without a top rail	2-7-2014 by CCS	Approved
16	Travel Distances		
17	Measure Travel Distance Once Inside	4-16-2014 by CCS	Denied
18	Horizontal Exit on Event Level	3-14-2014 by CCS	Approved
19	Stair 10 and Ramp from Upper Concourse to Main Concourse		Stair 10 okay as open per meeting with the city on 1-25-2014. Ramp enclosed and alternate withdrawn. Ramp to be pressurized per telephone conversation with the city on April 16, 2014. The Fire Department stated that the lowest level of fire department vehicle access will be considered the field.

4. Construction Materials:

Construction materials:

1. Walls, Floors and Structural Elements: Noncombustible (Section 602.2).

Use of Wood

2. Wood boards (e.g., plywood, OSB, etc.): Plywood on Interior Metal Studs: Permitted. Required to be fire-retardant-treated. (Section 603.1, #1).

3. Plywood within roof assemblies: Permitted in roof construction over 20 feet above upper floor. Required to be fire retardant treated (Section 603.1, #1.3).

4. Exterior wall Sheathing (Section 602.2 & 603.1): Noncombustible (or fire retardant treated, etc.)

5. 2x Blocking (Section 603.1, #11): Permitted. Not required to be fire-retardant-treated.

Rigid or Sprayed Insulation and Exterior Wall Plastic Facings

6. Rigid or sprayed Insulation (Section 603.1, #3): Required to be separated from the interior space by a directly applied thermal barrier of 15 minutes (or ½" gypsum board).

7. Exterior wall - rigid or sprayed insulation and, facings and coatings (Section 2603.5)
   a. Rigid or sprayed insulation and, facings and coatings to have a flame spread index of 25 or less and a smoke developed rating of 450 or less.
   b. The exterior wall assembly is required to be tested per (and pass) NFPA 285.
   c. The exterior wall assembly is required to be tested per (and pass) NFPA 268 (exterior wall burning due to exterior fire source). This is not required if there is ½" drywall, brick, stone, concrete or 1" stucco, on the outside of the exterior wall.

8. Roofing – rigid or sprayed insulation installed above the roof deck (i.e., as part of the roof covering), (Section 2603.6)
   a. With a thermal barrier -- The roof-covering assembly is tested per ASTM E108 or UL 790 as a class A, B or C roof covering assembly.
   b. Without a thermal barrier -- The roof-covering assembly is tested per FM 4450 or UL 1256 as a class A, B or C roof covering assembly.

Concealed Spaces with Combustible Construction

9. Concealed Cavities - Sprinklers required in the concealed space unless one of the following applies or is implemented:
   a. The insulation is protected by a directly-applied thermal barrier of 15 minutes (or ½" gypsum board). Or,
   b. If the rigid or sprayed insulation material has a heat content (potential heat) of not more than 1,000 Btu/ft^2 (NFPA-13 Section 8.15.1.2.12 – 2007 edition and all editions since 2000). Or,
   c. If the rigid or sprayed insulation material has a flame spread index of 25 or less not propagating flame for more than 10.5 feet (per ASTM E84 extended for an additional 20 minutes), (NFPA-13 Section 8.15.1.2.10 – 2007 edition and all editions since 2000). Or,
   d. If the rigid or sprayed insulation material meets the definition of "limited combustible" material i.e., it has a flame spread index of 25 or less and a heat potential or not more than 3,500 Btu/pound per NFPA 259, (NFPA-13 Section 8.15.1.2.2 – 2007 edition and all editions since 2000).

5. Passive Fire Resistive Requirements:

Elements	Required Fire Resistance
Structural Frame	3 hour (Table 601)
Floors	2 hour (Table 601)
Seating Platforms	1 hour with non fire rated joints (See Item 3.19 of this report)
Roof	1.5 hour or 0 hour when more than 20 feet above any floor below (Table 601)
Stair Enclosures & Exit Passageways	2 hour. Required for all levels. (Section 1020.1)
Elevator Hoistway	2 hour with 90 minute doors and fire dampers (Section 707.4)
Elevator Machine Room	2 hour with 90 minute doors and fire dampers (Section 3006.4)
Elevator Lobbies	Required on non-smoke protected levels high rise…(See Item 3.12 of this report)
Shafts	2 hour (Section 707.4)
Permanent Partitions	0 hour (Table 601)
Corridors	0 hour (Table 1017.1)
Laundry and Trash Rooms > 100 ft^2 & Boiler Room	1 hour (walls & ceiling or continue to deck above) with 45 minute doors and fire dampers (Table 508.2)
Occupancy Separations	Not required (See Item 3.2 of this report)
Fire Pump Room	If provided - 2 hour enclosure (walls & ceiling) with 90 minute doors and fire dampers recommended (required by 2009 IBC Table 508.2.5 for highrise buildings)
Transformer Room	If provided - 1 hour enclosure with structural elements within the room protected to maintain 1 hour unless dry type transformer with class 155 or better insulation
Emergency Generator	2 hour enclosure (walls & ceiling) with 90 minute doors and fire dampers and directly ventilated to the exterior
Transfer Switch Rooms	Separated from normal power and housed in 1 hour enclosures with 45 minute doors and fire dampers (Section 909.11) and directly ventilated to the exterior
Electrical Rooms	1 hour if housing any of the following: FA equipment, 122.5 kVA dry type transformer, 75 kVA oil type (NEC Article 450)
Parking Garage	1 hour separation
Fire Command Room	1 hour with 45 minute doors and fire dampers (Section 911.1)
Penetrations at rated walls	F rating = rating of the wall penetrated (Section 712.3.1.2) T rating = 0
Penetrations at Floors & ceilings	F rating = rating of the wall or floor penetrated T rating = rating of the floor penetrated; however, T rating = 0 if in the cavity of a wall (Section 712.4.1.1.2 and Exception)

6. Exiting:

Occupant Load Factors	(Table 1004.1.1)
Seating Bowl **Suites** Office Kitchen Mechanical Storage Retail Locker room Exercise room Press Box	Number of fixed seats **Number of seats (fixed seats and bar stools) plus 50%** 100 ft^2/person 200 ft^2/person 300 ft^2/person 300 ft^2/person 30 ft^2/person 50 ft^2/person 50 ft^2/person Length of counter at 24 inches per person
Required No. of Exits	(Sections 1015 and 1019)
1	The occupant load is 49 or less AND the common path of travel is not exceeded, else 2 exit paths are required
2	1 – 500 occupants
3	501 – 1,000 occupants
4	More than 1,000 occupants
Required Exit Separation	One-third the diagonal (Section 1015.2.1)
Common Path of Travel	Smoke Protected Assembly occupancy = 50 feet Non Smoke Protected Assembly occupancy = 20 feet Non Smoke Protected Business occupancy = 100 ft
Panic Hardware	Required but not at exterior gates when they are under the immediate supervision of staff while the building is occupied (Section 1008.2.1)
Exit Signs	Required (Section 1011.1) Not Required on the bowl side of vomitories (Section 1011.1, Exception 5)
Egress Illumination	Normal Power Required throughout the building including exit discharge to the public way when the building is occupied. Permitted to be 0.2 foot-candle during performances (Section 1006.2) if connected to the fire alarm system.
Egress Illumination	Emergency Power Required when 2 means of egress are required plus immediately adjacent to exterior exit doors (Section 1006.3)
Accessible Means of Egress	One elevator in each bank on emergency power (Section 1007.2.1)

7. Number of Seats per Row (Section 1025.10)

Row Width Available for Egress	**Maximum Permitted Number of Seats (Access to aisles at both ends of row)**	**Maximum Permitted Number of eats (Access to aisle at one end of row)**
12 inches	19 Seating Positions	9 Seating Positions
12.6 inches	21 Seating Positions	10 Seating Positions
13.2 inches	23 Seating Positions	11 Seating Positions
13.8 inches	25 Seating Positions	12 Seating Positions
14.4 inches	27 Seating Positions	13 Seating Positions
15 inches	29 Seating Positions	14 Seating Positions
15.6 inches	31 Seating Positions	15 Seating Positions
16.2 inches	33 Seating Positions	16 Seating Positions
16.8 inches	35 Seating Positions	17 Seating Positions
17.4 inches	37 Seating Positions	18 Seating Positions
18 inches	39 Seating Positions	19 Seating Positions
18.6 inches	41 Seating Positions	20 Seating Positions
19.2 inches	43 Seating Positions	21 Seating Positions
19.8 inches	45 Seating Positions	22 Seating Positions
20.4 inches	47 Seating Positions	23 Seating Positions
20.8 inches	49 Seating Positions	24 Seating Positions
21.2 inches	51 Seating Positions	25 Seating Positions
21.8 inches	53 Seating Positions	26 Seating Positions
22 inches	54 to 100 Seating Positions	27 to 40 Seating Positions

8. Minimum Stepped Aisle Widths (Section 1025.9.1)

Serving rows on both sides	**Serving rows on one side**
48 inches 36 inches < 50 people	36 inches

9. Aisle Steps (Section 1025.11)

Element	Dimensions	Dimensional Uniformity	Tolerance between adjacent steps
Treads	11 inches minimum	Uniform	3/16 inch maximum
Risers	4 inches min. 9 inches max.	Non-uniformity permitted in order to coincide with the bowl	3/16 inch or less: provide *contrasting* stripe on nosing or leading edge (Section 1025.11.3) greater than 3/16 inch: provide *distinctive* stripe different from (and in addition to) the *contrasting* stripe. The distinctive stipe is required to be a minimum of 1 inch and a maximum of 2 inches at the nosing or leading edge of the non uniform risers (Section 1025.11.2, Exception 1)

10. Dead Ends

Row (Section 1025.8, Exception 2)	Stepped Aisle (Section 1025.9.5, Exception 4)
50 feet common path of travel	Beyond 21 rows the row width beyond is required to be **12 inches plus 0.3 inches per seat for each seat beyond 7 for a maximum of 40 seats.**

11. Exit Width Factors (Sections 1025.6.3 and 1025.6.1)

Smoke protected exit factors are based upon an arena population of 18,000 occupants.

Egress Element	Smoke-Protected Width Factor (bowl and spaces open to the bowl)	Non Smoke-Protected Width Factor for Assembly Occupancies (enclosed clubs, lounges and conference rooms)
Aisle Steps and Stairs	0.060inches per person	0.3 inches per person
Doors and Ramps < 1:10	0.044 inches per person	0.2 inches per person

12. **Egress Capacities serving smoke-protected areas (Section 1025.6.3)**
Bowl and concourses are smoke-protected.

Stepped Aisles:

36 inch wide stepped aisle	48 inch wide stepped aisle
600 persons	800 persons

Stairs:

4 foot wide stepped aisle	5 foot wide stair	9 foot wide stair	10 foot wide stair	11 foot wide stair
800 persons	1,000 persons	1,800 persons	2,000 persons	2,200 persons

Level Surfaces & Ramps:

36 inch wide	42 inch wide	5 foot wide	6 foot wide	15 foot wide
818 persons	954 persons	1,363 persons	1,636 persons	4,090 persons

13. **Egress Capacities serving non smoke-protected areas (Section 1025.6.1)**

Assembly Aisles & Stairs:

48 inch wide stair	60 inch wide stair	72 inch wide stair
160 persons	200 persons	240 persons

Assembly Doors:

36 inch single door	48 inch single door	Double doors 6 foot opening
165 persons	220 persons	340 persons

14. Travel Distances (Section 1025.7)

Smoke-protected Seat to Vomitory	**Smoke-protected bowl seat to exterior door or enclosed stair**	**Non smoke-protected spaces From any point to exterior door or enclosed stair (Assembly, Storage, Mercantile)**	**Non smoke-protected spaces From any point to exterior door or enclosed stair (Business)**
Unlimited	Unlimited	250 feet	300 feet

15. Guard Heights (Section 1025.14)

Behind the top row (30 inch or more drop)	**Sightline obstructed guards**	**At the bottom of aisles**
26 inches Balusters to prevent passage of a 4 inch sphere	26 inches Balusters to prevent passage of a 4 inch sphere	42 inches measured diagonally from the top rail and the nosing of the nearest tread. Below 26 inches: Balusters to prevent passage of a 4 inch sphere Above 26 inches: Balusters to prevent passage of an 8 inch sphere

16. Exiting Summary

Please refer to the LS plans.

17. Active Fire Protection:

Automatic Sprinkler System	Required
Secondary on-site water supply	Not required (Seismic design category A per email dated 05/14/2013)
Standpipes	Required
Manual Fire alarm system	Required, pull stations may be deleted
Voice Communication	Required
Scoreboard Messaging	Required
2-way communication	Required at each elevator lobby per approved alternate to omit areas of refuge
Fire extinguishers	Required
Mechanical Smoke Control	Required
Hoistway Venting	Required unless pressurized (Section 3016.5 (8.1) Exception)
Seismic Bracing	Not required (Seismic design category A per email dated 05/14/2013)

18. Back-Up Power:

Emergency Power	
Exit signs	Required
Egress Illumination	Required
Smoke detection	Required
Fire alarm system	Required
Voice Communication system and PA system	Required
Elevator Car Lighting	Required
Scoreboard Messaging	Required
Assistive Listening Devices	Required
Standby power	
Smoke Control	Required
Stair Pressurization	Required
Electric Fire Pumps	Required
Hoistway Pressurization	Required
Fire Command Center	Required
One elevator in each bank	Required

19. High Rise Systems

High-Rise Systems	Requirements
Smoke Control Systems Hoistway pressurization is not required.	Exit stair enclosure pressurization is required where stairs serve levels more than 30 below the level of exit discharge or more than 75 above the lowest level of fire department vehicular access (Sections 403.13 and 909.20.5). Pressurization is required to be activated by smoke detectors in the vicinity of each door entry into the enclosure (Section 909.20.6)
Smoke Detection (Section 907.2.12)	Required in return air plenums of systems with > 2,000 cfm At each connection to a vertical duct riser
Emergency Voice/Alarm Communication (1999 Nfpa-72) (Section 907.2.12)	Required to be activated by any smoke detector, sprinkler waterflow or pull station. Required to sound an alert tone followed by voice instructions. Manual override and live message capabilities are required. As a minimum, required to alert the fire floor and one floor above and below, to the following areas: 1. Elevator Groups 2. Exit stairways 3. Areas of Refuge 3. Each floor
Fire Department Communication System (1999 Nfpa-72) (Section 907.2.12) Not Required When Approved By The Fire Department -- If They Rely On Their Radio System	Two-way communication required to be provided between the fire command center and: 1. Elevators 2. Elevator lobbies 3. Secondary power rooms 4. Fire pump room 5. Inside enclosed exit stairs at each floor landing 6. Areas of refuge
Stairway Doors Locked From The Inside (Section 403.12)	Required to be unlocked upon a signal from the fire command center
Stairway Communication System	If stairway doors are locked then 2-way communication (to a constantly attended location) is required on every fifth floor
Fire Command Center	Required to have the following features

(Section 403.8)	1. The emergency voice/alarm communication system unit. 2. The fire department communications unit. 3. Fire detection and alarm system annunciator unit. 4. Annunciator unit visually indicating the location the elevators and whether they are operational. 5. Status indicators and controls for air-handling systems. 6. The fire-fighter's control panel required by section 909.16 for smoke control systems installed in the building. 7. Controls for unlocking stairway doors simultaneously. 8. Sprinkler valve and water-flow detector display panels. 9. Emergency and standby power status indicators. 10. A telephone for fire department use with controlled access to the public telephone system. 11. Fire pump indicators. 12. Schematic building plans indicating the typical floor plan and detailing the building core, means of egress, fire protection systems, fire-fighting equipment and fire department access. 13. Worktable. 14. Generator supervision devices, manual start and transfer features. 15. Public address system 16. Manual pull station.

20. Fire Extinguisher Spacing Requirements

- Fire extinguishers should be provided in every mechanical, electrical, laundry, boiler, furnace, garages, shops, kitchens, locker rooms, janitor's closets, trash, telecom and storage room, and concessions (State Fire Code, section 906).
- The following extinguisher sizes are minimums and the numbers preceding the letters may be larger.
- The sizes cited below represent small extinguishers which can be handled by most occupants.

Extinguisher Size (Minimum)	Spacing (Maximum Actual Travel Distance to an Extinguisher)	Maximum Area of Coverage for storage, parking garages, mercantile and restaurant service areas	Maximum Area of Coverage for other occupancies in the building
8A:10B:C (and larger)	75 feet 50 feet in areas where Type B fires can occur	11,250 sf	11,250 sf
4A:10B:C (and larger)	75 feet 50 feet in areas where Type B fires can occur	6,000 sf	11,250 sf
2A:10B:C	75 feet 50 feet in areas where Type B fires can occur	3,000 sf	6,000 sf
2A:5B:C	75 feet 30 feet in areas where Type B fires can occur	3,000 sf	6,000 sf
Type K	30 feet	N/A	N/A

A: Medium to Extinguish Cellulose (Paper, Cloth and Wood) Fires.
B: Medium to Extinguish Flammable Liquid Fires: Oil, Alcohol.
C: Electrically Non-Conductive Extinguishing Medium: To be used where energized electrical equipment is present.
K: Extinguishers to be provided in kitchens where oils are used in frying and cooking (in addition to the ABC extinguishers)

21. Toilet Fixture Count

Super Bowl Arrangement (Seating capacity = 72,000 + 500 staff = 72,500)

		Equal Dist. Of Men and Women, Population = (36,250 each gender)	
(A-4 or A-5 occupancy yields same counts)		**Rate**	**Number**
Women	Water Closets	1 per 40 for the first 1,500 and 1 per 60 for the remainder over 1,500	617
	Lavatories	1 per 150	242
Men	Water Closets (See Note 1)	1 per 75 for the first 1,500 and 1 per 120 for the remainder over 1,500	310
	Lavatories	1 per 200	182
Drinking fountains		1 per 1,000	73
Service sinks		1	1

1. Urinals may be provided for up to 50% the number of required Water Closets (Footnote I of Table 2902.1 added per State Amendment 1305.2902 Subp. 2).

2. Family Toilets: required. Section 1109.2.1 Family toilets provided are not included in these counts

22. Life Safety Evaluation (Emergency Preparedness Plan)

Required. (SBC Section 1028.6.2).

Appendices

APPENDIX – A

MAKEUP AND USE OF THE MINNESOTA STATE BUILDING CODE

Makeup of 2007 Minnesota State Building Code

Required Enforcement

Chapter 1300 Administration of the State Building Code

Chapter 1301 Building Official Certification

Chapter 1302 Construction Approvals

Chapter 1303 Minnesota Provisions of the State Building Code

Chapter 1303 Window Fall Prevention Provisions

Chapter 1305 Adoption of the *2006 International Building Code*

* Chapter 1307 Elevators and Related Devices

Chapter 1309 Adoption of the *2006 International Residential Code*

Chapter 1311 Adoption of the *Guidelines for the Rehabilitation of Existing Buildings*

* Chapter 1315 Adoption of the *2008 National Electrical Code*

Chapter 1322 Residential Energy Code

Chapter 1323 Commercial Energy Code

Chapter 1325 Solar Energy Systems

Chapter 1335 Floodproofing Regulations

* Chapter 1341 Minnesota Accessibility Code

Chapter 1346 Adoption of the *2006 International Mechanical and Fuel Gas Codes*

* Chapter 1350 Manufactured Homes

* Chapter 1360 Prefabricated Buildings

* Chapter 1361 Industrialized/Modular Buildings

Chapter 1370 Storm Shelters (Manufactured Home Parks)

1

- Chapter 4715 Minnesota Plumbing Code

Optional Enforcement

X International Building Code Appendix J (Grading) See chapter 1300.

X Chapter 1306 Special Fire Protection Systems, either 1306.0020, subpart 2 (existing and new buildings) or subpart 3 (new buildings only)

✓ Chapter 1335 Floodproofing Regulations Parts 1335.0600 to 1335.1200

- These codes have specific statutory authority and with limited exception, are mandatory throughout the state

Use of The Minnesota State Building Code

The Minnesota State Building Code is comprised of numerous chapters in Minnesota Rule that includes references to other adopted publications with any necessary amendments.

The Minnesota State Building Code, known also as the "State Building Code" or the "Code," includes chapters of Minnesota Rule as outlined in the "Makeup of the 2007 Minnesota State Building Code" located in this section. Each chapter is identified with a white index tab stating the topic and contains the Minnesota Rule chapter number on the opposite side of the tab. The State Building Code is comprised of the following:

Stand alone codes that do not incorporate by reference another published document:

- 1300 Administration of the State Building Code
- 1301 Building Official Certification
- 1302 State Construction Approvals
- 1303 Minnesota Provisions of the State Building Code
- 1306 Special Fire Suppression Systems
- 1325 Solar Energy Systems
- 1350 Manufactured Homes
- 1360 Prefabricated Buildings
- 4715 Minnesota Plumbing Code

2

Code chapters that incorporate by reference another published code, standard or other document and include any necessary amendments to the document:

- 1305 Adoption of the *2006 International Building Code** (and necessary amendments)
- 1307 Elevators and Related Devices
- 1309 Adoption of the *2006 International Residential Code** (and necessary amendments)
- 1311 Adoption of the Guidelines for the Rehabilitation of Existing Buildings* (and necessary amendments)
- 1315 Electrical Code ~~(2008~~ National Electrical Code*) 2011 (ON 8/8/2011)
- 1322 Residential Energy Code incorporates Chapter 11 of the *2006 International Residential Code* (with amendments)
- 1323 Commercial Energy Code incorporates ASHRAE Standard 90.1-2004 with amendments
- 1335 Floodproofing Regulations (adopts with amendments *1972 Floodproofing Regulations**)
- 1341 Minnesota Accessibility Code (this chapter is intended to conform to the Federal Americans with Disabilities Act Accessibility Guidelines and the Fair Housing Act)
- 1346 Adoption of the 2006 International Mechanical and Fuel Gas Codes (and necessary amendments)
- 1361 Industrialized/Modular Buildings (adopts the *1993 Model Rules and Regulations for Industrialized/Modular Buildings**)
- 1370 Storm Shelters (adopts with amendments the *1980 Interim Guidelines for Building Occupant Protection from Tornadoes and Extreme Winds**)

*These publications must be purchased separately

3

Specific Code Applications of Adopted Model Codes

Minnesota Rules, chapter 1305 – Adoption of the 2006 International Building Code

Mandatory chapters of the *2006 International Building Code* include chapters 2 through 33 and 35. See chapter 1300 for Administrative provisions. Amendments to Chapters 11 and 30 of the IBC are incorporated into 2007 SBC Chapters 1341 and 1307 respectively.

