Fire Protection Engineering Culminating Project
California Polytechnic State University

[19]

Fire Protection Engineering Analysis

Maumus Center — Arabi, Louisiana

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Table of Contents

Figures

Tables

Abstract

This report is a fire protection engineering analysis of the Maumus Center, a science center and planetarium, in Arabi, Louisiana. The objective of this analysis is to outline the code defined requirements and to confirm the minimum level of safety from fire is attained. Analyzed in the report are the design requirements prescribed in the adopted building and life safety codes, and the performance of the prescribed design. The prescriptive review addresses the building construction in regards to fire protection, the means of egress, the water-based fire suppression system, and the fire alarm system. The performance review incorporates the goals and objectives defined by the Life Safety Code, a performance criteria that establishes tenability limits that must not be exceeded, the selection of three realistic and conservative fire scenarios with the potential to affect a large population of occupants, and an analysis of one fire scenario using engineering empirical calculations and computer-based models to determine the effectiveness of the building fire protection systems.

The prescriptive design satisfies the code requirements; however, there are special situations, regarding the fire sprinkler system, that are not incorporated in the codes. For instance, the Planetarium dome projection screen's impact on the fire sprinkler system's activation time and water delivery to a hazard below the screen. Also, the lack of fire sprinkler protection below the telescopic seating system in the auditorium. Both of these applications require further analysis to better determine an adequate solution. The Lobby fire scenario analyzed estimates the building occupants will be unable to safely evacuate the building prior to being exposed to fire effects, more specifically diminished visibility and untenable temperatures. Possible solutions are recommended, but further analysis is required.

Introduction

Project Summary

The following report documents the fire protection engineering analysis of the Maumus Center, science center and planetarium, in Arabi, Louisiana. The information documented and analyzed is primarily from the building construction documents and images of the built conditions. The report begins with a description of the building, consisting of the building history and general information applicable to this analysis. Then the applicable codes and standards are addressed, leading into the prescriptive design requirements. The prescriptive design details the passive and active fire protection requirements prescribed in the noted codes and pertaining to the building's construction, occupant egress, water-based fire suppression system, and fire alarm system. To continue, the fire protection performance-based design documents the required performance criteria, three design fire scenarios, and evaluates one of the design scenarios using software to simulate actual fire conditions. As a conclusion, recommendations are outlined addressing aspects of the current design that could be improved upon or should be evaluated further.

Building History

The building is an existing two-story educational building constructed in 1929 with a later addition built, northeast of the original structure, in 1947. Between 1947 and 2005 the occupancy changed from educational to assembly, becoming a science center. In 2005, Hurricane Katrina severely damaged the building, and the building sat vacant until 2012. At this time, a construction process began to revitalize the science center. The revitalization project incorporated the complete renovation of the two existing two-story structures built in 1929 and 1947, the demolition of the original planetarium, the construction of a new contemporary planetarium located east of the existing structures, and a new lobby constructed between the existing structures and the new planetarium tying the building together. The historical composition of the building is illustrated in Figure 1.

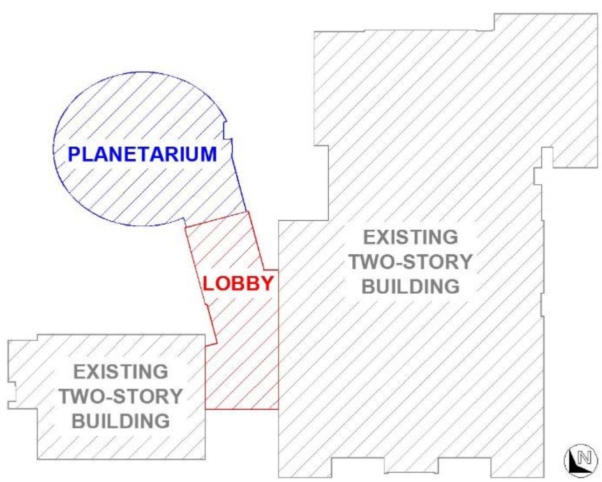

Figure 1 Existing/New Building Parts

General Information

The current state of the building analyzed in this report is an interactive science center, focused on educating children, for the St. Bernard Parish School District. The building is comprised of exhibit spaces, lab kitchens, an auditorium, a planetarium, and a cafeteria with a commercial kitchen. The science center's primary use is for educating children five to eighteen years of age, and the occasional use for community and school board events.

