FIRE PROTECTION AND LIFE SAFETY ANALYSIS OF A MODERN DISTRIBUTON FACILITY

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Statement of Disclaimer

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ASET
DETACT

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Abstract

Warehouse facilities are part of the backbone of American industry. The vast amounts of varying goods stored and distributed as part of American business has always driven the need for large, voluminous warehouses. And the increasing size of these facilities over the decades is very closely linked to the capabilities of and advances in fire protection knowledge and technology. Today's modern distribution centers easily and often exceed one million square feet in area, and the heights are ever increasing. In the 1970's and early 1980's, most warehouse facilities were built to an approximate height of 30 feet; this, at the time, was the extent of the fire protection (i.e., sprinkler) knowledge and capabilities. Factory Mutual (now FM Global) developed the early suppression fast-response ("ESFR") sprinkler in the 1980's and buildings have been increasing in height ever since. Many applicable standards list multiple design criteria for various storage configurations in building with roof peaks up to 45 feet. Just recently this year, Viking released a nominal K-28 ESFR sprinkler that is listed to protect rack storage as a ceiling-only design option (i.e., without the need of costly in-rack fire sprinkler systems) in warehouses having a maximum roof height of 48 feet, and it is unlikely that this trend will stop. The industry will continue to research and develop safe design solutions that will allow more and more storage in a cost effective method, and as such, building and fire code will likewise evolve to accommodate. However, in the meantime, architects and engineers work to design these facilities within the parameters of governing building and fire codes, and when necessary, use performance-based design approaches when the building does not fit inside the box.

1.0 PURPOSE

This report will describe the fire protection and life safety requirements of the 2012 editions of the *International Building Code* and *International Fire Code* as they pertain to the subject Facility, which is a modern distribution building exceeding 1.2 million square feet. For comparison sake, reference will at times be made to the 2012 edition of the *Life Safety Code*. In addition to the prescriptive requirements of the code, performance-based analyses will be performed to justify the building design regarding those aspects that do not strictly comply with certain provisions of the code.

2.0 APPLICABLE CODES AND STANDARDS

The code review and building analysis documented in this report is based upon the following codes and standards:

2.1 International Code Council

- *2012 International Building Code* ("IBC")
- *2012 International Fire Code* ("IFC")

2.2 NFPA Codes and Standards

- *NFPA 10, Standard of Portable Fire Extinguishers, 2010 edition* ("NFPA 10")
- *NFPA 13, Standard for the Installation of Sprinkler Systems, 2010 edition* ("NFPA 13")
- *NFPA 20, Standard for the Installation of Stationary Fire Pumps for Fire Protection, 2010 edition* ("NFPA 20")
- *NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances, 2010 edition* ("NFPA 24")
- *NFPA 72, National Fire Alarm and Signaling Code, 2010 edition* ("NFPA 72")
- *NPFA 92, Standard for Smoke Control System, 2012 edition* ("NFPA 92")
- *NFPA 101, Life Safety Code, 2012 edition* ("LSC")[1]
- *NFPA 204, Standard for Smoke and Heat Venting, 2012 edition* ("NFPA 204")
- *NFPA 220, Standard on Types of Building Construction, 2012 edition* ("NFPA 220")
- *NFPA 5000, Building Construction and Safety Code, 2012 edition* ("NFPA 5000")

3.0 BUILDING DESCRIPTION

The Facility is a modern distribution building of approximately 1,246,864 square feet (ft^2) on the ground level, which measures roughly 700 ft by 1,750 ft. It consists mostly of open floor space used for storage of ordinary combustibles in various storage configurations, including rack, palletized and shelf storage; several loading docks for used for shipping and receiving; numerous conveyor systems for transporting commodities throughout the Facility; and a number of platforms/ mezzanines for processing of commodities. There is one central process mezzanine with a multi-level mezzanine on either side (east and west). The eastern and western mezzanines each consist of two elevated levels over the main floor area while the central process mezzanine is a single level. These mezzanines add approximately

[1] The LSC will only sparingly be referred to for comparison purposes; the main analysis will be based upon the IBC and IFC.

1,228,259 ft^2 of usable space for the Tenant, totaling approximately 2,475,123 ft^2 of usable space. Approximately 80,248 ft^2 of the total space is dedicated for support areas, ancillary to the main occupancy of the Facility. This includes spaces such as restrooms, employee break rooms, office spaces, security and IT spaces, and training rooms.

The roof of the Facility is slightly sloped (less than 2 in 12) along the long dimension and peaks at approximately 40 ft. Automatic fire sprinkler protection is provided utilizing early suppression fast-response ("ESFR") sprinkler technology, which allows for a ceiling-only design solution (i.e., no in-rack fire sprinklers required). The Facility is also equipped with a fire sprinkler monitoring and occupant notification system.

The Facility, as designed, does not comply with all prescriptive code requirements, and is therefore inherently a hybrid building design, using both prescriptive and performance-based design approaches to achieve the intent of the building and fire codes.

4.0 OCCUPANCY CLASSIFICATION

In accordance with the above building description and the requirements of the IBC, the main use of the Facility is predominantly, and will be classified as, a moderate-hazard storage, Group S-1 occupancy [IBC §311.2]. The accessory spaces ancillary to the main use of the Facility are individually classified in accordance with their varying uses, which include business [IBC §304.1] and assembly [IBC §303.3 & §303.4]. A summary of the occupancy classifications of the various spaces throughout the Facility can be found below in the section discussing the calculated occupant load. Refer also to Attachment A for floor plans of the Facility and the various occupancy classifications.

It is interesting to note that Section 42.1.2.3 of the LSC indicates:

> Storage occupancies or areas of storage occupancies that are used for the purpose of packaging, labeling, sorting, special handling, or other operations requiring an occupant load greater than that normally contemplated for storage shall be classified as industrial occupancies.

The LSC refers the user to Chapter 40, which governs industrial occupancies. Therefore, in accordance with Section 40.1.2.1.1 of the LSC, the subject Facility would be treated as General Industrial Occupancy. This is interesting mainly for the fact that the description within the LSC noted above describes the subject Facility exactly, and for the differences between the LSC and the IBC with regards to certain areas of building design, such as exit access travel distance and occupant load. However, for the purpose of this report, the IBC will stand as the predominantly governing code, with references sparingly made to the LSC for informational and comparison purposes.

5.0 CONSTRUCTION TYPE

For any given facility, there are a number of options for construction types available to the designers and building owners. Many factors come into consideration, including use of automatic fire sprinkler systems for example, and ultimately a balance is struck between feasible constructability and economics. That being the case, there are various code paths to follow to arrive at a final construction type for any given project.

Based strictly on the use and occupancy classification and the size of the subject Facility, the construction type would be limited to Type IA:

Table 1: Construction Types for Group S-1 (extracted from Table 503 of the IBC)

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT (feet)	UL	160	65	55	65	55	65	50	40
		STORIES (S) AREA (A)								
S-1	S A	UL UL	11 48,000	4 26,000	2 17,500	3 26,000	2 17,500	4 25,500	3 14,000	1 9,000

Type IA construction, especially for a building of this size, can quickly become very expensive due to the inherent requirements for 3-hour fire-resistance rated primary structural frame, and exterior and interior load-bearing walls; 2-hour fire-resistance rated floor construction and associated secondary members; and 1½-hour fire-resistance rated roof construction and associated secondary members. These requirements would also impact any openings within these fire-rated assemblies (e.g., doors) to also be of a satisfactory minimum fire-resistance rating. A more cost-effective solution is available within the code.

The subject Facility is built with Type IIIB construction, which according to Table 1 above, is only allowed to be up to two (2) stories and/or 55 ft in height, with each story being up to 17,500 ft^2. Refer below to Section 6.0 for a discussion of height and area.

The LSC refers to NFPA 220, *Standard on Types of Building Construction* for construction classification (§8.2.1.2), which subsequently cites directly from NFPA 5000, *Building Construction and Safety Code*. Type IIIB construction per the IBC is synonymous with Type III(200) of the NFPA codes [NFPA 220 Table A.4.1.1]. And if the representative meanings of the numerals are understood, the NFPA nomenclature may be more intuitively describing the minimum prescribed fire-resistance rating requirements of major building components: the first numeral represents the fire-resistance rating (in hours) for exterior walls; the second numeral represents the necessary rating for columns, beams, girders, trusses and arches, supporting bearing walls, columns, or loads from more than one floor; and the third numeral represents the minimum rating for floor construction. This aligns with those values summarized below within Table 3.

It is worth noting that these types of buildings are typically constructed with Type IIB construction for the across-the-board requirement of 0-hour fire-resistance ratings of building elements, and for the noncombustible nature inherent of Type II (and Type I) construction. However, Type IIIB construction does not hinder the design basis of the Facility.

5.1 Construction Materials

Type III construction is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by code [IBC §602.3]. The IBC governs and specifies minimum design criteria for concrete (Chapter 19), aluminum (Chapter 20), masonry (Chapter 21), steel (Chapter 22), wood (Chapter 23), glass and glazing (Chapter 24), gypsum board and plaster (Chapter 25), and plastic (Chapter 26). Any use, or combination, of the aforementioned building materials is allowable for the subject Facility, given that the exterior walls are of noncombustible materials of sufficient capability to form a 2-hour fire-resistance rating.

The exterior walls of the Facility are cast-in-place, concrete tilt-up walls having a fire-resistance rating of 2-hours. The roof is 4-ply built up roof with a cap sheet, which effectively is rigid roof insulation sandwiched between wood layers, and additional ply layers on top, including asphalt and reflective roof covering. Interior walls are a mixture of rated and non-rated walls and partitions. Refer below to Section 8.0 for a discussion regarding the fire-resistance rating requirements for the Facility.

6.0 HEIGHT AND AREA

Chapter 5 of the IBC governs height and area limitations of any building. Table 503 tabulates these limitations in a matrix-style format for construction type and occupancy classifications. As previously stated, for the occupancy classification and size of the subject Facility, only Type IA construction would be available to building designers and owners. However, the code allows for various circumstances that provide for taller and larger buildings. More specifically, Sections 504 and 506 govern building heights and area modifications, respectively. Within these sections, increases to building heights and areas are allowed given meeting certain criteria, such as necessary minimum frontage distances or full building coverage with automatic fire sprinkler systems. Section 507 lists requirements necessary to achieve unlimited area buildings. For the subject Facility, Section 507.4 is invoked, which states the following:

> The area of a Group B, F, M or S building no more than two stories above grade plane shall not be limited where the building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1, and is surrounded and adjoined by public ways or yards not less than 60 feet (18,288 mm) in width.

The subject Facility is fully equipped with automatic fire sprinkler protection, has a single-story peak roof deck height of 40 ft, and meets the requirements of a minimum 60 foot-wide surrounding to public ways – as such, the chosen construction type for the Facility of Type IIIB, although other types could be utilized still, is acceptable.

6.1 Mezzanine Area Limitations

As described above, the Facility incorporates three (3) separate mezzanine areas: a central process mezzanine, and one multi-level mezzanine on either side of the central mezzanine. The total aggregate area of the mezzanine levels amounts to 1,228,259 ft^2, which is well more than the allowed one-third of the area of the main floor (aggregate mezzanine area equates to approximately 99% of the total ground level of the Facility).

Table 2: Comparison of Mezzanine Areas to Ground Level Area

	AREA DESCRIPTION	FLOOR AREA PER LEVEL (ft²)	NUMBER OF ELEVATED AREAS	TOTAL AREA (ft²)
A	CENTRAL MEZZANINE	256,039	1	256,039
B	EAST MEZZANINE	243,055	2	486,110
C	WEST MEZZANINE	243,055	2	486,110
D	AGGREGATE MEZZANINE AREA [= A + B + C]			1,228,259
E	GROUND LEVEL	1,246,864	N/A	1,246,864
F	MEZZANINE COVERAGE [= D / E]			99%

The code recognizes that noncombustible construction, fire sprinkler protection and emergency voice/ alarm communication systems are sufficient to not significantly contribute to the building's inherent fire hazard, and adequately notifies and protects occupants such that mezzanine areas are allowed to be increased to one-half of the overall floor area [IBC §505.2.1, Exception 2]. However, it is interesting that the provision was originally introduced and proposed by merely requiring an occupant notification system. The proposal was rejected simply because the term 'occupant notification system' was not a defined term within the code; therefore, the formal rejection was necessary so the proposal could be amended, at which point, the term was replaced by 'emergency voice/ alarm communication system' since it was already a defined system within the code.

The code also requires means of egress from the mezzanine to comply with Chapter 10 requirements [§505.2.2], and that the mezzanine be open and unobstructed to the space in which it is located [§505.2.3].[2]

The intent of the code provision allowing a larger mezzanine area is to provide adequate occupant notification of an emergency, and to provide adequate means of egress that is commensurate of the base code provisions. However, there is a practical difficulty involved in achieving intelligible voice communications (inherent to emergency voice/ alarm communication systems) in the Facility due to the large open nature, hard surfaces, and high roof deck (providing ample opportunity for reverberation), and to high ambient noise levels in select areas originating from normal operations. For this reason, an alternative is proposed and discussed later in this report.

It was considered to treat the elevated levels as stories rather than mezzanines, but their openness to the main atmosphere of the Facility makes them most resemble mezzanines rather than stories.

[2] Exception 5 allows for mezzanines having two or more means of egress, provided with complete automatic fire sprinkler systems, and are located within occupancies other than Group H or I that are no more than two stories above grade to be not be open to the space in which it is located. However, all the mezzanine levels in the subject Facility are open to the main atmosphere of the Facility.

Furthermore, if the Facility were to be considered a multi-story building, the logistical model of the Tenant could not be efficiently or economically achieved for various reasons, including cost, required separation of stories, and material handling difficulties. It is here in the building design where the citing of the code provisions for modifications [IBC §104.10] and alternates [IBC §104.11] originates.

The justification for the designed mezzanine areas will be discussed in the performance-based design approach (Section 10.0 of this report).

7.0 SEPARATION AND FIRE-RESISTANCE RATED CONSTRUCTION REQUIREMENTS

The Facility is constructed with Type IIIB construction, and is required to have certain building elements be of fire-resistance rated construction. The table below (an excerpt of IBC Table 601) tabulates those requirements:

Table 3: Fire-Resistance Rating Requirements for Type III Construction (extracted from Table 601 of the IBC)

BUILDING ELEMENT	TYPE III	
	A	B
Primary structural frame	1	0
Bearing walls Exterior Interior	 2 1	 2 0
Nonbearing walls and partitions Interior	0	0
Floor construction and associated secondary member	1	0
Roof construction and associated secondary member	1	0

Only the exterior walls of the Facility are required to be of fire-resistance rated construction. As such, the walls of the Facility are provided as 2-hour fire-resistance rated cast-in-place, tilt-up concrete walls.

The main use of the Facility is classified as Group S-1, moderate-hazard storage. The ancillary spaces necessary for proper function of the Facility are independently classified as Group A and B occupancies [IBC §508.2.2]; these spaces are considered accessory to the main occupancy, and subsequently meet the criteria of allowable area (i.e., < 10 percent of the Facility; [§508.2.1]) [§508.2]. As such, these spaces are not required to be separated from the main occupancy by way of fire-resistance rated construction [§508.2.4].

Other fire-resistance rated construction is required for interior exit stairways [IBC §1009.2.2]. The subject Facility is provided with eight (8) interior exit stairways serving the mezzanine levels. The interior exit stairways are provided with 1-hour fire-resistance rated enclosures since they serve less than four (4) stories [§1022.2]. Two (2) of these interior exit stairways serve the central mezzanine and discharge to the middle of the main occupancy; however, exit continuity is required [§1021.3]. Therefore, exit passageways are necessary to provide continued exit access from the two interior exit stairways to the exterior of the Facility. The exit passageways are also required to be provided with 1-hour fire-resistance rated construction [§1023.3].

Corridors within the Facility are not required to be of fire-resistance rated construction since the predominant Group S occupancy is provided with an automatic fire sprinkler system [IBC Table 1018.1].

Refer to Appendix A for a graphical representation of those rated and non-rated enclosures and corridors.

8.0 HIGH-PILE COMBUSTIBLE STORAGE REQUIREMENTS

High-piled combustible storage is defined by the IFC as follows [§202]:

> Storage of combustible materials in closely packed piles or combustible materials on pallets, in racks or on shelves where the top of storage is greater than 12 feet (3658 mm) in height. When required by the *fire code official*, *high-piled combustible storage* also includes certain high-hazard commodities, such as rubber tires, Group A plastics, flammable liquids, idle pallets and similar commodities, where the top of storage is greater than 6 feet (1829 mm) in height.

The very nature of such storage is vast and of practically infinite permutations. The fire code commentary, in a number of instances therein, acknowledges this fact[3]:

> The intent of this section [§3206.3.2.2] is to recognize that in actual circumstances storage arrays may contain a combination of Class I through IV commodities alongside high-hazard commodities. It is not unusual for arrays to consist of thousands of products.

Such is true for the subject Facility. Given the pervasiveness of storage facilities and the vast commodities therein, the fire code dedicates a chapter to the matter – Chapter 32 – and refers to a number of NFPA standards, some of which have the sole scope of one kind of storage or another (e.g., NFPA 13 Chapters 12-21; NFPA 30 for flammable and combustible liquids; NFPA 30B for aerosols; NFPA 400 for hazardous materials; etc.).

The majority of general requirements for high-piled combustible storage areas (and/or buildings) are conveniently provided in Table 3206.2 of the IFC. These requirements include topics such as size of storage areas; automatic fire extinguishing systems; fire detection system; building access; smoke and heat removal; draft curtains; and quantity/volume of storage limitations. Additional requirements for high-piled combustible storage areas or buildings include fire department hose connections; aisle width, height, and configuration; and portable fire extinguishers.

8.1 Size and Separation of Storage Areas

Storage areas and/or buildings can vary largely in regards to size, stored commodities, and storage configurations. The fire code recognizes this and tabulates general requirements based upon the commodity class (i.e., Class I-IV or High-hazard) and size of the storage area. For these various

[3] 2012 IFC Code and Commentary, page 32-13.

combinations of stored commodities and size of storage area, requirements vary. For example, practically all of the systems or building features are not required for storage areas only up to 500 ft^2 in area. On the other end of the spectrum, 500,000 ft^2 and larger, most of the systems and building features are required.

The subject Facility stores in various configurations (including palletized, solid-piled, shelf, and rack) predominantly Class I-IV ordinary combustibles with some high-hazard (i.e., Group A plastic) commodities. Table 3206.2 has a row tabulated for areas of Class I-IV commodities greater than 500,000 ft^2; in regards to high-hazard commodities, the table provides a row for 300,001-500,000 ft^2. Since the commodities are predominantly Class I-IV, authorities having jurisdiction ("AHJ") allow the storage area to be greater than 500,000 ft^2 without fire-resistance rated separations normally required for high-hazard storage areas. A main reason for this allowance is due to the fact that the automatic fire sprinkler systems are provided to protect the commodities as if they were all Group A plastics [Table 3206.2 note g].

8.2 Automatic Fire Sprinklers

Automatic fire sprinkler systems are required for the subject Facility for a couple of reasons. The first is the building design following the requirements of an unlimited area building per the IBC [§507]. The second is due to the requirement by Table 3206.2 of the IFC. The table refers the user to Section 3206.4, which in turn states, *"Automatic sprinkler systems shall be provided in accordance with Sections 3207, 3208, and 3209."* Those sections govern, respectively, solid-piled and shelf storage; rack storage, and automated storage (the latter of which does not apply to the subject Facility).

The subject Facility stores Class I-IV commodities with some cartoned and exposed, unexpanded Group A plastics commodities in standard racks up to 32 ft in height under a maximum 40 ft roof. The latter commodity (i.e., the cartoned and exposed, unexpanded Group A plastics) in this storage configuration drives the roof-level fire sprinkler system design, which is the most hydraulically demanding throughout the Facility.

The Facility is provided with fire sprinkler systems at the roof level designed for twelve (12) pendent K-16.8 ESFR sprinklers each operating at no less than 52 psi, plus an additional 250 gpm hose stream allowance [NFPA 13 Table 12.8.6.1; Table 17.3.3.1; §22.4.4.3]. This design results in a nominal fire sprinkler demand of about 1,750 gpm at about 115 psi.[4] Refer to Figure 1 for an example of a pendent K-16.8 ESFR sprinkler:

[4] The Facility is provided with thirty two (32) roof-level ESFR sprinkler systems. Each system has its own unique sprinkler demand based upon where it is located within the Facility. The nominal demand includes a 3 percent overage (with respect to water flow), and estimated pressure requirements which consider operating pressure, elevation, and friction loss. However, it is worth noting that given a fire pump, the systems could afford more friction loss (i.e., a higher pressure demand).

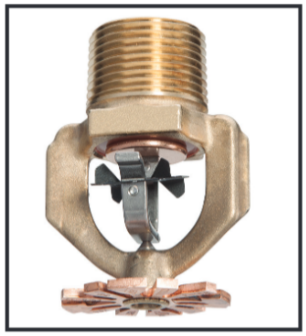

Figure 1: Tyco Model ESFR-17 (TY7223)

The roof-level systems, being the most hydraulically demanding, also dictate the overall fire water design of the Facility. The design includes a 150 HP horizontal split case electric motor-driven fire pump having a rated capacity of 2,000 gpm at 95 psi. The fire pump takes suction from the city distribution system via a 12 in. ductile-iron pipe; it discharges into a 10 in. ductile-iron pipe, which supplies the dedicated fire water loop around the Facility. The loop consists of a 10 in. leg on the general south portion of the Facility, and 12 in. leg around the east, north and western portions of the Facility.

The dedicated fire water loop is also provided with a secondary connection near the Facility's plan southwest corner. This connection from the city distribution system serves as a bypass in the case of an impairment impacting the main pump suction line, that portion in which the pump suction line is connected, or to the fire pump itself. The city can, through the secondary connection, still supply the Facility with some meaningful water flow and pressure. The fire pump installation also has a pump bypass, as required by NFPA 20 [4.14.4.1]. Refer to Figures 2-5 on the following pages for graphical representations of the overall fire water loop[5], fire pump room layout, and fire pump room section view, and fire water lead-in and riser section[6], respectively.

It is worth noting that this Facility is provided with many more fire water lead-ins and risers than is typical. Each riser in this case is provided with its own fire water lead-in. This is not an efficient design as it required more underground work, including necessary underground flushing operations, which would need to be repeated if a section of underground pipe were ever to be replaced. Refer to Figure 6 for a representative photo of a more typical fire water lead-in and riser manifold.

In addition to the roof-level ESFR fire sprinkler systems, the various elevated mezzanines are provided with systems underneath each level designed to protect an Extra Hazard (Group 2) occupancy.[7] NFPA 13 actually prescribes a slightly lower hazard for the commodities and storage configurations under the various elevated mezzanines for commodities up to and including Class IV. Refer to Figure 7 for building cross sections for graphical representation of the elevated levels.