Optional Appendix Chapter J (Grading) may be adopted by reference. See Chapter 1300, Optional Administration.

Several chapters in this Code have not been adopted but the Minnesota State Building Code provides mandatory provisions elsewhere to replace some of the chapters not adopted here. The information relative to these chapters is as follows:

- For provisions relative to chapter 1, please refer to Minnesota Rules, chapter 1300, Administration of the State Building Code.
- For provisions relative to chapter 11, please refer to Minnesota Rules, chapter 1341, the Minnesota Accessibility Code.
- For provisions relative to chapter 30, please refer to Minnesota Rules, chapter 1307, Elevators and Related Devices.
- For information relative to chapter 34, please refer to Minnesota Rules, chapter 1311, Adoption of *the Guidelines for the Rehabilitation of Existing Buildings*.
- For provisions related to floodproofing, please refer to Minnesota Rules, chapter 1335, Floodproofing.

Any seismic or earthquake provisions in this code are deleted and not required.

For a complete description of all applicable chapters and related information in this code, please refer to Minnesota Rules, section 1305.0011.

Minnesota Rules, chapter 1309 – Adoption of the 2006 International Residential Code

Mandatory chapters of the *2006 International Residential Code* include chapters 2 through 10, chapter 43.

Several chapters in this Code have not been adopted but the Minnesota State Building Code provides mandatory provisions elsewhere to replace the chapters not adopted here. The information relative to these chapters is as follows:

- For provisions relative to chapter 1, please refer to Minnesota Rules, chapter 1300, Administration of the State Building Code.
- For provisions relative to chapter 11, please refer to Minnesota Rules, chapter 1322.

- For provisions relative to chapters 12 through 24, please refer to Minnesota Rules, chapter 1346, Minnesota Mechanical Code.
- For provisions relative to chapters 25 through 32, please refer to Minnesota Rules, chapter4715, Minnesota Plumbing Code.
- For information relative to chapters 33 through 42 (other than section R313 Smoke Alarms), please refer to Minnesota Rules, chapter 1315, Minnesota Electrical Code.
- For provisions related to floodproofing, please refer to Minnesota Rules, chapter 1335, Floodproofing.

Any seismic or earthquake provisions in this code are deleted and not required.

For a complete description of all applicable chapters and related information in this code, please refer to Minnesota Rules, section 1309.0010.

Minnesota Rules, chapter 1311 – Adoption of the Guidelines for the Rehabilitation of Existing Buildings

Mandatory chapters of the *Guidelines for the Rehabilitation of Existing Buildings* include chapters 1 through 6.

Appendices 2, 3, and 4 are deleted and not a part of the Minnesota State Building Code. If a reference is made to the appendices in this code, the appendices shall not apply.

Resources 1 through 6 are considered useful information intended to assist the user and shall not be adopted as part of the Minnesota State Building Code, with the exception of Resource 2, as referenced in section 504.1 of this code.

For a complete description of all applicable chapters and related information in this code, please refer to Minnesota Rules, sections 1311.0010 and 1311.0100.

Minnesota Rules, chapter 1315 – Adoption of the ~~2008~~ 2011 National Electrical Code (8/8/2011)

The 2008 *National Electrical Code* is incorporated by reference and made part of the Minnesota State Building Code.

Minnesota Rules, chapter 1346 – Adoption of the 2000 International Mechanical and Fuel Gas Codes

Mandatory chapters of the 2000 International Mechanical Code include chapters 2 through 15, as amended. Mandatory chapters of the 2000 International Fuel Gas Code include chapters 2 through 7 as amended.

For a complete description of all applicable chapters and related information in this Code, please refer to Minnesota Rules, sections 1346.0050 and 1346.5050.

5

APPENDIX -- B

Effective Dates of Minnesota Code and Rule Adoptions

EFFECTIVE DATE OF ADOPTION:	ACTION:
July 1, 1971	Surcharges
July 1, 1972	*State Building Code* applies statewide; supersedes and takes the place of the building code of any municipality. Specifically the code applied to any municipality which as of May 28, 1971, had a building code and further applies to any municipality choosing to adopt a building code thereafter. The *State Building Code* adopts the *1970 Uniform Building Code* by reference
October 1972	Supplement to the 1972 SBC
June/July 1973	Amendments to 1972 SBC
January 14, 1974	*1973 Uniform Building Code* adopted by reference
October 3, 1975	*Minnesota Uniform Fire Code* adopted the *1973 Uniform Fire Code*
November 18, 1975	Adoption of the Handicapped Code, Chapter 55, and new Uniform Building Code Section 1717, Foam Plastics
January 14, 1976	*1976 State Building Code*
January 30, 1976	*Energy Conservation in Buildings*
October 29, 1977	*Solar Energy Code*
September 19, 1978	*1978 State Building Code* adopted the *1976 Uniform Building Code* by reference; the *Energy Conservation in Buildings* code is amended
October 27, 1978	*1978 National Electric Code*
September 9, 1980	*1980 State Building Code* adopted the *1979 Uniform Building Code*
October 20, 1980	Elevator Rules — Home Energy Disclosure Rules
March 9, 1981	Energy Conservation Standards for Existing Residences
April 6, 1981	*1981 National Electric Code*
March 1, 1983	Amended *1980 State Building Code* adopted the *1982 Uniform Building Code*

14

Effective Dates of Minnesota Code and Rule Adoptions

EFFECTIVE DATE OF ADOPTION:	ACTION:
April 11, 1983	*Minnesota Uniform Fire Code* adopted the *1982 Uniform Fire Code*
April 25, 1983	Optional Appendix "E". Automatic Fire Suppression Systems
January 1, 1984	*Energy Conservation in Buildings* adopted the *1983 Model Energy Code*
January 14, 1985	Rules adopted updating the State Building Code and governing Handicapped Accessibility, Electrical, Elevators and Plumbing
February 18, 1986	Amended Energy Code Rules and Rental Housing Energy Standards
February 17, 1987	*1985 State Building Code* adopted the *1985 Uniform Building Code*
January 11, 1988	Adopted the Group E Division 3 Rules
April 15, 1988	Adopted Rules relating to Manufactured Home Park Storm Shelter Design
October 1, 1989	*1989 Minnesota Uniform Fire Code* adopted the *1988 Uniform Fire Code*
July 2, 1990	*1990 National Electrical Code*
July 16, 1990	*1990 State Building Code* adopted *1988 Uniform Building Code, 1988 Uniform Mechanical Code, 1987 ANSI Code for Elevators,* Minnesota Plumbing Code
May 13, 1991	*1991 Minnesota Energy Code* adopted the *1989 Model Energy Code*
September 7, 1992	*1992 Minnesota Energy Code. (1989 Model Energy Code)*
August 9, 1993	*1993 National Electrical Code*
August 23, 1993	*1993 Minnesota Uniform Fire Code* adopted the *1991 Uniform Fire Code*
June 16, 1994	*1994 Minnesota Energy Code*
July 12, 1994	Amended Building Official Certification Rules. (Access Specialist, Building Official - Limited)
September 19, 1994	*1994 Minnesota Plumbing Code*
December 19, 1994	*1994 Minnesota Mechanical Code* adopts *1991 Uniform Mechanical Code*

Effective Dates of Minnesota Code and Rule Adoptions

EFFECTIVE DATE OF ADOPTION:	ACTION:
March 20, 1995	*1995 Minnesota State Building Code* adopts the *1994 Uniform Building Code*
January 23, 1996	New Accessibility rules - chapter 1340
April 29, 1996	Adopted Rules updating chapters 1300, 1310, 1315, 1325, 1360 and 1361
July 1, 1996	*1996 National Electrical Code* adopted
June 29, 1998	*Minnesota Fire Code* adopted the *1997 Uniform Fire Code*
October 5, 1998	*1997 Uniform Building Code* adopted with state amendments
October 5, 1998	*1998 Plumbing Code* amendments adopted
May 3, 1999	*1996 ASME A17.1, A17.3, A17.5, B20.1 and 1997 A90.1 Elevators and Related Related Devices* adopted with amendments
May 3, 1999	*Minnesota Accessibility Code* adopted – based on the Americans with Disabilities Act Accessibility Guidelines – replaced chapter 1340 with chapter 1341
July 6, 1999	*1999 National Electrical Code* adopted
July 20, 1999	*Minnesota Energy Code* adopted - chapters 7676 and 7678
April 15, 2000	*Minnesota Energy Code* adopted - chapters 7672 (with option of chapter 7670) and 7674
June 26, 2000	Rules relating to Manufactured Homes updated
September 16, 2002	*2002 National Electrical Code* adopted
March 31, 2003	*2000 International Building Code* adopted with state amendments
March 31, 2003	*2000 International Residential Code* adopted with state amendments
March 31, 2003	*Guidelines for the Rehabilitation of Existing Buildings* adopted with state amendments
March 31, 2003	Adopted rules updating chapters 1300, 1301, 1303 and 1306

Effective Dates of Minnesota Code and Rule Adoptions

EFFECTIVE DATE OF ADOPTION:	ACTION:
September 20, 2004	2000 International Mechanical and Fuel Gas Codes, chapter 1346
January 29, 2007	Elevators and Related Devices ASME A17.1-2004 with addenda and supplement, A17.3-2002, A17.5-2004, A18.1-2005, A90.1-2003 and B20.1-2003, chapter 1307
July 10, 2007	*2006 International Fire Code* adopted with state amendments, new chapter 7511
July 10, 2007	*2006 International Building Code* adopted with state amendments, chapter 1305
July 10, 2007	*2006 International Residential Code* adopted with state amendments, chapter 1309
July 10, 2007	Adopted Rules updating chapters 1300, 1303, 1306 and 1341
September 15, 2008	*2008 National Electrical Code* adopted
June 1, 2009	*Minnesota Residential Energy Code* adopted – chapter 1322
June 1, 2009	*Minnesota Commercial Energy Code* adopted – chapter 1323
July 1, 2009	Window Fall Prevention Provisions adopted – 1303.2300-1303.2330 and 1305.1405
October 26, 2009	Minnesota Mechanical and Fuel Gas Codes (*2006 International Mechanical and Fuel Gas Codes*), chapter 1346
October 26, 2009	Minnesota Plumbing code, chapter 4715
December 29, 2009	Manufactured Homes (1350.6710 effective 4/3/2009)
August 8, 2011	2011 National Electrical code adopted

APPENDIX C

FSC, Inc.
CONSULTING ENGINEERS

- Fire Protection Engineering
- Code Consulting
- Mechanical/Electrical Engineering

Meeting Minutes

Project:
Minnesota Multi-purpose Stadium Code Review Meeting

Date:
May 1, 2013

Location:

Minneapolis City Hall
350 South Fifth Street
Minneapolis, MN 55415

Attendees:

Steve Maki,	MSFA
Dan Callahan,	CPED/Plan Review
Brad Schmoll,	MFD
Hilary Dvorak,	CPED – Land Use, Design, Preservation
Jeff Handeland,	MPLS Public Works
Paul Miller,	MPLS Public Works
Linda Roberts	MPSL Business Licensing
Patrick Higgins,	Building Insp.
Sony Monzel,	MPLS Health
Jim Cimas	Vikings
John Hutchings,	HKS
Kevin Taylor	HKS
Jay Caddell,	HKS
Ed Homfeck,	M-E Engineers
Linda D. French,	Coastwise Fireguard
Scott Stenman,	Hammes
Todd Schmall,	Mortenson
Kevin Dalager,	Mortenson
Craig Sharpe,	Mortenson
Ali Alaman,	FSC Inc
Michael Koop,	FSC Inc

9225 Indian Creek Parkway, Suite 300 ■ Overland Park, KS 66210
Tel. (913) 722-3473 ■ Fax: (913) 722-3484 ■ web. www.fsc-inc.com

Code Discussion:

1. Jay Caddell of HKS gave an introductory overview of the new Minnesota Multipurpose Stadium.

2. Ali Alaman of FSC reviewed the authorities having jurisdiction and the codes. The City of Minneapolis will be the authority for the building code which is the 2006 IBC with state amendments (SBC). The Electrical Code will be enforced by the state of Minnesota.

3. The new Minnesota Multi-purpose Stadium (MMPS) will be a large volume building. As currently designed it will be over 300 feet from the field to the peak of the roof, and about 500 feet wide by 700 feet long. It is tall enough for the Statue of Liberty to be located inside with its torch scraping the roof. Intuitively it is an open stadium.

4. The new MMPS will be a type I-A construction building with a 3-hr rated structural frame and 2-hr rated floors.

5. Smoke protected assembly seating principles will be utilized for spectator seating in the new MMPS with a mixture of passive venting in open concourses and mechanical extraction where necessary to meet code requirements. Egress routes must be maintained tenable for 1.5 times the egress time or 20 minutes, whichever is less.

6. Ali Alaman presented an FDS simulation of a large stage fire (>20 MW) on the field. After 20 minutes the temperature rise and soot accumulation at the roof is minimal and the occupied areas like the Upper Seating Bowl and Upper Concourse are unaffected by the products of combustion. It behaves like an open air outdoor stadium in that smoke does not accumulate in occupied areas of the MMPS. It acts just like an A-5 in the SBC.

7. Dan Callahan asked why an A-4 designation would not address all the code requirements for this stadium. Ali Alaman pointed out that the open design of the concourses demands some of the stairs to be open as well and the shear size of the building makes some travel distances simply too long for the A-4 requirements. The A-5 designation allows these conditions.

8. The PA system will be used to supplement the performance of the FA system within the seating bowl. It will be an automatic, pre-recorded message from the fire command room with back-up power. The reliability of PA systems meet or exceed those of FA speakers and due to the frequent use of the system, function is confirmed more frequently than required by FA testing. Enclosed spaces will be provided with traditional speaker/strobes. Strobes cannot be spaced in the bowl to meet the minimum illumination requirements of the building code.

9. Sprinklers will be provided on all concourses and enclosed spaces. Sprinklers will be omitted at the high roof over the field and the seating bowl. The SBC allows the omission of sprinklers over the field and while not explicit in the SBC, the Life Safety Code allows the deletion of sprinklers over the seating bowl.

10. Where the structural steel trusses supporting the roof are within 20 feet of the floor below, an equivalent fire rating will be provided by sprinkler wetting of the structural steel elements. A very limited number of roof elements are within 20 feet of the floor below and those elevations are only in some perimeter locations.

11. The number of drinking fountains required by the plumbing table will be reduced in lieu of free water being available at concession stands. Drinking fountains are generally not used by the public in these types of venues. HKS intends to provide approximately 10 drinking fountains in public areas with the remainder of the requirements to be met by free water at the concession stands.

12. Minnesota has a state statute that mandates minimum ratios of female to male water closets. HKS has design standards that provide greater than the code required minimum of men's fixtures to improve the fan experience. The number of women's fixtures will meet code requirements which are newer than the state statute and reflect current approaches on potty parity for these types of venues. HKS standards increase the number of fixtures for males while leaving the number of fixtures for female the same. It will require further discussion to determine if there is a means to provide additional men's fixtures without triggering a further increase in the number of women's fixtures.

13. A portion of the roof will be a light transmitting plastic material, ETFE. It meets the code requirements for a CC1 light transmitting plastic and if the total roof area covered is less than 30% will not require a variance.

14. Linda French of Coastwise Fireguard stated that standpipes will be provided in all stairs. They will ask to increase from 200 to 400 foot the coverage for Concourse standpipes as more appropriate for a building of this size. Brad Schmoll of the Minneapolis Fire Department indicated that standpipes on the Field Level in the vomitories will be required to be provided.

15. Steve Gomer is the person to contact about roof drainage, elevators, and plumbing issues. The telephone number is (612) 673-3848.

16. Steam piping is specifically regulated. Dan Callahan indicated further discussion will be necessary.

17. Listed grease duct systems will be allowable.

18. Natural ventilation of individual open spaces like concession stands in lieu of providing HVAC supply will additional discussion. If the bowl is open to the outdoors, positive pressure in concession stands may be required.

19. Patrick Higgins stated that sump pumps are not allowed in elevator pits with drains.

20. Smoke control make-up air may require the opening of man doors. Will sensors to confirm fully open doors be required or will closed door sensors indicating that a door has been opened be sufficient?

21. The Minneapolis Fire Department was asked to consider their preferred location for the Fire Pump Room and the Fire Command Center. Follow up meetings with the Fire Department will be required to discuss FCC and Fire Pump room locations as well as Fire Safety.

22. The project schedule was discussed.

    The May 14th SD submittal will go too the Implementation Committee and City Council but will not be a formal submittal to the Building Department.

    The 30% DD submittal will be May 20th according to the contract.

    July 15th will be the 100% DD submittal.

    Underground Utilities will be submitted in early September.

    Foundation plans will be submitted in September or October.

    The existing Metrodome is scheduled to be demolished in February of 2014.

23. Electronic submittals are preferred.

24. The smoke modeling analysis will be presented in a report for review.

25. A Life Safety Evaluation in accordance with the NFPA101 will be required to be provided by the owner/operator before occupancy.

26. Dan Callahan will review the preliminary code analysis provided with the presentation.

27. Hillary Dvorak said that the project team will review the proposed parking garage components of the project.

Attendees

Pat Higgins	City of Minneapolis
Dan Callahan	City of Minneapolis
Brad Schmoll	City of Minneapolis
Scott Anderson	City of Minneapolis
Scott Knudson	City of Minneapolis
Steve Maki	MFSA
Scott Stenman	Hammes
Jim Cima	Vikings
John Hutchings	HKS
Kevin Taylor	HKS
Anice Stephens	HKS
Sergio Chavez	HKS
Tom Schmoll	Mortenson
Josh Miller	Mortenson
Ali Alaman	FSC

The following documents the discussions during our meeting of January 24th, 2014.

Issue	Response by the City of Minneapolis
Alternate Design Omission of Sprinklers at the roof of the Bowl	• Omission of sprinklers above the field is acceptable. • Under consideration: Omission of sprinklers over the seats. The city is considering requiring sprinklers up to a height of 50 feet. Design team stated the fire load is minimal with concrete rows, plastic seats are light which are distributed (not in a pile) and which are in an open environment (unlike enclosed rooms). The design team proposed hose connections at the upper concourse vomitory stairs. The city requested a plan of the hose connections and information regarding combustibles such as banners, compressors, advertising, etc.
Alternate Design Use of the PA system for fire alarm purposes in the bowl and concourses	Acceptable
Alternate Design Omission of fire proofing at specific perimeter steel columns	• West columns are acceptable • Columns totally within vestibules are acceptable • It is acceptable for remaining columns are to be fire proofed up to 20 feet or provided with a guard at a distance where there is a 100% factor of safety of temperature per the modeling

Issue	Response by the City of Minneapolis
Alternate Design Fire Protection of Super Truss by Sprinklers	Under consideration: Protection of the two inclined columns initially identified and the two outward leaning trusses by a deluge sprinkler system from the foundation up to 30 feet above the upper concourse.
Alternate Design Bowl volume as A-5 Occupancy (open stairs, travel distance, horizontal exit)	• Stair 10 acceptable as open within the bowl volume • Stair 9 is not in bowl volume. Design team said this stair will be enclosed and pressurized. • Ramp is not in bowl volume. Design team to Investigate additional exterior doors on the east side at bottom of ramp, address impact of the mechanical smoke management system and the inclusion of draft curtains.
Alternate Design Overhead doors in the means of egress.	Acceptable: make the following amendments: • Doors locked in the open position: include Purple Club doors in request. • Doors that open upon fire alarm activation: Amend request as follows: add smoke detectors on each side. Power failure will cause door to open.
Alternate Design Exit ramp from Event Level as smoke proof enclosure. The design is based on removing smoke from the dock area so it does not enter the egress ramp.	Under consideration: • Identify where make-up air is coming from. • Keep smoke layer at 3 feet above openings into egress ramp.
New Issue Glass Guards per the 2012 IBC which does not require a top rail	Acceptable. Needs to be submitted as an alternate design. Suggested overdesign. Wanted field testing.
Plan Review Comment Unenclosed exit access stairs serving club and suite levels	Acceptable
Plan Review Comment Gate on main concourse at ramp going down. Gate will be in the closed position and an attendant posted to deter patrons from going down to the Event level.	Acceptable
Plan Review Comment Field egress is by the dock. Sleeves will be added at the change in elevation. Staff will be there to direct patrons. Bicycle racks will be used to patrons do not go into the dock area.	Under consideration

Issue	Response by the City of Minneapolis
Plan Review Comment Event level service corridor and vehicles. Parking will be valet parking. Bicycle racks will be used to delineate pedestrian and vehicular paths.	Acceptable. Review egress.
Plan Review Comment Dead-ends at Escalators	Acceptable. Needs to be submitted as an alternate design based on this being a unique situation and the fact that it is open-air.
Plan Review Comment Occupant Load: The occupant load will be based upon 72,000 seats for a Super Bowl mode. For normal NFL game day the occupant load will be 65,000 seats plus 5,000 for staff. The total combined population will be 77,000. The LS sheets do double count areas due to exiting schemes on the Main concourse and Lower club levels. Toilet counts are based on normal NFL game day seat counts.	Acceptable

Please advise if you have any comments within 5 working days.