Noted below, is general information regarding the occupancy, construction, and the building design. The information is extracted from the architectural plans, and required to effectively analyze the fire protection capabilities of the building.

- Occupancy Classification – Non-Separated Mixed Occupancy (Figures 2 & 3)
  - Assembly
    - A2 – Cafeteria with associated Commercial Kitchen
    - A3 – Exhibit Spaces
    - A4 – Auditorium and Planetarium (indoor spectator seating)
  - Business (B)
- Construction Classification – Type IIIB
- Automatic Fire Sprinkler Protection – Protected throughout per NFPA 13
- Maximum Occupiable Floor Elevation – 25'-6½"
- Maximum Building Height – 42'-2½"
- Building Area (Gross)
  - 1st Floor 29,600 ft.^{2} (Figure 2)
  - 2nd Floor 16,680 ft.^{2} (Figure 3)
  - Total 49,280 ft.^{2}

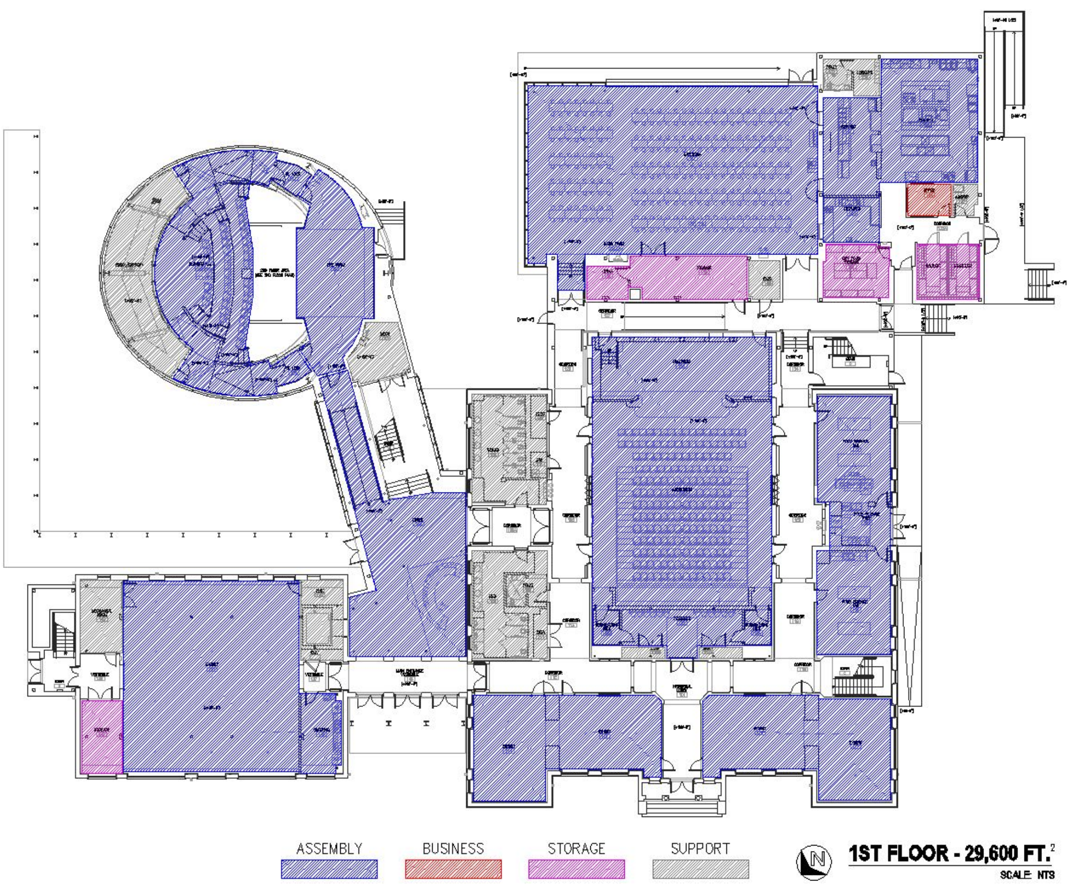

Figure 2 First Floor Occupancy Plan

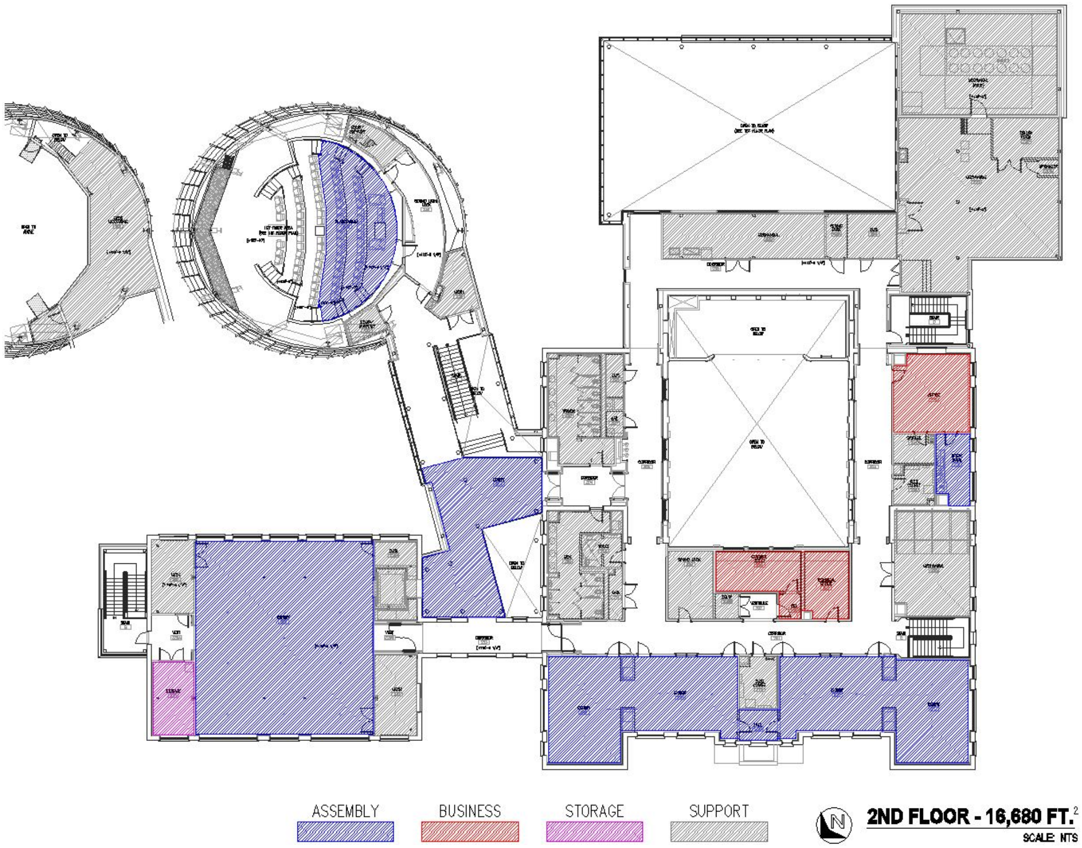

Figure 3 Second Floor Occupancy Plan

Applicable Codes & Standards

The authority having jurisdiction (AHJ) empowered to enforce the required codes regarding the building fire protection is the Louisiana Department of Public Safety and Corrections Office of the State Fire Marshal. The following codes were adopted by the AHJ at the time of construction:

- International Building Code (IBC) – 2009 Edition
- NFPA 101 Life Safety Code (LSC) – 2009 Edition

This analysis references and applies the following editions of the codes and standards:

- International Building Code (IBC) – 2012 Edition
- NFPA 101 Life Safety Code (LSC) – 2012 Edition
- NFPA 13 Standard for the Installation of Sprinkler Systems – 2013 Edition
- NFPA 24 Standard for the Installation of Private Fire Service Mains & their Appurtenances – 2013 Edition
- NFPA 25 Standard for the Inspection, Testing, & Maintenance of Sprinkler Systems – 2014 Edition
- NFPA 70 National Electrical Code – 2013 Edition
- NFPA 72 National Fire Alarm & Signaling Code – 2013 Edition
- NFPA 90A Standard for the Installation of Air-Conditioning & Ventilating Systems – 2012 Edition
- NFPA 291 Recommended Practice for Fire Flow Testing & Marking of Hydrants – 2013 Edition

Prescriptive Design

Introduction

The prescriptive design aspect of the fire protection engineering analysis is based on explicitly defined requirements stated in the applicable codes and standards regarding materials, design, and installation. This section addresses the prescriptive requirements specific to the Maumus Center regarding construction, egress, the fire sprinkler system, and the fire alarm system.