[5] Figure 2 is an engineering-level drawing that may not exactly represent as-built conditions; it is provided as a reference to show schematically the exterior underground fire water layout, including the two (2) connections to the city distribution system, pump suction and discharge, fire water lead-in locations, fire hydrants, and fire department connections.
[6] Figure 5 is also an engineering-level drawing.
[7] As defined by NFPA 13, and not to be confused with occupancy classifications of the IBC.

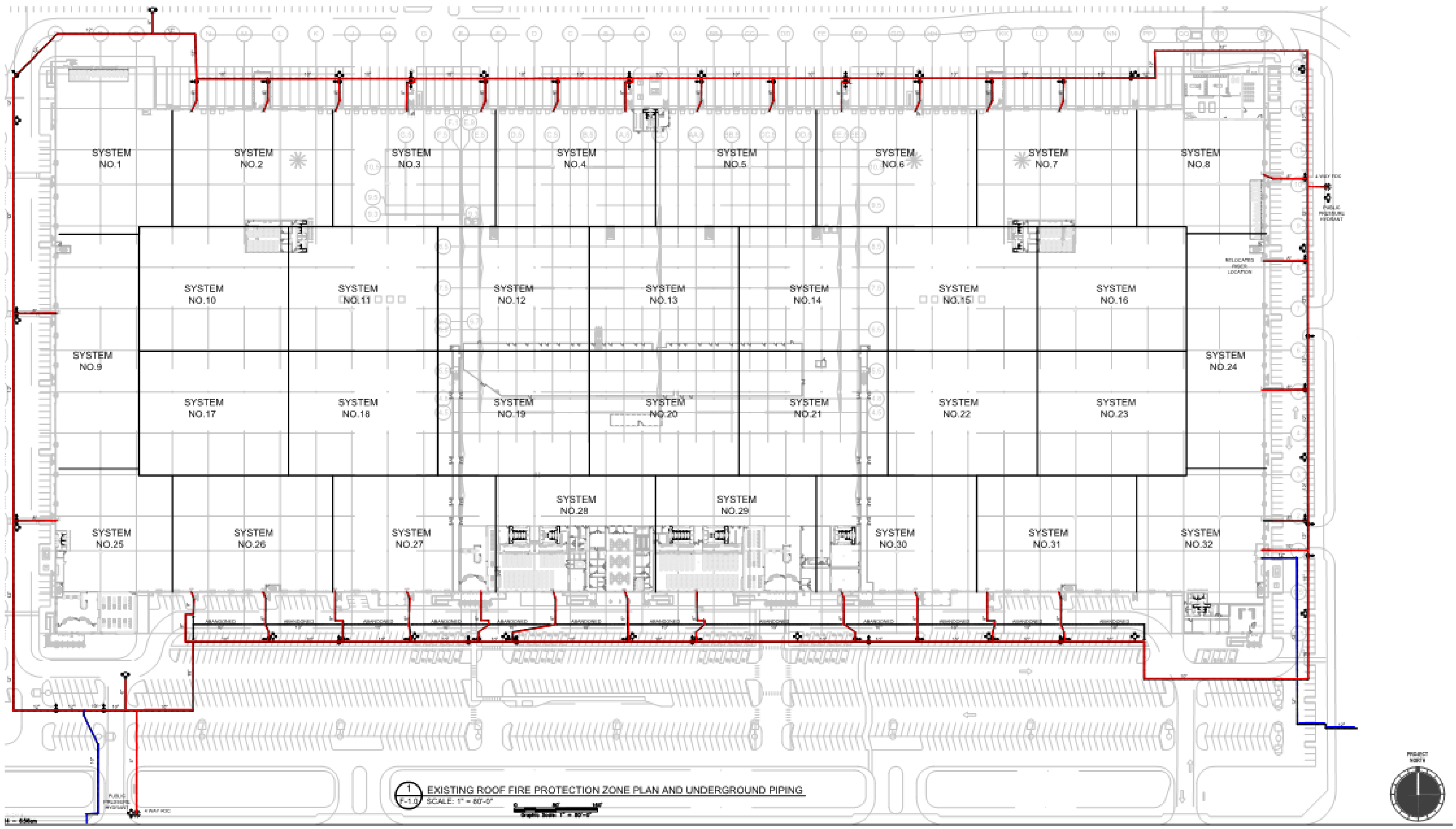

Figure 2: Underground Fire Water Loop with Connections to City Supply

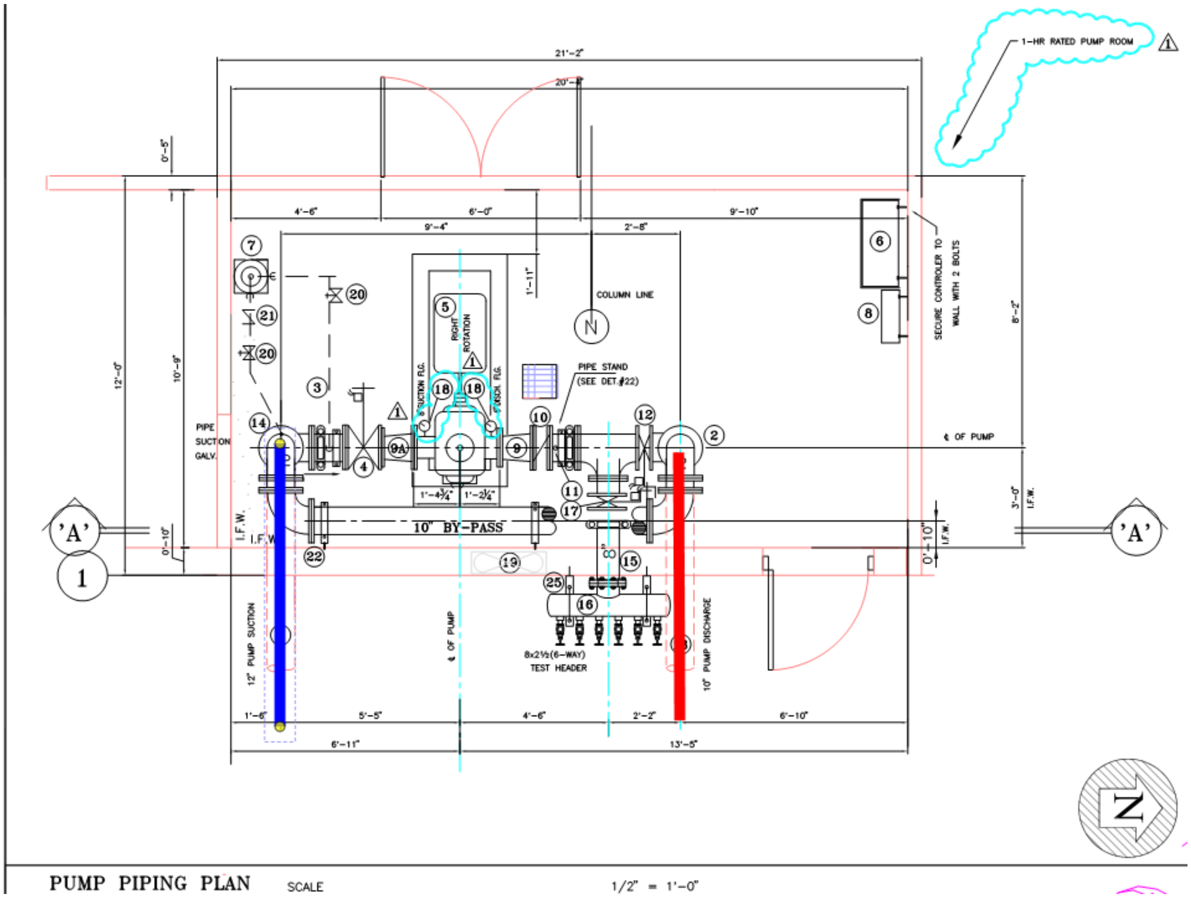

Figure 3: Fire Pump Room – Plan View

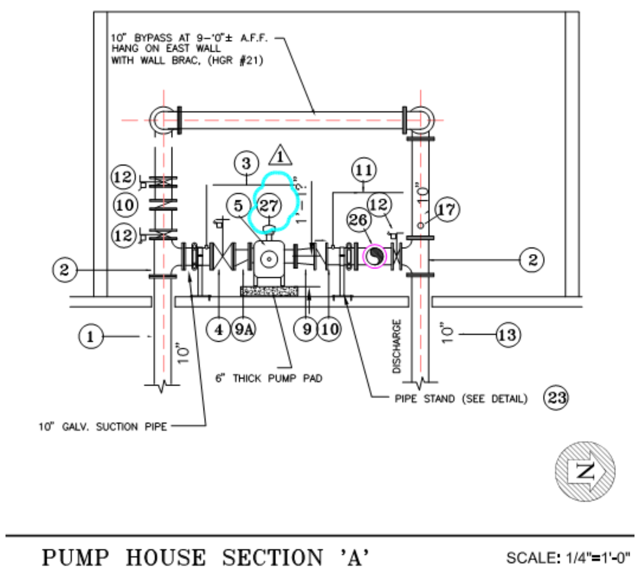

Figure 4: Fire Pump Room – Section View[8]

[8] Note that the section view incorrectly identifies the pump suction as 10 in. in diameter.

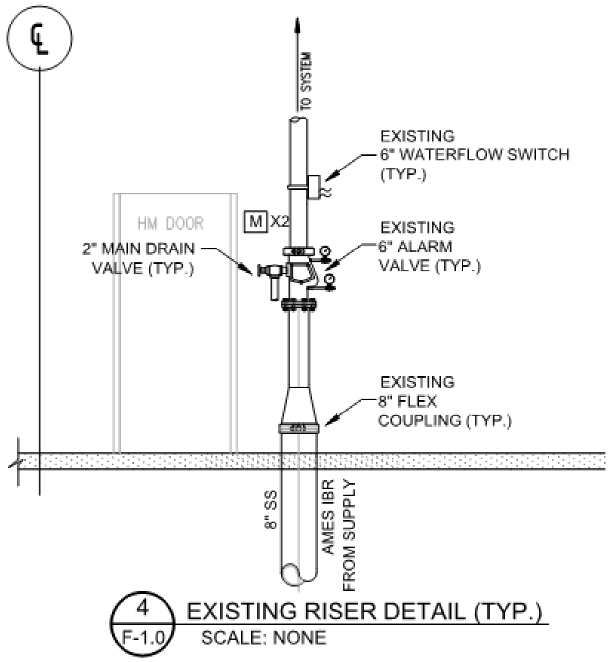

Figure 5: Fire Water Lead-In and Riser Detail

Figure 6: Representative Photo of a More Typical Riser Installation

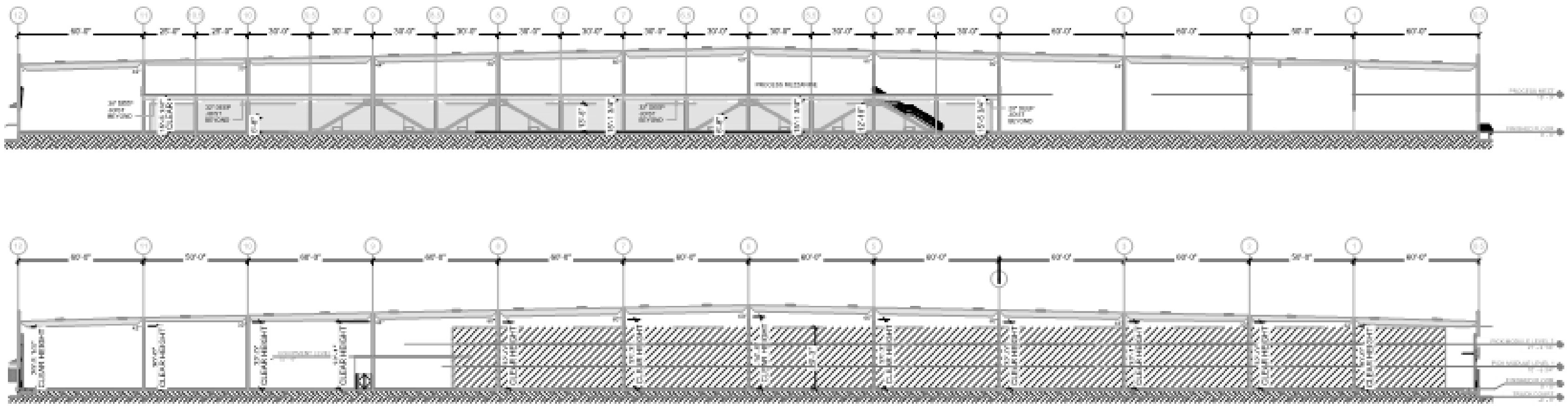

Figure 7: Cross Section Through Facility Showing Elevated Levels

Storage under the central mezzanine includes palletized, solid-piled, and shelf storage up to 8 ft in height of predominantly Class I-IV commodities, with some cartoned and exposed, unexpanded Group A plastics. The central mezzanine floor is located at 18 ft above finished floor ("AFF"). For this configuration, NFPA 13 requires for the Class I-IV commodities a minimum design of Ordinary Hazard (Group 2) [§14.2.3.1; Table 13.2.1]. However, given the presence of Group A plastics, although not the predominant commodity, a more robust sprinkler design is chosen.

Storage under the east and west elevated mezzanines consist of the same commodities and configurations, except the mezzanine ceiling/floor assembly above is only 10 ft AFF relative to each level. Therefore, fire sprinkler systems protecting these mezzanine levels are also provided to protect the higher-hazard Group A plastics.

The palletized, solid-piled, and shelf storage of exposed, unexpanded Group A plastics, NFPA 13 requires an Extra Hazard (Group 2) designation [Figure 15.2.2; Table 15.2.6(a)],[9] which aligns with the design of the systems underneath the various mezzanines in the subject Facility. These systems are designed in accordance to the density/area method of NFPA 13 [§11.2.3.2], and to the following criteria: a fire sprinkler water density of 0.40 gpm/ft^2 applied to the hydraulically most remote 2,500 ft^2, plus an additional 500 gpm hose stream allowance [§15.2.8(2); Figure 13.2.1; Table 12.8.6.1]. Refer to Figure 8 for a representative hydraulic graph sheet for one of these Extra Hazard (Group 2) systems.[10]

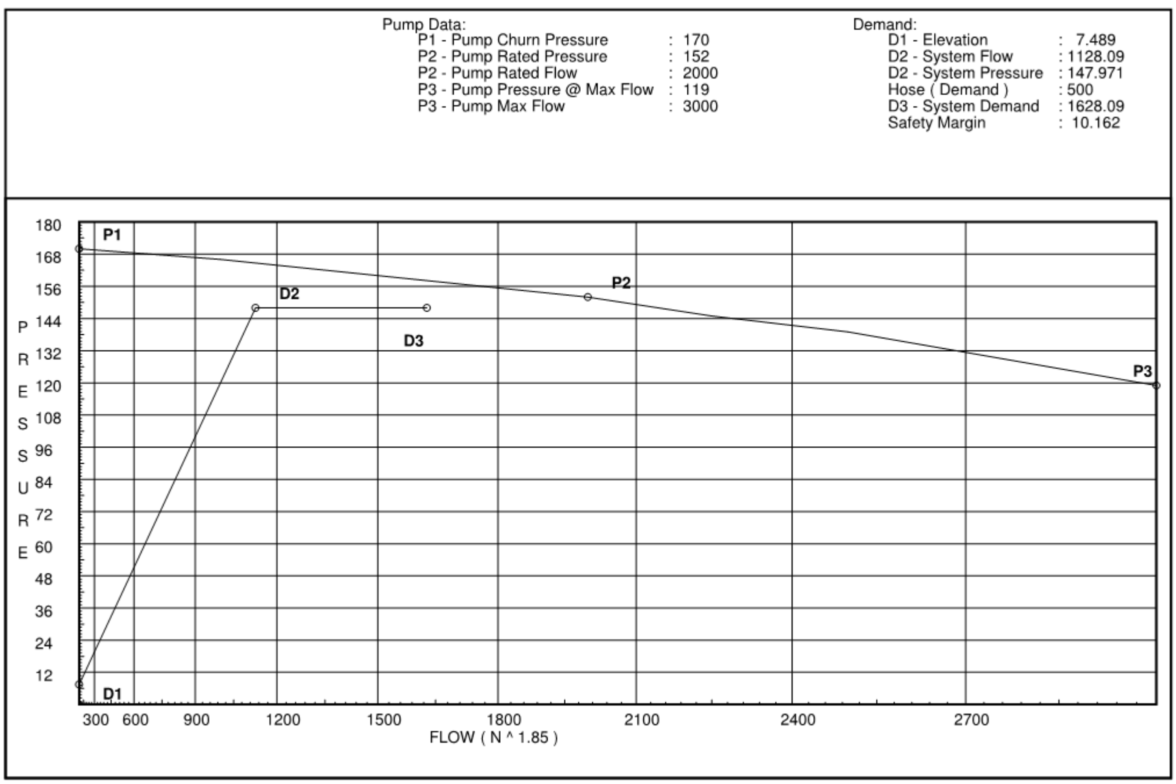

Figure 8: Hydraulic Graph Sheet of Representative Extra Hazard (Group 2) System

[9] Figure 15.2.2 points to Column E in Table 15.2.6(a) for Group A plastic, nonexpanded, stable, exposed.

[10] It is worth noting that the supply curve should be generated from a net pump curve and incoming water supply, thus producing the combined pump curve. Figure 8 simply shows the combined curve without showing the two individual components.

The systems under the various mezzanine levels are provided with listed quick-response K-11.2 upright-type storage sprinklers. It is worth noting that NFPA 13 allows the sprinkler design area to be reduced 25 percent but to not less than 2,000 ft^2 when K-11.2 or larger sprinklers are used, regardless of temperature rating [§15.2.8(2)(b)]. The engineering design chooses not to allow this reduction even though it is permitted by NFPA 13.[11] This is considered an improvement to the minimum protection required by code, as is the use of quick-response as opposed to standard-response sprinklers.

NFPA 13 does not allow the use of quick-response sprinklers to protect an Extra Hazard occupancy [11.2.3.2.2.2]. A general requirement of NFPA 13 regarding storage applications is that quick-response spray sprinklers shall be permitted when listed for such use (i.e., for the protection of storage) [§12.6.6]. Refer to Figure 9 for a representative listed quick-response storage sprinkler that is commercially available.

Figure 9: Tyco Series ELO-231FRB (TY5131)

The use of quick-response sprinklers under the mezzanines aids in quicker responses to a fire scenario, but also provide the means for not having to provide draft curtains to adequately separate the roof-level ESFR sprinklers from sprinklers having a dissimilar response time index ("RTI") [8.4.6.4.1]. Draft curtains will again be discussed later on in this report in relation to smoke and heat removal.

Finally, the accessory office and utility spaces are provided with automatic fire sprinkler protection designed to protect Light and Ordinary Hazards, respectively, using the density/area method of NFPA 13. A centralized computer room that controls operations within the Facility is included in the accessory spaces; however, due to the sensitive nature of the equipment, that space is provided with a dedicated double-interlock preaction sprinkler system. The double-interlock consists of the typical electric-pneumatic configuration. The system is dry and provided with supervisory air pressure to monitor the integrity of the sprinkler piping network. Activating a sprinkler (or even mechanically impairing one) will allow the air pressure to dissipate and force the pneumatic solenoid to switch positions – this is one necessary event. The space is also provided with spot-type smoke detection. Activation of two (2) spot-type smoke detectors serves as the second necessary event. The preaction valve will not trip unless both inputs are received; having one or the other (including a single smoke detector activating) will provide supervisory signals to the fire alarm control unit ("FACU"), which is discussed in the below section.

The Facility is considered fully sprinklered as far as the IBC requirement for an unlimited area building is concerned, and the storage hazards are adequately protected.

[11] This engineering specification supersedes the allowance of NFPA 13.

8.3 Fire Detection and Alarm

A fire detection system is not required for the subject Facility [IFC §907.2.15; Table 3206.2; §3206.5]. However, the automatic fire sprinkler systems are required to be supervised and provided with certain alarms [§903.4]. All valves included in the fire protection system controlling the water supply to the fire sprinkler systems, including those in the fire pump installation and underground fire water loop, are required to be electrically supervised by a listed FACU. THE FACU is also required to monitor the required waterflow switches for the fire sprinkler systems.

The sprinkler supervising system is required to provided distinct signals for alarm, supervisory, and trouble conditions, and is required to transmit those signals to an approved supervising station [§903.4.1]. A single approved audible device is required be provided on the exterior of the Facility in an approved location for each fire sprinkler system, and must activate the building fire alarm system when such a system is provided [§903.4.2]. Lastly, a single fire alarm box (i.e., manual pull station) is required to be provided in an approved location to initiate a fire alarm signal for fire alarm systems employing waterflow devices [§907.2].

The requirement for a single manual pull station should not be construed as a requirement of the code for a manual fire alarm system. A manual fire alarm system employs manual pull stations at various locations throughout a building, and *"is generally determined by the number of occupants, the height of the building or the ability of the occupants for self-preservation."* The fire code commentary explains the need for a single pull station:[12]

> The single manual fire alarm box required by this section [§907.2] is needed to provide a means of manually activating a fire alarm system that only contains automatic devices such as sprinkler waterflow switches or smoke detectors. Its primary use is for alarm system maintenance technicians to be able to manually activate the fire alarm system in the event of a fire during the time the system or portions of the system is down for maintenance. Note that this requirement is not subject to any of the exceptions in Sections 907.2.1 through 907.2.23 that might waive the need for manual fire alarm boxes in certain buildings.

The Facility is provided with an automatic fire sprinkler monitoring system that includes all necessary valve supervisory (i.e., tamper) switches and waterflow switches. The entire Facility is also provided with an occupant notification system that employs typical combination horn/ strobes throughout. This occupant notification is not a requirement of the code for the subject Facility; however, it is a necessary system that is integral to the performance-based design approach that is discussed later in this report.

The FACU is located in the electrical room immediately adjacent and to the south of the fire pump room. Refer to Figure 10 for a schematic plan view of the electrical room.

[12] 2012 IFC Code and Commentary, page 9-61.