Sincerely,

Ali H. Alaman

APPENDIX D

Minnesota Multipurpose Stadium
Documentation of Smoke-Protected Approaches for Life Safety
Smoke-Protected by Natural Ventilation
Smoke-Protected by Mechanical Ventilation

Table of Contents

1) Introduction

This report documents Smoke-Protected Approaches for Life Safety in the new Minnesota Multipurpose Stadium. The Minnesota State Building Code which is based on the 2006 International Building Code (IBC) defines Smoke-Protected Assembly Seating as seating served by means of egress that is not subject to smoke accumulation within or under a structure. The concept of smoke protected assemblies was developed to account for the unique nature of spaces which housed a large number of spectators. It was recognized that spaces that served a large number of spectators necessarily had large volumes and higher than normal ceilings. The large size and height of these types of space created large volumes that gave the smoke from a potential fire a place to accumulate without immediately impacting the conditions that occupants would encounter while egressing the space in the event of a fire. By providing a means for the smoke to accumulate away from the occupants more time is allowed the occupants to escape. This is recognized by the enhanced exit factors in modern accounts that implicitly recognize a longer time for people to move through the egress elements allowing even allowing significant queues to form.

A. Smoke-Protected by Natural Ventilation

As indicated above, the first considerations of smoke protected assembly seating occurred in large buildings like arenas. In early applications of this approach, the volume of those buildings was sufficient to allow the occupants to egress from the seating area before the smoke layer would descend to the occupied areas. This is the simplest approach and its application is still apparent in the smoke-protected exit factor table found in section 1025.6.2 of the IBC in which the larger the number of occupants, the greater the capacity of the egress elements become. This reflects the idea that larger buildings have larger smoke reservoirs and thus much longer queuing times are implicitly allowed at egress elements.

B. Smoke-Protected by Mechanical Ventilation

To address conditions where the size of a space may not be large enough to contain the smoke safely away from the occupants while they exit but is still an assembly related space where smoke protected exit factors are desired to be used, mechanical smoke control approaches have been recognized by the building code. These approaches usually involve mechanical extraction of smoke from the space but can include the creation of pressure differences to control or oppose the movement of smoke.

This report establishes the smoke protected properties of the new Minnesota Multipurpose Stadium. The first sections review the applicable codes and standards that will apply to this building. Next the building will be analyzed to determine which spaces require smoke protected concepts and for which standard exiting principles are more appropriate. Finally, the environment in these building areas will be addressed along with the appropriate methodologies.

2) Code Approach

A. Applicable Codes

The State of Minnesota has adopted the 2006 IBC as the State Building Code (SBC) which references the 2005 edition of NFPA-92B. The SBC and the specific provisions of the NFPA 92B standard will be used to design the smoke control systems for this new stadium.

B. Smoke Protected Assembly Seating

Central to this approach is the code concept of *smoke protected assembly seating.* As defined by section 1002.1 of the SBC:

SMOKE-PROTECTED ASSEMBLY SEATING. *Seating served by means of egress that is not subject to smoke accumulation within or under a structure.*

This approach recognizes the openness and volume of the building, as well as the benefits of sprinklers and smoke control in providing a tenable environment and thus a longer egress time compared to traditional buildings. SBC Sections 1025.6.2 through 1025.14 prescribe the specialized egress provisions regulating the means of egress design of the bowl and the building.

a. **Smoke Protected by Natural Ventilation** – the space has openness that allows smoke to naturally ventilate into the large volume of the dome. In this fashion, smoke does not build down and impede the egress path. Section 4.3.1 of the NFPA 92B standard allows the use of smoke filling of an unoccupied volume and modeling smoke layer descent to determine whether the smoke layer interface will reach a height at which occupants will be exposed to smoke prior to their ability to egress from the space. By using this approach this report documents that the new stadium (seating bowl and open concourses) behaves as if it is truly an open air stadium.

b. **Smoke Protected by Mechanical Ventilation** - The prescriptive equations of Section 6.2 of the NFPA 92B standard were used to estimate the required exhaust capacity of interior spaces. In complicated internal spaces like the Executive Suite corridor system which do not conform to the assumptions of the simple closed form solutions computer-based computational models are used to confirm smoke exhaust system performance.

C. SBC Provisions

a. Purpose of smoke control: Section 909.1 of the SBC states that smoke control is only for life safety of the occupants.

b. Duration: Section 909.4.6 of the SBC prescribes the smoke control time frame to be 1.5 times the calculated egress time or 20 minutes whichever is less. The modeling will be run for 20 minutes

c. Smoke Control System Options: Section 909.1 of the SBC permits mechanical or natural (passive) ventilation. Both will be utilized.

d. Mechanical Ventilation: Will be provided as permitted by section 909.1 of the SBC.

e. Natural Ventilation: Will be utilized based on the large open internal volume of the building as permitted by section 909.1 of the SBC.

f. Back-up Power: Standby power is required for mechanical fans and the make-up air doors. Emergency power is required for the fire alarm panel.

g. Special Inspector: Required (section 909.18).

h. Smoke Bombs: Please see part 19 of this report. The SBC requires duct pressure testing and system component testing. Smoke bombs are not required by the SBC nor by NFPA 92B which states:

> Smoke bomb tests do not provide the heat, buoyancy, and entrainment of a real fire and are not useful in evaluating the real performance of the system. A system designed in accordance with this document and capable of providing the intended smoke management might not pass smoke bomb tests. Conversely, it is possible for a system that is incapable of providing the intended smoke management to pass smoke bomb tests. Because of the impracticality of conducting real fire tests, the acceptance tests described in this document are directed to those aspects of smoke management systems that can be verified.

i. Fire Fighter's Smoke Control Panel: Required (section 909.16).

i. Fire Command Center: Required (section 909.16).

j. Periodic Testing: The SBC refers to NFPA-92B which recommends periodic testing of the equipment as recommended by the manufacturer. Moreover, the entire system is recommended to be tested "at least semiannually by persons who are thoroughly knowledgeable in the operation, testing and maintenance of the systems. The results of the test should be documented in the operation and maintenance log and made available for inspection." Tests are recommended to be conducted under normal and standby power.

3) Calculation Methodology

A. Algebraic Equations

The NFPA 92B standard provides closed form solutions for use in determining required exhaust quantities in simple spaces. Those equations will be utilized in this report where applicable.

B. Fire Dynamics Simulator

More complex spaces or ones which do not conform to the assumptions made in the development of those equations, higher fidelity models will be used. The Fire Dynamics Simulator (FDS) is computer program published by the National Institute of Standards and Technology (NIST) a US governmental agency. FDS solves conservation of mass, momentum and energy equations iteratively in a three-dimensional computational domain. Results can be tabulated, graphed or viewed in Smokeview – another NIST computer program that shows the three-dimensional domain and animates the results.

C. Fire Modeling Assumptions

The following assumptions are made in the fire modeling that was done for this stadium.

a) Interior temperature: The interior temperature is assumed to be about 70°F.

b) Fire Location: Fires are assumed to be away from walls which is a configuration that yields the most smoke.

c) Stack Effect: Stack effects occur in shafts which is not the case here because this is a large open volume.

d) Temperature Effects of the Fire: Fire temperatures are accounted for in the design of the equipment.

e) Wind Effects: This is a forced air system where the discharge points are well away from intake openings.

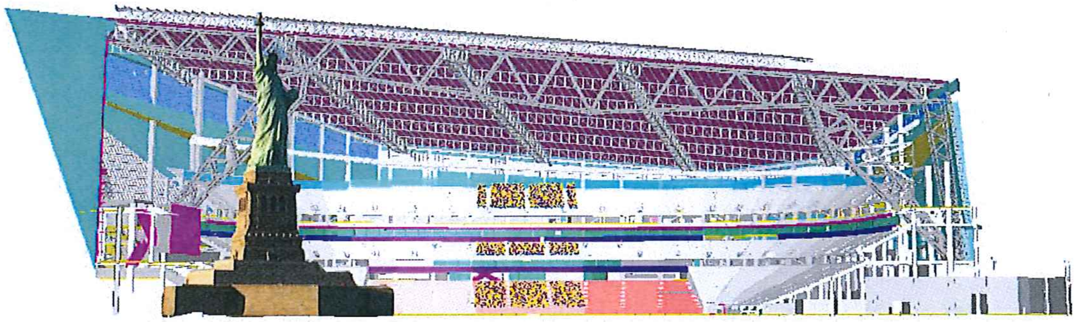
f) Smoke Layer Height: Section 1025.6.2.1 requires smoke layer to be kept at 6 feet above the highest egress path. The cited section refers to the algebraic equations that maintain the smoke layer at a certain height. The basis for these equations is the two-zone model which assumes that there is a straight line demarcation between the hot smoke layer and the fresh air below it. The Fire Dynamics Simulator is a much more complex tool which displays results as a range. As a result, it does not show the "smoke layer". It shows the results as a range. Acceptable tenability values are based on the Society of Fire Protection Engineering (SFPE) Handbook.

g) Sprinkler Protection: All of the interior spaces are sprinkler protected, except the bowl.

h) Make-up Air: Adequate make-up air will be provided for mechanical exhaust systems in enclosed spaces in the stadium including club and suite spaces as well as open concourses and the truck dock.

4) Minnesota Multi-Purpose Stadium Environment.

The new Minnesota Multi-purpose Stadium is an enclosed structure that has many of the same properties of an open stadium. The concourses and seating bowl are open to such a large interior space that the accumulation of the products of combustion in the egress paths is not possible in a code determined amount of time. The high roof of the new stadium exceeds 300 feet above the field level in some locations.



The Statue of Liberty along with its base could fit inside the new stadium. Because of this extraordinarily large volume the environment of the seating bowl and open concourses is no different than in an outdoor stadium. There are several occupied levels of the new stadium, from the Field Level up to the Upper Seating Bowl. The egress of those spaces have been analyzed to determine whether smoke protection is required or not. All open spaces, including the playing field, seating bowl, and main and upper concourses are open to the interior of the building and so inherently smoke protected. Specific spaces that are smoke protected environments and those that are not are indicated in the following table.

The table below shows which levels are smoke protected. Accordingly, the specialized egress provisions of section 1025.6.3 apply. Smoke protection by natural ventilation indicates that openness to the bowl and above bowl volume provides the ability to vent any and all products of combustion so that the means of egress remain tenable.

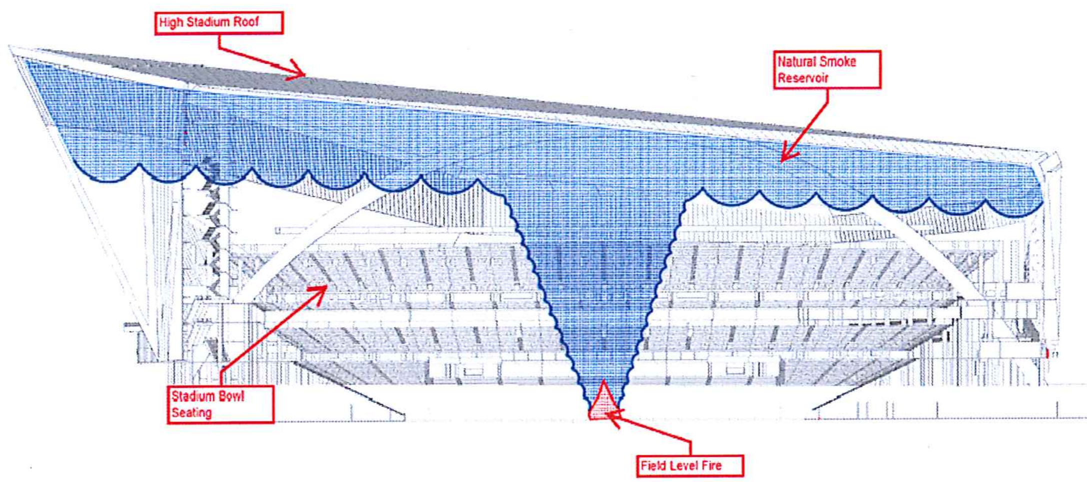
Level	**Smoke Protected / Not Smoke Protected**
Field	Smoke Protected by Natural Ventilation
Southeast Field Vomitory and Truck Dock	Vomitory: Smoke Protected by Natural Ventilation Truck Dock: Smoke Protected by Mechanical Ventilation
Field Level Sideline Club	Smoke Protected by Mechanical Ventilation
Field Level South Major Loop Corridor	Smoke Protected by Mechanical Ventilation
Event Level Other Indoor	Not Smoke Protected
South Red Zone Lounges	Smoke Protected by Mechanical Ventilation
Executive Suites Lounge	Smoke Protected by Mechanical Ventilation
Lower Club Level North	Smoke Protected by Mechanical Ventilation
Lower Club Level South	Smoke Protected by Mechanical Ventilation
North Red Zone Lounge	Smoke Protected by Mechanical Ventilation
Main Concourse	Smoke Protected by Natural Ventilation. In addition, mechanical ventilation along sidelines
Lower Seating Bowl	Smoke Protected by Natural Ventilation
Upper Club Level – north	Smoke Protected
Upper Club Level – south	Smoke Protected
Upper Suite Level – north	Smoke Protected
Upper Suite Level - south	Not Smoke Protected
Upper Concourse	Smoke Protected by Natural Ventilation
Mechanical Mezzanine	Smoke Protected by Natural Ventilation
Upper Seating Bowl	Smoke Protected by Natural Ventilation

5. Seating Bowl Environment

The egress surface above which the bottom of the smoke layer must be maintained in the Seating Bowl throughout egress is the top of the Upper Bowl. The egress surface is 157 feet 6 inches above the event surface in the Stadium, so the bottom of the smoke layer is required to not descend below a minimum of 163 feet 6 inches above the Playing Field during egress with a suitable safety factor. No mechanical smoke exhaust system is provided as the massive volume of the stadium bowl under the roof provides a natural smoke reservoir that is so large that even a large fire will not produce enough smoke to affect tenability in occupied outer levels of the stadium. This Descending Smoke Layer Approach is one of the design approaches found in Section 4.3.1 of the 2005 NFPA92B Standard for Smoke Management Systems in Malls, Atria, and Large Spaces.

(1) Natural smoke filling for an unoccupied volume or smoke reservoir and modeling smoke layer descent to determine whether the smoke layer interface will reach a height at which occupants will be exposed to smoke prior to their ability to egress from the space.

The following illustration depicts the large volume available for smoke filling in the stadium and the principle of its function.

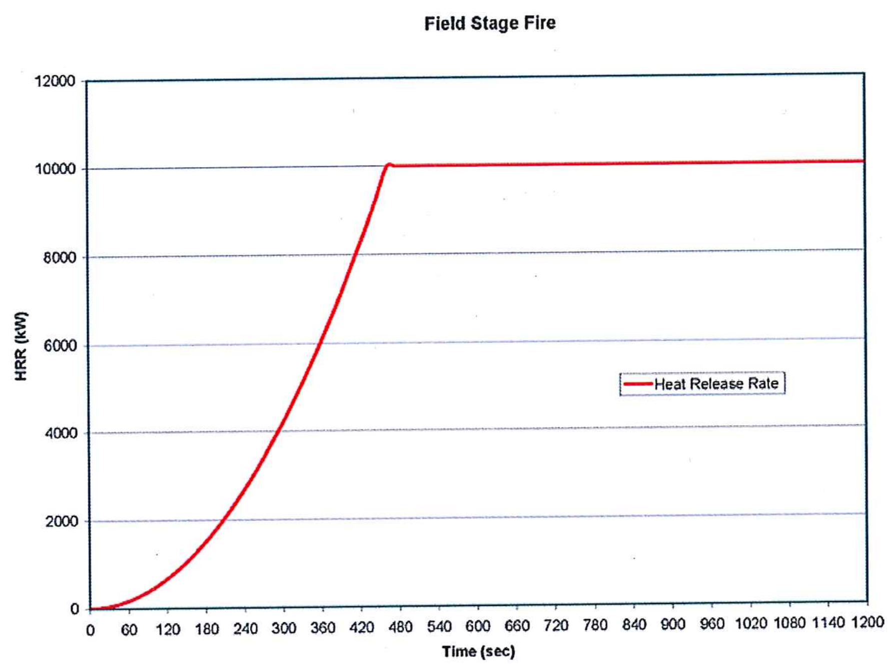


A. Fire Sizes

a. Concert

While a typical event in a Stadium presents only a very limited amount of fuel for a potential fire, other uses need to be considered in the development of requirements for a smoke exhaust system. For the purpose of this analysis, a fire heat release rate curve was selected that exceeds or bounds the fire from possible fuel packages that may be located on the field during a period in which the Seating Bowl is occupied. A fast growth fire that peaks and holds steady at 10 MW was used for this simulation. Fires in fuel packages typically grow to a peak then die down. This is a very conservative assumption.

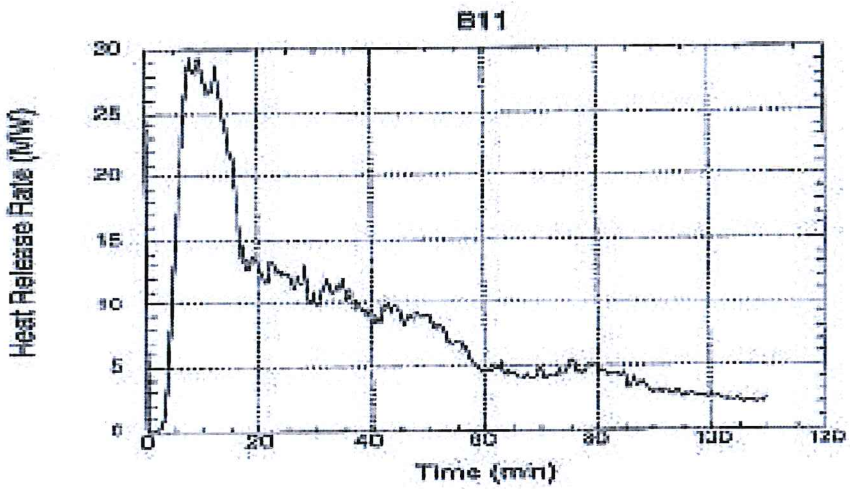
During a rock concert a large stage may be located on the field and numerous occupants may be located on the field or in the bowl seating area. A concert stage presents a large concentration of flammable material. A stage fire was considered and determined to be within the bounds of the simulation heat release curve. Based upon an average heat release rate of 160 kw/m^2, over 650 square feet of plywood[3] stage would have to be engulfed to maintain a steady state heat release rate of 10 MW as was modeled for the purposes of this analysis. The fire is not limited to only 650 square feet of stage area by this assumption as it is assumed to engulf additional area as the fire in other areas burn out.