Construction

The following section identifies the construction limitations based on the construction classification, the fire-resistance rating of the building's structural elements, the interior finishes, and the fire protection separations. The construction classification, the building limitations, and the required fire-resistance ratings are in reference to the IBC. The requirements regarding interior finishes and separations are in accordance with the LSC.

Limitations

According to the IBC Section 503, the building height and area is limited based on the construction type and the occupancy classification. Considering the building is classified as having a non-separated mixed occupancy, Section 508.3.2 states the building limitations shall be based on the most restrictive occupancy.

Table 1 below is the IBC Table 503 condensed to only show the respective occupancy classifications and the limitations based on a Type IIIB construction classification and an automatic fire sprinkler system installed throughout the building.

Table 1 Allowable Building Heights & Areas

	Occupancy			
	A-2	**A-3**	**A-4**	**B**
Stories	2	2	2	3
Area/Story (ft^2)	9,500	9,500	9,500	19,000
Height (ft)*	55			

**Above Grade* *IBC Table 503* [1]

Table 1 clearly indicates the assembly occupancies are the most restrictive occupancies limiting the building to a maximum of two stories, 9,500 ft.^{2} area per story, and a 55 ft. building height. IBC Section 504 allows for a building height increase of 20 ft. and one additional story for having an automatic fire sprinkler system installed; however, this increase is not necessary for this building considering the number of stories and the building height do not exceed the prescribed limitations in the IBC Table 503.

The area limitation noted in Table 1 is far exceeded by both the 1st floor, at 29,600 ft.^{2}, and the 2nd floor, at 16,680 ft.^{2}. Therefore, the building area modifications stated in Section 506 must be applied.

First, the Frontage Increase must be calculated in accordance with Section 506.2. The face of the building along the entire perimeter is setback a minimum of 30 ft.; therefore, W equals 30 ft. And, the building Frontage Perimeter (F) equals the Entire Building Perimeter (P); thus, F/P is equal to 1. The Frontage Increase (I_f) is then

I_f = [F/P – 0.25]W/30 = [1-0.25]30/30 = 0.75 (75%). Figure 4 below, indicates the building in red and no other structures separating the exit discharge from the public way allowing clear access to the public way along the building perimeter.