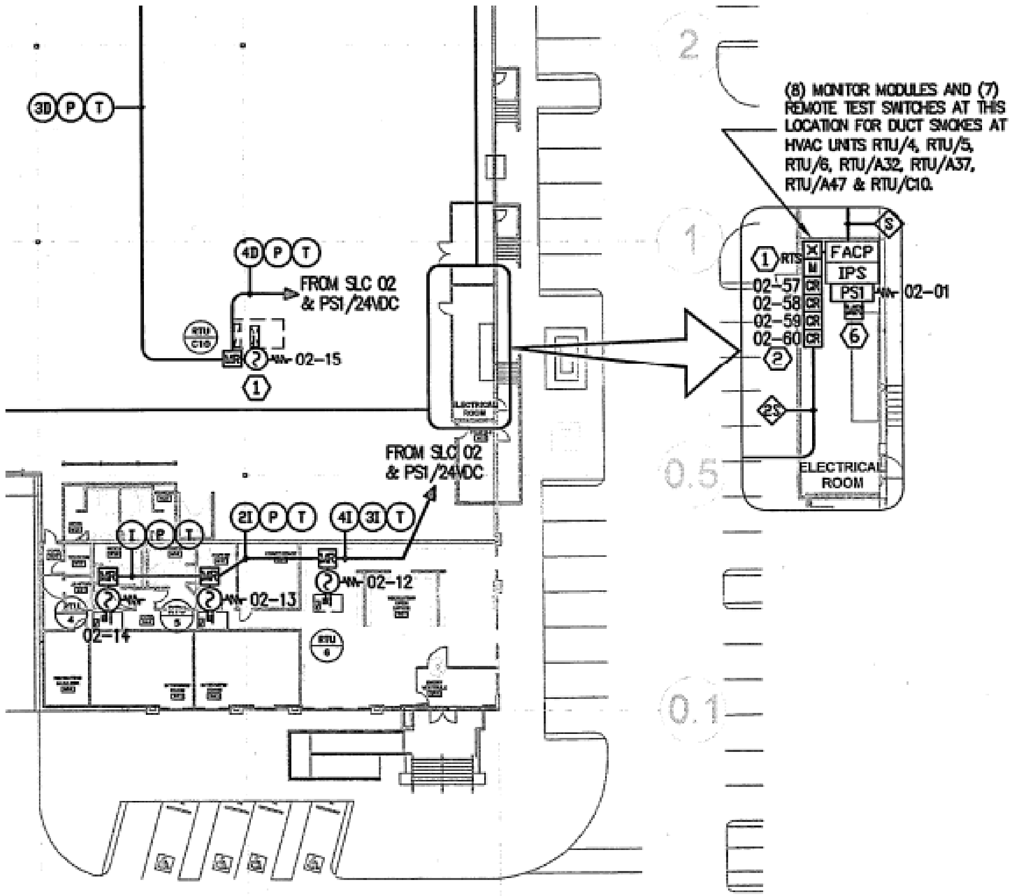

Figure 10: Schematic Plan View of Electrical Room Housing the FACU[13]

The FACU is a Silent Knight Farenhyt IFP-1000 intelligent analog/addressable control unit that is both UL Listed and FM Approved. The system incorporates an RPS-1000 module, which is an intelligent distributed power module that generates a synchronization signal for all downstream notification appliances while also providing additional power for notification appliance circuits. Additional necessary power is provided for all the Facility notification appliances via twenty seven (27) Silent Knight Model 5499 remote power supplies. The system is provided with a single remote annunciator at the main point of entry, which is the main security desk, and three (3) manual pull stations are provided: the first is adjacent to the FACU in the main electrical room; the second in the fire pump room adjacent to the exit doors; and the third is adjacent to the remote annunciator panel near the main security desk.

In addition to monitoring the fire sprinkler systems and providing Facility-wide occupant notification, the fire alarm system also monitors, and is capable of controlling, various pieces of air handling equipment (i.e., roof-top AHUs, HVLS fans, smoke exhaust fans and louvers, etc.), the preaction releasing control panel, the smoke exhaust system control panel, building access control system, and elevator recall. Refer to Figure 11 for the engineering-level sequence of operations for the main FACU.

[13] The acronyms "FACP" and "FACU" are interchangeable; "FACU" (i.e., fire alarm control unit) is the term defined in NFPA 72, but "FACP" is a long-standing industry standard and is equally accurate and acceptable.

		Control Unit Annunciation					Notification				Misc.			Elevator Functions				Smoke Exhaust Control				
		Actuate common Alarm signal indicator	Actuate audible signal at panel	Actuate common Supervisory indicator	Actuate common Trouble indicator	Annunciate origin and description of signal on LCD display	Actuate horn/ strobe device(s)	Transmit distinct Alarm signal to monitoring station	Transmit distinct Supervisory signal to monitoring station	Transmit distinct Trouble signal to monitoring station	Shutdown all warehoused air handling equipment (RTUs, GFUs AND HVLV fans)	Shutdown respective RTU	Disable Access Control System	Initiate Phase 1 Elevator Recall (Main Floor)	Initiate Phase 1 Elevator Recall (Alt. Floor)	Initiate Visual Warning Signal (Flashing HAT)	Activate Elevator Power Shunt Trip Breaker	Open supply louvers, delay 10 seconds and then start exhaust fans	Stop exhaust associated exhaust fans	Open supply louvers, delay 10 seconds and then start associated exhaust fan(s)	Illuminate active fan LEDs on smoke exhaust panel	
	System Inputs	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
1	Sprinkler waterflow	•	•			•	•	•			•		•					•			•	1
2	Smoke detector (FACP)	•	•			•	•	•			•		•									2
3	Manual pull station	•	•			•	•	•			•		•									3
4	Duct smoke detector		•	•		•			•			•										4
5	Valve tamper switch		•	•		•			•													5
6	Fire alarm system AC power failure		•		•	•				•												6
7	Fire alarm system low battery		•	•		•			•													7
8	Open circuit		•		•	•				•												8
9	Ground fault		•		•	•				•												9
10	Wire-to-wire short (SLC & NAC)		•		•	•				•												10
11	Wire-to-wire short (IDC) Alarm devices	•	•			•	•	•			•		•									11
12	Wire-to-wire short (IDC) Supervisory devices		•	•		•			•													12
13	Loss of carrier		•		•	•				•												13
14	Preaction Alarm Signal	•	•			•	•	•					•									14
15	Preaction Supervisory Signal		•	•		•			•													15
16	Preaction Trouble Signal		•		•	•				•												16
17	Fire pump running		•	•		•			•													17
18	Fire pump loss of power		•	•		•			•													18
19	Fire pump phase reversal		•	•		•			•													19
20	Elevator Lobby Smoke Detector (Main)	•	•			•	•	•			•				•							20
21	Elevator Lobby Smoke Detector (Alt.)	•	•			•	•	•			•			•								21
22	Elevator Equipment Room Smoke Detector	•	•			•	•	•			•				•							22
23	Elevator Equipment Room Heat Detector	•	•			•	•	•			•					•	•					23
24	Elevator Power Shunt Trip – Loss of Power to Control Circuits		•	•		•			•													24
25	Smoke Exhaust Panel Switch "OFF"		•	•		•			•										•			25
26	Smoke Exhaust Panel Switch "ON"		•	•		•			•											•	•	26
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	

FIRE ALARM SYSTEM SEQUENCE OF OPERATIONS

Figure 11: Engineering-level Fire Alarm Sequence of Operations

8.4 Building Access

Building access refers to the accessibility for fire department purposes. IFC Table 3206.2 requires such building access for this Facility.

Fire department apparatus roads are required to be provided in accordance with IFC Section 503 within 150 ft of all portions of the exterior walls of the Facility used for high-piled storage (i.e., the entire Facility) [§3206.6]. This requirement is related to the provisions of the IBC related to an unlimited area building, which requires minimum 60 ft clear space around the entire Facility. The requirements outline in Section 503 include minimum dimensions, type of surface, turning radius, dead ends, grade, and angles of approach and departure [§503.2].

The fire apparatus road is required to have an unobstructed width of not less than 20 ft and an unobstructed vertical clearance of not less than 13 ft-6 in. [§503.2.1]. The surface of the roads must be provide all-weather driving capabilities [§503.2.3]; the turning radius is to be as determined by the fire code official (minimum radius varies due to type of vehicles the fire department has) [§503.2.4]; dead ends longer than 150 ft must be provided with a turn-around area; the grade must also be as determined by the fire code official (for the same reason as the minimum turning radius) [§503.2.7]; and angles of approach and departure must be as determined by the fire code official (again, same reasoning as others) [§503.2.8].

Appendix D of the IFC provides specific specifications for fire apparatus roads; however, not all jurisdictions adopt Appendix D as being applicable law/ordinance. It is incumbent upon the design team to verify with the AHJ which specifications actual apply to the given project.

The subject Facility is provided with access roads around all four (4) sides of the Facility, all of which are sufficiently wide and within an appropriate proximity to all portions of the Facility's exterior.

Building access also includes doors for fire fighter access, which must be accessible without the use of a ladder [§3206.6.1]. Sufficient doors are required along all portions of the exterior of the Facility so that spacing between any two doors does not exceed 100 lineal ft [§3206.6.1.1]; each door must not be less than 3 ft in width and not less than 6 ft-8 in. in height (roll-up doors are not permitted unless approved) [§3206.6.1.2]; and each door is required to have approved locking devise [§3206.6.1.3].

The Facility is provided with sufficient doors to meet the above-noted requirements of the IFC. These fire fighter ingress doors will also double as means of egress for occupants of the Facility. Means of egress will be discussed in Section 9.0 of this report.

8.5 Smoke and Heat Removal & Draft Curtains

It was noted earlier in this report that draft curtains were not necessary for fire sprinkler system separation since the under-mezzanine systems are provided with quick-response storage sprinklers, which have a similar RTI as the ESFR sprinkler systems provided at the roof level.[14] However, Chapter 32 of the IFC has requirements that may include draft curtains with necessary smoke and heat removal systems for a given building. Section 3206.7 governs such systems for high-piled combustible storage areas, and refers to Table 3206.2. Smoke and heat removal is required for the subject Facility, but draft curtains are not [IFC Table 3206.2]. However, the matter is not that simple.

First, it is permitted by the fire code to not provide smoke and heat removal when storage areas are protected by ESFR sprinkler systems installed in accordance with NFPA 13 [Table 3206.2, note j; §910.1, Exception 2], which alludes to the incompatibility issues associated with smoke and heat removal systems and automatic fire sprinkler systems.[15] Second, the building code has at times (most recently, in the 2006 edition) required smoke and heat removal systems for increased exit access travel distances.

[14] Both quick-response sprinklers and ESFR sprinklers are required, by definition, to have a thermal element which has an RTI of 50 $(\text{meters-seconds})^{1/2}$ or less.

[15] It is important to distinguish that the code provisions for not providing smoke and heat removal are when ESFR sprinklers are present; however, the concepts of incompatibility are applicable to all sprinkler systems, not just those equipped with ESFR sprinklers.

The latter will be discussed in more detail in Section 9.0 of this report; however, it is relevant to the following discussion.

The basic premise and objective of smoke and heat removal is *"to slow, stop, or reverse the descent of a smoke layer produced by a fire in a building, by exhausting smoke to the exterior"* [NFPA 204 §4.4.1]. The goal of doing so is to limit the exposure of building elements (i.e., structure) and occupants to the effects of a fire (i.e., heat and smoke). The concept is a simplistic one: as heat and smoke are produced, remove those products from the space so occupants are provided with more time to safely exit the building. When required by code, a smoke and heat removal system is required to be operate both automatically and manually [§910.3.2]. This requirement, although seemingly sound at first thought, is impractical with automatic sprinkler systems.

If a smoke and heat removal system were to activate automatically, it could either 1) operate before the sprinkler system activates, or 2) operate after the sprinkler system. Considering the former, removal of heat prior to sprinkler system activation may adversely impact the system response time, thus delaying water delivery to the fire. Considering the latter, if sprinklers activated prior to the vents, it is feasible that the vents would never operate since sprinklers, especially ESFR sprinklers, are expected to drastically reduce the heat release rate ("HRR") of the fire.

NFPA 204 provides design guidelines for smoke and heat venting. The 2012 edition of the standard includes a statement, which reads as follows:[16]

> Chapters 4 through 10 represent the state of technology of vent and draft curtain board design in the absence of sprinklers. A broadly accepted equivalent design basis for using sprinklers, vents, and curtain boards together for hazard control (e.g., property protection, life safety, water usage, obscuration) is currently not available. Designers are strongly cautioned that use of venting with automatic sprinklers is an area of ongoing research to determine its benefit and effect in conjunction with automatic sprinklers.

NFPA 13 also addresses the issue: Section A.12.1.1.1 states, *"Sprinkler protection criteria are based on the assumption that roof vents and draft curtains are not being used."* NFPA 13 permits manual or automatic roof vents only if the operating element has a higher temperature rating than the automatic sprinklers [§12.1.1.1]; the standard reiterates that ESFR sprinkler systems shall not be used in buildings equipped with heat or smoke vents unless the vents use high-temperature rated, standard-response thermal elements. These provisions of governing codes and standards would imply that it is not desirable for automatic smoke and heat vents to operate before sprinkler systems, and is clear in the requirements to help ensure this.

Research efforts by numerous organizations have generally concluded that sprinkler systems in fire tests employing venting responded differently than those that did not. The most recent research by the Fire Protection Research Foundation confirmed the simple concepts noted previously: 1) vents generally did no operate due to the cooling effect of water discharged from the activated sprinklers; 2) vents that opened prior to sprinkler activation delayed the time for the first sprinkler to activate. Another

[16] Section F.3 of the 2012 edition of NFPA 204, page 204-76.

important discovery was that opened vents did not significantly reduce the temperature of the smoke layer at the ceiling[17] – i.e., the intended objective of the vents is not realized.

There are also the historical code provisions of the IBC that are relevant to this discussion. The 2006 edition of the IBC permitted increased exit access travel distances in one-story Group F-1 and Group S-1 occupancies provided with automatic sprinkler protection simply by also providing smoke and heat removal [2006 IBC §1016.2].[18] Again, the concept is simple: if products of combustion are removed from the space, occupants would be afforded more time to safely escape, thus, longer travel distances are justified. However, the practicality of this theory, as previously discussed, is flawed. This is further evident by the provision being removed beginning in the 2009 edition of the IBC; the omission of the increased travel distance allowance due to the presence of a smoke and heat removal system was continued in the 2012 edition of the IBC. It is worth noting, however, that the 2015 edition of the code has been modified to again allow the increased travel distance. This code provision will be discussed further in Sections 9.0 and 10.0.

The subject Facility is not provided with a traditional smoke and heat removal system or draft curtains. However, mechanical smoke exhaust is included as part of the performance-based design approach.

8.6 Fire Department Hose Connections

The IFC contains provisions for fire department hose connections in high-piled combustible storage areas, as does NFPA 13 in storage occupancies. First, the fire code requires a Class I standpipe system to be provided when exit passageways are required by the IBC [§3206.8]. NFPA 13 leaves the requirement of small hose connections (i.e., 1½ in.)[19] to the determination of the AHJ [12.2.1].

The subject Facility is provided with two (2) exit passageways (to be discussed more thoroughly in Section 9.0). Since the exit passageways are required by the IBC, the fire code provision cited above requires a Class I standpipe system. However, through discussions with the AHJ, it was agreed that 2½ in. hose connections could be provided throughout the Facility in accordance with the provisions of NFPA 13. In other words, in lieu of a standard Class I standpipe system, hose valve connections supplied from adjacent roof-level sprinkler systems are provided to cover the entire Group S-1 occupancy.

8.7 Aisles

Chapter 32 of the IFC provides guidance on and requirements for aisles within high-piled combustible storage areas/buildings. In essence, aisles are meant for access to exits and fire department access doors, and for adequate separation of adjacent storage piles/racks [§3206.9]. Aisles in sprinklered buildings are required to be not less than 44 in. in width (i.e., 3 ft-8 in.) [3206.9.1.1]; however, NFPA 13 also has minimum aisle width requirements.

Storage of Group A plastics in a back-to-back shelf configuration is required to be provided with minimum 60 in. (i.e., 5 ft) aisle widths [§15.2.2(3)], and aisles in rack storage configurations are generally

[17] McGratten, K.B. Hamins, A., and Stroup, D., "International Fire Sprinkler – Smoke & Heat Vent – Draft Curtain Fire Test Project, Large Scale Experiments and Model Development," Technical Report (National Fire Protection Research Foundation, 1998), pp. 64, 101.
[18] The provision is also found in the 2003 edition [§1015.2], and the 2000 edition [§1004.2.4.1].
[19] Small hose connections as governed by NFPA 13 are for first-aid firefighting and overhaul operations [§12.2.1].

not to be less than 3 ft-6 in. in width [Ch. 3 definitions for double- and single-row racks, respectively: §3.9.3.7.1; §3.9.3.7.5]. Even still, further minimum requirements are placed on aisles from a means of egress perspective; refer to Section 9.0 for more information.

8.8 Portable Fire Extinguishers

Portable fire extinguishers are required in practically every building under the governance of the IBC and IFC – no exception is made for high-piled combustible storage areas/buildings. Such areas are required to be provided with portable fire extinguishers in accordance with Section 906 [IFC §3206.10]. The requirement can also be found in the base section governing fire extinguishers; Section 906.1 requires new and existing Group S, A, and B (all applicable to the subject Facility) to be provided with portable fire extinguishers. And finally, it is again reiterated in Table 906.1, which cites the requirement for rack storage areas. The selection, installation and maintenance of portable fire extinguishers is required to be done in accordance with the IFC and NFPA 10 [906.2].

The Facility contains predominantly Class A fire hazards, which are those fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics [NFPA 10 §5.2.1], and is considered an extra (high) hazard. Therefore, fire extinguishers are provided throughout the Facility having a minimum 4-A rating, and in sufficient quantity so the maximum travel distance to any given extinguisher is not more than 75 ft [IFC Table 906.3(1)]. This agrees with the requirements for Class A fires as prescribed in NFPA 10 [Table 6.2.1.1].

9.0 EGRESS SYSTEMS

Egress systems are a major focal point of building codes. The main objective of such systems is to preserve life of the occupants in buildings, and is such an important topic that the National Fire Protection Association dedicates a rather large and comprehensive code to the matter – NFPA 101, *Life Safety Code*. The IBC also dedicates quite a large portion of itself to the matter via Chapter 10 Means of Egress; but really, the intent of the entire IBC and IFC is aimed at life safety. Section 101.3 of the IBC and IFC respectively read as follows:

> [IBC §101.3] The purpose of this code is to establish the minimum requirements to safeguard the public health, safety and welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations.

> [IFC §101.3] The purpose of this code is to establish the minimum requirements consistent with nationally recognized good practice for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings, structures and premises, and to provide safety to fire fighters and emergency responders during emergency operations.

Requirements of the code for means of egress are at times general in nature, and are driven by number of occupants, for example. And other times, the severity of the hazard present will dictate limitations. The following subsections of this report will identify and discuss various aspects of egress systems as they pertain to the subject Facility.

9.1 Occupant Load

The occupant load of any building is crucial for designing and providing adequate means of egress capacity. The IBC details minimum occupant load requirements within Section 1004 [§1004.1.2; Table 1004.1.2]; likewise, the LSC details similar requirements within Section 7.3.1. Both codes stipulate minimum requirements for various occupancies – occupant loads may be increased from those tabulated within the IBC and LSC as long as all other provisions of the respective codes are also followed (e.g., adequate capacity for the increased occupant load is provided per the applicable and governing sections). This provision of the code has been invoked for the Locker spaces; it has been classified as a Group B space but has a decreased the occupant load factor ("OLF") from 100 ft^2/ person to 50 ft^2/ person, resulting in a more conservative calculated occupant load.

The spaces within the subject Facility are tabulated in the below table with respect to their areas, occupancy type, OLF, and calculated occupant load:

Table 4: Summary of Occupancies, Calculated Occupant Load

Occupancy	Area (ft^2)	Occupany Type	Occupant Load Factor (ft^2/ person)	Occupants
Warehouse - Ground Level	1,173,709	S-1	500	2,347
Main Office Area				
Office, Toilet Rooms	23,621	B	100	236
Breakroom (Large)	7,128	A-2	15	475
Breakroom (small)	5,561	A-2	15	371
Training Room (1st Day)	2,031	A-3	20	102
Training Room (Large)	2,889	A-3	20	144
Training Room (Small)	830	A-3	20	42
Lockers	4,496	A-3	50	90
Recruiting Office	4,894	B	100	49
Southwest Entry - Lockers	3,331	A-3	50	67
Maintenance Area	7,366	B	300	25
Central Office West				
Breakroom	1,485	A-2	15	99
Office, Toilet Rooms	2,775	B	100	28
Central Office East				
Breakroom	1,485	A-2	15	99
Office, Toilet Rooms	2,775	B	100	28
Trucker's Lounge	1,627	A-2	15	108
Remote Toilet, Misc.	861	B	100	9
Total Ground Level	1,246,864			4,318
Process Mezzanine Level	240,300	S-1	500	481
Office, Toilet Rooms	4,123	B	100	41
Equipment Platform	8,646	S-1	500	17
Breakroom	2,970	A-2	15	198
Total Process Mezz. Level	256,039			737
Mezzanine Level 1	486,110	S-1	500	972
Mezzanine Level 2	486,110	S-1	500	972
Total Mezz/ Platform	972,220			1,944
Total Area	2,475,123		Total Occupant Load	6,999

The OLFs are extracted from Table 1004.1.2 of the IBC. The factor tabulated for Group S-1 occupancies is derived from the value provided for warehouses; however, per Table 7.3.1.2 of the LSC, General Industrial occupancies call for a factor of 100 ft^2/ person. The same LSC table also prescribes a factor of 500 ft^2/ person for storage use in other than storage and mercantile occupancies, which agrees with that which is used for the subject Facility based upon the IBC factors. Section 40.1.7 of the LSC states (paraphrased) “that the occupant load must be based upon the factors within Table 7.3.1.2 that are characteristic of the use of the space” – an OLF of 100 ft^2/ person for the main space of the Facility is unreasonably high and not indicative of the expected occupant load of the Facility based upon Tenant operations.

The total calculated occupant load of 6,999 persons is the maximum anticipated number of occupants during peak seasonal operation – otherwise, typical shift operations would result in an occupant load less than that tabulated within Table 4. However, code requirements dictate that means of egress be provided for the maximum expected occupant load per the applicable factors, or the actual anticipated number of persons, whichever is greater. Therefore, a calculated occupant load of 6,999 persons will be used for design and analysis purposes.

9.2 Means of Egress Sizing and Configuration

The total capacity of all exits shall be sufficient to provide adequate egress for the maximum anticipated occupant load [IBC §1005.3]. The capacity of the means of egress is calculated using capacity factors of 0.3 in/ person for stairways [§1005.3.1] and 0.2 in/ person for all other egress components [§1005.3.2]. These capacity factors are mirrored in Table 7.3.3.1 of the LSC for “All other” areas (those areas other than board and care, health care and high hazard areas). Often times, however, the minimum travel distance requirement of the code will drive the minimum number of exits required rather than minimum egress capacity necessary for the given occupant load [LSC §A.40.1.7]. And in some cases, such as this Facility, fire fighter building access will play a prominent role, which was discussed previously in Section 8.4 of this report.