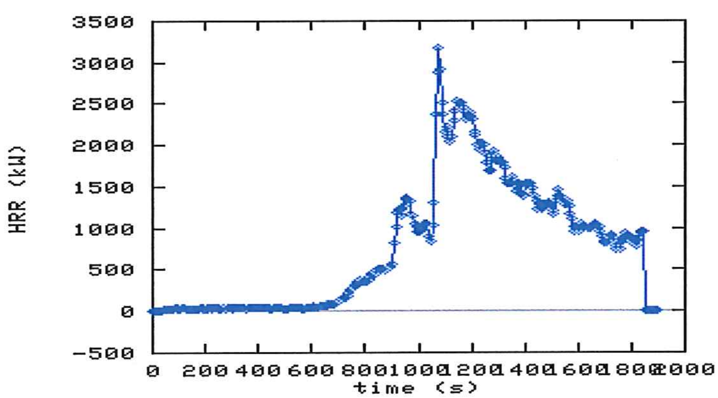
The results of the simulation will be provided in more detail in a subsequent revision of this report. The smoke layer is more than six feet above the highest egress levels during the calculated time of egress.

b. Exhibit

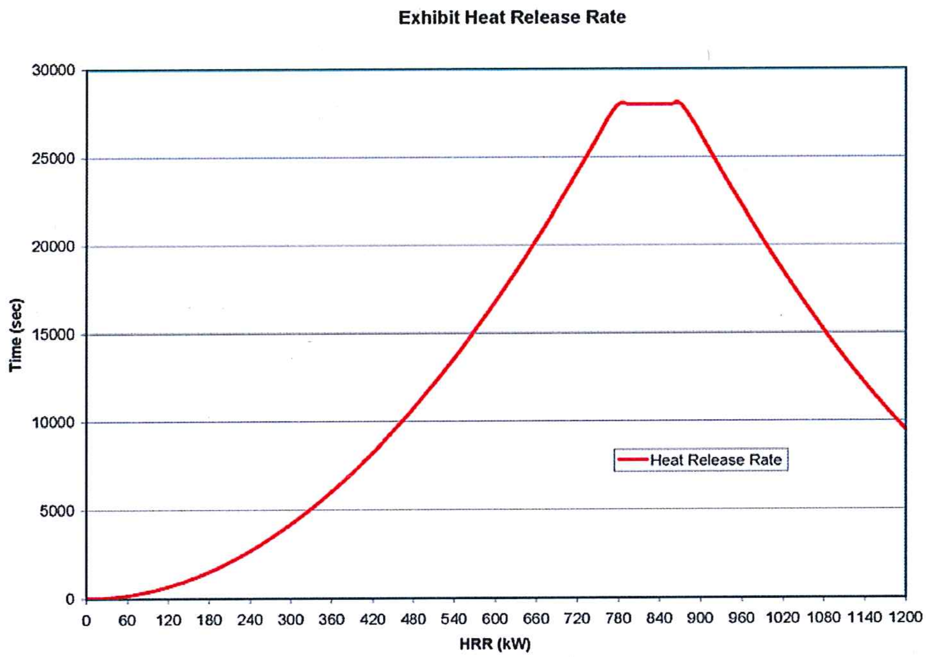
An exhibit on the event field during non-game days could include booths, large displays, or even large vehicles. Large vehicles, such as recreational vehicles or buses, which could potentially be parked on the Event Field during an exhibition present some of the largest potential fires which could be experienced in a space which is typically characterized by low combustibles such as a football or baseball game. The following graph is the heat release rate of a burning bus and is shown to demonstrate the upper boundedness of the heat release rate curve used for this analysis. The bus heat release rate grows rapidly to about 28 MW and then declines.



Other potential fire scenarios were considerably less than the heat release rate for a burning bus. For instance, the following is the heat release rate for a display booth which is considerably less than that for a vehicle.



The following is the fire curve used for the exhibit condition. It is a fast growth fire which increases until a maximum heat release rate of 28 MW is achieved. Like the bus data shown in the chart above it burns at the maximum value for awhile and then begins to die down. It has a total heat release rate of slightly under 10 MW after 20 minutes have elapsed.



B. Egress (Smoke Layer)

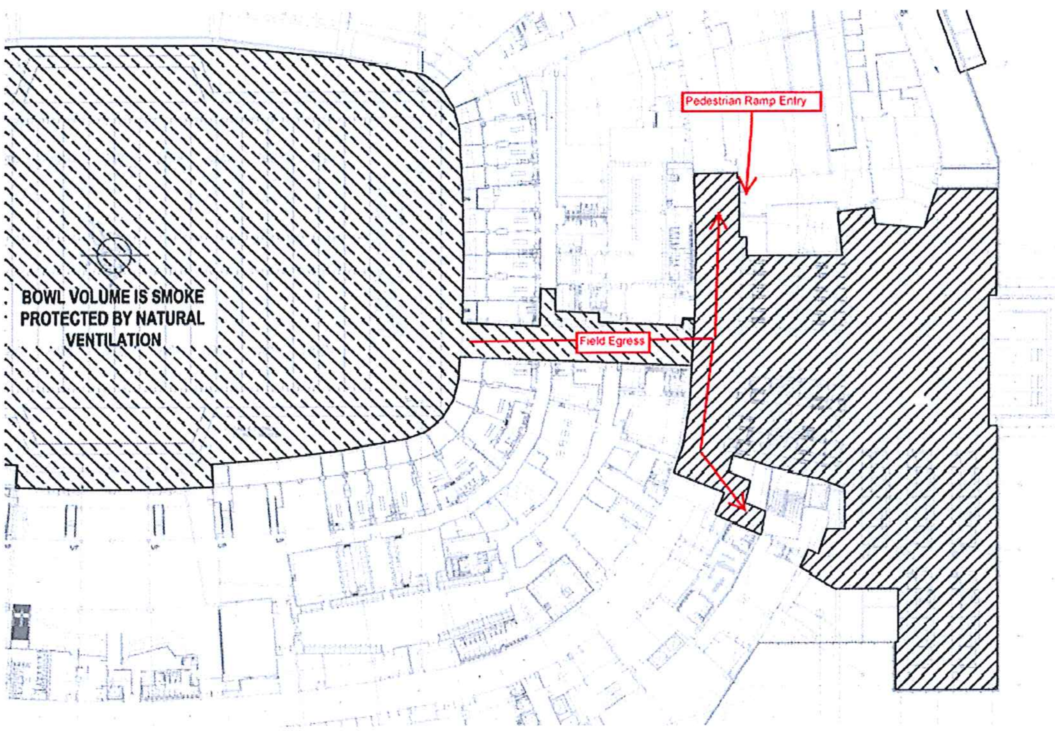
a. Concert – The top of the Upper Seating Bowl is 135 feet above the field level in the new Minnesota Stadium. The apex of the stadium roof is over 300 feet above the field level. The lowest portion of the roof is over 200 feet above the field level and 40 feet above the back of the upper bowl. During the course of a stage fire the incredibly large volume of the building above the Seating Bowl will act as a buffer, absorbing the products of combustion produced by a large fire allowing the occupants ample time to egress before a smoke zone grows large enough to descend into the means of egress and render them untenable. The Upper Concourse is 110 feet above the field level. During the 20 minute time period required by the building code not only do conditions remain tenable at all locations in the seating bowl, but no significant indications of smoke are detected either.

b. Exhibit – There is no expectation that there will be a population in the Upper Bowl during an exhibit so there is not a requirement to protect the exit paths on the Upper Concourse. The largest fire that may be located on the field during an exhibition might typically be a large vehicle like a bus or recreational vehicle. These types of vehicles typically produce very large fires as their interior contents burn. The second curve above was selected for this analysis but though it results in a more challenging fire, the Main Concourse which is only about 55 feet above the field level requires protection. During the 20 minute time period required by the building code not only do conditions remain tenable at all locations in the seating bowl, but no significant indications of smoke are detected either.

6. Truck Dock Environment

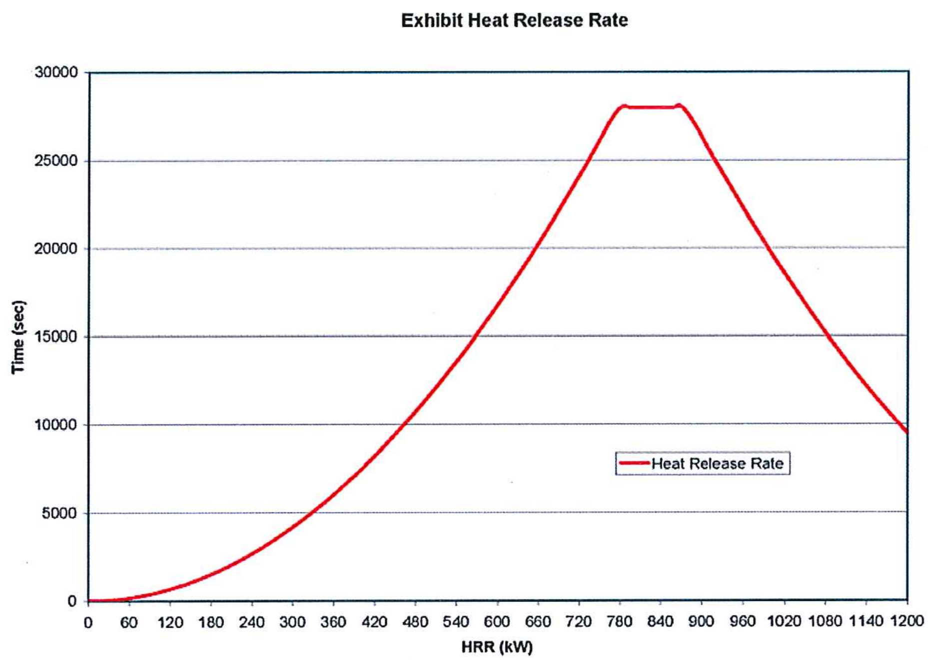
The interior of the Truck Dock provides access for patrons on the Field Level during a concert through a vomitory off the field to the pedestrian ramp that will take the field patrons up to a level of exit discharge. The goal of the smoke management system in the Truck dock is to maintain tenable conditions at 6 feet above the walking surface on the egress path from the vomitory to the pedestrian ramp as well as prevent smoke from spilling into the ramp itself. In the event of a fire in the Truck Dock it is required that a smoke control system be provided that maintains tenable conditions along all egress paths for the field level patrons. Additionally, the smoke exhaust system in the truck dock is sized to contain the smoke from a large fire in the dock area and keep it from spilling up the pedestrian ramp or into the main volume of the stadium where the seating bowl is.

For proper performance, it is required that the exhaust grill be located as high in the smoke layer as practicable. The smoke exhaust system will not function correctly if the exhaust grill is located near the floor.



A. Fire Sizes

The truck dock will be the location of large vehicles including semi-trucks which deliver material to the stadium as well as broadcast trucks which will be parked in designated spaces during events. These vehicles constitute the largest potential fuel load for a fire in the space and are used for the calculation sizing the mechanical exhaust system for the truck dock. As such it will use the same fire curve as is used for the exhibit fire scenario for the Seating Bowl in Section D of this report.



For the purpose of sizing the exhaust fan in the truck dock, an averaged heat release rate of 25,000 Btu/sec was used and the exhaust was size to maintain the smoke layer 15 feet above the floor so it does not enter the egress ramp.

The axisymmetric plume formula in Section 6.2.1.1 of the NFPA 92B will be used to calculate the smoke quantity generated. The base of the fire is assumed to be 6 feet above the walking surface to account for the height of the broadcast trucks so the bottom of the smoke layer will be 11 feet above the base of the flame or 17 feet above the floor. The height of the opening to pedestrian ramp is 10 feet so this locates the bottom of the smoke layer fully 7 feet above the opening to the pedestrian ramp.

Flame Height:
The Limiting Flame Height is the top of the flame and is calculated as follows by Section 6.2.1.1, Equation (6.2.1.1c).

$$Z_1 = 0.533 Q_c^{2/5}$$

Z_1 = *Limiting flame height*

Q_c = *Convective heat release rate, which equals 70% of the total heat release rate of* 25,000 *Btu/second*

$= 25{,}000\ Btu/second \times 70\% = 17{,}500\ Btu/second$

$$Z_1 = 0.533 \times 17{,}500^{2/5}$$

$= 26.6$ *feet flame height*

Mass Flow of Plume into Smoke Layer:
Since the limiting flame height is greater than the height of the bottom of the smoke layer:

$$m = 0.0208 Q_c^{3/5} Z$$

$z = 9$ *feet* (distance from floor to bottom of the smoke layer)

m = *Mass flow rate, lb/second*

Q_c = *Convective heat release rate* $= 25{,}000\ Btu/second \times 70\% = 17{,}500\ Btu/second$

$$m = 0.0208(17{,}500)^{3/5}(9)$$

$$m = 0.0208(351.4)(9)$$

$m = 65.8$ *lbs/mass flow from plume into smoke layer*

Smoke Layer Temperature:
The temperature of the smoke in the plume is calculated using Equation 9-9 in Section 909.10.1. The actual smoke layer temperature will be limited to 212° F by the sprinkler system. Using the higher temperature over-predicts the exhaust quantity required since it results in a lower calculated smoke density. The lower the density, the higher the exhaust fan capacity necessary to exhaust the same mass.

$$T_s = T_o + \frac{Q_c}{mC_p}$$

T_s = *Temperature of fire plume in* °F

T_o = *Ambient temperature in* °F

C_p = *Specific heat of smoke* = 0.24 *Btu/lb* °F

Q_c = *Fire heat convective release rate* = 17,500 *Btu/second*

$$T_s = 70 + \frac{17{,}500}{65.8(0.24)} = 1178°F$$

Smoke Density:
To calculate smoke density, assume that the smoke layer temperature is the same as the temperature of the smoke in the plume. Note that this is a conservative assumption as it treats the smoke layer as uniform and adiabatic. (It assumes that there is no cooling of the smoke within the layer.) Smoke layer density is then calculated using Charles' Law.

$$T_o = \textit{Ambient temperature in } ^\circ R$$

$$T_s = \textit{Temperature of smoke plume in } ^\circ R$$

$$\rho = \textit{Smoke density in lb/feet}^3$$

$$\rho_o = \textit{Ambient density } = 0.075 \textit{ lb/feet}^3$$

$$\rho = \rho_o \frac{T_o}{T_s} = 0.075 \frac{530}{460 + 1178} = 0.024 \textit{ lb/feet}^3$$

Exhaust Flow Rate:
The required exhaust rate is then calculated using the calculated plume mass flow rate and densities with Equation (9-4) in Section 909.8.2 of the SBC.

$$V = \textit{Exhaust rte in cfm}$$

$$m = \textit{Mass flowrate } = 65.8 \textit{ lb/second}$$

$$p = \textit{Density ofsmoke at} 1180\ ^\circ F = 0.024 \textit{ lb/feet}^3$$

$$V = 60\frac{m}{\rho} = 60\frac{65.8}{0.024} = 162{,}700 \textit{ cfm (Equation 6.4)}$$

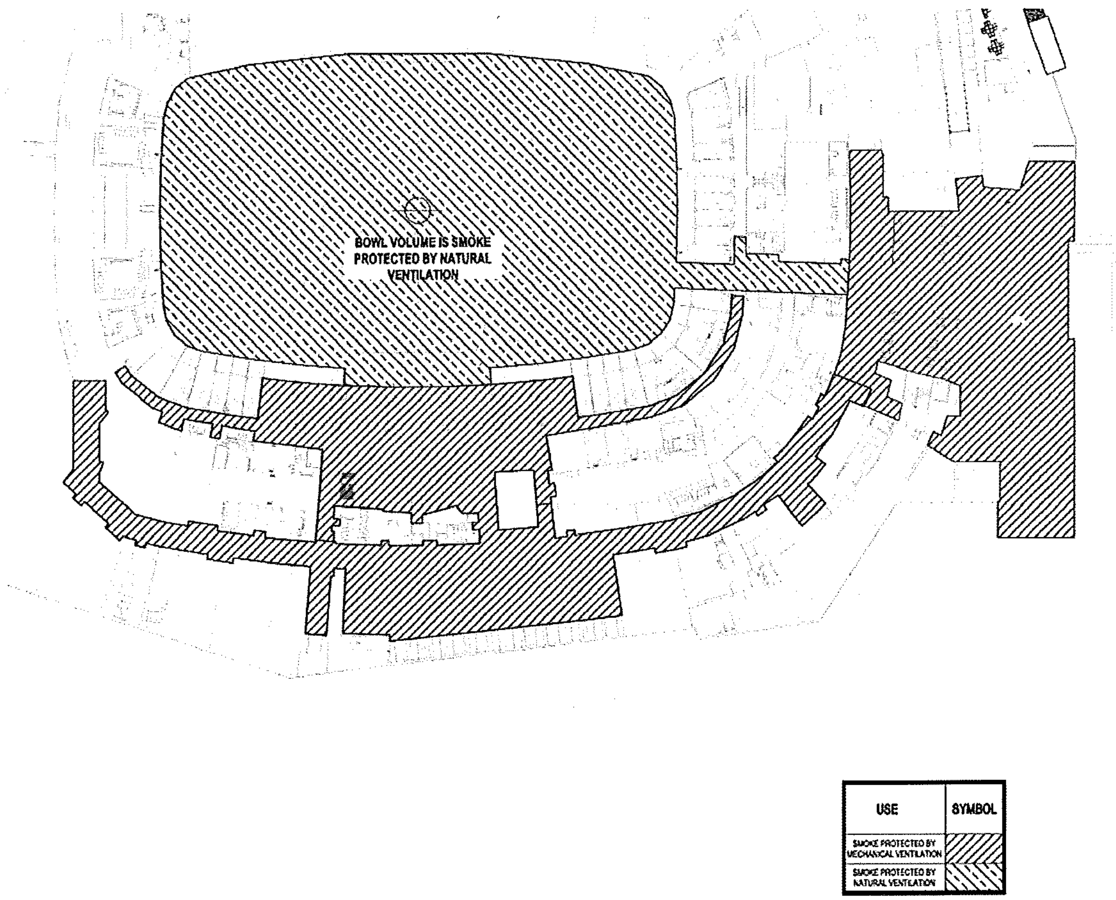
An exhaust volume of 175,000 cfm was selected to provide conservative performance. An FDS simulation is being run to verify performance of the system and temperatures.

B. Egress

The bottom of the smoke layer is maintained greater than 6 feet above the egress surface and additionally the exhaust capacity is seized sufficiently to keep smoke from infiltrating into the pedestrian ramp or spilling out into the bowl volume through the large vomitory between the Truck Dock and the Event Field.

7. Field Level Sideline Club Environment

The Sideline Club on the south side of the new stadium will be provided with a smoke protected interior environment. Since the Lower Club is an interior space, the smoke management will be accomplished with a mechanical exhaust system.



A. Fire Sizes

The fire size for the main open space Sideline Club will be the standard large fire of 5,000 Btu/sec as described in other sections of this report. Since the ceiling space in the Sideline Club is high, about 15 feet the algebraic equations in the NFPA92B standard will be used for sizing the exhaust equipment. The fire will be assumed to be steady state for this analysis.

The corridors of the Sideline Club have low ceilings similar to the Executive Suites corridor and a similar exhaust system will be used in those areas reflecting the reduced fire size due to sprinkler limiting and thin smoke layer. Exhaust grills of 1,000 cfm capacity will be placed every thirty feet along the corridors.

B. Smoke Exhaust

The axisymmetric plume formula in Section 6.2.1.1 of the NFPA 92B will be used to calculate the smoke quantity generated. A standard fire size of 5,000 Btu/second has been selected as the fire size. This fire size does not take credit for sprinkler limiting of the fire so it is a conservative assumption.

Flame Height:
The Limiting Flame Height is the top of the flame and is calculated as follows by Section 6.2.1.1, Equation (6.2.1.1c).

$$Z_1 = 0.533 Q_c^{2/5}$$

$$Z_1 = \textit{Limiting flame height}$$

$$Q_c = \textit{Convective heat release rate, which equals 70\% of the total heat release rate of 5,000 Btu/second}$$

$$= 5{,}000 \textit{ Btu/second} \times 70\% = 3{,}500 \textit{ Btu/second}$$

$$Z_1 = 0.533 \times 3{,}500^{2/5}$$

$$= 13.9 \textit{ feet flame height}$$

Mass Flow of Plume into Smoke Layer:
Since the limiting flame height is less than the height of 13.9 feet is greater than the 6 feet to the bottom of the smoke layer:

$$m = 0.0208 Q_c^{3/5} Z$$

$$z = 6 \textit{ feet} \text{ (distance from floor to bottom of the smoke layer)}$$

$$m = \textit{Mass flow rate, lb/second}$$

$$Q_c = \textit{Convective heat release rate} = 5{,}000 \textit{ Btu/second} \times 70\% = 3{,}500 \textit{ Btu/second}$$

$$m = 0.0208(3{,}500)^{3/5}(6)$$

$$m = 0.0208(133.8)(6)$$

$$m = 16.7 \textit{ lbs/mass flow from plume into smoke layer}$$

Smoke Layer Temperature:
The temperature of the smoke in the plume is calculated using Equation 9-9 in Section 909.10.1. The actual smoke layer temperature will be limited to 212° F by the sprinkler system. Using the higher temperature over-predicts the exhaust quantity required since it results in a lower calculated smoke density. The lower the density, the higher the exhaust fan capacity necessary to exhaust the same mass.

$$T_s = T_o + \frac{Q_c}{mC_p}$$

$$T_s = \textit{Temperature of fire plume in } ^\circ F$$

$$T_o = \textit{Ambient temperature in } ^\circ F$$

$$C_p = \textit{Specific heat of smoke} = 0.24 \textit{ Btu/lb } ^\circ F$$

$$Q_c = \textit{Fire heat convective release rate} = 3{,}500 \textit{ Btu/second}$$

$$T_s = 70 + \frac{3{,}500}{16.7(0.24)} = 943^\circ F$$

Smoke Density:
To calculate smoke density, assume that the smoke layer temperature is the same as the temperature of the smoke in the plume. Note that this is a conservative assumption as it treats the smoke layer as uniform and adiabatic. (It assumes that there is no cooling of the smoke within the layer.) Smoke layer density is then calculated using Charles' Law.

$$T_o = \textit{Ambient temperature in } ^\circ R$$

$$T_s = \textit{Temperature of smoke plume in } ^\circ R$$

$$\rho = \textit{Smoke density in lb/feet}^3$$

$$\rho_o = \textit{Ambient density} = 0.075 \textit{ lb/feet}^3$$

$$\rho = \rho_o \frac{T_o}{T_s} = 0.075 \frac{530}{460 + 943} = 0.028 \textit{ lb/feet}^3$$

Exhaust Flow Rate:
The required exhaust rate is then calculated using the calculated plume mass flow rate and densities with Equation (9-4) in Section 909.8.2 of the SBC.

$$V = \textit{Exhaust rate in cfm}$$

$$m = \textit{Mass flow rate} = 16.7 \textit{ lb/second}$$

$$p = \textit{Density of smoke at } 943\ ^\circ F = 0.028 \textit{ lb/feet}^3$$

$$V = 60 \frac{m}{\rho} = 60 \frac{49}{0.028} = 35{,}400 \textit{ cfm (Equation } 6.4)$$

An exhaust volume of 60,000 cfm in the main club space with additional 1,000 cfm grills spaced olong the corridors at 30 foot maximum intervals the same as is provided in the Executive Suite Corridors was selected to provide conservative performance.