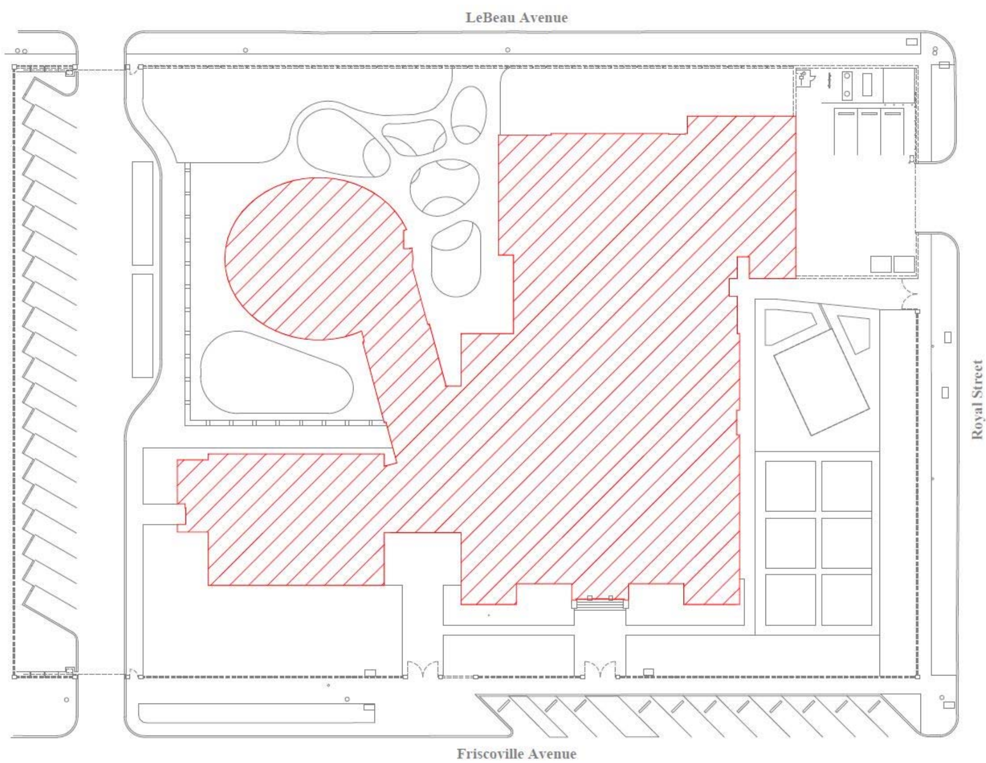

Figure 4 Building Site Plan

Second, the Automatic Sprinkler System Increase must be calculated in accordance with Section 506.3. The building consists of two-stories; therefore, exceeding the allowable one story above grade plane limit to apply the 300% increase. However, the area limitation may be increased 200% (I_s = 2).

Now that the Frontage Increase and the Automatic Sprinkler System Increase is calculated, the allowable area per story may be calculated:

$$A_a = \{A_t + [A_t \times I_f] + [A_t \times I_s]\} = \{9,500 + [9,500 \times 0.75] + [9,500 \times 2]\} = 35,625 \text{ ft.}^2$$

The adjusted allowable building area per story exceeds the actual floor areas:

- 1st Floor – 29,600 ft.^{2} < 35,625 ft.^{2}
- 2nd Floor – 16,680 ft.^{2} < 35,625 ft.^{2}

Thus, the floor areas are now within the applicable limitations set forth by the IBC.

Building Elements

The IBC Section 602 defines the fire-resistance ratings required for the building elements based on the construction classification.

Table 2 Fire-Resistance Rating Requirements for Building Elements

Building Element	**Hours**
Primary Structural Frame	0
Bearing Walls - Exterior	2
Bearing Walls - Interior	0
Nonbearing Walls & Partitions - Exterior (per Table 602) *	0
Nonbearing Walls & Partitions - Interior	0
Floor Construction & Associated Secondary Members	0
Roof Construction & Associated Secondary Members	0

**Fire Separation Distance $\geq$ 30 ft.* *Table 601* [1]

Table 2, shown above, represents the required fire-resistance ratings for Type IIIB construction building elements defined in the IBC Table 601; including, the fire-resistance rating for exterior nonbearing walls and partitions based on a fire separation distance greater than 30 ft. per Table 602.

According to Table 2, only the exterior load-bearing walls require a fire-resistance rating, and the minimum rating is 2 hours.

The existing portions of the building have exterior load-bearing walls constructed of multiwythe masonry, shown in Figure 5. To be specific, the existing exterior load-bearing walls are constructed with two wythes of unfilled hollow core 3-5/8 in. clay brick. Using Equation 7-8, from the IBC [1], an equivalent thickness of a clay masonry unit is calculated:

$T_e = V_n/LH = 2.175 \times 2$ (wythe) $= 4.35$

T_e = Equivalent Thickness
V_n = Net Volume of Unit (in.^{3}) = 37.31 in.^{3}
L = Specified Length of Unit (in.) = 7.625 in.
H = Specified Height of Unit (in.) = 2.25 in.

Applying the equivalent thickness to Table 722.4.1(1) for an unfilled hollow brick, the fire-resistance rating for the exterior masonry load-bearing walls is 3 hours; thus, the existing masonry walls exceed the minimum rating requirement.