The typical means of egress along the perimeter of the Facility serving as exits from the main warehouse area are provided with standard 36 in. (3 ft) wide doors that discharge onto external stairs, which provide access to grade level exit discharge; the stairs are nominally 66 in. (5 ft-6 in.) wide. The capacity of each exit is determined by the limiting component. With the aforementioned factors considered, the capacity of the single 36 in. wide door is 180 persons, while the capacity of the 66 in. wide stair is 220 persons. There are also a total of six (6) ramps that provided exit discharge to a total of fifteen (15) means of egress in addition to those typical stairs previously mentioned. These ramps are, from handrail to handrail, 60 in. (5 ft) wide and are provided for disabled employees.[20] Adequate capacity is otherwise provided via the stairways; therefore, the ramps are not factored into egress capacity.

In order to adequately egress the total maximum calculated occupant load of 6,999 people through the limiting door components of each exit, a capacity equivalent to thirty-nine (39) man doors are necessary, each no less than 36 in. wide. A minimum level-component width of 1,400 in. is required, which corresponds to the rounded-up figure of thirty-nine (39) 36 in. wide man doors.

The number of exits provided, however, is driven more by the required fire fighter building access doors that can double as means of egress. Section 413.1 of the IBC refers to the IFC for high-piled combustible storage. As discussed previously, the subject Facility requires a fire fighter access door every 100 lineal feet along exterior walls that face required fire apparatus roads. All sides of the Facility are required to have fire apparatus access roads within 150 ft of all exterior points of the Facility. In order to meet this

[20] Disabled employees, permanent or temporary, are limited in the type of work they can perform. Due to the nature of the work performed throughout the majority of the Facility, disabled personnel are limited to light-duty roles if they are normally on the floor; the office areas are made completely accessible.

requirement as well as other means of egress requirements (such as minimum number of means of egress from individual spaces and maximum allowed exit access travel distance) the Facility is provided with a total of sixty six (66) doorways. Twelve (12) of those doorways are 68 in. (5 ft-8 in.) wide double doors, and eight (8) are through fire-resistance rated stairways or exit passageways, which provide egress from the various mezzanine levels. The total nominal egress width provided is 2,376 inches, which far exceeds the minimum required width of 1,400 in.

In addition, meeting the IFC requirements for high-piled combustible storage means the location of the various exits will inherently comply with the requirements of Section 1015 of the IBC, which requires two or more exits to be sufficiently separated so a given fire or emergency scenario does not impair an excessive amount of means of egress. The LSC has the same requirements for location (i.e., separation of exits) [§7.5.1.3.2].

Individual ancillary spaces are provided with an adequate number and capacity of exits. For example, IT spaces along the exterior (plan east and west portions of the Facility) are provided with their own exits so occupants in those spaces would not have to enter the main warehouse space before exiting the Facility. Assembly occupancies (i.e., break rooms) are provided with no less than two means of egress.

Finally, the various levels of mezzanines are provided with enclosed, fire-resistance rated interior exit stairways [IBC §1009.2], and unenclosed exit access stairways [§1009.3].[21] The eastern and western elevated mezzanines are provided access to four (4) interior exit stairways, which when combined provides an egress capacity of 594 persons. This provided egress capacity exceeds that which is needed per the calculated occupant load of each individual mezzanine level (486 people).[22] The central process mezzanine is provided access to two (2) of the total eight (8) interior exit stairways, which provides an egress capacity for 312 persons. The remaining calculated occupant load is evenly distributed to the various unenclosed exit access stairways where occupants can exit the Facility within the maximum allowed exit access travel distance.

Refer to Appendix C for a ground level floor plan showing the various exits, means of egress travel paths, etc.

9.3 Means of Egress Signage and Illumination

All exits and exit access doors are provided with exit signs, in accordance with Section 1011.1 of the IBC and Section 7.10.1.2.1 of the LSC. This includes all exits along the perimeter of the Facility and exit access doors to the several noted stairways. The signage illumination will also comply with the provisions of the code [IBC §1011.3; LCS §7.10.5].

9.4 Fire-Resistance Rating of Means of Egress

The required interior exit stairways are provided with not less than 1-hour fire-resistance rated construction since the stairs connect less than four (4) stories [IBC §1009.2; §1022.2]. Corridors within

[21] The unenclosed exit access stairs are able to be unenclosed due to atmospherically communicating between two stories (i.e., the subject stairways communicate between levels in a single story) [IBC §1009.3 Exception 1].

[22] Total egress capacity for the various mezzanine levels in the eastern and western portions are provided through fire-resistance rated enclosed interior exit stairways. The unenclosed stairways are provided for operational needs, and are not factored into the egress capacity for those levels.

the Facility are not required to be of fire-resistance rated construction since the Facility is provided with automatic fire sprinkler protection [Table 1018.1]; however, the two (2) interior exit stairways that terminate in the middle of the Facility are required to discharge into rated exit passageways to maintain exit continuity [§1003.7; §1022.3 Exception]. The required exit passageways are required to be of 1-hour fire-resistance rated construction [§1023.3].

All of the above-noted fire-resistance rated construction is required to be provided in accordance with the Section 707, which provides the requirements for fire barriers (as opposed to fire walls, which are inherently structurally independent).

The Facility complies with the minimum fire-resistance rated construction code provisions.

9.5 Exit Access Travel Distance

The maximum exit access travel distance is limited for the subject Facility to 250 ft [IBC Table 1016.2]. However, previous editions of the IBC (i.e., 2006 and earlier editions) had included a provision to extend the maximum travel distance within similar facilities (i.e., Group F-1 and Group S-1) to 400 ft when those facilities are equipped throughout with automatic sprinkler systems and equipped with automatic smoke and heat vents. It is interesting to note that the LSC tabulates a maximum travel distance of 400 ft for fully sprinklered ordinary hazard storage occupancies, and 250 ft for general industrial occupancies [Table A.7.6]. In order to meet the functional needs of the tenants of these types of large, modern distribution facilities, a maximum travel distance of 400 ft is necessary.

The issue of smoke and heat vents has already been discussed in this report; however, it is worth noting again that while the basic theory of smoke and heat removal allowing for extended periods of safe egress, and thus farther egress travel distances, the code provision to achieve this by smoke and heat venting in a sprinklered building is questionable. The issue of maximum allowed exit access travel distance is one for which the Facility does not comply with the prescriptive requirements of the code. Therefore, the justification for the extended travel distance is one of the objectives of the performance-based design approach.

The Facility is subjected to a maximum common path of egress travel of 100 ft in an occupancy provided with an automatic fire sprinkler system [IBC Table 1014.3], with which the Facility complies.

10.0 PERFORMANCE-BASED DESIGN

The subject Facility cannot comply with all provisions of the building and fire code as designed. However, the code provides for what is commonly referred to as “alternate means and methods,” or a performance-based design. The two (2) applicable sections of the IBC and IFC read as follows:

> [IBC §104.11] The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been *approved*. An alternative material, design or method of construction shall be *approved* where the *building official* finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, *fire resistance*, durability and safety.

> [IFC §104.9] The provisions of this code are not intended to prevent the installation of any material or to prohibit any method of construction not specifically prescribed by this code, provided that any such alternative has been *approved.* The *fire code official* is authorized to approve an alternative material or method of construction where the *fire code official* finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, *fire resistance*, durability and safety.

In addition, the codes provide for modifications (from the code prescriptions) when there are practical difficulties in achieving strict compliance with one or multiple provisions of the code. The two (2) applicable sections of the IBC and IFC read as follows:

> [IBC §104.10] Wherever there are practical difficulties involved in carrying out the provisions of this code, the *building official* shall have the authority to grant modifications for individual cases, upon application of the owner or owner's representative, provided the *building official* shall first find that special individual reason makes the strict letter of this code impractical and the modification is in compliance with the intent and purpose of this code and that such modification does not lessen health, accessibility, life and fire safety, or structural requirements. The details of action granting modifications shall be recorded and entered in the files of the department of building safety.

> [IFC §104.8] Whenever there are practical difficulties involved in carrying out the provisions of this code, the *fire code official* shall have the authority to grant modifications for individual cases, provided the *fire code official* shall first find that special individual reason makes the strict letter of this code impractical and the modification is in compliance with the intent and purpose of this code and that such modification does not lessen health, life and fire safety requirements. The details of action granting modifications shall be recorded and entered in the files of the department of fire prevention.

The above-cited code provisions provide the Facility with a means for undertaking a performance-based design approach to meet the intent of certain code sections where the configuration is not in compliance with the prescriptions, and to provide a modified systems (i.e., an alternative) when a code prescription involves a practical difficulty. Such a design process requires the development of certain criteria, which will be used to evaluate the design compared to the intent of the provisions of the code. Closely related to these criteria are the Facility configuration and occupant characteristics. Also involved is the development of a design basis fire that is representative of the hazards present in the Facility; most notable is the consideration of multiple scenarios to understand and design for the most reasonable worst-case conditions that may exist. And finally, fire and smoke modeling and egress analyses are used to compare available safe egress time ("ASET") to the calculated required safe egress time ("RSET") through occupant exit calculations.

10.1 Design Objectives

It is important to note the overall objective of this performance-based design approach, which is "to provide a tenable environment to occupants during evacuation and relocation of occupants. These provisions are not intended for the preservation of contents, the timely restoration of operations of for assistance in fire suppression or overhaul activities."[23] This general intent aligns with the requirements of allowed alternate means and methods as cited previously, as well as the concept behind the historical code provisions that allowed extended travel distances by the installation of smoke and heat vents.

The performance-based design will show that the building configuration (i.e., increased mezzanine size, voluminous open space), and fire protection systems provided therein, provides an equivalent amount of quality, effectiveness, and safety, thus meeting the overall intent of the applicable building and fire codes.

10.2 Design Criteria

Tenability criteria often considered in performance-based design approaches are 1) toxicity; 2) heat (i.e., temperature); and 3) visibility. All three (3) criteria are directly related to the products of combustion in a fire scenario, and are all directly related to the smoke layer that would be expected to develop in a built environment.[24] Therefore, it is important to understand when and where the smoke layer would be considered to create an untenable environment for the building occupants. Refer below to Figure 12.

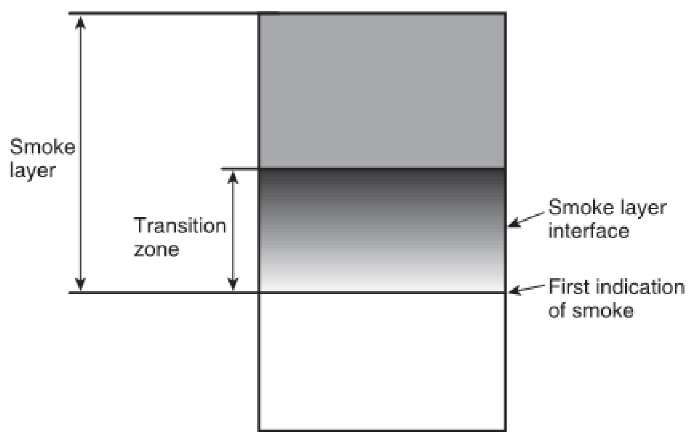

Figure 12: First Indication of Smoke[25]

NFPA 92 defines the first indication of smoke as, "The boundary between the transition zone and the smoke free air" [§3.3.13.1]. Equations within NFPA 92 attempt to calculate the first indication of smoke, as identified in Figure 12. NFPA 92 explains:

> [§A.5.4.2.1] The equations in 5.4.2.1 are for use with the worst-case condition, a fire away from any walls. The equations provide a conservative estimate of hazard because z relates to the height where there is a first indication of smoke, rather than the smoke layer interface position. Calculation results yielding $z/H > 1.0$ indicate that the smoke layer has not yet begun to descend.

This is important to keep in mind when evaluating results from computer fire modeling. For this purposes of this report, the smoke layer interface will occur when the suggested tenability thresholds

[23] Section 909.1 of both the IBC and IFC describes the scope and purpose of smoke control systems.
[24] The fire itself obviously exposes the building occupants to elevated temperatures; however, during building egress, it is the smoke layer that predominantly exposes occupants to the products of combustion.
[25] Figure 12 is Figure A.3.3.13.1 from the 2012 edition of NFPA 92.

are exceeded – "untenable conditions occur when it is predicted that occupants inside or entering an enclosure are likely to be unable to save themselves due to the effects of exposure to smoke, heat, and/or toxic gases."[26] The tenability criteria for the Facility are:

- ≤ 1,000 ppm of carbon monoxide ("CO"). "At constant level of activity, and, thus, respiration, the animals (primates) became unconscious when exposed to approximately 27,000 ppm-min of CO at concentrations between 1,000 and 8,000 ppm."[27] Therefore, a threshold of 1,000 ppm is considered conservative, especially since egress is not expected to take 27 minutes or longer.

- ≤ 140°F (60°C). The tolerance time is greater than 30 minutes at this temperature with 100 percent saturated air (i.e., water vapor produced by fire and due to sprinkler discharge).[28]

- ≥ 33 ft (10 m) of visibility. The threshold will be evaluated first at 33 ft; however, this is not a hard and fast rule. Research has shown that very few occupants turn back during egress when visibility is 33 ft or more.[29] However, a vast majority (i.e., > 75 percent) of study participants initiated behavior (i.e., turned back) when visibility fell below 13 ft (4m). Also, "those who know the inside geometry of the building on fire need a visibility of 4 m for safe escape while those who do not need a visibility of 13 m."[30] As shown, this is not an exact science. However, 33 ft (10 m) is considered a conservative set point, especially when considering that most of Facility occupants present at any given time will be employees who are well trained in their surroundings as well as emergency responsiveness – the Tenant has in place a rigorous safety program that includes regular fire drills. If and when visibility falls below the set threshold, that area of concern will be scrutinized more closely to also consider the other tenability criteria, as well as when the threshold was breeched.

The tenable environment will be evaluated at a commonly used industry elevations threshold – 6 ft above the highest occupied level,[31] which, in the subject Facility, is the topmost level of the eastern and western mezzanines. The 'critical height' will be 27 ft (the topmost mezzanine level is elevated at 21 ft AFF).

The tenable environment must be maintained for a sufficient duration to allow for Facility occupants to safely escape. Historic code provisions have been a bit unclear on this matter, but it has been clarified in the 2015 edition of the IBC. In previous editions of the code, the duration for smoke control system operation was specified as the *lesser* of 20 minutes or 1.5 times the calculated egress time. The 2012 code commentary explains:

> [Commentary to §909.4.6] The intent of the smoke control provisions is to provide a tenable environment for occupants to either evacuate or relocate to a safe place. Evacuation and

[26] Pursar, D.A., "Assessments of Hazards to Occupants from Smoke, Toxic Gases, and Heat," *SFPE Handbook of Fire Protection Engineering*, 4th Edition, P.J. DiNenno ed., NFPA 2008, pg. 2-96.
[27] Ibid. pg. 2-101.
[28] Ibid. pg. 2-145.
[29] Bryan, John L., "Behavioral Response to Fire and Smoke," *SFPE Handbook of Fire Protection Engineering*, 4th Edition, P.J. DiNenno ed., NFPA 2008, pg. 3-347.
[30] Tadahisa, Jin, "Visibility and Human Behavior in Fire Smoke," *SFPE Handbook of Fire Protection Engineering*, 4th Edition, P.J. DiNenno ed., NFPA 2008, pg. 2-59.
[31] Section 909.8.1 discusses the smoke layer for exhaust method smoke control systems; it is here where the code specifies that the smoke layer interface shall be maintained at least 6 ft above any walking surface that forms a portion of a means of egress.

> relocation activities include notifying occupants, possible investigation time for occupants, decision time and the actual travel time. In order to achieve this goal, the code has established 20 minutes or 1.5 times the calculated egress time, whichever is *less*, as a *minimum* time for evacuation or relocation. … It is stressed that the 20 minute duration as well as the calculated egress time, whichever approach is chosen, begins after the detection of the fire event and notification to the building occupants to evacuate has occurred, since occupants need to be alerted before evacuation can occur. … It is stressed that the code states 20 minutes or 1.5 times the egress time, whichever is *less* (i.e., 20 minutes is a *maximum*).

Intuitively, the lesser of the two options does not make sense. This error in the code, and commentary, was corrected in the 2015 edition of the IBC:

> [Commentary to §909.4.6] It is stressed that the code states 20 minutes or 1.5 times the egress time, whichever is *greater* (i.e., 20 minutes is a *minimum*).

These code provisions govern the operation of the smoke control system; however, they also provide a basis for minimum performance-based design analyses. In the subject performance-based design approach, the tenable conditions will be evaluated at the *greater* of either 1.5 times the calculated egress time or 20 minutes (i.e., 20 minutes is a *minimum*, as correctly stipulated in the 2015 edition of the IBC).

10.3 Building Configuration and Features

The building geometry, and features therein, and characteristics of occupants are important factors to consider in a performance-based design. It is, therefore, important to briefly discuss these topics here.

The Facility is a large, open-space building having approximately 4,375,000 ft^3 of volume. This approximation is the product of the general footprint of the Facility (i.e., 1,250,000 ft^2) and the average roof height (i.e., 35 ft) – it does not account for volume occupied by the various mezzanine levels, storage configurations, or equipment within the Facility, and is not intended to be precise. The intent of noting the volume is to simply provide an idea of the vastness of the space, which for all intents and purposes is a continuous atmosphere (other than the accessory office space, which is separated from the main Group S-1 occupancy by floor-to-roof walls). This large volume provides for a significant smoke reservoir to contain smoke and heat above the highest occupied floor level.

The Facility is provided with a total exit capacity that far exceeds the minimum required by code simply from a capacity perspective (i.e., that minimum width required by the calculated occupant load). The additional exits are provided to comply with other provisions of the code, such as fire fighter building access and maximum exit access travel distance. The maximum exit access travel distance used in the performance-based design is 400 ft, which is the historical maximum distance allowed when a building is equipped with smoke and heat vents, among other features, such as automatic fire sprinkler systems.

The Facility is provided with a number of active fire protection systems, including automatic fire sprinkler systems. The roof level is provided with ESFR sprinklers that, according to fire tests and applicable standards, are expected to suppress a fire within the bulk storage areas of the Facility (i.e., the tall rack storage areas are of main concern). The various mezzanine levels are also provided with sprinkler protection underneath, which are designed as control-mode sprinkler systems, which are expected to control a fire rather than to suppress it completely. All automatic fire sprinkler systems within the Facility are of the wet pipe type, and are provided in accordance with NFPA 13. These types of fire sprinkler systems have a tremendous historical track record of reliability, especially when properly maintained, which these systems presumably are based upon the Tenant's maintenance program.

The automatic fire sprinkler systems are supplied by an electric motor-driven fire pump that is provided in accordance with NFPA 20. The fire pump is regularly tested and maintained in accordance with NFPA 25, and is monitored by the Facility's fire alarm system.

The Facility is provided with an area-wide occupant notification system. The fire alarm system employs few automatic smoke detectors, as required by code (i.e., above various fire alarm panels, and in certain small computer areas), and is primarily activated by waterflow switch devices installed in all of the fire sprinkler systems. The provided fire alarm system uses standard horn/strobe notification devices located throughout the Facility in accordance with NFPA 72, and is monitored by a supervising station for code compliance, insurance regulations, and emergency response.

The performance-based design approach also includes an engineered automatic smoke exhaust system. The code allows for mechanical smoke exhaust as an alternative when approved by the AHJ [§910]. The total exhaust capacity, number of fans, fan sizes and spacing, and make-up air configuration is based upon the performance-based design rather than the code provisions of the IBC and IFC.

The smoke exhaust system includes a total of fifty two (52) fans evenly distributed over the eastern and western mezzanines (twenty six [26] per mezzanine). Each fan has a capacity of 35,000 cubic feet per minute ("cfm"). The system is provided with emergency back-up power by way of diesel engine-powered generators located onsite. The system includes a fire fighter's smoke control panel, which is located in the same electrical room as the main FACP (which is immediately adjacent to the fire pump room). The smoke control panel provides the capability of manually controlling the smoke exhaust system. The Facility's overall maintenance program includes regular inspections and maintenance of the smoke exhaust system to ensure its functionality at all times.

The smoke exhaust system will be provided with make-up via wall louvers/dampers distributed evenly along the Facility's exterior walls. Louvers along the plan north and south exterior walls (i.e., the long dimension of the Facility) were placed at approximately 16 ft AFF to account for truck dock doors; louvers in the plan east and west walls were located within a few feet of the floor. All louvered openings provide approximately 3,072 ft^2 of free area, which corresponds to an inlet air velocity of about 600 ft/min (nominally, fifty two [52] fans each with a capacity of 35,000 cfm will exhaust 1,820,000 cfm of air; 3,072 ft^2 of free area at 600 ft/min is nominally 1,843,200 cfm of air).[32] Refer below to Figure 13, which illustrates the modeled fan and vent locations, as well as the general intent for installation purposes.

[32] The code provision for make-up air in smoke exhaust systems is to provide no less than 50 percent of the required exhaust [§910.4.5].

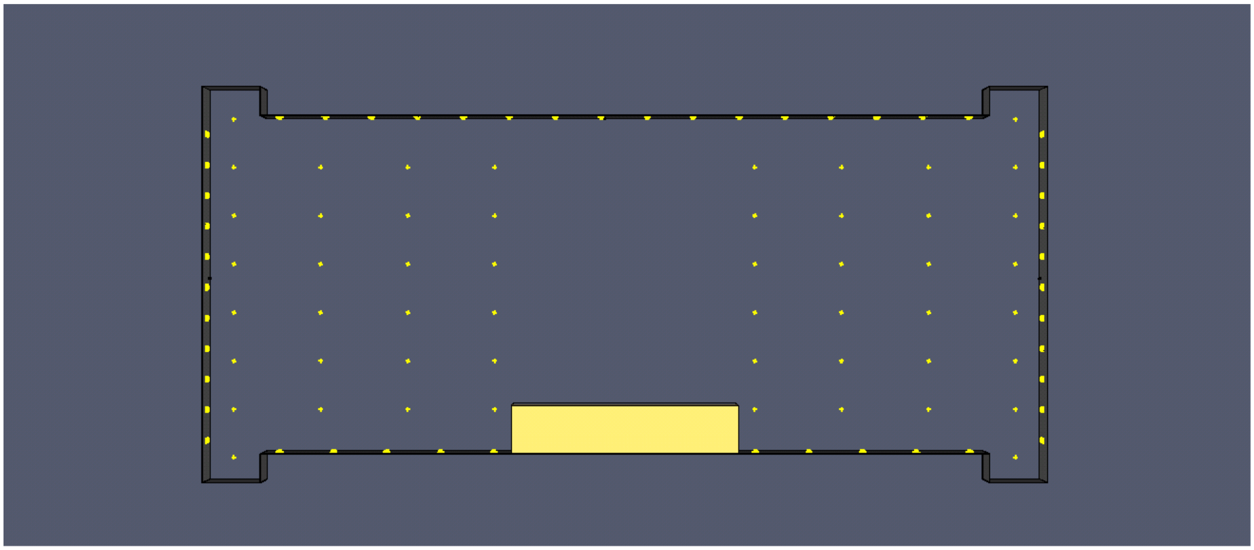

Figure 13: Modeled Fan and Vent Locations

10.4 Occupant Characteristics

The occupants of the Facility, as previously noted, are well-trained and fully capable of responding appropriately to a fire scenario. Just as the code assumes, these occupants are awake and are familiar with their immediate areas and surroundings. The Tenant trains and instructs the occupants to exit the Facility upon becoming aware of a fire emergency; occupants are not expected to remain-in-place, nor are they expected to assist in firefighting efforts.