C. Egress

The smoke exhaust system is required to maintain tenable conditions within the Sideline Club for 20 minutes. This code compliant approach allows the use of smoke protected egress factors in the club space.

8. South Major Loop Corridor Environment

The Event Level Main Loop Corridor on the south side of the new stadium will be provided with a smoke protected interior environment from the Sideline Club space to the exits that are accessed from the Loop Corridor. Since the Loop Corridor is an interior space, the smoke management will be accomplished with a mechanical exhaust system.

D. Fire Sizes

The fire size for the Loop Corridor will be the standard large fire of 5,000 Btu/sec as described in other sections of this report. Since the ceiling space in the Loop Corridor is high, above 15 feet the algebraic equations in the NFPA92B standard will be used for sizing the exhaust equipment. The fire will be assumed to be steady state for this analysis.

E. Smoke Exhaust

The axisymmetric plume formula in Section 6.2.1.1 of the NFPA 92B will be used to calculate the smoke quantity generated. A standard fire size of 5,000 Btu/second has been selected as the fire size. This fire size does not take credit for sprinkler limiting of the fire so it is a conservative assumption.

Flame Height:
The Limiting Flame Height is the top of the flame and is calculated as follows by Section 6.2.1.1, Equation (6.2.1.1c).

$$Z_1 = 0.533 Q_c^{2/5}$$

Z_1 = *Limiting flame height*

Q_c = *Convective heat release rate, which equals 70% of the total heat release rate of 5,000 Btu/second*

$= 5{,}000 \text{ Btu/second} \times 70\% = 3{,}500 \text{ Btu/second}$

$$Z_1 = 0.533 \times 3{,}500^{2/5}$$

$= 13.9$ *feet flame height*

Mass Flow of Plume into Smoke Layer:
Since the limiting flame height is less than the height of 13.9 feet is greater than the 6 feet to the bottom of the smoke layer:

$$m = 0.0208 Q_c^{3/5} Z$$

$z = 6\,feet$ (distance from floor to bottom of the smoke layer)

$m = Mass\ flow\ rate,\ lb/second$

$Q_c = Convective\ heat\ release\ rate = 5{,}000\ Btu/second \times 70\% = 3{,}500\ Btu/second$

$$m = 0.0208(3{,}500)^{3/5}(6)$$

$$m = 0.0208(133.8)(6)$$

$$m = 16.7\ lbs/mass\ flow\ from\ plume\ into\ smoke\ layer$$

Smoke Layer Temperature:
The temperature of the smoke in the plume is calculated using Equation 9-9 in Section 909.10.1. The actual smoke layer temperature will be limited to 212° F by the sprinkler system. Using the higher temperature over-predicts the exhaust quantity required since it results in a lower calculated smoke density. The lower the density, the higher the exhaust fan capacity necessary to exhaust the same mass.

$$T_s = T_o + \frac{Q_c}{mC_p}$$

$T_s = Temperature\ of\ fire\ plume\ in\ °F$

$T_o = Ambient\ temperature\ in\ °F$

$C_p = Specific\ heat\ of\ smoke = 0.24\ Btu/lb\ °F$

$Q_c = Fire\ heat\ convective\ release\ rate = 3{,}500\ Btu/second$

$$T_s = 70 + \frac{3{,}500}{16.7(0.24)} = 943°F$$

Smoke Density:
To calculate smoke density, assume that the smoke layer temperature is the same as the temperature of the smoke in the plume. Note that this is a conservative assumption as it treats the smoke layer as uniform and adiabatic. (It assumes that there is no cooling of the smoke within the layer.) Smoke layer density is then calculated using Charles' Law.

$T_o = Ambient\ temperature\ in\ °R$

$T_s = Temperature\ of\ smoke\ plume\ in\ °R$

$\rho = Smoke\ density\ in\ lb/feet^3$

$\rho_o = Ambient\ density = 0.075\ lb/feet^3$

$$\rho = \rho_o \frac{T_o}{T_s} = 0.075 \frac{530}{460 + 943} = 0.028\ lb/feet^3$$

Exhaust Flow Rate:
The required exhaust rate is then calculated using the calculated plume mass flow rate and densities with Equation (9-4) in Section 909.8.2 of the SBC.

$V = \textit{Exhaust rate in cfm}$

$m = \textit{Mass flow rate} = 16.7 \ \textit{lb/second}$

$p = \textit{Density of smoke at } 943\ ^\circ F = 0.028\ \textit{lb/feet}^3$

$$V = 60\frac{m}{\rho} = 60\frac{49}{0.028} = 35{,}400\ \textit{cfm}\ \ (\textit{Equation}\ \ 6.4)$$

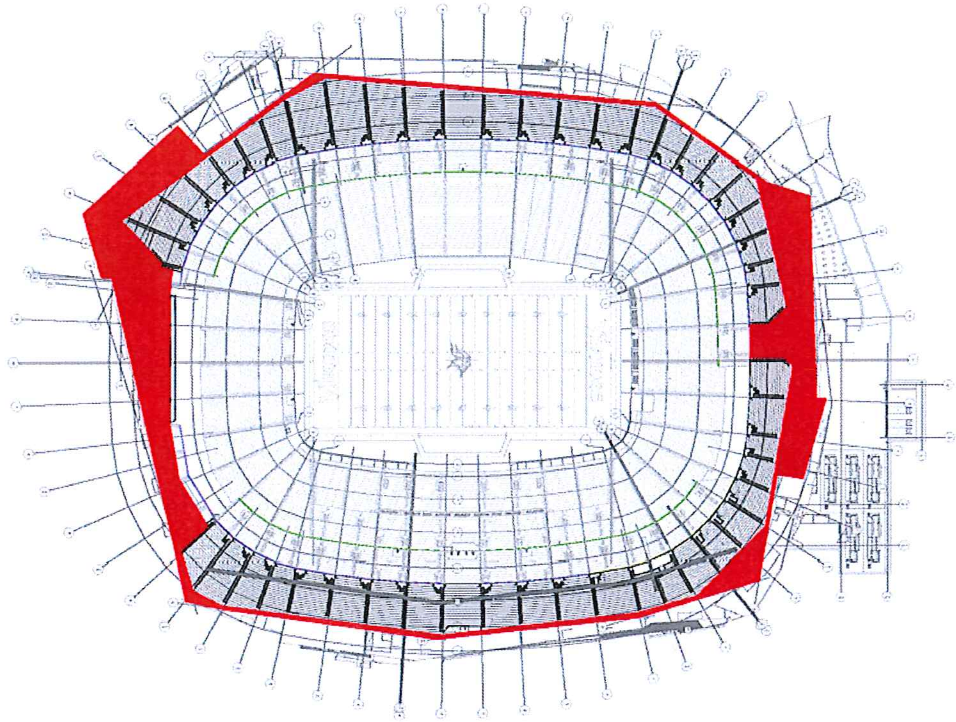
A total exhaust volume of 80,000 cfm in the south Loop Corridor distributed across four exhaust grills of 20,000 cfm each. All four grills will operate simultaneously assuring that any potential fire will located near to at least two grills for a total local exhaust rate of 40,000 cfm.

F. Egress

The smoke exhaust system is required to maintain tenable conditions within the Sideline Club for 20 minutes. This code compliant approach allows the use of smoke protected egress factors in the club space.

9. Upper Concourse

The Upper Concourse serves as the circulation area for the Upper Seating Bowl and is largely open to the enormously large bowl volume of the new Minnesota Multi-purpose Stadium. The upper seating bowl is set back from the exterior skin of the building along the sidelines leaving a gap around the perimeter of the concourse that allows smoke to vent into the bowl volume from any location. No mechanical exhaust will be required in the Upper Bowl. The following schematic indicates where the Upper Concourse is open to above.



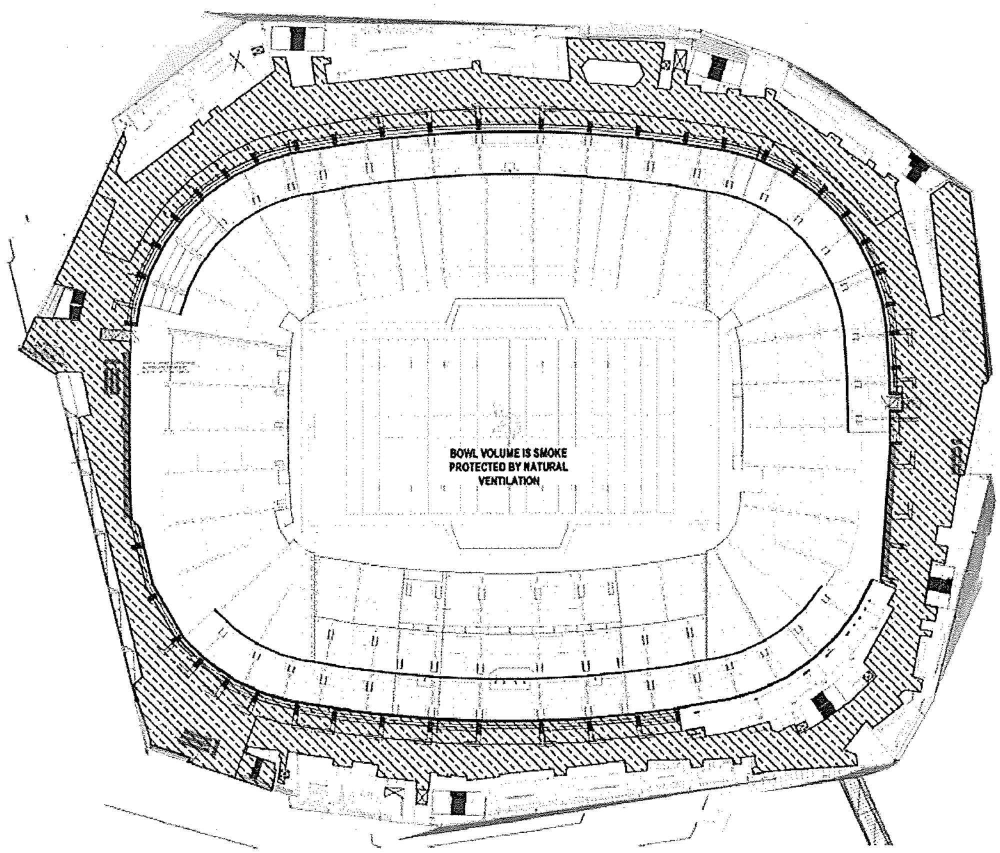
The smoke created by combustion located in those spaces naturally vents to the 'outside' bowl environment and does not require additional venting to maintain tenable conditions in those areas. The front lip of the upper bowl is fully 8 feet above the concourse floor which further provides natural ventilation in the front section of the upper concourse.

A. Portion that naturally vents into the space above the concourse

   a. Egress – There is no smoke layer accumulation in the areas that are open to the bowl volume so tenable conditions are maintained throughout the 20 minute required egress time.

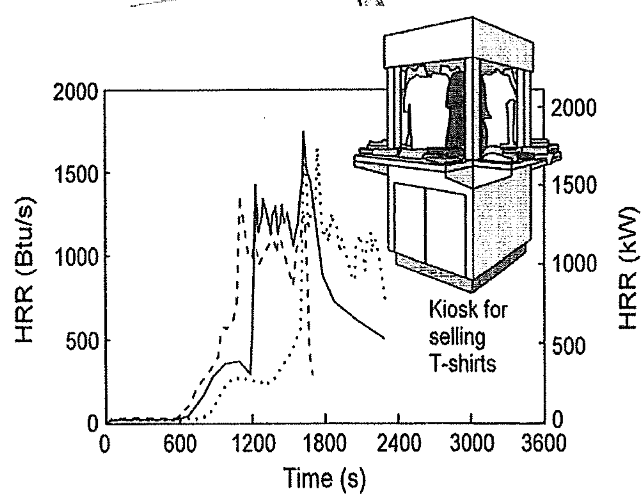
B. Partially-enclosed portion under seating bowl

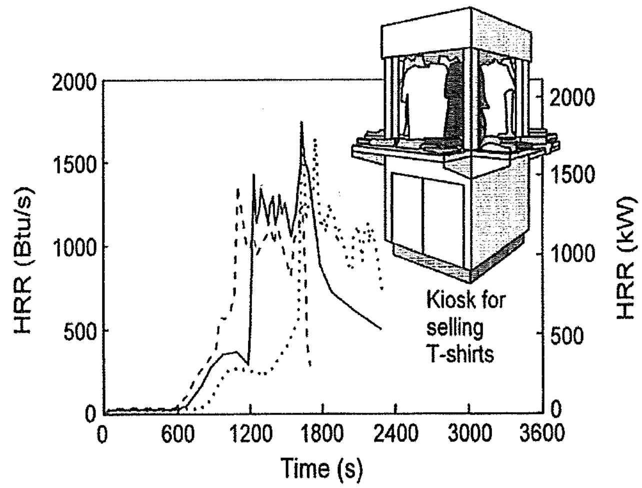
   a. Much of the Upper Concourse is open to the bowl and is smoke protected by natural venting. There are sections which are covered by the Upper Seating Bowl but are provided with a sufficient gap between the top of the bowl and exterior wall to allow the smoke to vent into the large bowl volume and maintain tenable conditions at least 6 feet above the walking surface. There is no smoke layer accumulation in the areas that are under the seating bowl so tenable conditions are maintained throughout the 20 minute required egress time. The following image show the results of a simulation of the smoke venting characteristics of the Upper Bowl.



A. Fire Size

a. In locations around the concourses, the types of fuel sources which might be found in a stadium are considered. Kiosks from which souvenirs or concessions may be sold represent the largest concentration of combustible material that typically must be considered. The following graph depicts typical heat release rates from cone calorimeter testing that has been performed.



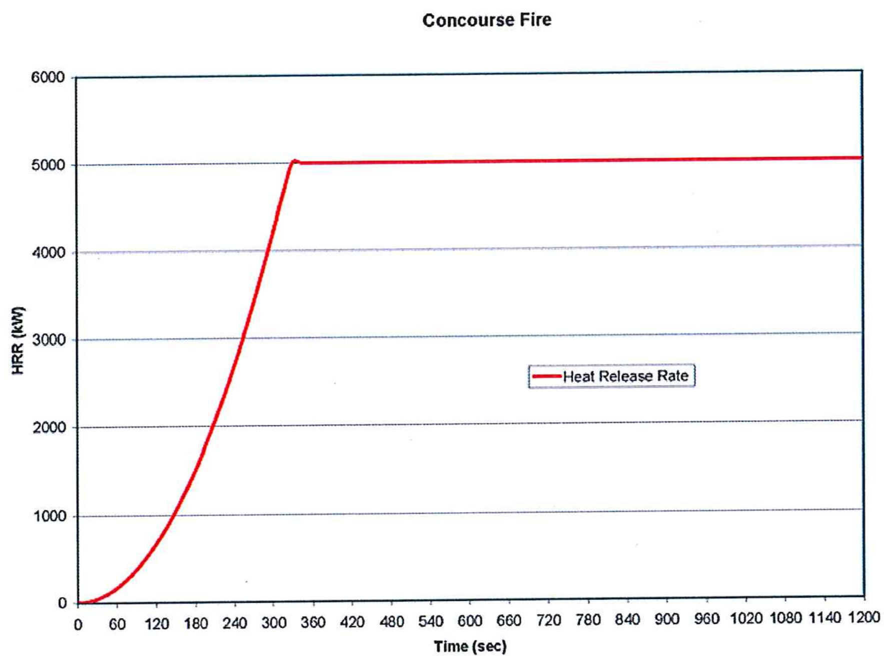


Kiosk Fire Heat Release Rate

For the purpose of this analysis a design fire with a constant heat release rate of 5,000 Btu/sec will be used. This heat release rate value is greater than the maximum heat release rate measured from a family of curves established by cone calorimeter testing as found in the SFPE Handbook of Fire Protection Engineering, p. 3-20.

As can seen in the figure, the heat release rate for a typical kiosk fire increases to a maximum and then decays to lower values after burning at the highest rate for a limited time. Using a constant value of 5,000 Btu/sec for the exposure in this analysis is a conservative assumption. Sprinkler limiting or suppression is conservatively not assumed for this analysis.

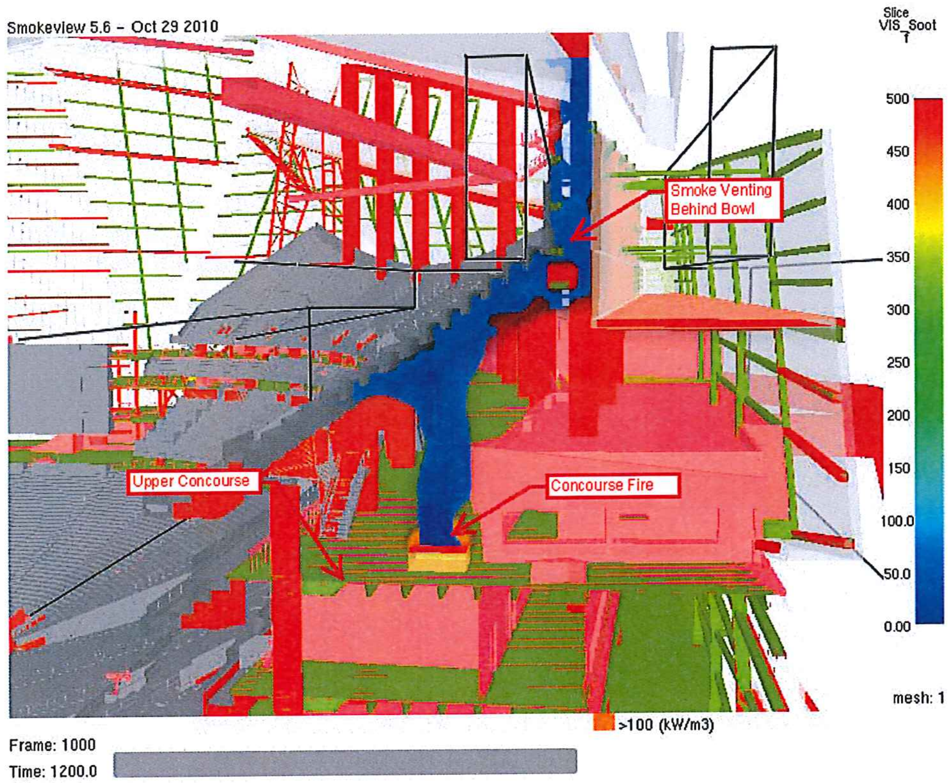
The following curve which incorporates a fast fire growth rate into the heat release rate profile will be used in locations where detailed modeling is required with FDS. All locations that yield to a simple closed form solution will utilize the constant heat release rate of 5,000 Btu/sec.



b. Results —The bottom of the smoke layer is maintained at 6 feet above the floor below to maintain tenability in the elevated egress paths as demonstrated by the following graphically presented results for the Upper Concourse.

C. Egress

With natural venting tenable conditions will be maintained on the upper concourse for at least the code required 20 minutes.



10. Upper Suite Level –Smoke Protected

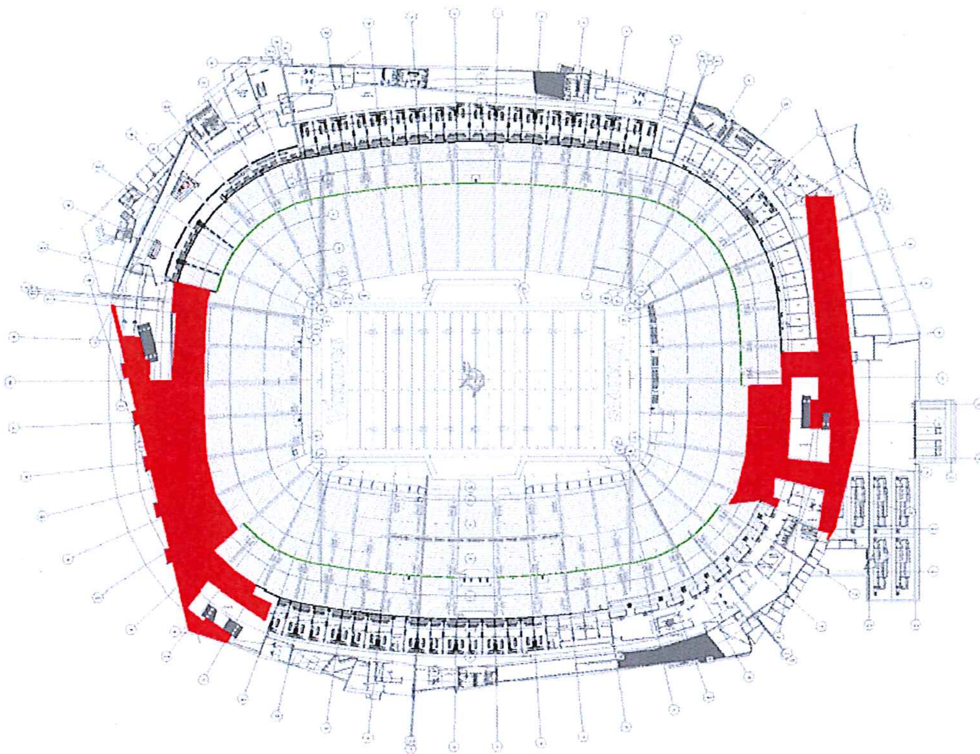
This is a smoke protected level but is a separate zone than the Main Concourse. There is a floor opening to the Main Concourse below which creates a high ceiling space for the Main Concourse. While this high ceiling space of the Main Concourse below is at the same level as the ceiling of the Upper Suite Level, the volumes are separated by construction. There is no connection between the Upper Suite Level and the Main Concourse below that would make it part of the same smoke protected volume. Additional information will be provided on the Upper Suite Smoke Management System in a subsequent revision to this report.