Through the ongoing training program that is in place, occupants respond rather quickly to a fire alarm (i.e., occupant notification devices). This topic, however, will be discussed later in this report.

Finally, the performance-based design does not include the assistance of fire department activities. The features of the Facility are relied upon for the sake of the performance-based design. However, it is reasonable to expect that the fire department will respond to the Facility within 20 minutes; due to the features discussed above, it is expected that firefighting operations will be possible within the Facility well beyond the 20 minute mark.

10.5 Design Fire

A design fire must be specified for the performance-based design, and part of that specification is the consideration of multiple fire scenarios. The scenarios considered should be reasonable and conservative for the given building. These various scenarios include different fire locations throughout the Facility, possible ignition sources, and available fire protection features (active and/or passive).

The Facility is designed to store ordinary Class I-IV commodities with some Group A plastics. A design fire scenario should consider this hazard, and the severity of a fire in differing locations and in different storage configurations (i.e., rack vs. palletized vs. shelf). Based upon the principles and governing equations for heat release rate, smoke production, etc., the most reasonable worst-case fire scenario would result from the highest heat release rate under the highest ceiling and involves a fuel with the highest soot production. A fire such as this would result in the most smoke production, the highest smoke layer temperatures, and the lowest potential visibility. A fire scenario that fits this description for the subject Facility would be located in the rack storage configuration that is open to the roof deck of the Facility.

Similar qualitative analysis can be applied to other areas of the Facility. The central mezzanine floor is located 18 ft AFF, and the fire loading both under and on top of the mezzanine are not as substantial as the rack storage configuration. The under-mezzanine storage consists of palletized/ solid-piled and shelf storage, but up to heights of only about 8 ft. The clearance from the top of storage to the fire sprinkler systems provided is only a nominal 10 ft. The Extra Hazard (Group 2) fire sprinkler systems design with quick-response sprinklers would be expected to activate fairly quickly to a fire under the mezzanine and would be fully expected to control the fire; thus, this scenario is not considered a reasonable worst-case option. Likewise is true for a scenario under one of the eastern or western mezzanine levels, which have a floor-to-ceiling clearance of only 10 ft-6 in., with shelf storage up to 8 ft in height. A developing fire in this case would not be expected to be more severe than the rack storage, especially considering the presence of noncombustible metal shelving within the storage configuration and the close proximity of quick-response sprinklers to the top of storage. Preliminary fire hazard and sprinkler activation calculations were performed for all scenarios (discussed in more detail later) and none proved to be more severe than the rack storage configuration under the maximum facility roof deck height.

All of the considered fire scenarios were analyzed with the same set of general circumstances. The most high-hazard storage commodity was used for each – Group A plastic – even though the Facility is not completely and solely storing this type of commodity (i.e., most is Class I-IV ordinary combustibles); the fire growth curve was allowed to continue to grow for a period of 30 seconds after sprinkler activation; and the growth curve was specified to remain steady after the 30 second post-sprinkler activation time, which is more conservative than having the curve enter a decay phase (i.e., the sprinkler systems are not controlling the fire and decreasing the heat release rate as they would be expected).

Group A plastics range in chemical and physical properties. It is the intent of the performance-based design approach to select a representative worst-case Group A plastic that has conservative properties for fire growth, soot production, and CO yield. NFPA 204 contains relevant data to this end, as does the SFPE Handbook. Polystyrene (“PS”) jars packed in compartmented cartons stacked 4.57 m (15 ft) high is tabulated as having a growth rate of 55 seconds, which is quicker than the standard ultra-fast t^2 fire [NFPA 204 Table F.1(a) & Table F.1(b)].[33] Refer to Figures 14 and 15 for comparative fire growth curves, and some representative fuels which correspond to those curves.

[33] t^2 fire growth rates are categorized as slow, medium, fast, and ultra-fast, and each is defined as reaching 1,000 kW in heat release rate at 600 seconds, 300 seconds, 150 seconds, and 75 seconds, respectively.

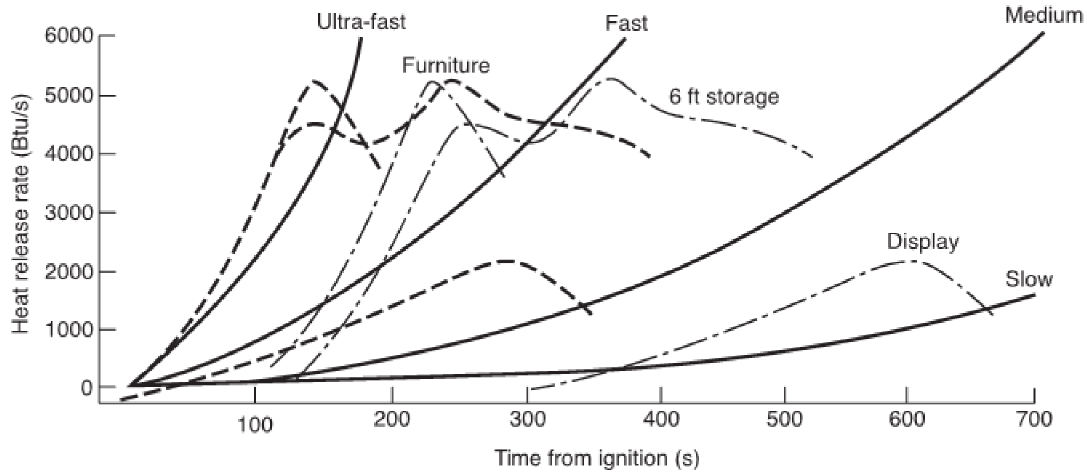

Figure 14: Heat Release Rates for t^2 Fires

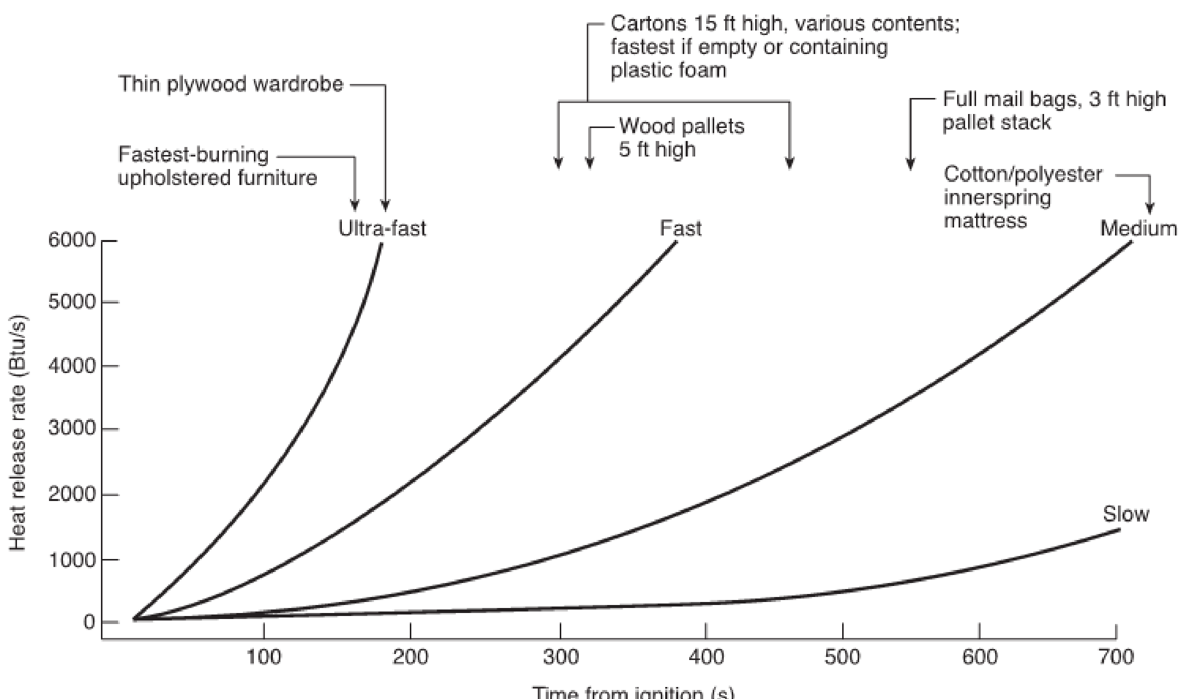

Figure 15: Relation of t^2 Fires to Some Fire Tests

Not only will PS produce a very rapidly growing fire, it also has other properties that prove it to be a conservative commodity choice. It is interesting to compare the heat of combustion of PS to acetone, which is a Class IB flammable liquid – PS has a heat of combustion of 39.85 kJ/g, while acetone is tabulated as having a heat of combustion of 30.79 kJ/g [SFPE HB Table 1-5.3].[34] PS also has a relatively high soot yield compared to a common plastic specimen used in small-scale fire tests – PMMA. PS has a soot yield of 0.164, while PMMA has a soot yield of 0.022 [SFPE HB Table 3-4.16]. PS has a CO yield that is also comparatively high – 0.060 [SFPE HB Table 3-4.16].

[34] It is not the intent to compare the flammability (i.e., the ignitability) of the two commodities, but simply their heats of combustion.

A summary is provided below of the three (3) fire scenarios considered in the performance-based design, all of which are based upon PS as the commodity:

1. Scenario #1: An ultra-fast fire with a growth time of 55 seconds to 1,055 kW in high-piled rack storage configuration of cartoned unexpanded Group A plastics (i.e., PS), which is controlled (not suppressed) by the ESFR sprinkler systems provided at the roof of the Facility; located in the rack storage area.
2. Scenario #2: An ultra-fast fire with a growth time of 75 seconds to 1,055 kW in shelf storage configuration of cartoned unexpanded Group A plastics (i.e., PS), which is controlled by the control-mode fire sprinkler system provided under the mezzanines of the Facility; located under the eastern mezzanine.
3. Scenario #3: An ultra-fast fire with a growth time of 75 seconds to 1,055 kW in palletized/ solid-piled and/or shelf storage configuration of cartoned unexpanded Group A plastics (i.e., PS), which is controlled by the control-mode fire sprinkler system provided under the mezzanines of the Facility; located under the central mezzanine.

Refer below to Figure 16 for graphical representation of fire scenario locations within the Facility.

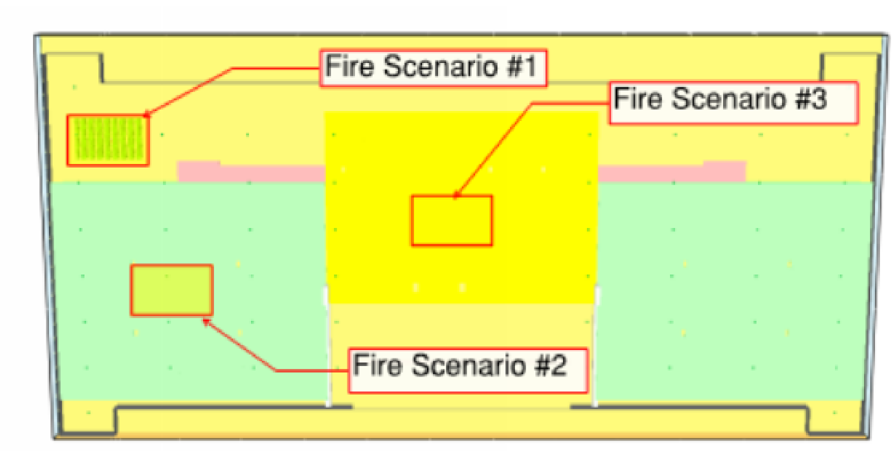

Figure 16: Location of Fire Scenarios

Since it was discussed that the fire growth curve would be allowed to continue to develop for 30 seconds after sprinkler activation, the time at which the sprinkler activates is obviously of importance. The Excel workbook entitled DETACT.xls, a commonly accepted and recognized tool in the fire industry, is capable of modeling the fire growth curve from specified input parameters, as well as predicting the activation time of a thermally-sensitive element (i.e., fire sprinkler, heat detector). This tool was used to evaluate the three (3) fire scenarios.

Scenario #1 – DETACT: The sprinkler system above the Scenario #1 location is equipped with ESFR sprinklers having an RTI of 50 $(m\text{-}s)^{1/2}$ or less, which was used for the model. The sprinklers were modeled as having 214°F activation temperature, spaced on a 10 ft x 10 ft grid with the fire centered between four (4) sprinklers, and ceiling height of 40 ft. The DETACT tool predicted the first sprinkler to activate at 139 seconds. Allowing the additional 30 seconds of fire growth time, the resulting fire curve reaches the steady phase at 9.9 MW, and is as follows:

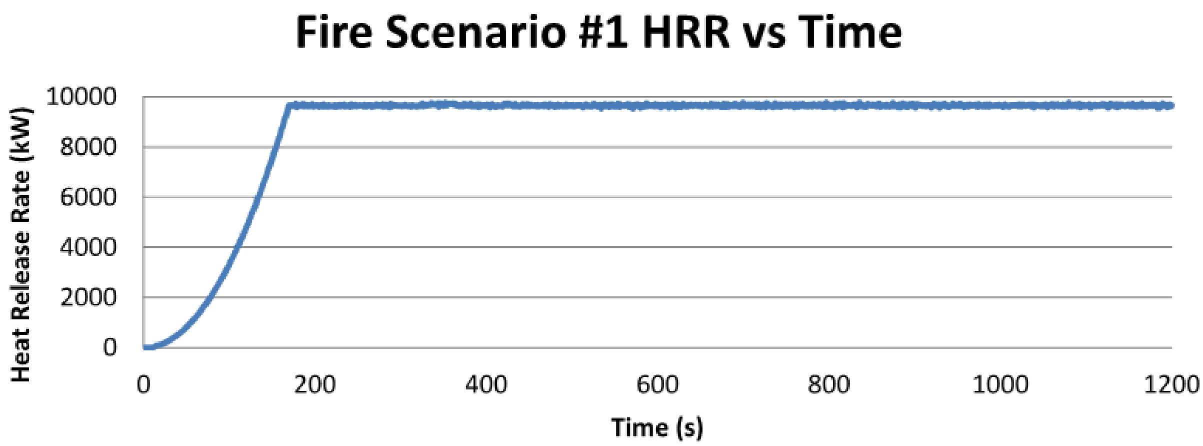

Figure 17: Design Fire Curve – Scenario #1

Scenario #2 – DETACT: The sprinkler system above the Scenario #2 location is equipped with quick-response sprinklers having an RTI of 50 $(m\text{-}s)^{1/2}$ or less, which was used for the model. The sprinklers were modeled as having 165°F activation temperature, spaced on a 10 ft x 10 ft grid with the fire centered between four (4) sprinklers, and ceiling height of 10 ft-6 in. The DETACT tool predicted the first sprinkler to activate at 81 seconds. Allowing the additional 30 seconds of fire growth time, the resulting fire curve reaches the steady phase at 2.3 MW, and is as follows:

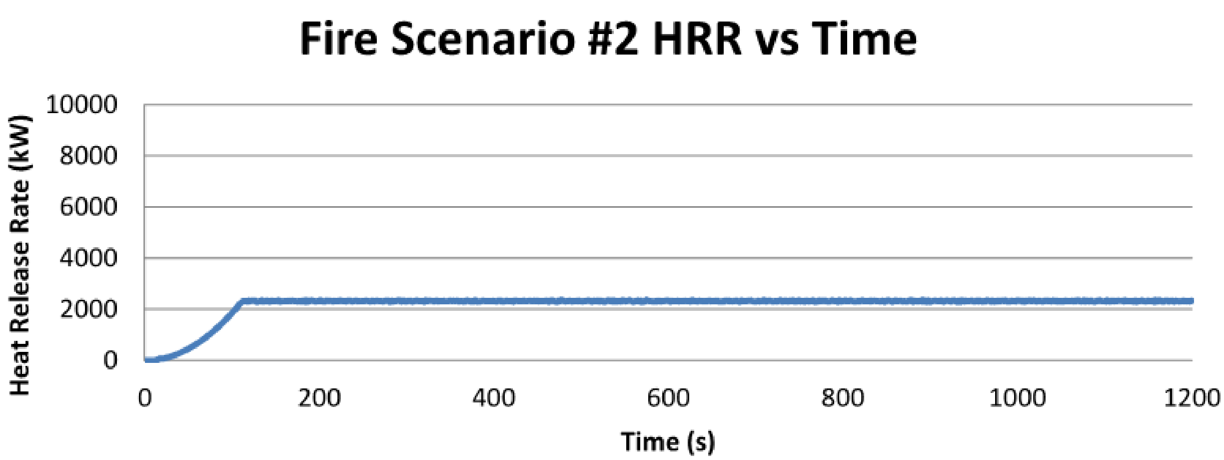

Figure 18: Design Fire Curve – Scenario #2

Scenario #3 – DETACT: The sprinkler system above the Scenario #3 location is equipped with quick-response sprinklers having an RTI of 50 $(m\text{-}s)^{1/2}$ or less, which was used for the model. The sprinklers were modeled as having 165°F activation temperature, spaced on a 10 ft x 10 ft grid with the fire centered between four (4) sprinklers, and ceiling height of 18 ft. The DETACT tool predicted the first sprinkler to activate at 102 seconds. Allowing the additional 30 seconds of fire growth time, the resulting fire curve reaches the steady phase at 3.3 MW, and is as follows:

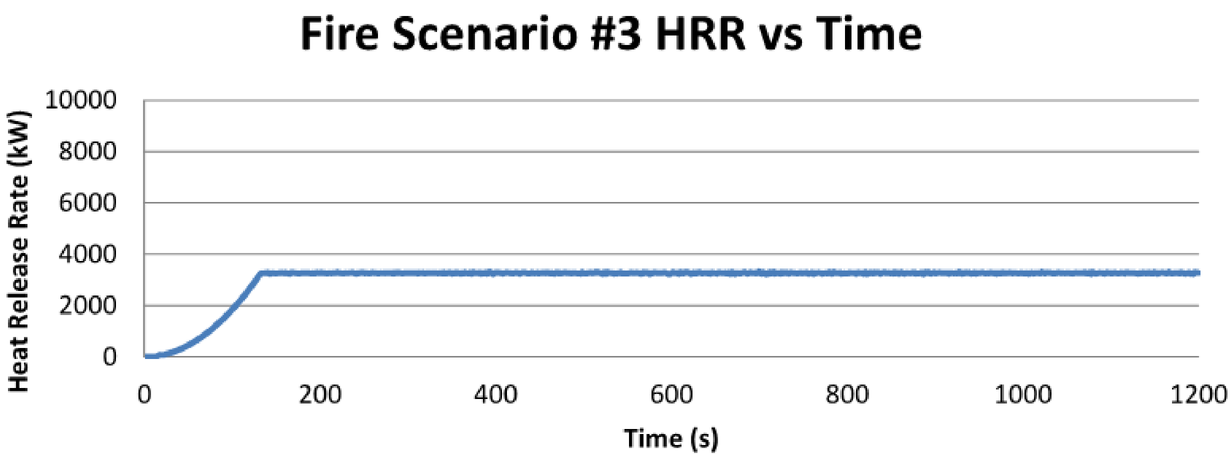

Figure 19: Design Fire Curve – Scenario #3

It has been demonstrated with reasonable levels of conservatism that the worst-case fire scenario would be located in the rack storage area under the full height of the Facility. The complete DETACT worksheets can be found in Appendix D of this report.

10.6 Egress Calculations

The performance-based design is concerned primarily with the safe egress of all occupants from the Facility; however, from an evaluation perspective, the design is concerned about the topmost occupied level, which is the upper level of both the eastern and western mezzanines. Since the design fire scenario considers only a single fire at any given time, the performance-based design will focus on a single topmost elevated level rather than both. It is assumed that due to the proximity to an event occurring on the other side of the Facility, and the Facility's fire protection features, that occupants on the western mezzanine will have more than enough ASET (i.e., RSET < ASET) when the fire is near the eastern mezzanine, and vice versa. Therefore, the egress analysis is performed with respect to the calculated occupant load on the topmost elevated mezzanine (eastern or western, the two are identical).

Table 4 provided above in Section 9.1 of this report details the calculated occupant load for the Facility, illustrating that Mezzanine Level 2 has a calculated occupant load of 972 persons. This calculated occupant load is for the highest level for both the eastern and western mezzanines – each individual level has a calculated occupant load of 486 persons. It is this calculated occupant load that is of concern with respect to the design fire scenario and RSET.

When considering RSET, multiple factors play a role.

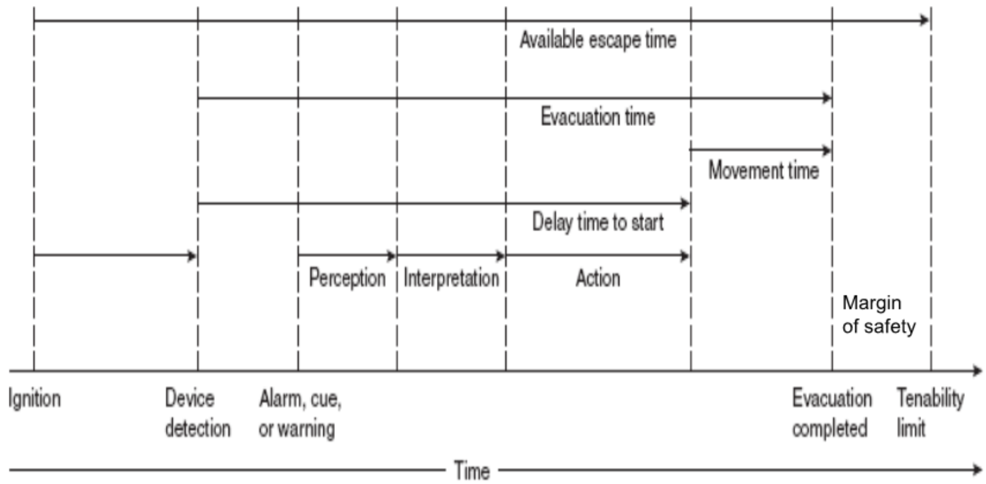

Figure 20: RSET vs. ASET Chart

As Figure 20 shows, it is expected that there will be some delay from actual ignition to detection (whether detection is by human interaction or by automatic fire protection means), and even another delay from alarm to action. This entire delayed response, from detection to action, is considered the 'delay time to start'; once action begins, the calculated egress time (i.e., movement time in Figure 20) will reasonably describe the expected time for occupants to evacuate. The length of time from ignition through the end of movement time is considered the RSET value; the additional margin of safety from that time until a tenable environment no longer exists is included with that value and is considered the ASET value.

Ideally, building occupants would react quickly to the various stimuli that may prompt action in an emergency situation (e.g., one's own sense of sight or smell, or emergency notification stimuli). This performance-based design approach assumes that the alarm/notification to occupants will be through the properly functioning fire alarm system, activated by a waterflow switch device installed in an automatic fire sprinkler system. As discussed previously as part of the design fire scenarios considered, sprinkler activation for the basis of design fire will be at 139 seconds, with the fire alarm system activated 30 seconds thereafter. The total time from ignition to alarm is, therefore, 169 seconds (2.8 minutes).

It is important to note that this should be considered conservative given the nature of the Facility. The subject Facility is occupied and operated 24 hours per day, 7 days per week. Security personnel are in constant attendance and regularly perform security/fire walks around the Facility, and with the relatively dense occupant load for a building of this nature, it is highly unlikely that a fire would go unnoticed for nearly three (3) minutes.

When analyzing RSET and ASET, occupant behavior (response to stimuli in emergency situations) is an important factor to consider. However, the field of human behavior in emergency situations is one lacking in research. While studies have been performed, the very nature of the subject is difficult to duplicate in a research setting. Statistics may be gathered during planned fire evacuation drills in various buildings and occupancies, but the duplication of an actual emergency is impractical. There simply is not sufficient evidence from which firm conclusions can be drawn regarding human behavior in a fire emergency. *"All researchers in the field of human behavior in fire are hesitant at suggesting numbers* [re: delay time to start] *because of the limited research findings in this area."*[35] However, some relevant data is available.

Research, while limited, has produced some nonmandatory guidelines in the field of human behavior. *"When groups of building occupants are considered, a range of common situations and developing scenarios can be identified."*[36] The scenarios identified generally group building occupants into categories based upon occupant alertness, familiarity with surroundings, occupant density, and enclosure complexity [SFPE HB Table 3-12.3]. Based upon these factors, the Facility would be most closely defined as Category A, which characterizes the occupant group as awake, familiar, low density, and one or many enclosures (i.e., enclosure complexity may vary).

The subject Facility houses a large industrial process of commodity process and handling. It is typical in these types of Facilities that the Tenant places a high value on the health and safety of their employees. Such is the case with the particular Tenant of this Facility. Immense training is undertaken by employees on a regular basis to prepare for potential emergency situations. The policies and procedures put in place by the Tenant are such that occupants are well aware of their surroundings and are trained on proper reactions/ responses to potential emergencies and stimuli that may be present. The occupancy does not contain sleeping/dwelling units, and all occupants are familiar with their surroundings, and the Facility as a whole. Therefore, it is reasonable to expect that occupants will react favorably and with appropriate timeliness to emergency stimuli – i.e., a significant delay would not be expected, but a nominal delay of 60 seconds could be employed reasonably. This length of time (i.e., 60 seconds) will serve as the perception/ interpretation/ action portion of the total delay time to start.

This period of a 60 second (1 minute) hesitation time added to the 169 seconds (2.8 minutes) from ignition to alarm encompasses the total time from ignition to the point of action for this performance-based design approach.

Again, this performance-based design approach is considering the topmost elevated level of a single mezzanine (eastern or western), and considers the evacuation time to have completed once all occupants have entered the provided 1-hour fire-resistance rated stair enclosures. The eastern and western elevated mezzanines are each provided with four (4) enclosed interior exit stairways, but this analysis assumes one (1) is not available – all 486 occupants must egress through three (3) of the four (4) stairways provided.

There are many egress calculation methodologies available, which vary in complexity and sophistication. The subject performance-based design utilizes hand calculations made available in numerous texts, codes, standards, etc., including the SFPE Handbook. In order to perform these calculations, certain parameters must be known, such as occupant density and types of egress components.

The occupant density of a single elevated mezzanine is approximately 0.002 persons/ft^2 (i.e., 486 people evenly distributed throughout the 243,055 ft^2 mezzanine). The egress components consist of level

[35] Proulx, Guylène, "Evacuation Time," *SFPE Handbook of Fire Protection Engineering*, 4th Edition, P.J. DiNenno ed., NFPA 2008, pg. 3-362.
[36] Ibid. pg. 3-363.

pathways, doors, and stairs. Since the analysis is concerned with the time it takes to get all 486 occupants into the fire-resistance rated stair enclosures, travel down the stairs will not be calculated.

The density noted previously results in a maximum speed (along the line of travel) of 235 ft/min [SFPE HB Figure 3-13.7; Table 3-13.4]. Therefore, a conservative value of 200 ft/min will be used in the egress calculations, which corresponds to a slightly higher density (i.e., more occupants in the same given area). The calculated occupant density results in a rather low specific flow through a doorway [Figure 3-13.8]; this is due to the low number of occupants passing through a doorway, and not due to queuing. The maximum specific flow through a doorway is indicated as 24.0 persons/min/ft of effective width of exit. This analysis will assume that, for simplicity and conservatism, 1) all 486 occupants will travel the maximum 400 ft exit access travel distance; and 2) after all occupants have traveled the maximum distance, all occupants will pass through the three (3) available exit stairway doors – i.e., the analysis will arbitrarily increase the occupant density at the available exit stairway doors, thus requiring queuing. This is considered as an added level of conservatism. It would normally be expected that the low density of occupants would be evenly distributed about the space, with each occupant passing through the doorway and into the stairway with little to no queuing. By assuming all occupants must traverse the maximum 400 ft exit access travel distance, the density at the three (3) available exits is arbitrarily and exponentially increased. Therefore, any specific flow less than the maximum should be considered reasonable and conservative for the subject scenario. A specific flow of 14 persons/min/ft of exit width will be used for the available exit doorways.

The total evacuation time from the topmost elevated mezzanine level, and in general, can be algebraically described as:

$$t_{Total} = t_{Delay} + t_{Travel} + t_{Queue}$$

First, as discussed above, the delay time to start is:

$$t_{Delay} = 3.8 \text{ min}$$

Next is the travel time:

$$t_{Travel} = \frac{400\ ft}{200\ ft/\text{min}} = 2 \text{ min}$$

Finally, the queuing time, as discussed above:

$$t_{Queue} = \frac{486\, persons}{14\, persons/\text{min}/ft} \times 2\, ft/exit \times 3\, exits = 5.8 \text{ min}$$

The total calculated egress time from the topmost elevated mezzanine level, plus the safety factor required by code is:

$$t_{Total} = (t_{Delay} + t_{Travel} + t_{Queue}) \times 1.5 = (3.8 \text{ min} + 2 \text{ min} + 7.8 \text{ min}) \times 1.5 = 17.4 \text{ min}$$

The performance-based design will be evaluated at 17.4 minutes (1,044 seconds), as well as 20 minutes (1,200 seconds), as discussed previously in this report.

10.7 Fire and Smoke Modeling

NFPA 92 governs the design and installation of smoke control systems in buildings, and allows for a few methods of analysis to be used for the design of a smoke management system. Those methods are algebraic equations [§5.1.1], scale modeling [§5.1.2], and compartment fire models [§5.1.3], the latter of which are required to be zone fire models or computational fluid dynamics ("CFD") models.

The subject performance-based design utilized the Fire Dynamics Simulator ("FDS"), which is a CFD model. In addition, a third-party graphical user interface – PyroSim®, developed by Thunderhead Engineering Consultants, Inc. – was used to assist in the creation of the FDS input file. The graphical model was converted from a 3D architectural drawing file provided by the project architect. Figure 21 below shows the overall model space, including mezzanine levels and simulated rack storage.

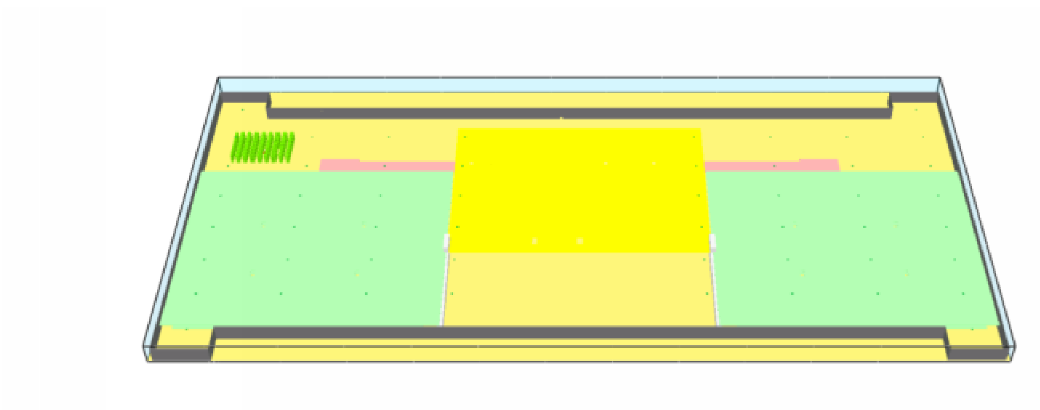

Figure 21: FDS Facility Model

The following parameters were used in the FDS model:

- Fuel: Polystyrene (PS) – C_8H_8
  - Soot Yield of 0.164 g soot/g PS;
  - CO Yield of 0.060 g CO/g PS;
  - Heat of Combustion of 39.85 kJ/g PS
- Mesh Size
  - Due to the large volume within the Facility, the overall model was provided with 2 ft (61 cm) cubic cells, while the area immediately around the fire was provided with 1 ft (30 cm) cubic cells.
- Exhaust Fans
  - Refer above to Figure 13;
  - Each fan was modeled as a 4 ft x 4 ft opening;
  - Fans were modeled to start operating 40 seconds after the DETACT calculated sprinkler activation time (i.e., 139 seconds), and with a 10-second ramp-up period.

- Makeup Air
  - Refer above to Figure 13;
  - Forty eight (48) openings each 8 ft x 8 ft were modeled to represent the total free air area of 3,072 ft^2;
  - The openings were activated simultaneously with exhaust fans.
- Burners
  - Modeled as eight (8) 4 ft x 4 ft (1.22 m x 1.22 m) surfaces of cubes representing palletized rack storage commodities;
  - Heat release rate per unit area (HRRPUA) specified to achieve the total stead-state phase of the design fire scenario, 9.9 MW; HRRPUA specified as 832.

The following are images taken from Smokeview and are representative of Scenario #1 showing CO concentrations and temperature at 1,200 seconds (20 minutes), which was the run length of the model. Slice files are also provided for visibility at 1,040 and 1,200 seconds. Due to the mesh size throughout most of the model, the Smokeview images are provided at 28 ft AFF. The critical height for the performance-based design was set at 27 ft; however, if tenable conditions are maintained at 28 ft then those same conditions, if not slightly better, can be assumed to be present at 27 ft AFF. Refer to the following pages for Figures 22-25.

Figure 22: Scenario #1 – CO Concentration at 28 ft after 1,200 seconds

Figure 23: Scenario #1 – Temperature at 28 ft after 1,200 seconds

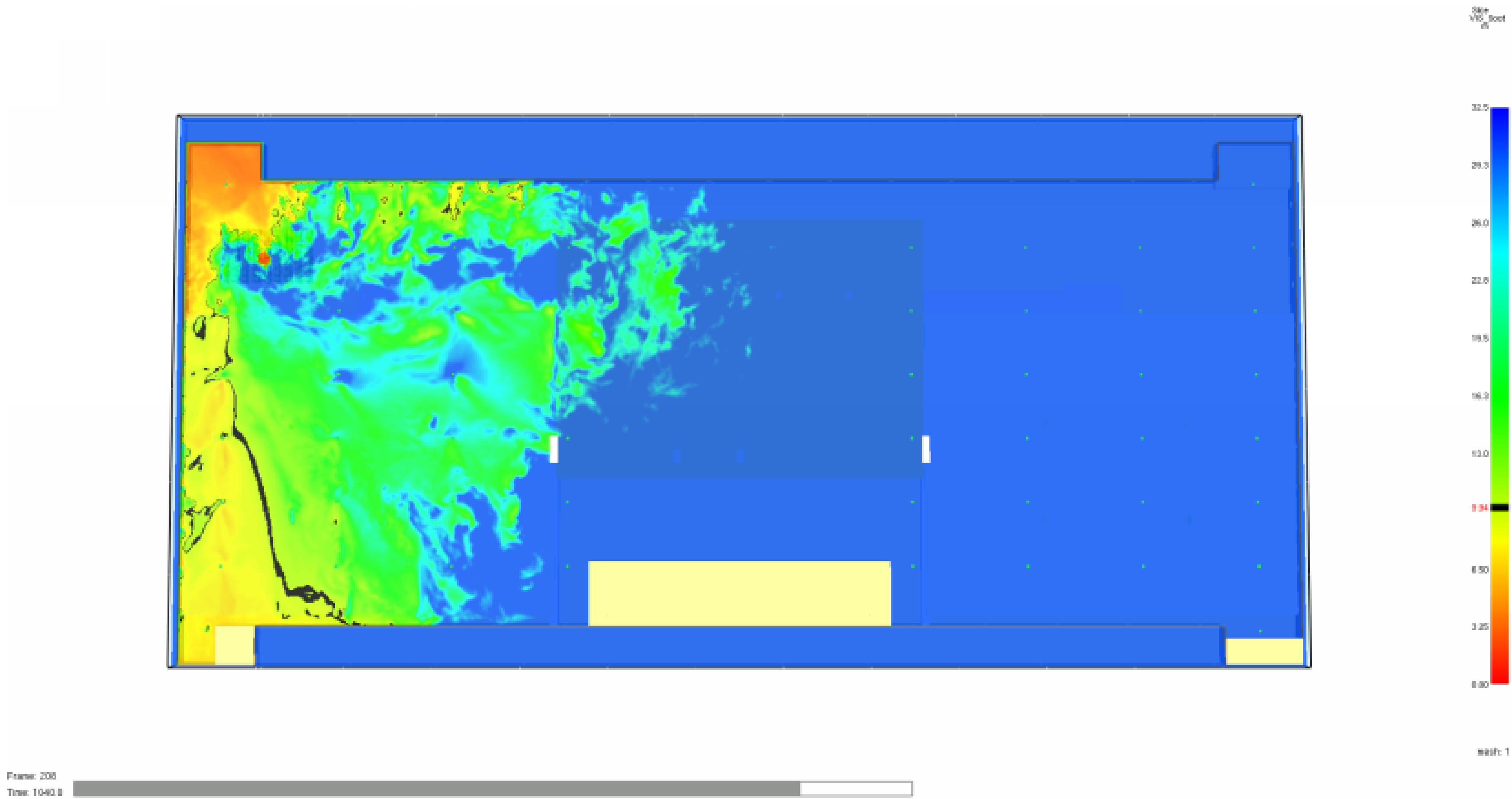

Figure 24: Scenario #1 – Visibility at 28 ft after 1,040 seconds

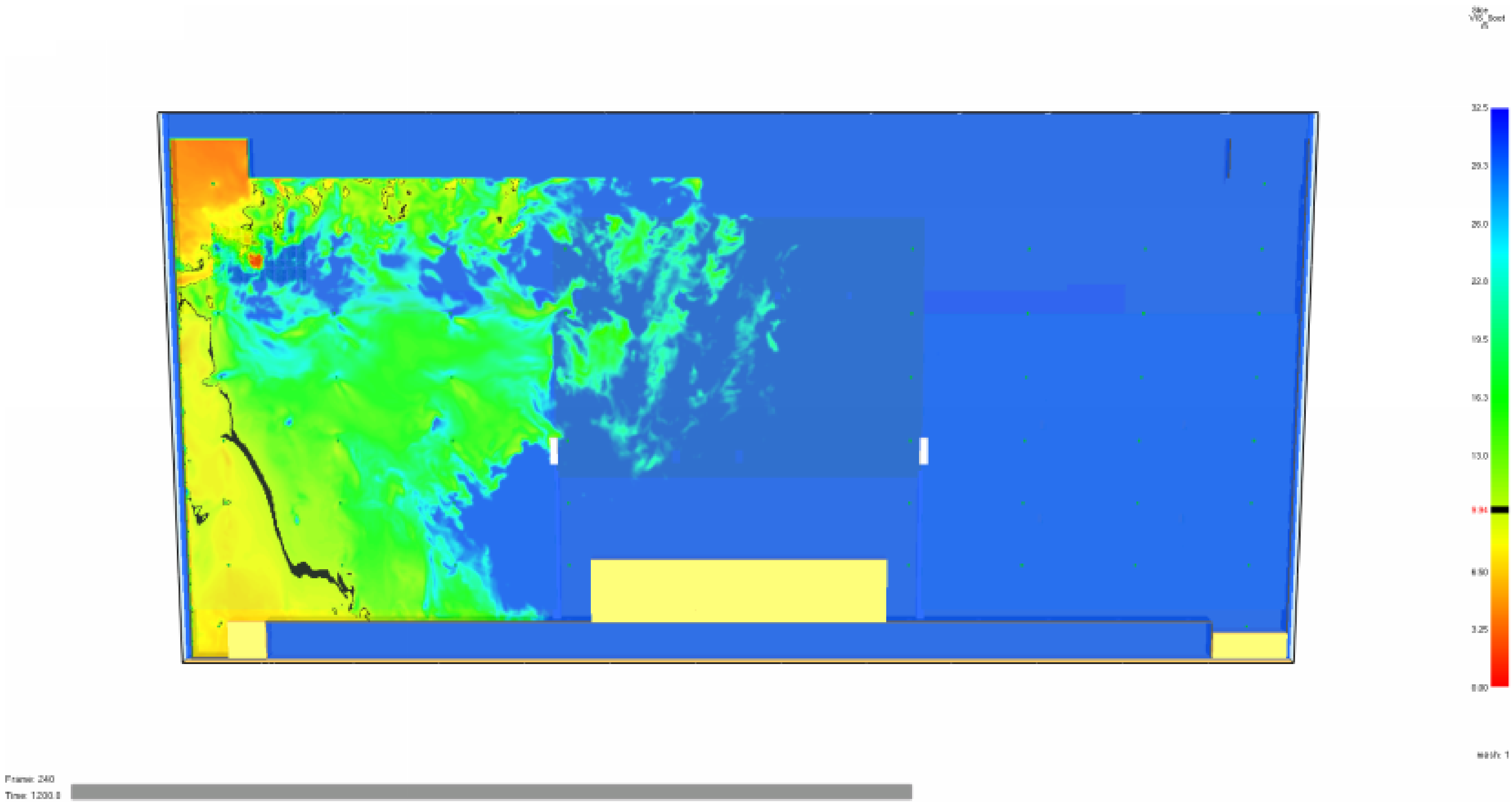

Figure 25: Scenario #1 – Visibility at 28 ft after 1,200 seconds

Based on the fire and smoke modeling, toxicity (due to CO) and temperature are not factors. This can mostly be attributed to the massive volume of space the Facility encompasses. As expected, visibility proves to be the most significant factor.

Figures 24 and 25 both show the visibility at 28 ft AFF, which is 7 ft above the topmost elevated mezzanine level. While both show that visibility has dropped below the threshold of 33 ft (10 m), it is not a significant drop. Visibility remains within the range of about 16 ft (5 m) or greater throughout the duration of the model and necessary egress time. Given that these occupants are well-trained and are aware of their surroundings, some research suggests that visibility of as little as 13 ft (4 m) is sufficient. Moreover, since the other tenability criteria are not factors, this should not be deemed as a failure. Another point towards this end is the method used for the egress calculations – it was assumed that all 486 occupants on the topmost level would need to traverse the maximum exit access travel distance of 400 ft, and given the moderate speed of travel, were calculated to arrive at three (3) of the available four (4) exit stairways in two (2) minutes. Figure 26 shows the provided enclosed interior exit stairways.

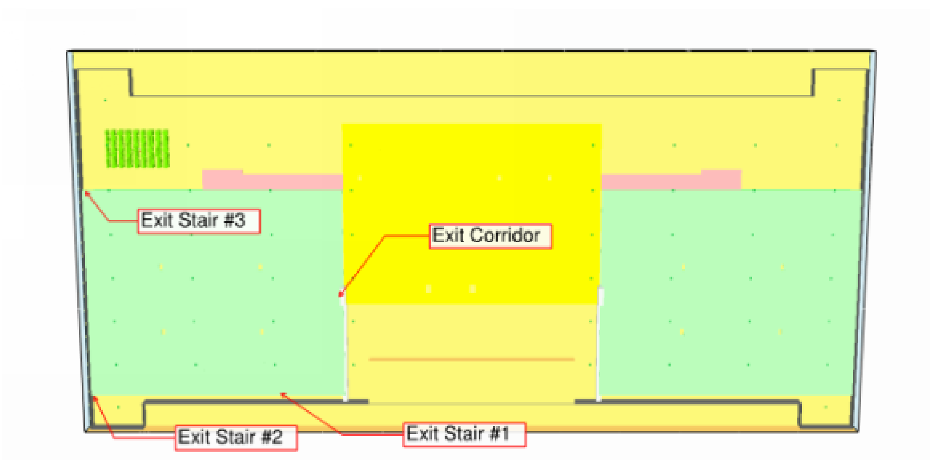

Figure 26: Exit Stairways Provided to the Eastern Mezzanine[37]

Even if Exit Stair #3 were considered to be untenable, the egress calculations accounted for such an occurrence. Thus, given the fire protection systems, the Facility configuration, and the conservative assumptions included within the performance-based design, the amount of smoke exhaust provided should be expected to maintain tenable conditions for the duration of the calculated egress time (i.e., 17.4 minutes or 1,044 seconds) as well as the minimum 20 minute (1,200 second) system operation requirement.

11.0 CONCLUSION

The basic and broad intent of the code, as identified in both documents in Section 101.3, is to keep people safe from fire and other potential hazards. The codes (IBC, IFC, and the like) have evolved over time due to the increase in research, advances in technology, and, unfortunately, tragedies that have provided lessons learned. These codes provide guidelines for many building scenarios; however, they do not and cannot anticipate all possible building configurations and/or scenarios. With the advances in

[37] Exit Corridor identified as such due to that stairway discharging into an exit passageway, which provided exit access to the exterior through fire-resistance rated construction.

the areas of science associated with the architectural and engineering disciplines necessary for modern building design and construction, the code allows for performance-based designs – those that, while not meeting the strict provisions of the code, do meet their intent.