11. Upper Club Level –Smoke Protected

This is a smoke protected level but is a separate zone than the Main Concourse. The interior space of the Upper Level Club is separated from Main Concourse below by solid construction in the lounge area. One egress corridor is open to the concourse below; fire shutters will be used to close off the opening. Additional information will be provided on the Upper Suite Smoke Management System in a subsequent revision to this report

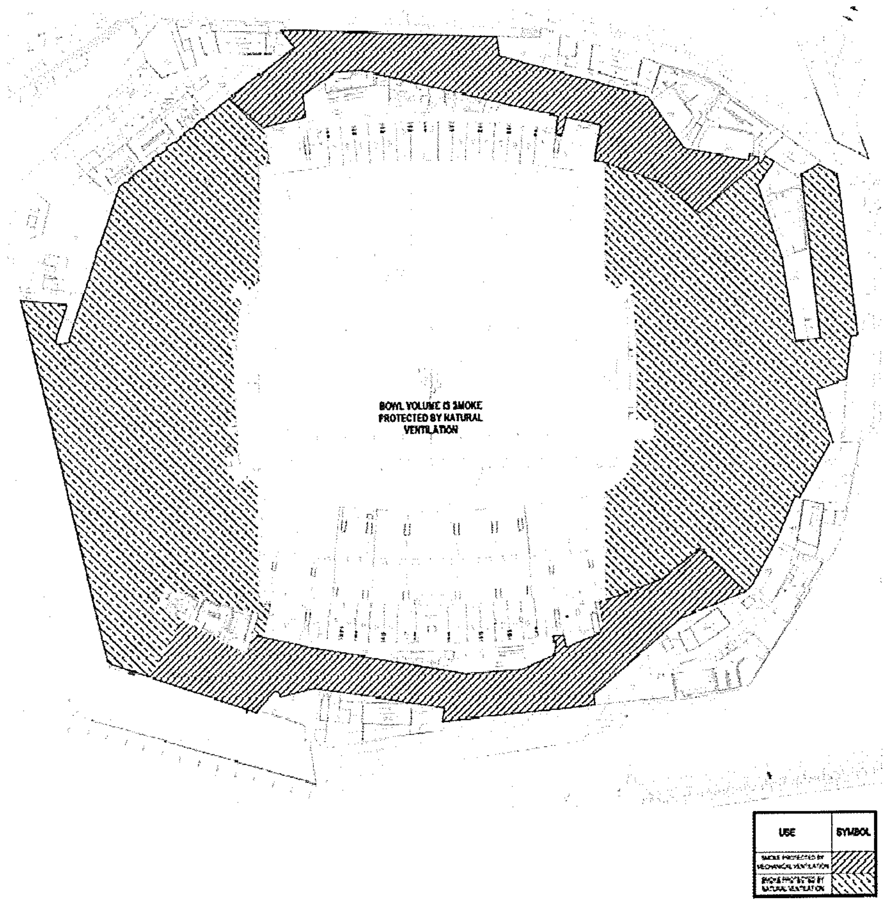
12. Main Concourse

The Main Concourse is fully open to the bowl in most locations while semi-enclosed in some areas. The following schematic indicates which areas of the Main Concourse are essentially open to the bowl volume and protected by natural ventilation.



Along the north and south sidelines there is an open volume between the building skin and the Upper Club and Upper Suite level slabs which will allow smoke from a fire on the Main Concourse to rise to the level of the underside of the Upper Concourse slab. However, the spaces on the Upper Club and Upper Suite levels are separated from the high ceiling space over the floor by construction. The extraction fans for the Main Concourse will be located above the Main Concourse floor in these void spaces up near the top under the Upper Concourse slab.

Activation of the smoke removal system will be by Main Concourse sprinkler or supplemental smoke detectors under the Upper Concourse slab in the high spaces along the sidelines.



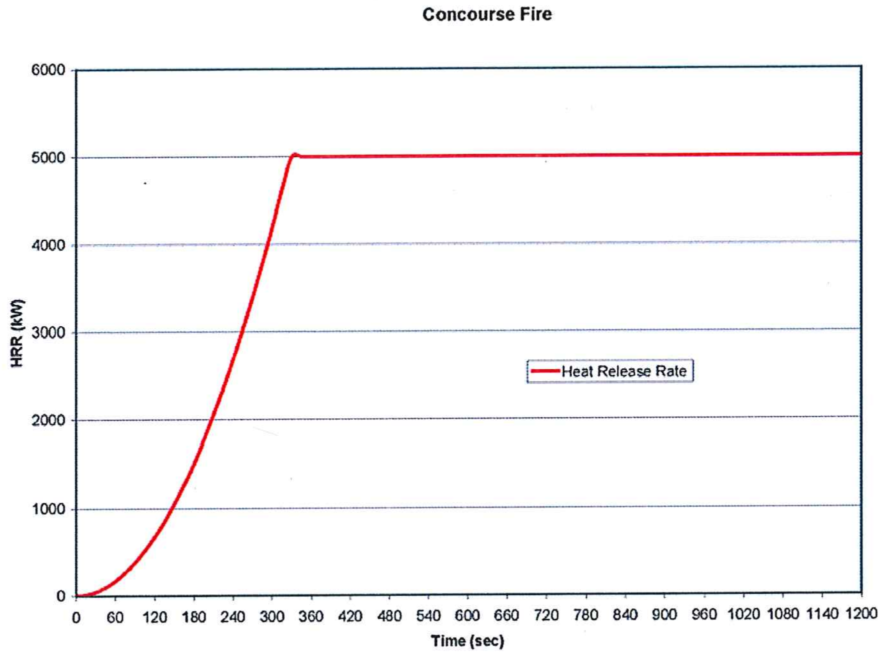
C. Portion that naturally vents into the bowl volume

   a. Egress – There is no smoke layer accumulation in the areas that are open to the bowl volume so tenable conditions are maintained throughout the 20 minute required egress time.

D. Partially-enclosed portion under slab of Lower Club and Suites above

   a. Most of the Main Concourse is open to the bowl and is smoke protected by natural venting. There are sections which are effectively enclosed and will require a mechanical smoke exhaust system to maintain tenable conditions at least 6 feet above the walking surface.

      The same conservative fire curve that is utilized on the Upper Concourse is also utilized on the Main Concourse. The following curve which incorporates a fast fire growth rate into the heat release rate profile will be used in locations where detailed modeling is required with FDS. All locations that yield to a simple closed form solution will utilize the constant heat release rate of 5,000 Btu/sec.



Kiosk Fire Heat Release Rate

b. Exhaust Rate –- The Main Concourse has a high ceiling located at or above 15 feet above the floor so the simpler algebraic solutions may be applied. The bottom of the smoke layer is maintained at 6 feet above the floor below to maintain tenability in the elevated egress paths.

The axisymmetric plume formula in Section 6.2.1.1 of the NFPA 92B will be used to calculate the smoke quantity generated. A standard fire size of 5,000 Btu/second has been selected as the fire size. This fire size does not take credit for sprinkler limiting of the fire so it is a conservative assumption.

Flame Height:
The Limiting Flame Height is the top of the flame and is calculated as follows by Section 6.2.1.1, Equation (6.2.1.1c).

$$Z_1 = 0.533 Q_c^{2/5}$$

Z_1 = *Limiting flame height*

Q_c = *Convective heat release rate, which equals 70% of the total heat release rate of 5,000 Btu/second*

= 5,000 *Btu/second x* 70% = 3,500 *Btu/second*

$$Z_1 = 0.533 \times 3{,}500^{2/5}$$

= 13.9 *feet flame height*

Mass Flow of Plume into Smoke Layer:

Since the limiting flame height is less than the height of 13.9 feet is greater than the 6 feet to the bottom of the smoke layer:

$$m = 0.0208 Q_c^{3/5} Z$$

$z = 6\ feet$ (distance from floor to bottom of the smoke layer)

$m = Mass\ flow\ rate,\ lb/second$

$Q_c = Convective\ heat\ release\ rate = 5{,}000\ Btu/second\ x\ 70\% = 3{,}500\ Btu/second$

$$m = 0.0208(3{,}500)^{3/5}(6)$$

$$m = 0.0208(133.8)(6)$$

$$m = 16.7\ lbs/mass\ flow\ from\ plume\ into\ smoke\ layer$$

Smoke Layer Temperature:
The temperature of the smoke in the plume is calculated using Equation 9-9 in Section 909.10.1. The actual smoke layer temperature will be limited to 212° F by the sprinkler system. Using the higher temperature over-predicts the exhaust quantity required since it results in a lower calculated smoke density. The lower the density, the higher the exhaust fan capacity necessary to exhaust the same mass.

$$T_s = T_o + \frac{Q_c}{mC_p}$$

$T_s = Temperature\ of\ fire\ plume\ in\ ^\circ F$

$T_o = Ambient\ temperature\ in\ ^\circ F$

$C_p = Specific\ heat\ of\ smoke = 0.24\ Btu/lb\ ^\circ F$

$Q_c = Fire\ heat\ convective\ release\ rate = 3{,}500\ Btu/second$

$$T_s = 70 + \frac{3{,}500}{16.7(0.24)} = 943^\circ F$$

Smoke Density:
To calculate smoke density, assume that the smoke layer temperature is the same as the temperature of the smoke in the plume. Note that this is a conservative assumption as it treats the smoke layer as uniform and adiabatic. (It assumes that there is no cooling of the smoke within the layer.) Smoke layer density is then calculated using Charles' Law.

$T_o = Ambient\ temperature\ in\ ^\circ R$

$T_s = Temperature\ of\ smoke\ plume\ in\ ^\circ R$

$\rho = Smoke\ density\ in\ lb/feet^3$

$\rho_o = Ambient\ density = 0.075\ lb/feet^3$

$$\rho = \rho_o \frac{T_o}{T_s} = 0.075 \frac{530}{460 + 943} = 0.028\ lb/feet^3$$

Exhaust Flow Rate:
The required exhaust rate is then calculated using the calculated plume mass flow rate and densities with Equation (9-4) in Section 909.8.2 of the SBC.

$V = \text{Exhaust rate in cfm}$

$m = \text{Mass flow rate} = 16.7 \text{ lb/second}$

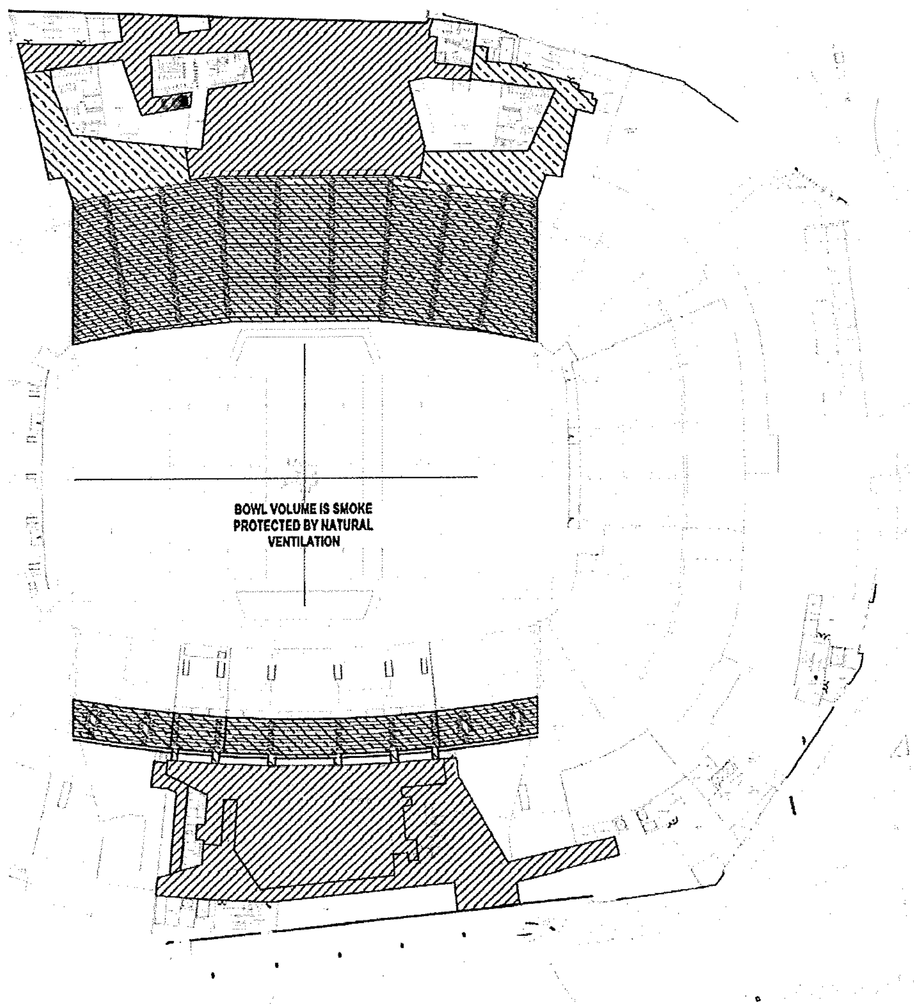
$p = \text{Density of smoke at } 943\ °F = 0.028 \text{ lb/feet}^3$

$$V = 60\frac{m}{\rho} = 60\frac{49}{0.028} = 35{,}400 \text{ cfm (Equation 6.4)}$$

An exhaust volume of 80,000 cfm was selected to provide conservative performance.

13. Lower Club North and South

The Lower Club on the North side of the new stadium will be provided with a smoke protected interior environment. Since the Lower Club is an interior space, the smoke management will be accomplished with a mechanical exhaust system.



G. Fire Sizes

The fire size for the North Lower Club will be the standard large fire of 5,000 Btu/sec as described in other sections of this report. Since the ceiling space in the North Upper Club is high, about 15 feet the algebraic equations in the NFPA92B standard will be used for sizing the exhaust equipment. The fire will be assumed to be steady state for this analysis.

H. Smoke Exhaust

The axisymmetric plume formula in Section 6.2.1.1 of the NFPA 92B will be used to calculate the smoke quantity generated. A standard fire size of 5,000 Btu/second has been selected as the fire size. This fire size does not take credit for sprinkler limiting of the fire so it is a conservative assumption.

Flame Height:
The Limiting Flame Height is the top of the flame and is calculated as follows by Section 6.2.1.1, Equation (6.2.1.1c).

$$Z_1 = 0.533 Q_c^{2/5}$$

$$Z_1 = \textit{Limiting flame height}$$

$$Q_c = \textit{Convective heat release rate, which equals 70\% of the total heat release rate of } 5{,}000 \textit{ Btu/second}$$

$$= 5{,}000 \textit{ Btu/second} \times 70\% = 3{,}500 \textit{ Btu/second}$$

$$Z_1 = 0.533 \times 3{,}500^{2/5}$$

$$= 13.9 \textit{ feet flame height}$$

Mass Flow of Plume into Smoke Layer:
Since the limiting flame height is less than the height of 13.9 feet is greater than the 6 feet to the bottom of the smoke layer:

$$m = 0.0208 Q_c^{3/5} Z$$

$$z = 6 \textit{ feet} \text{ (distance from floor to bottom of the smoke layer)}$$

$$m = \textit{Mass flow rate, lb/second}$$

$$Q_c = \textit{Convective heat release rate} = 5{,}000 \textit{ Btu/second} \times 70\% = 3{,}500 \textit{ Btu/second}$$

$$m = 0.0208 (3{,}500)^{3/5} (6)$$

$$m = 0.0208 (133.8)(6)$$

$$m = 16.7 \textit{ lbs/mass flow from plume into smoke layer}$$

Smoke Layer Temperature:
The temperature of the smoke in the plume is calculated using Equation 9-9 in Section 909.10.1. The actual smoke layer temperature will be limited to 212° F by the sprinkler system. Using the higher temperature over-predicts the exhaust quantity required since it results in a lower calculated smoke density. The lower the density, the higher the exhaust fan capacity necessary to exhaust the same mass.

$$T_s = T_o + \frac{Q_c}{mC_p}$$

$$T_s = \textit{Temperature of fire plume in } {}^\circ F$$

$$T_o = \textit{Ambient temperature in } {}^\circ F$$

$$C_p = \textit{Specific heat of smoke} = 0.24 \textit{ Btu/lb } {}^\circ F$$

$$Q_c = \textit{Fire heat convective release rate} = 3{,}500 \textit{ Btu/second}$$

$$T_s = 70 + \frac{3{,}500}{16.7(0.24)} = 943^\circ F$$

Smoke Density:
To calculate smoke density, assume that the smoke layer temperature is the same as the temperature of the smoke in the plume. Note that this is a conservative assumption as it treats the smoke layer as uniform and adiabatic. (It assumes that there is no cooling of the smoke within the layer.) Smoke layer density is then calculated using Charles' Law.

T_O = *Ambient temperature in* °*R*

T_S = *Temperature of smoke plume in* °*R*

ρ = *Smoke density in lb/feet*^{3}

ρ_O = *Ambient density* = 0.075 *lb/feet*^{3}

$$\rho = \rho_O \frac{T_O}{T_S} = 0.075 \frac{530}{460 + 943} = 0.028\ lb/feet^3$$

Exhaust Flow Rate:

The required exhaust rate is then calculated using the calculated plume mass flow rate and densities with Equation (9-4) in Section 909.8.2 of the SBC.

V = *Exhaust rate in cfm*

m = *Mass flow rate* = 16.7 *lb/second*

p = *Density of smoke at* 943 °*F* = 0.028 *lb/feet*^{3}

$$V = 60 \frac{m}{\rho} = 60 \frac{49}{0.028} = 35{,}400\ cfm\ \ (Equation\ \ 6.4)$$

An exhaust volume of 50,000 cfm was selected to provide conservative performance.

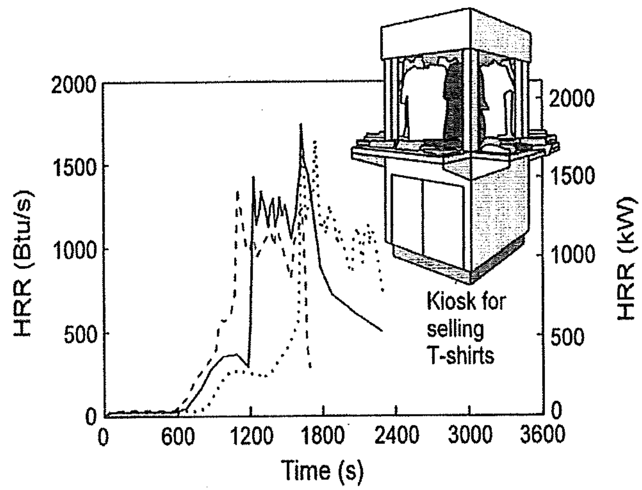
I. Egress

The smoke exhaust system is required to maintain tenable conditions within the Club for 20 minutes. This code compliant approach allows the use of smoke protected egress factors in the club space.

14. Red Zone North

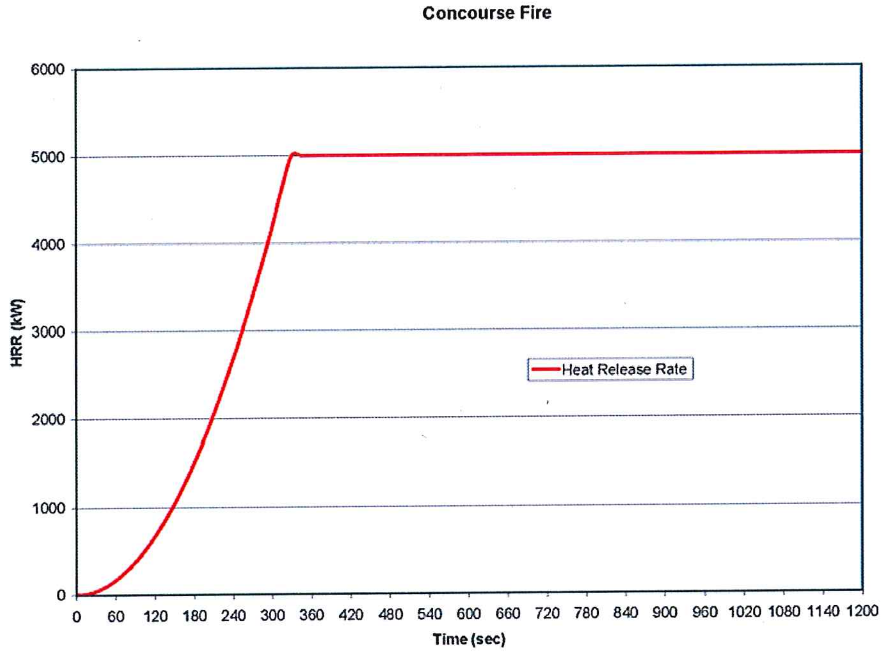
A. Fire Sizes

a. In locations around the concourses, the types of fuel sources which might be found in a stadium are considered. Kiosks from which souvenirs or concessions may be sold represent the largest concentration of combustible material that typically must be considered. The following graph depicts typical heat release rates from cone calorimeter testing that has been performed.