The subject Facility is a prime example of a building configuration that is not strictly anticipated by the code. Therefore, its design and construction is a hybrid between the prescriptive requirements of the code in some areas, and meeting the intent of the code through performance-based design in those areas where the Facility is not in strict compliance with certain code provisions.

The Facility complies with most provisions of the code; however, where the desired building configuration does not comply with certain provisions, it has been shown through acceptable means that the level of protection afforded to building occupants is not diminished from that which is prescribed by and is the intent of the governing building and fire codes. The performance-based approach, allowed by the code sections noted previously in this report, has been used to demonstrate the effectiveness of the building configuration and systems therein of maintaining at least the minimum level of quality and safety prescribed by the code.

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NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2013 Edition; National Fire Protection Association, One Batterymarch Park, Quincy, MA.

NFPA 101, *Life Safety Code,* 2012 Edition; National Fire Protection Association, One Batterymarch Park, Quincy, MA.

NFPA 204, *Standard for Smoke and Heat Venting,* 2012 Edition; National Fire Protection Association, One Batterymarch Park, Quincy, MA.

Appendix A
Floor Plans and Associated Occupancy Classifications

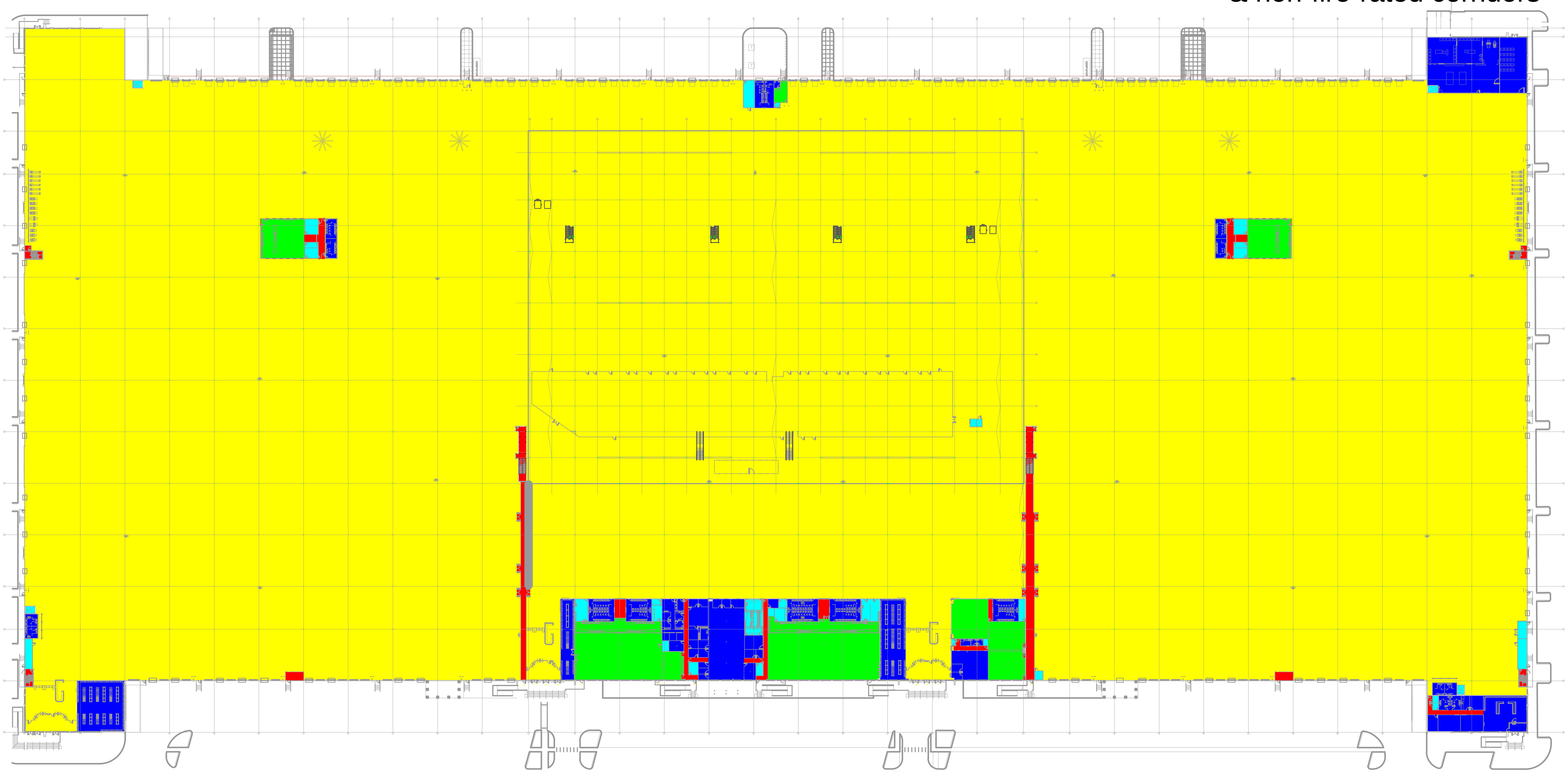
Group S-1 Occupancy

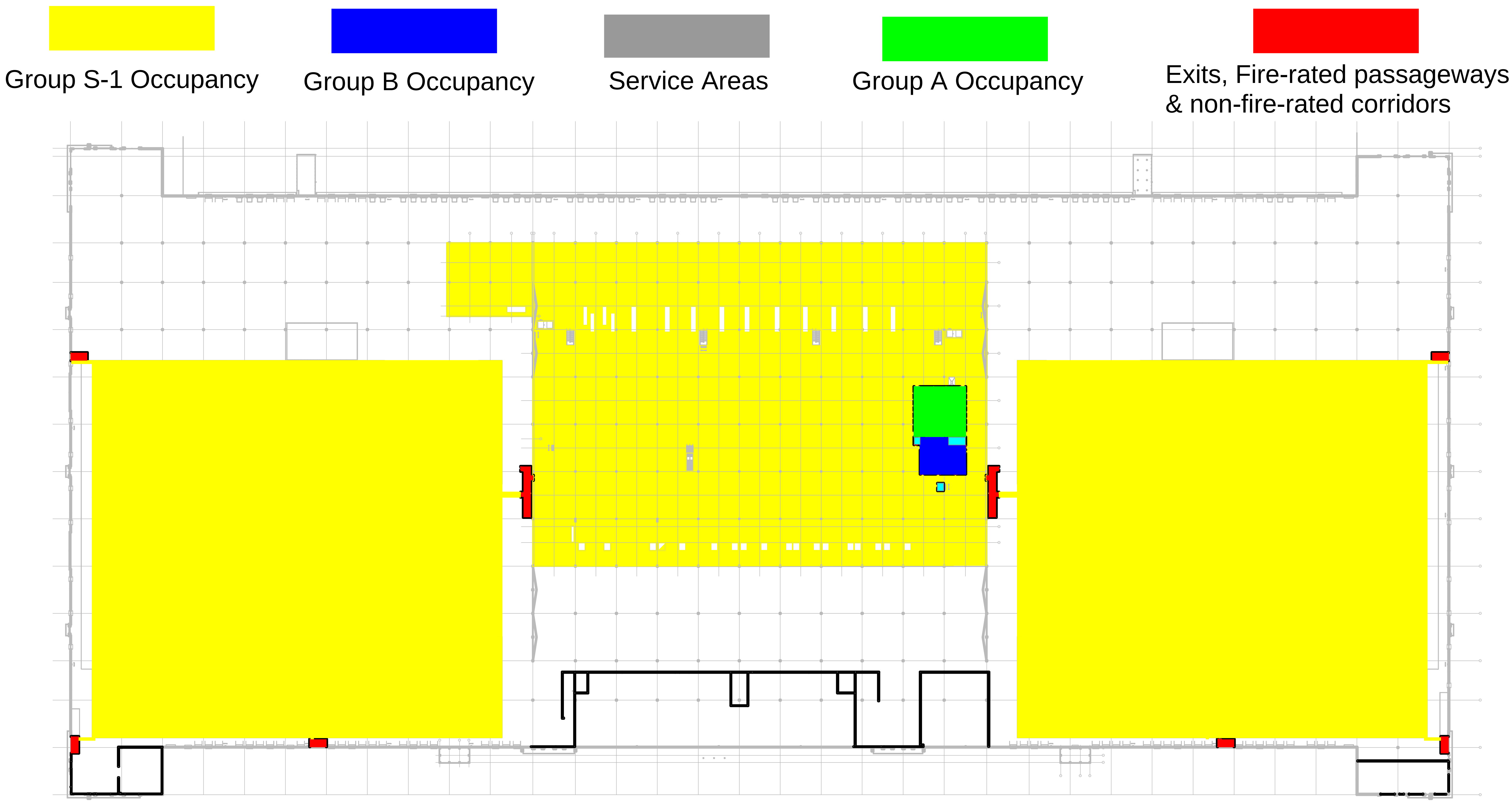
Group B Occupancy

Service Areas

Group A Occupancy

Exits, Fire-rated passageways, & non-fire-rated corridors




Group S-1 Occupancy
Group B Occupancy
Service Areas
Group A Occupancy
Exits, Fire-rated passageways, & non-fire-rated corridors

Appendix B
Silent Knight Fire Alarm Product Data

Farenhyt

SILENT KNIGHT
by Honeywell

Addressable Fire Control Panel

Analog/Addressable Fire Alarm Control System

IFP-1000/IFP-1000HV

The IFP-1000 and IFP-1000HV are intelligent analog/addressable fire alarm control panels (FACPs). The basic IFP-1000 system has one signal line circuit (SLC) loop that supports up to seven 5815XL signal line circuit expanders.The IFP-1000HV offers the same functionality and features as the IFP-1000 but is configured for 240 VAC operation.

IFP-1000/HV has six on-board Flexput™ circuits that can be configured for auxiliary power, notification outputs, or for conventional smoke detector inputs (Class A or Class B). The FACP also has a built-in, dual-line digital fire communicator, Form C trouble relay, and two programmable Form C relays. The firmware has powerful features such as detector sensitivity, day/night thresholds, drift compensation, pre-trouble maintenance alert, and calibration trouble alert.

IFP-1000/HV supports a variety of devices, including RA-1000 remote annunciator, 5824 serial/parallel printer interface module (for printing system reports), RPS-1000 intelligent power module, and Hochiki or Intelligent Device Protocol (IDP) devices.

Agency Listings

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IFP-1000

Features

- Built-in support for up to 127 Hochiki devices or 99 IDP detectors and 99 IDP modules, expandable to 1016 Hochiki devices or 792 IDP detectors and 792 IDP modules
- Uses standard wire—no shielded or twisted pair required
- Built-in UL listed digital communicator for remote reporting of system activity and system programming
- Central station reporting by point or by zone
- Supports Class B (Style 4) and Class A (Style 6 or Style 7) configuration for SLC, and SBUS
- Distributed, intelligent power
- Sensor sensitivity settings, day/night sensitivity setting and automatic drift compensation
- Flexput™ I/O circuits configurable for auxiliary power, notification outputs, or conventional smoke detector inputs. Notification circuits can be configured as Class A (Style Z) or Class B (Style Y). 2- and 4-wire smoke detectors can be configured as Class A (Style D) or Class B (Style B)
- Built-in annunciator with a backlit 80-character LCD display
- RS-485 bus provides communication to system accessories
- Built-in RS-232 and USB interface for programming
- Upload or download programming, event history, or detector status onsite or from a remote location using a PC and 5650/5651 Silent Knight Software Suite (SKSS)
- Improvements in SKSS delivers five times faster upload/downloads
- Built-in Form C trouble relay rated at 2.5 amps at 27.4 VDC
- Two built-in Form C programmable relays rated at 2.5 amps at 27.4 VDC
- Individual addressable devices can be tested
- SLC device locator can locate a single or multiple devices on a SLC loop
- System automatically tests addressable devices
- 13 preset notification cadence patterns (including ANSI 3.41) and four user programmable patterns
- Programmable to automatically display initial event first or display tally of system events
- Built-in synchronization for appliances from AMSECO, System Sensor®, Faraday, Gentex®, and Wheelock®
- Acknowledge function allows operator to keep track of event status
- Jumpstart® auto-programming
- Modular design
- Nonvolatile event history stores up to 1000 events
- 125 software zones and 250 output groups
- 6 amp power supply and maximum charging capacity of 35 amp hours (An additional cabinet enclosure is required for batteries in excess of 18 amp hours)
- Programmable date setting for Daylight Saving Time
- Plex-1 door option combines a dead front cabinet door with a clear window, limiting access to the panel while providing single button operation of the reset and silence functions

P/N 350093 Rev L

Installation

The IFP-1000/HV can be surface or flush mounted.

Compatibility

The IFP-1000/HV SLC supports multiple device types of the *same* protocol:

- IDP or Hochiki

You cannot mix Hochiki and IDP devices on a FACP. However, any combination of addressable devices of the same protocol can be used on the IFP-1000/HV.

Specifications

Physical

Flush Mount Dimensions: 14.5"W x 24.75"H x 3.9"D (36.8 W x 62.9 H x 9.8 D cm)

Overall Dimensions: 16.2"W x 26.4"H x 4.2"D (40.6 W x 67 H x 11.8 D cm)

Weight: 28 lbs. (12.8 kg)

Color: Red

Environmental

Operating Temperature: 32ºF – 120ºF (0ºC – 49ºC)

Humidity: 10% – 93% non-condensing

Electrical

IFP-1000 Primary AC: 120 VRMS @ 50/60 Hz, 2.7A
IFP-1000HV Primary AC: 240 VRMS @ 50/60 Hz, 1.4A

Total Accessory Load: 6A @ 27.4 VDC power-limited

Standby Current: 215 mA

Alarm Current: 385 mA

Battery Charging Capacity: 7 to 35 AH

Battery Size: 18 AH max. allowed in control panel cabinet. Larger capacity batteries can be housed in RBB accessory cabinet.

Flexput Circuits

Six circuits that can be programmed individually as:
Notification Circuits: 3A per circuit @ 27.4 VDC, power-limited
Auxiliary Power Circuits: 3A per circuit @ 27.4 VDC, power-limited
Initiation Circuit: 100 mA per circuit @ 27.4 VDC, power-limited

Indicator Lights

General Alarm (Red): Flashes when in alarm; solid when alarm silenced

Supervisory (Yellow): Flashes when a supervisory condition exists; solid when supervisory silenced

System Troubles (Yellow): Flashes when a trouble condition exists; solid when trouble silenced

System Silenced (Yellow): On when an alarm, trouble or supervisory condition has been silenced but not yet cleared

System Power (Green): Flashes for AC failure; solid when power systems are normal

Telephone

Requirements: FCC Part 15 & Part 68 approved

Jack: RJ31X (two required)

Approvals

NFPA 13, NFPA 15, NFPA 16, NFPA 70, &
NFPA 72: Central Station; Remote Signalling; Local Protective Signalling Systems; Auxiliary Protected Premises Unit; & Water Deluge Releasing Service. Suitable for automatic, manual, waterflow, sprinkler supervisory (DACT non-coded) signalling services.

Other Approvals: UL Listed; CSFM 7170-0559: 135; MEA 429-92-E Vol. IX; FM Approved; OSHPD (CA) OSP-0065-10

Approved Releasing Solenoids

Manufacturer	Part Number	Rating	Current	Freq
Asco	T8210A107	24 VDC	3 A max	0 Hz
Asco	8210G207	24 VDC	3 A max	0 Hz

Ordering Information

IFP-1000	Intelligent Fire Alarm Control Panel.
IFP-1000HV	Intelligent Fire Alarm Control Panel. High voltage (240 VAC).

SBUS Accessories

RA-100	Remote Annunciator. Similar in operation and appearance to FACP annunciator. Gray.
RA-100R	Remote Annunciator. Similar in appearance and operation to FACP annunciator. Red.
RA-1000	Remote Annunciator. Four line LCD annunciator with 20 characters per line.
5815XL	Signal Line Circuit (SLC) Expander.
RPS-1000	Intelligent Power Module.
5496	Intelligent Power Module.
5824	Serial/Parallel Printer Interface Module.
5880	LED I/O Module.
5865-3 & 5865-4	LED Fire Annunciators.
5883	Relay Interface Board.

Hochiki and IDP Devices

See the specification sheets listed below for a complete listing of the Hochiki and IDP devices.

350360	Hochiki Devices Specification Sheet
350361	Intelligent Device Protocol Devices Specification Sheet

Miscellaneous Accessories

5650/5651	Silent Knight Software Suite. Provides programming, upload/download, and event reporting.
5670	Silent Knight Software Suite. Provides facility monitoring.
Plex-1	Door Accessory. Dead front cabinet door with clear window to limit access to panel.
RBB	Remote Battery Box Accessory Cabinet. Use if backup batteries are too large to fit into FACP cabinet. Dimensions: 16" W x 10" H x 6" D (406 mm W x 254 mm H x 152 mm D).
SK-SCK	Seismic Compliance Kit

Farenhyt

SILENT KNIGHT
by Honeywell

6 Amp Intelligent Distributed Power Module

RPS-1000

RPS-1000 intelligent distributed power module adds 6.0 amps of power, six Flexput™ I/O circuits, and two Form C relay circuits to a compatible Farenhyt addressable system. RPS-1000 connects to the FACP via the RS-485 system bus allowing up to an additional 6,000 feet of wiring. Each RPS-1000 is optically isolated providing ground loop isolation and transient protection. RPS-1000 supports its own backup battery and monitors the AC power. The Flexput circuits can be programmed as notification appliance circuits, continuous, resettable, or door holder power, or as conventional initiation circuits for 2 or 4-wire smoke detectors and contact devices (e.g. pull stations).

Features

- Six onboard Flexput circuits programmable for:
  - Notification appliance circuits (Class B/Style Y & Class A/Style Z)
  - Conventional initiation circuits (Class B/Style B & Class A/Style D) both 2- and 4-wire
  - Auxiliary power (for door holders, continuous power, or resettable power)
- 6.0 amps output power
- Supports Class A (Style 6) and Class B (Style 4) configuration of the SBUS
- Two Form C programmable relays rated at 2.5A @ 24 VDC
- Ground loop isolation and transient protection
- Provides SBUS optical isolation and re-conditions the RS-485 signal
- Built-in synchronization for appliances from System Sensor®, AMSECO, Gentex®, Faraday, and Wheelock®
- Up to 6,000 foot wiring distance from the RPS-1000
- Battery charging capacity is 35 Ah
- Large cabinet size can house two 18 Ah backup batteries or RBB accessory cabinet can house battery sizes larger that 18 Ah
- Room to mount two 5815XL SLC expander modules

Agency Listings

MEA approved
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RPS-1000

Compatibility

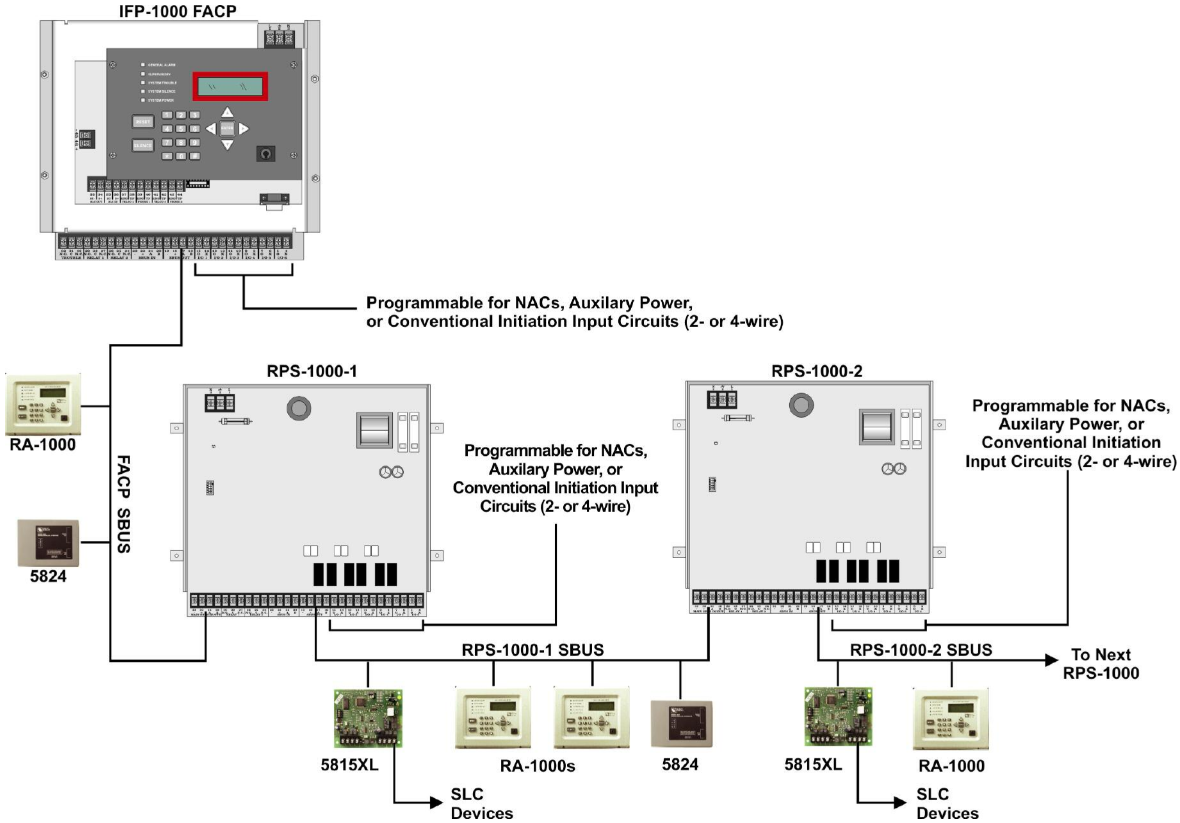
RPS-1000 is compatible with the following FACPs:

- IFP-2000/RPS-2000 (63 max per panel)
- IFP-2000ECS (63 max per panel)
- IFP-1000 (8 max per panel)
- IFP-1000ECS (8 max per panel)
- IFP-100 (8 max per panel)
- IFP-100ECS (8 max per panel)
- IFP-50 (8 max per panel)

Installation

RPS-1000 can be surface or flush mounted.

P/N 350070 Rev J



Specifications

Electrical

Primary AC:
120 VRMS, 50 or 60 Hz, 2.7A, or
240 VRMS 50 or 60 Hz, 1.4A

Total Accessory Load: 6A @ 24 VDC

Standby & Alarm Current: 10 mA

Flexput Circuits:
Notification: 3 amps per circuit (6A system total)
Initiation: 100 mA power limited @ 24 VDC

Physical

Mounting Dimensions:
14.5"W x 24.75"H x 3.9"D
(36.8 cm W x 62.9 cm H x 9.8 cm D)

Overall Dimensions:
16.1"W x 26.4"H x 4.1"D
(40.6 cm W x 67 cm H x 11.8 cm D)

Color: Red

Environmental

Operating Temperature: 32ºF – 120ºF (0ºC – 49ºC)

Humidity: 10% – 93% non-condensing

Approvals

- UL 864
- NFPA 13, NFPA 15, NFPA 16, NFPA 70, NFPA 72, & NFPA 101
- CSFM
- MEA 429-92-E Vol. IX
- FM
- OSHPD (CA) OSP-0065-10

Ordering Information

RPS-1000	Intelligent Distributed Power Module. Specify 120 VAC or 240 VAC operation when ordering.

Accessories

RBB	Remote Battery Box Accessory Cabinet. 16" W x 10" H x 6" D (406 mm W x 254 mm H x 152 mm D)
AB-55	Remote Battery Box Accessory Cabinet. 20"W x 12" H x 7.5" D
5815XL	SLC Expander Module
SK-SCK	Seismic Compliance Kit

SILENT KNIGHT®
by Honeywell

12 Clintonville Road, Northford, CT 06472-1610 Phone: (800) 328-0103,
Fax: (203) 484-7118. For Technical Support, Please call 800-446-6444.
www.farenhyt.com

Assembled in the U.S.A

SILENT KNIGHT®
by Honeywell

5499 Distributed Power Module

The NAC expander that packs quite a combination punch, a whopping nine amps and built-in synchronization for appliances

The 5499 Distributed Power Module by Silent Knight is the most-powerful and cost-effective power supply available today. It delivers 9 amps of notification appliance circuit power and built-in synchronization for appliances from System Sensor®, AMSECO, Faraday, Gentex®, and Wheelock® — what you need to drive power-hungry components like ADA notification appliances. The 5499's advanced microprocessor design is years ahead of the competition. Its switch mode power supply design is up to 50% more efficient than competitive linear mode power supplies. And, ADA retrofits are easier and less expensive with the 5499 because it integrates into current systems without the costly investment in new components.

For the most sophisticated and cost-effective notification power supply available, you need the 5499. Call Silent Knight today for more information at 1-800-328-0103.

Description

The 5499 is a 9 amp notification power expander that provides its own AC power connection, battery charging circuit, and backup battery for use with fire and security controls that have 9-32 VDC outputs, such as the Silent Knight Model 5208 Fire Control/Communicator. The 5499 is the cost-effective solution for powering notification appliances required by the Americans with Disabilities Act (ADA). The 5499 has built-in ANSI cadence pattern, which can upgrade older control panels that lack cadence capability.

Features

- UL Listed for 9 amps of notification power
- Built-in synchronization for appliances from System Sensor®, AMSECO, Faraday, Gentex®, and Wheelock®
- Power supply's advanced switch mode design reduces damaging heat and manages power up to 50% more efficiently than other systems
- Dip switches allow for easy reconfiguration
- 24 VDC filtered output voltage
- Four power-limited notification outputs; 2 Class A (Style Z) or 4 Class B (Style Y), or 1 Class A and 2 Class B
- Additional continuous auxiliary output
- 3 amps per output circuit
- 2 inputs; 2 Class B (Style B) or 2 Class A (Style D)
- Ground fault detector/indicator
- Independent trouble relay
- AC loss delay option shuts off power to non-essential high-current accessories like magnetic door holders
- Stand alone operation.
- Lightweight design adds to ease of installation and reduces shipping costs
- Operates with most polarized, UL Listed notification devices
- ANSI Cadence pattern output capability built-in

Connection to Local Fire Control

Firepower 5499 may be connected to a local fire control which utilizes Class A or Class B type notification circuits operating between 9 and 32 VDC. The control panel's notification circuit is connected to one of the inputs on the 5499. The control panel's notification circuit end-of-line resistor is also connected across two terminals on the Firepower 5499, which provides supervision between the 5499 and the fire control panel. Polarized audible and/or visual notification devices are then connected to the 5499 signal circuits using the 4.7kW end-of-line resistors provided. Since the 5499 draws very little power from the control, it is possible to connect one Firepower 5499 to each notification circuit on the control panel and still provide full supervision of the notification circuits all the way back to the control panel.

5499

Supervision

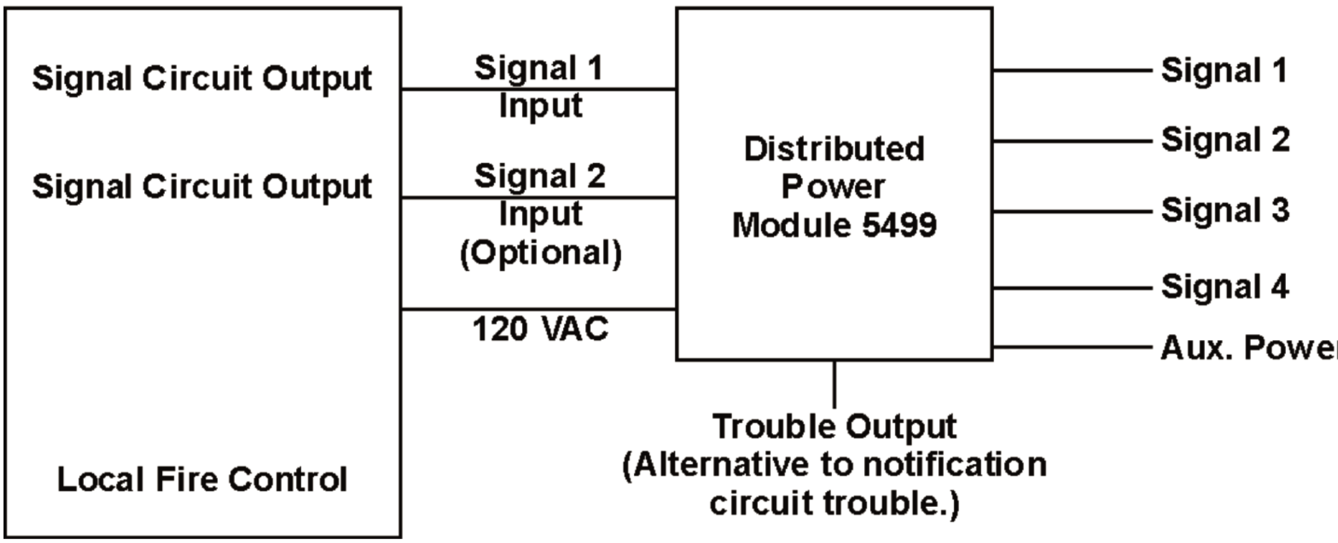
The 5499 supervises a variety of functions including:

- Low AC power.
- Low battery condition.
- Earth ground fault.
- Auxiliary output power limit condition.
- EOL supervision trouble or power limited condition at an output.

When a trouble condition occurs, Firepower 5499 creates a trouble condition on the host control signal circuits to which it is connected. Firepower 5499 still maintains the ability to be activated by the host control. In addition, the 5499 provides a Form C trouble relay output as an alternative to using the notification circuit trouble.

Model 5499
Distributed Power Module

Model 5499 Block Diagram



Electrical Specifications

AC Input: 120 VAC at 3.0A

Output: 24 VDC at 9 A

Current
  Standby: 75 mA
  Alarm: 205 mA

Auxiliary Power Circuit: 1

Notification Circuits: 4

Output Configuration:
  2 Class A (Style Z)
  4 Class B (Style Y)
  (1 Class A & 2 Class B)

Amps Per Output: 3.0 (9.0 amps total)

Notification Circuit Output: 20.4 to 27.3 VDC @ 3.0 amps each, 4.7 kΩ EOL resistor required on each Class B circuit

No. of Inputs: 2

Input Configuration: 2 Class B (Style Y) or 2 Class A (Style Z)

Input Voltage Range: 9 - 32 VDC

Battery charging Capacity: 35.0 AH

Mechanical Specifications

Dimensions: 12.25” W x 16” H x 3” D
30.88 cm W x 40.64 cm H x 7.62 D cm

Operating Temp:
  32° to 120° F (0° to 49° C)

Humidity: 93% non-condensing max.

Indicator Lights

AC power on :	Green
Battery trouble:	Yellow
Ground fault:	Yellow
Aux Trouble:	Yellow
Output troubles (1-4):	Yellow

Installation

Surface mount

Approvals

- NFPA 72
- UL Listed
- CSFM 7300-0559: 123
- MEA 429-92-E Vol. XII
- OSHPD (CA) OSP-0065-10
  (see accessories)

Ordering Information

5499 Distributed Power Module

Accessories:

SK-SCK Seismic Compliance Kit

SILENT KNIGHT
by Honeywell

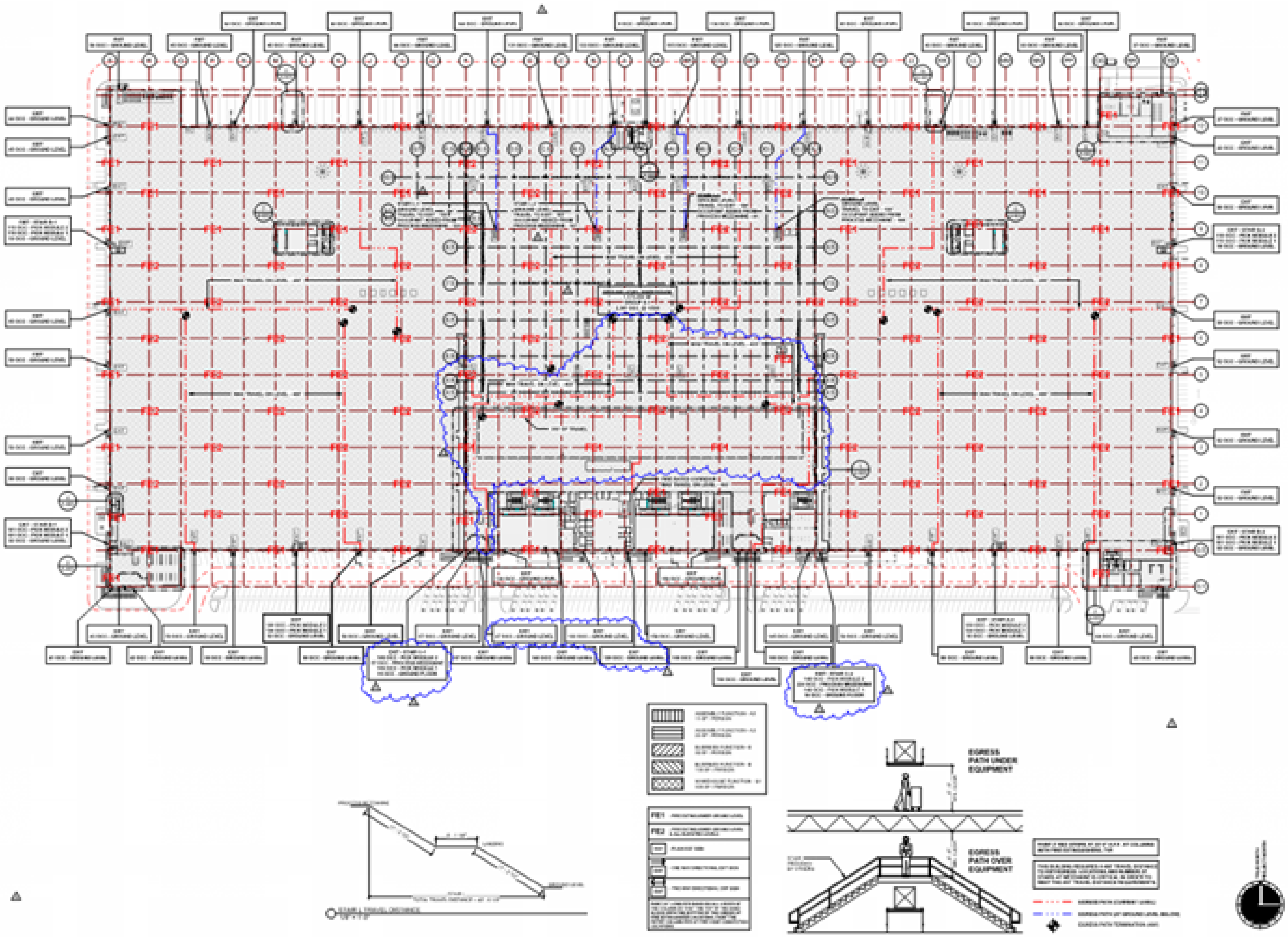
 For more information, contact Silent Knight 7550 Meridian Circle Suite 100, Maple Grove, Mn 55369-4927. Phone: (800) 328-0103 or (203) 484-7161, Fax: (203) 484-7118. For Techinical Support, Please call 800-446-6444. **www.silentknight.com**

MADE IN AMERICA

FORM# 350396 Rev F

Appendix C

Ground Level Architectural Life Safety Plan



1 OCCUPANT FUNCTION GROUND LEVEL

Appendix D
DETACT Calculations for Considered Fire Scenarios

DETACT.XLS: Estimate of the response time of ceiling mounted fire detectors

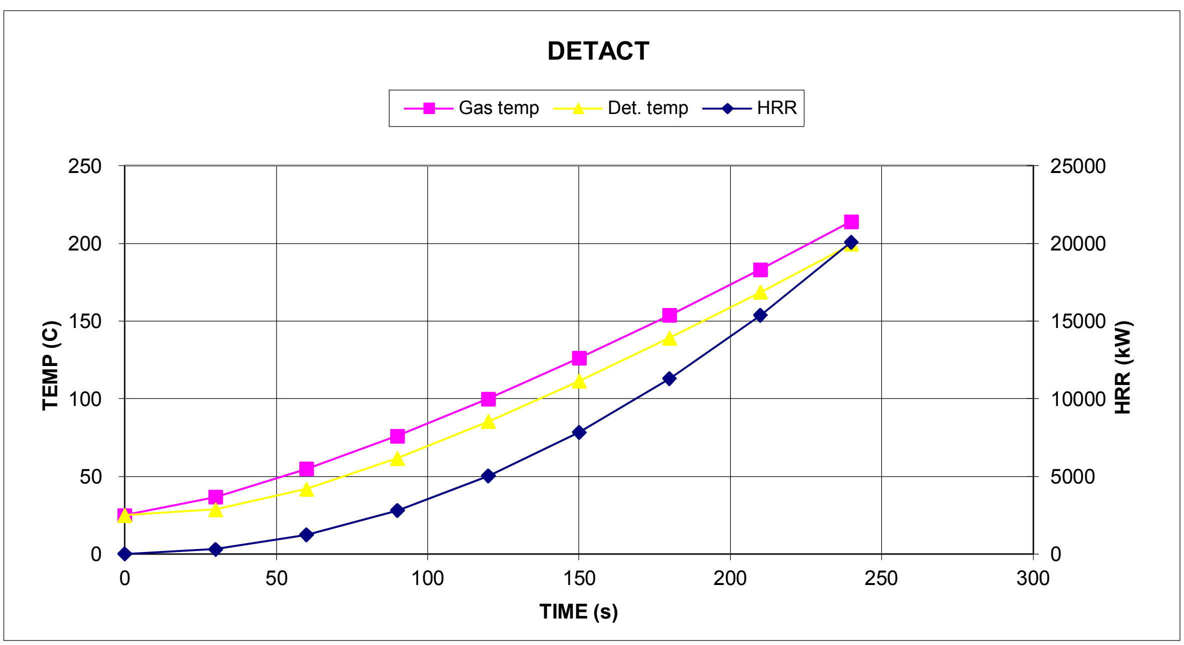
INPUT PARAMETERS			CALCULATED PARAMETERS		
Calculation reset	1	0 or 1	R/H	0.178	-
Ceiling height (H)	12.36	m	W/H	17.267	-
Room width (W)	213.36	m	Temperature factor	1	-
Radial distance (R)	2.20	m	Velocity factor	0.95	-
Ambient temperature (To)	25	C	Calculation time (t)	301	s
Actuation temperature (Ta)	101.11	C	Fire HRR (Q)	31620	kW
Rate of rise rating (ROR)	8.3	C/min	Gas temperature (Tg)	280.87	C
Response time index (RTI)	50	(m-s)1/2	Gas velocity (Ug)	12.994	m/s
Fire growth power (n)	2	-	ROR at detector	68.045	C/min
Fire growth coefficient (k)	0.349	kW/s^n	Detector temp (Td)	266.27	C
Fire location factor (kLF)	1	-	Detection trigger	163	284

Representative t2 coeff.	k
Slow	0.003
Medium	0.012
Fast	0.047
Ultrafast	0.188

CALCULATION RESULTS	FT	ROR	
Transport lag time (tl)	8	8	s
Detection time (td)	139	18	s
HRR at detection (Qd)	6743	113	kW
HRR w/transport lag (Ql+d)	7590	244	kW

< Press PgDn key for additional results >

Calculation time (s)	HRR	Gas temp	Det. temp
0	0	25	25
30	314	37	29
60	1256	55	42
90	2827	76	62
120	5026	100	85
150	7853	126	111
180	11308	154	139
210	15391	183	169
240	20102	214	200



DETACT.XLS: Estimate of the response time of ceiling mounted fire detectors

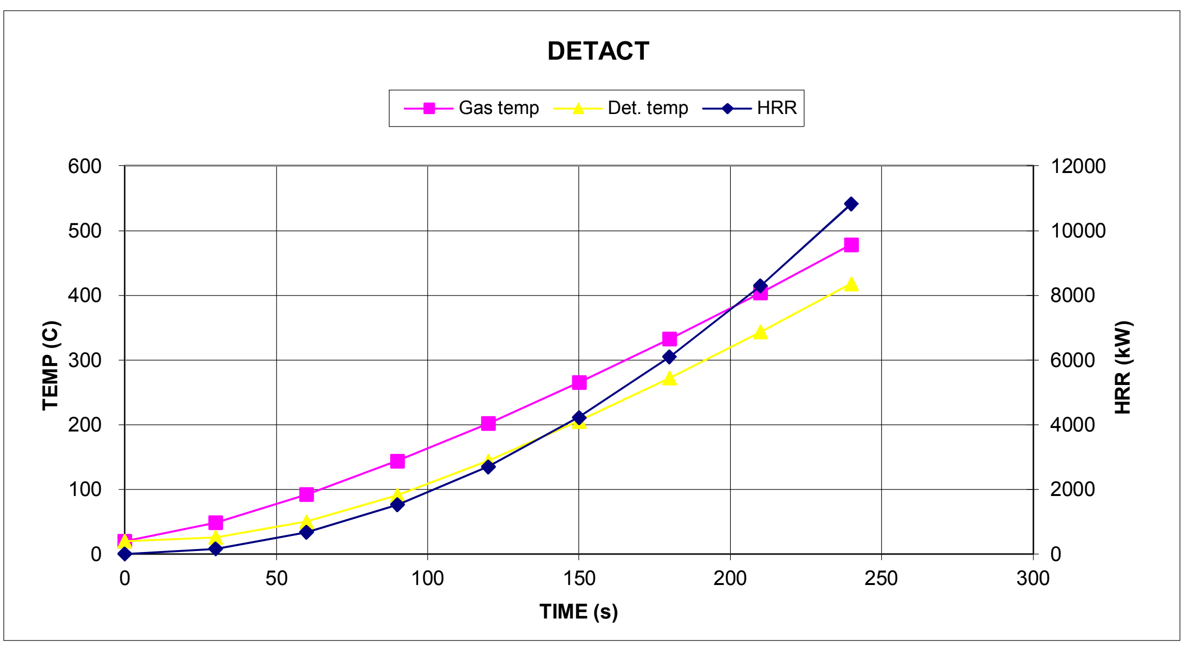
INPUT PARAMETERS			CALCULATED PARAMETERS		
Calculation reset	1	0 or 1	R/H	0.687	-
Ceiling height (H)	3.20	m	W/H	66.667	-
Room width (W)	213.36	m	Temperature factor	0.3853	-
Radial distance (R)	2.20	m	Velocity factor	0.2735	-
Ambient temperature (To)	20	C	Calculation time (t)	301	s
Actuation temperature (Ta)	76	C	Fire HRR (Q)	17033	kW
Rate of rise rating (ROR)	8.3	C/min	Gas temperature (Tg)	640.24	C
Response time index (RTI)	50	(m-s)1/2	Gas velocity (Ug)	4.7745	m/s
Fire growth power (n)	2	-	ROR at detector	164.94	C/min
Fire growth coefficient (k)	0.188	kW/s^n	Detector temp (Td)	580.08	C
Fire location factor (kLF)	1	-	Detection trigger	221	288

Representative t2 coeff.	k
Slow	0.003
Medium	0.012
Fast	0.047
Ultrafast	0.188

CALCULATION RESULTS	FT	ROR	
Transport lag time (tl)	8	8	s
Detection time (td)	81	14	s
HRR at detection (Qd)	1233	37	kW
HRR w/transport lag (Ql+d)	1503	94	kW

< Press PgDn key for additional results >

Calculation time (s)	HRR	Gas temp	Det. temp
0	0	20	20
30	169	49	26
60	677	92	50
90	1523	144	91
120	2707	202	144
150	4230	265	205
180	6091	332	272
210	8291	404	343
240	10829	479	418



DETACT.XLS: Estimate of the response time of ceiling mounted fire detectors

INPUT PARAMETERS			CALCULATED PARAMETERS		
Calculation reset	1	0 or 1	R/H	0.401	-
Ceiling height (H)	5.49	m	W/H	38.889	-
Room width (W)	213.36	m	Temperature factor	0.5521	-
Radial distance (R)	2.20	m	Velocity factor	0.4287	-
Ambient temperature (To)	20	C	Calculation time (t)	301	s
Actuation temperature (Ta)	76	C	Fire HRR (Q)	17033	kW
Rate of rise rating (ROR)	8.3	C/min	Gas temperature (Tg)	381.94	C
Response time index (RTI)	50	(m-s)1/2	Gas velocity (Ug)	6.2545	m/s
Fire growth power (n)	2	-	ROR at detector	96.254	C/min
Fire growth coefficient (k)	0.188	kW/s^n	Detector temp (Td)	351.47	C
Fire location factor (kLF)	1	-	Detection trigger	200	284

Representative t2 coeff.	k
Slow	0.003
Medium	0.012
Fast	0.047
Ultrafast	0.188

CALCULATION RESULTS	FT	ROR	
Transport lag time (tl)	8	8	s
Detection time (td)	102	18	s
HRR at detection (Qd)	1956	61	kW
HRR w/transport lag (Ql+d)	2295	132	kW

< Press PgDn key for additional results >

Calculation time (s)	HRR	Gas temp	Det. temp
0	0	20	20
30	169	37	24
60	677	62	39
90	1523	92	64
120	2707	126	96
150	4230	163	133
180	6091	202	172
210	8291	244	213
240	10829	288	257