Kiosk Fire Heat Release Rate

For the purpose of this analysis a design fire with a constant heat release rate of 5,000 Btu/sec will be used. This heat release rate value is greater than the maximum heat release rate measured from a family of curves established by cone calorimeter testing as found in the SFPE Handbook of Fire Protection Engineering, p. 3-20. As can seen in the figure, the heat release rate for a typical kiosk fire increases to a maximum and then decays to lower values after burning at the highest rate for a limited time. Using a constant value of 5,000 Btu/sec for the exposure in this analysis is a conservative assumption. Sprinkler limiting or suppression is conservatively not assumed for this analysis.
The following curve which incorporates a fast fire growth rate into the heat release rate profile will be used in locations where detailed modeling is required with FDS. All locations that yield to a simple closed form solution will utilize the constant heat release rate of 5,000 Btu/sec.

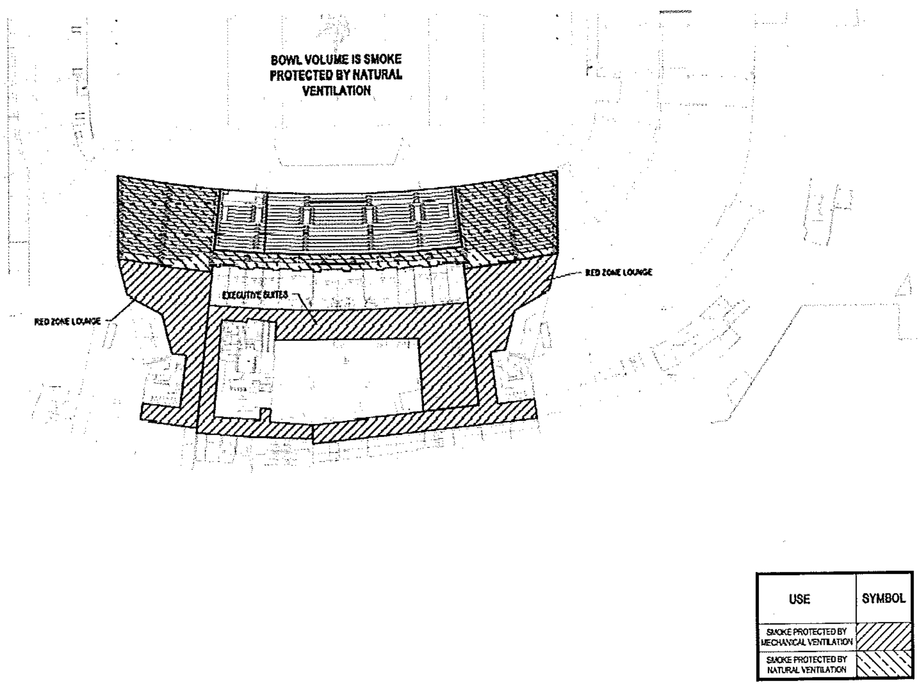


B. Smoke Exhaust

a. The Red Zone Lounges are open to the volume of the bowl and do so are not subject to the accumulation of products of combustion.

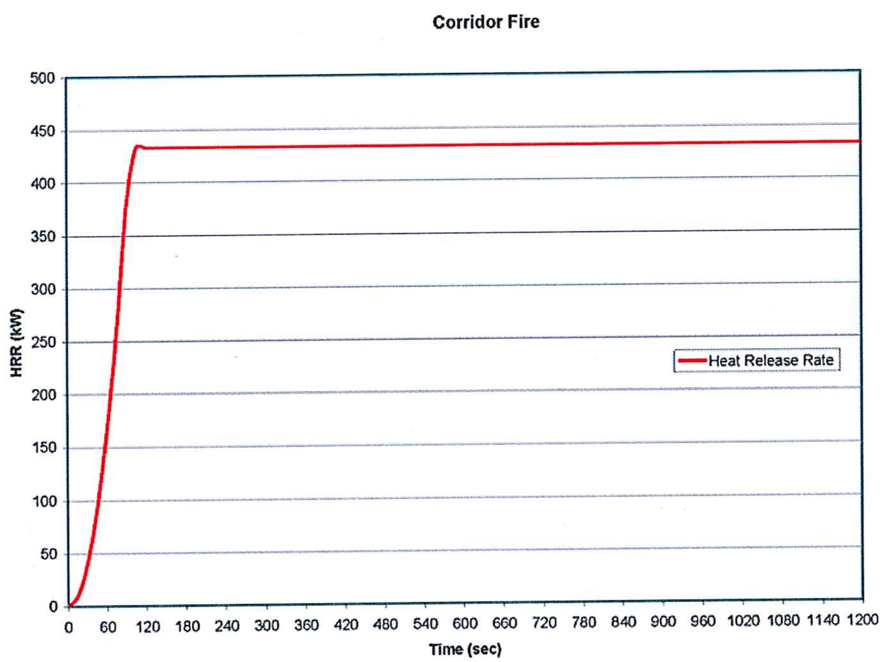
15. Lower Executive Suite and Red Zone South Lounges

A. The Super GA Lounges serve as the means of egress for the upper and lower super GA sections on the south sideline. Access to the main exit stair enclosures that serve the Super GA sections on the south sideline is provided by the corridors of the Executive Suites space. Smoke protected exit factors are required because of the large populations using these exits so a mechanical smoke exhaust system is required to maintain tenable conditions in these spaces.



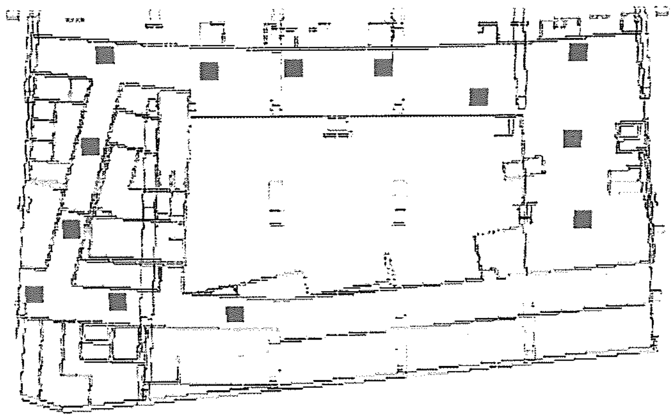
a. The Red Zone Lounges are high ceiling spaces which are partly open to the large volume of the Stadium. The corridors of the Executive Suites space are low ceiling spaces with less than 14 feet of elevation between the slabs. The assumptions made in the derivation of the simple equations of the NFPA 92B standard cannot be applied in these long, relatively narrow, low-ceilinged spaces so the higher fidelity FDS tool is used to evaluate the required smoke exhaust quantities and vent locations to maintain tenable conditions for egress in the corridor system. Tenability conditions will be monitored at the level of 6 feet above the floor of the Executive Suite corridors.

A potential fire in the corridor system is considered. The corridor system of the Executive Suites area will contain bars and seating for patrons. Some of these furnishings may be significant sources of combustible material. The corridors are provided with automatic sprinkler protection and the effect of sprinkler activation is quantified. The DETACT algorithm found in the FPETool suite of software tools originally provided by NIST was used to estimate sprinkler activation time and fire size in the corridors. The maximum fire size with a conservative fast fire growth rate was found to be 433 Btu/sec reached at about 100 seconds. Without modeling suppression (allowing the fire to burn at constant maximum rate) the heat release rate curve for this fire is shown in the following chart.



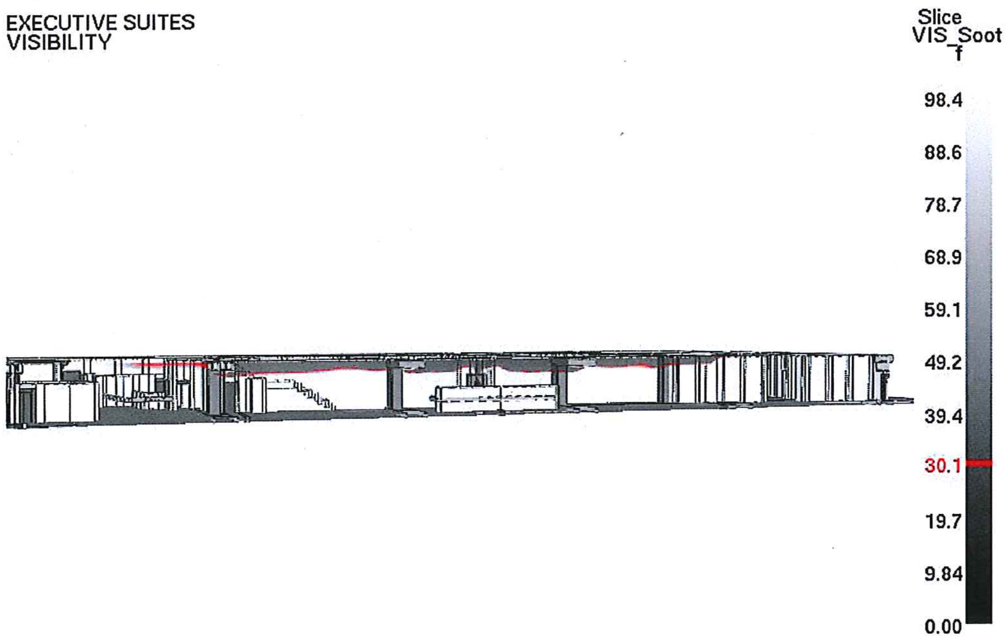
The exhaust system in the corridors and lounge area of the Executive Suites consists of 1,000 cfm exhaust grills spaced approximately 30 feet on centers. The following layout was used for this preliminary simulation.

EXECUTIVE SUITES



The results of simulation will be found in an appendix of future versions of this report. The following graphically represents the results of a fire at the central bar area of the circulation area of the Executive Suites lounge.

EXECUTIVE SUITES
VISIBILITY



b. The Red Zone lounges have a high ceiling space so the simpler solutions may be applied. Because some of the patrons exiting through the Red Zone Lounge area are descending from above, the bottom of the smoke layer is required to be maintained at or above a level that would be encountered by patrons entering the space through the vomitories above and descending the stairs into the main lounge area. The bottom of the smoke layer is maintained at 16 feet above the floor below to maintain tenability in the elevated egress paths.

The axisymmetric plume formula in Section 6.2.1.1 of the NFPA 92B will be used to calculate the smoke quantity generated. A standard fire size of 5,000 Btu/second has been selected as the fire size. This fire size does not take credit for sprinkler limiting of the fire so it is a conservative assumption.

Flame Height:
The Limiting Flame Height is the top of the flame and is calculated as follows by Section 6.2.1.1, Equation (6.2.1.1b).

$$Z_1 = 0.533 Q_c^{2/5}$$

Z_1 = *Limiting flame height*

Q_c = *Convective heat release rate, which equals 70% of the total heat release rate of 5,000 Btu/second*

$= 5{,}000\ Btu/second \times 70\% = 3{,}500\ Btu/second$

$$Z_1 = 0.533 \times 3{,}500^{2/5}$$

$= 13.9$ *feet flame height*

Mass Flow of Plume into Smoke Layer:
Since the limiting flame height is less than the height of 13.9 feet is less than the 16 feet to the bottom of the smoke layer:

$$m = 0.022 Q_c^{1/3} Z^{5/3} + 0.0042 Q_c$$

z = 16 *feet (dis tance from Event Flo or to 6 feet abov e the* Upper Super GAVomitory Floor *)*

m = *Mass flow rate, lb/ second*

Q_c = *Convective heat rele ase rate* = 5,000 *Btu/secon d x* 70% = 3,500 *Btu/ second*

$$m = 0.022(3{,}500)^{1/3}(16)^{5/3} + 0.0042(3{,}500)$$

$$m = 0.022(15.2)(101.7) + 14.7$$

m = 49 *lbs/mass flow from plume into smoke lay er*

Smoke Layer Temperature:
The temperature of the smoke in the plume is calculated using Equation 9-9 in Section 909.10.1. The actual smoke layer temperature will be limited to 212° F by the sprinkler system. Using the higher temperature over-predicts the exhaust quantity required since it results in a lower calculated smoke density. The lower the density, the higher the exhaust fan capacity necessary to exhaust the same mass.

$$T_s = T_o + \frac{Q_c}{mC_p}$$

T_s = Temperature of fire plume in °F

T_o = Ambient temperature in °F

C_p = Specific heat of smoke = 0.24 Btu/lb °F

Q_c = Fire heat convective release rate = 3,500 Btu/second

$$T_s = 70 + \frac{3{,}500}{49(0.24)} = 370°F$$

Smoke Density:
To calculate smoke density, assume that the smoke layer temperature is the same as the temperature of the smoke in the plume. Note that this is a conservative assumption as it treats the smoke layer as uniform and adiabatic. (It assumes that there is no cooling of the smoke within the layer.) Smoke layer density is then calculated using Charles' Law.

T_o = Ambient temperature in °F

T_s = Temperature of smoke plume in °F

ρ = Smoke density in $lb/feet^3$

ρ_o = Ambient density = 0.075 $lb/feet^3$

$$\rho = \rho_o \frac{T_o}{T_s} = 0.075 \frac{530}{460 + 370} = 0.048\ lb/feet^3$$

Exhaust Flow Rate:

The required exhaust rate is then calculated using the calculated plume mass flow rate and densities with Equation (9-4) in Section 909.8.2 of the SBC.

$$V = \textit{Exhaust rate in cfm}$$

$$m = \textit{Mass flow rate} \ = 49 \ \textit{lb/second}$$

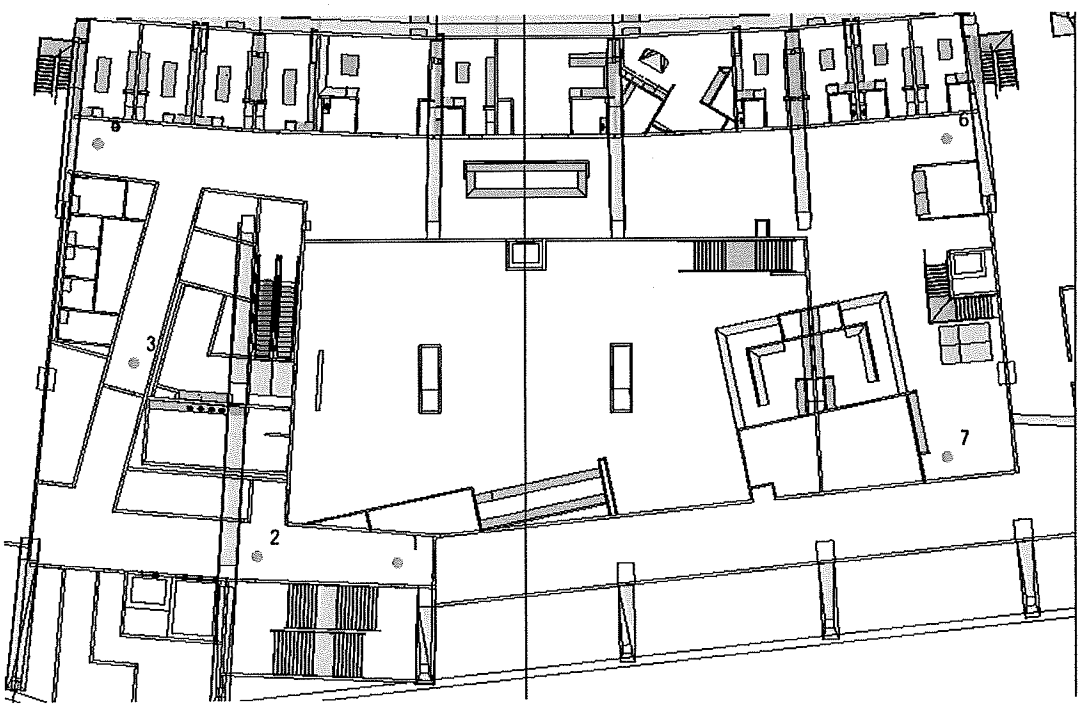
$$p = \textit{Density of smoke at } 370\ °F \ = 0.048\ \textit{lb/feet}^3$$

$$V = 60\frac{m}{\rho} = 60\frac{49}{0.048} = 60{,}000\ \textit{cfm}\ \ (\textit{Equation}\ \ 6.4)$$

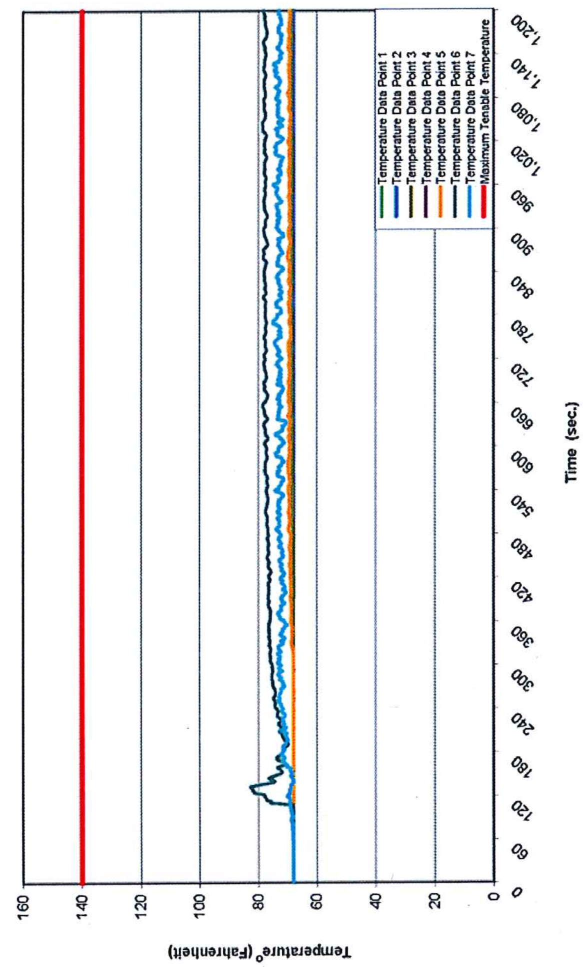
An exhaust volume of 75,000 cfm was selected to provide conservative performance.

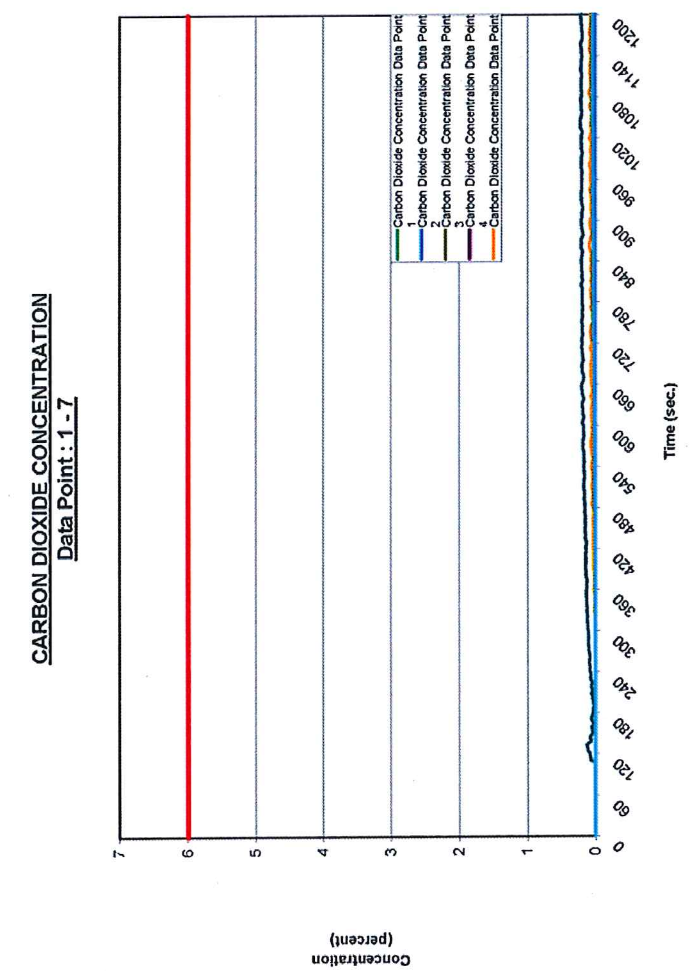
B. Egress (Smoke Layer at South Red Zone Lounge and Interior Corridor)

a. An FDS simulation was performed to determine if the proposed mechanical smoke exhaust system in the Executive Suites area would maintain tenable conditions. Those results are presented here.

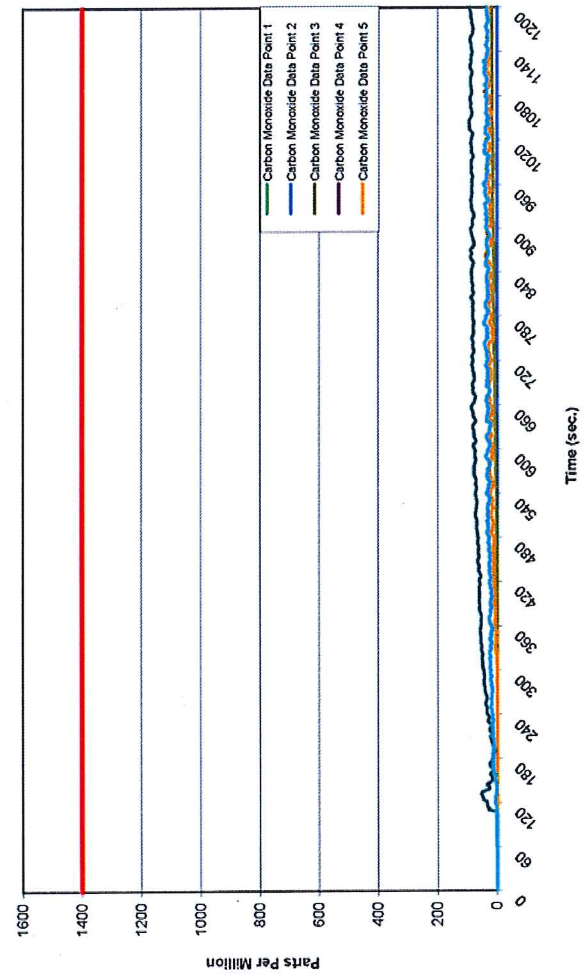


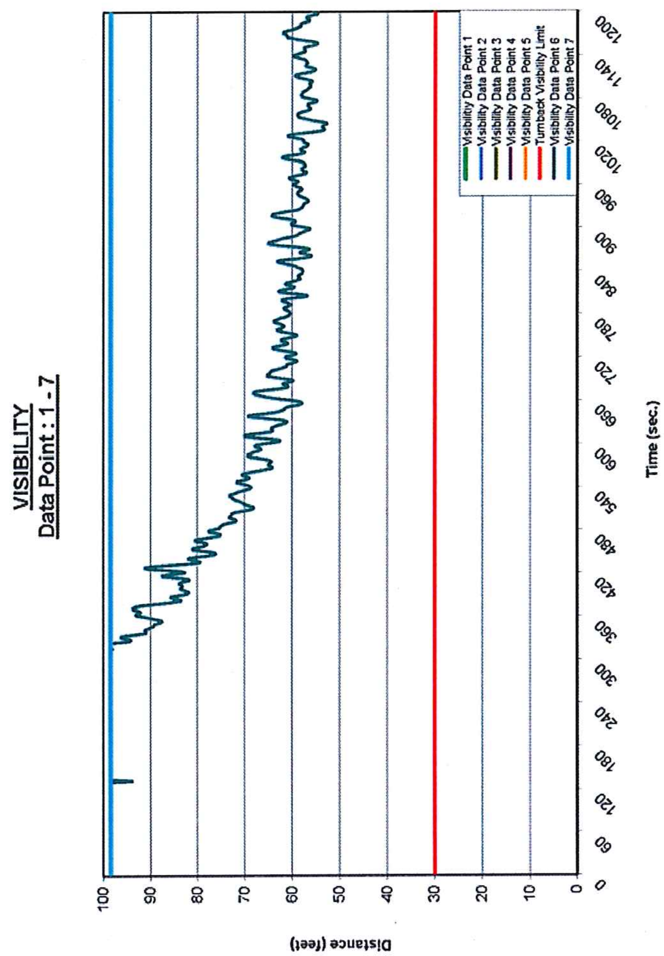
TEMPERATURE
Data Point : 1 - 7




CARBON DIOXIDE CONCENTRATION
Data Point : 1 - 7
Carbon Dioxide Concentration Data Point
Carbon Dioxide Concentration Data Point 1
Carbon Dioxide Concentration Data Point 2
Carbon Dioxide Concentration Data Point 3
Carbon Dioxide Concentration Data Point 4
Concentration (percent)
Time (sec.)
0
1
2
3
4
5
6
7
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
1020
1080
1140
1200

CARBON MONOXIDE CONCENTRATION
Data Point : 1 - 7



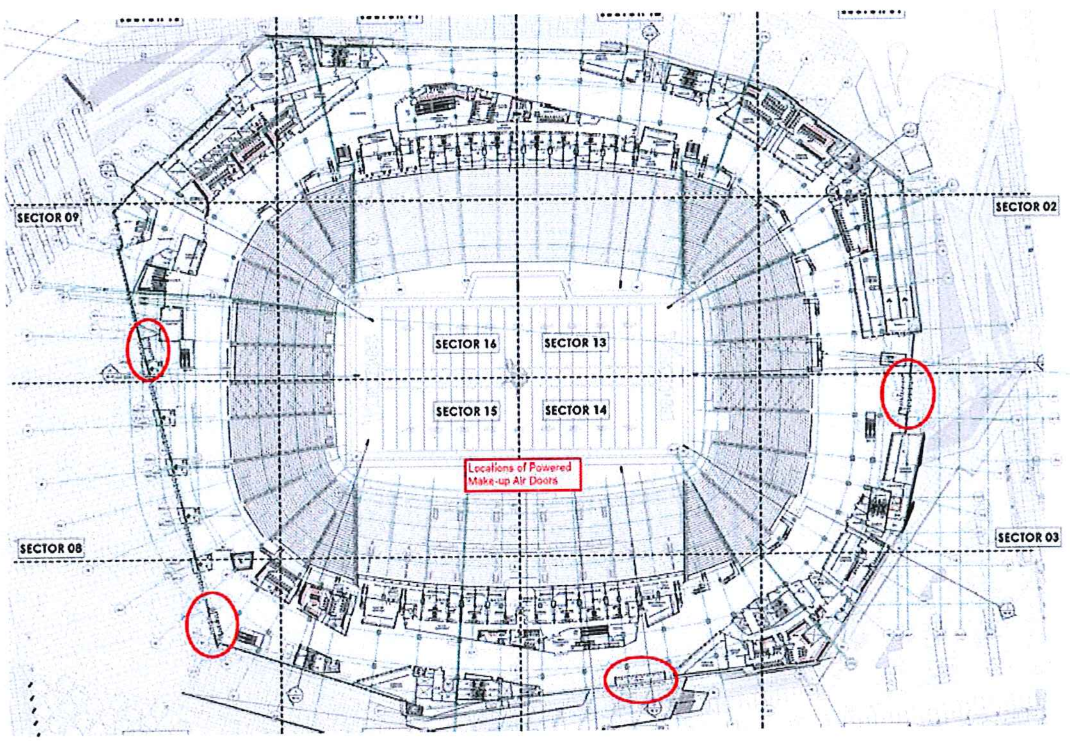

VISIBILITY
Data Point : 1 - 7
Distance (feet)
Time (sec.)
Visibility Data Point 1
Visibility Data Point 2
Visibility Data Point 3
Visibility Data Point 4
Visibility Data Point 5
Turnback Visibility Limit
Visibility Data Point 6
Visibility Data Point 7

16. Make Up Air

Where mechanical exhaust operation extracts air from the stadium a source of make-up air must be provided. Make-up air is not necessary when the bowl volume is used as a passive reservoir for the products of combustion to disperse into without being extracted from the building. In smaller spaces which are not directly connected to the large bowl volume in a way that would allow natural ventilation make-up air will be drawn into the stadium by way of exterior doors that will be opened when a mechanical smoke exhaust system is activated.

The below grade truck dock is accessed by a large ramp which slopes down and is enclosed and sealed from inclement conditions by two large over head doors in series. Additionally, the interior of the truck dock is connected to the bowl volume at the Event Level through a large vomitory that can be closed off with another overhead door. While in Truck Dock Smoke Exhaust evacuation mode, make-up air will be provide from the bowl though the large vomitory to the Field in the open volume and through infiltration from surrounding spaces.

In addition to the truck dock make-up air, additional outside air will be provided through powered man doors on the Main Concourse level.



17. Summary of Results for Mechanical Ventilation

The following table summarizes the design parameters for the smoke exhaust systems required for the Stadium. Note that exhaust quantities typically exceed the minimum required calculations to provide a factor of safety for calculations and installations.

Space	Exhaust (cfm)	Activation (Sprinklers or Smoke Detection)	Make-up Air Suply	Time from Detection to Full Exhaust	Smoke Temperature
Field	Passive Bowl Volume	N/A	N/A	N/A	N/A
Truck Dock	175,000	Sprinklers	Truck Dock Ext. Door, Elephant Vom.	90 seconds	212° F
Sideline Club	80,000	Sprinklers	Vomitory Doors.	90 seconds	212° F
South Loop Corridor	80,000	Sprinklers	Corriodor Doors.	90 seconds	212° F
Red Zone Lounge South*	80,000 each southeast and southwest	Sprinklers	Bowl volume	90 seconds	212° F
Executive Suite Level	1,000 cfm exhaust every 30 feet of corridor	Sprinklers	Man doors to Bowl volume	90 seconds	212° F
Lower Club Lounge South	80,000	Sprinklers	Man doors to Bowl volume	90 seconds	212° F
Lower Club Concourse South	80,000	Sprinklers	Man doors to exterior	90 seconds	212° F
Red Zone Lounge, North*	75,000 each northeast and northwest	Sprinklers	Bowl volume	90 seconds	212° F
Lower Club Level North	80,000	Sprinklers	Man doors to Bowl volume	90 seconds	212° F
Main Concourse*	Passive Bowl Volume, with 80,000 cfm per each sideline zone mechanical supplementation	Sprinklers with smoke detector supplementation	Bowl volume	90 seconds	212° F
Lower Seating Bowl	Passive Bowl Volume	N/A	N/A	N/A	N/A
Upper Concourse*	Passive Bowl Volume	Sprinklers	Bowl volume	90 seconds	212° F

Upper Seating Bowl	Passive Bowl Volume	N/A	N/A	N/A	N/A

*Will vent into the Bowl Volume.

18. Conclusion

This report documents Smoke-Protected Approaches for Life Safety in the new Minnesota Multipurpose Stadium. The Minnesota State Building Code which is based on the 2006 International Building Code (IBC) defines Smoke-Protected Assembly Seating as seating served by means of egress that is not subject to smoke accumulation within or under a structure.

This report demonstrates that the field, the seating bowl, upper concourse and most of the main concourse are smoke-protected by natural ventilation and that the Executive suite, Red Zones and lower club levels are smoke-protected by mechanical ventilation.

19. FDS

Background

The Fire Dynamics Simulator (FDS) is computer program published by the National Institute of Standards and Technology (NIST) a US governmental agency. FDS solves conservation of mass, momentum and energy equations iteratively in a three-dimensional computational domain. Results can be tabulated, graphed or viewed in Smokeview – another NIST computer program that shows the three-dimensional domain and animates the results.

Tenability

Predicted tenability conditions are monitored at the different locations in the building space and recorded. Those devices are sensors which measure carbon dioxide, carbon monoxide, oxygen, temperature and visibility. The visibility recorded by FDS for these simulations is to an illuminated EXIT sign. The values are shown in for these location of this report and presented in the form of graphs.
The safe levels of the tenability parameters are shown below. Based on values cited in literature, the limits given below are used as tenability criteria for this analysis.
<u>Table Tenability Criteria</u>

Tenability Parameters	Temperature (°F)	Oxygen (% vol)	Carbon Dioxide (% vol)	Carbon Monoxide (ppm)	Visibility (ft)
Acceptable limits	Maximum 140° F (60° C) exposure less than 30 minutes. (2)	Greater than 12% for less than 30 minutes; Initial oxygen percentage of air is 21%. (1)	Maximum 60,000 ppm (6%) exposure for less than 30 minutes. (1)	Maximum 1,400 ppm (0.14%) exposure less than 30 minutes. (1)	30 feet minimum visibility for turn back. (3)

<u>REFERENCES</u>
1. Toxicity Assessment of Combustion Products, SFPE Handbook of Fire Protection Engineering, Third Edition, 2002; Table 2-6B(a); p.2-165.
2. Toxicity Assessment of Combustion Products, SFPE Handbook of Fire Protection Engineering, Third Edition, 2002; Table 2-6.19; p2-129.
3. Hazard Calculation, SFPE Handbook of Fire Protection Engineering, Third Edition, 2002; Table 3-12.20; p3-334.

20. Testing – Smoke Bombs

The State Building Code requires component testing.

Smoke bombs are not required by the State Building Code, the IBC nor NFPA 92B as per the following excerpts.

NFPA 92B

Smoke bomb tests do not provide the heat, buoyancy, and entrainment of a real fire and are not useful in evaluating the real performance of the system. A system designed in accordance with this document and capable of providing the intended smoke management might not pass smoke bomb tests. Conversely, it is possible for a system that is incapable of providing the intended smoke management to pass smoke bomb tests. Because of the impracticality of conducting real fire tests, the acceptance tests described in this document are directed to those aspects of smoke management systems that can be verified.

ICC Guide to Smoke Control in the 2006 IBC

Real smoke and artificial smoke must not be used for acceptance testing of smoke control systems with the exception of tracer testing. Artificial smoke can be produced by smoke bombs or other kinds of smoke generators, and it almost always lacks the buoyancy of smoke from the design fire. Smoke control systems do not perform as intended when subjected to such artificial smoke. Testing with smoke can only be realistic when the fire is the design fire, and this typically has unacceptable risks to life and property. If artificial smoke is heated to the temperature of the design smoke, the danger to life and property is the same as that from the design fire. Acceptance testing is required by Section 909.18 of the IBC which is discussed in this chapter.

IBC (2012) Commentary

~~make changes at this stage.~~ Note that the test does not actually place smoke into the space and demonstrate the smoke layer interface location. Instead, the testing is focused on all the elements of the design such as airflow and duct closure as prescribed by the specific design.

21. Smoke Control Special Inspection Testing Procedures

I. Background On Building

A. General
The Minnesota Multi-Purpose Stadium has been constructed under the 2006 IBC with the State of Minnesota amendments.

B. Smoke Protected Exiting
The Minnesota Multi-Purpose Stadium is utilizing smoke protected assembly exit factors. Some areas utilized natural venting and some areas require mechanical ventilation.

C. Stair Pressurization
Stair pressurization is utilized to maintain a smoke free environment to the exit discharge.

D. Elevator Pressurization
Elevator Hoistway Pressurization is required for elevators as elevator lobbies have not been provided.

II. Smoke Control Special Inspection Testing Procedures

A. General

1. All devices and total system tested must operate correctly in each of the following modes:
    a. Normal Power
    b. Stand By power
    c. Manual override (all components of the smoke control system must be capable of being manually overridden by the Fire Fighter's Smoke Control Panel).

2. Testing shall be performed by the subcontractor and witnessed by the special inspector and witnessed by a representative of the City of Minneapolis.

3. Test and balance report approved by the engineer of record shall be provided to the special inspector and to City of Minneapolis

4. When testing as a system, the intent is for the correct sequence of operations to occur. The IBC (section 909.18.8.1) does not require the use of test smoke through smoke bombs or canned smoke as supported by the "ICC Guide to Smoke Control in the 2006 IBC". In addition, the following publications do not recommend the use of canned smoke tests for the reasons that misleading and false results are produced.
    - "The SFPE Handbook of Fire Protection Engineering" (Third Addition, pg 4-290)
    - The "ASHRAE Applications" on Fire and Smoke Management (2007 Addition, pg 52.17)
    - "Principles of Smoke Management" (John H. Klote, James A. Milke, 2002, pg 237)

5. All testing shall be performed with all stair shafts pressurization systems activated. Individual zone smoke control systems shall be activated for testing.

B. Component Testing

The following tests will be performed for all components of the smoke control system:

1. Duct leakage test:
2. System Test and Balancing
3. Functional test: all components shall be tested to ensure that each is working properly.

C. List Of Components For Testing:

The following list of equipment and controls is required to be installed for testing of the stair pressurization system:

1. Fire Fighter's Smoke Control Panel (verify UUKL listing)
2. Sprinkler flow switches
3. Ceiling smoke detectors
4. Duct smoke detectors
5. Pull stations
6. Emergency power source
7. Stair pressurization fans (check correct rotation, measure voltage, amperage, rpm, and belt tension and number of belts)
8. Smoke exhaust fans (check correct rotation, measure voltage, amperage, rpm, and belt tension and number of belts)
9. Any duct dampers required for smoke exhaust
10. Make up air intake for smoke exhaust
11. Static Pressure Indicators
12. Stairway Doors

III. Smoke Exhaust Systems

A. Equipment and System Test

Functional test: all components shall be tested to ensure that each is working properly. List of components and systems to be tested:

1. Activation is required to be by smoke detectors at areas requiring smoke detectors

The stair pressurization fans shall be activated as per the following on normal power then with emergency power already on.

a. Smoke detectors – Required
b. Sprinkler water flow is activated – Required
c. Pull station/ manual activation – Required

Activation Method	Normal Power	Comments
Smoke detectors		
Sprinkler water flow		
Pull station/ manual		

2. Verify multiple alarms do not reset the system

a. Start the smoke exhaust system by activating the sprinkler water flow switch. Visually verify operation of mechanical equipment.

b. Start the smoke exhaust system by activating a pull station. Visually verify operation of mechanical equipment.

c. Verify a second alarm doesn't reset the system.

d. Visually verify operation of mechanical equipment.

e. Stop system.

3. Verify all manual controls are able to shut system down while in alarm mode.

4. Verify the system is able to run for 20 min (909.4.6)

5. Verify all make up air vents open in all modes.

IV. Stair Pressurization

A. Equipment and System Test

Functional test: all components shall be tested to ensure that each is working properly. List of components and systems to be tested:

6. Pressurization equipment, fans and shafts are required to be separated by 2 hour construction (Section 909.20.2 and 909.20.6.1).

7. Verify system operation using all manual controls – all fans will turn on.

8. Activation is required to be by smoke detectors at an approved location to the stair doors (Section 909.20.6).

The stair pressurization fans shall be activated as per the following on normal power then with emergency power already on.
d. smoke detectors – Required

The stair pressurization fans are **not required** to be activated as per the following on normal power but shall be tested if other building fire alarm system activates the fans.
e. Sprinkler water flow is activated – **Optional**
f. Pull station/ manual activation – **Optional**

9. Verify

Activation Method	Normal Power	Comments
Smoke detectors		
Sprinkler water flow - **Optional**		
Pull station/ manual - **Optional**		

multiple alarms do not reset the system

f. Start the stair pressurization system by supplying test smoke at one random detector outside the stair. Visually verify operation of mechanical equipment.

g. Start the stair pressurization system by supplying test smoke at a second random detector outside the stair. Visually verify operation of mechanical equipment.

h. Verify second alarm doesn't reset the system.

i. Visually verify operation of mechanical equipment.

j. Stop system.

Verify all manual controls are able to shut system down while in alarm mode.

10. Verify the system is able to run for 20 min (909.4.6)

B. When the stair pressurization fans activate:

1. All stairwell doors must close, latch, and unlock.

2. Observe any dampers that open or close on the panel and visually.

3. The stair enclosures shall be tested to ensure proper pressurization levels between a minimum of 0.15 and a maximum of 0.35 inches water with all doors closed.

4. The doors into the stair enclosures shall be pull tested to ensure the following properties of the door.
   a) Doors are able to latch without fans on.
   b) A maximum of 30 pounds of force to set the door in motion and
   c) Swing to a fully open position with a maximum force of 15 pounds.
   d) Panic and Fire Exit hardware shall have a maximum unlatching force of 15 lbs.
   e) Doors are able to latch with fans on.

5. The exit discharge doors from the stair enclosures to the out side shall be pull tested to ensure the following properties of the door;
   a) Doors are able to latch without fans on.
   b) A maximum of 30 pounds of force to set the door in motion and
   c) Swing to a fully open position with a maximum force of 15 pounds.
   d) Panic and Fire Exit hardware shall have a maximum unlatching force of 15 lbs.
   e) Doors are able to latch with fans on.

Level	Stair ___ Measured Pressure (inch wc)	Stair ___ Measured Pressure (inch wc	Stair___ Measured Pressure (inch wc)	Comments
1				
2				
3				
4				
5				

Sequence Of Operations

☐ Sequence verified by Special Inspector

V. Additional Testing: Standby Power System

A. Equipment and System Test

List of components and systems to be tested:

1. Transfer Switch: Verify the transfer switch is located in a room conforming to IBC 909.11.

   ☐ Standby power and its transfer switches are required to be in a separate room from the normal power and constructed of not less than 2 hr fire barriers.

   ☐ Ventilated directly to the exterior of the building.

2. Normal power mode then stand by power mode (transfer to stand by must be automatic and take place within 60 seconds of loss of primary power 909.11).

3. Generator Start: With the smoke control system off, start the standby power system by discontinuing power at the main building disconnect.

4. Stair Shaft Pressurization: Manually start stair shaft pressurization systems and verify all equipment is operational by standby power.

If VFDs are present:

5. Verify stair fans work on generator and insure stay working when generator starts. Pressurization fans with VFD's sometimes do not restart with power loss.

6. VFD Alarm: Verify VFD switch doesn't override smoke panel, without causing an Alarm.

7. The stair pressurization fans shall be activated as per the following on normal power then with Stand By power already on.
   a. Elevator lobby smoke detectors – Required

   The stair pressurization fans are **not required** to be activated as per the following on Stand By power but shall be tested if other building fire alarm systems activate the fans.

   b. Sprinkler water flow is activated – **Optional**
   c. Pull station/ manual activation – **Optional**

Activation Method	Normal Power	Comments
Smoke detectors		
Sprinkler water flow -**Optional**		
Pull station/ manual - **Optional**		

END