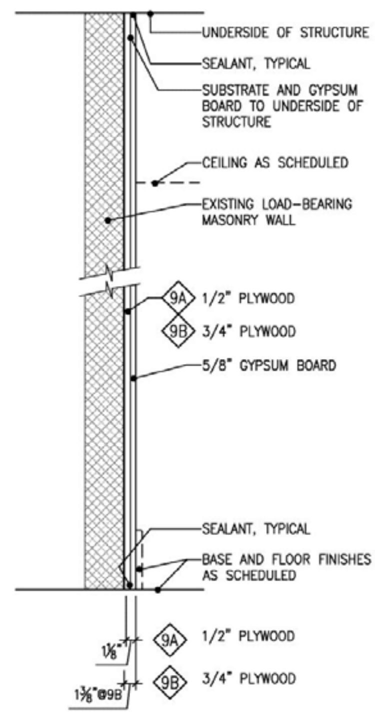

Figure 5 Exterior Wall Section [20]

Along with the existing exterior masonry walls, the fire-resistance rating requirements apply to the structural steel located along the exterior perimeter of the building, primarily within the area of new construction. The rating requirements are met with the use of Sprayed Fire-Resistant Material (SFRM); applied in accordance with the IBC Section 704.13, to a minimum thickness necessary to achieve the required fire-resistance rating. The construction documents define the specific steel members and the corresponding SFRM UL Design. The UL Design defines the required minimum thickness that must be applied for each steel member type. Figure 6 locates the steel members that require the SFRM and Table 3 identifies the structural element and the corresponding UL Design.

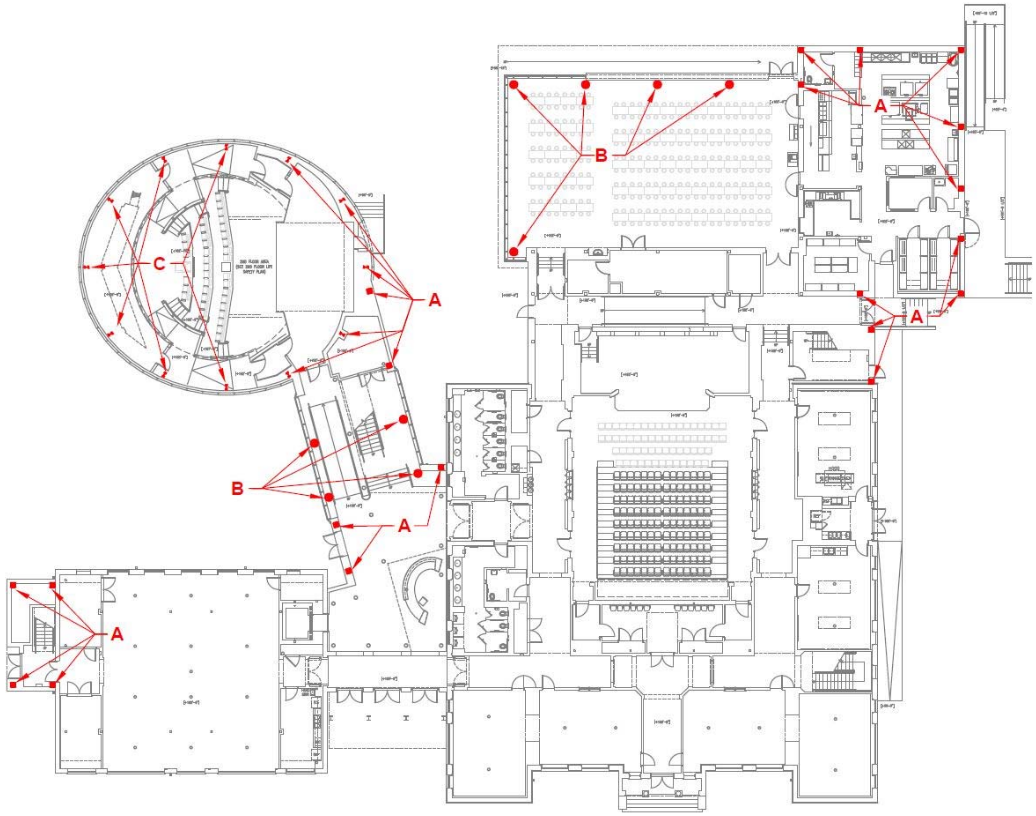

Figure 6 Structural Steel SFRM

Table 3 Steel Fire-Resistance Rating Requirements

ID	Rating (HR)	UL Design	Structure Element
A	2	X790	Hollow Square Steel Tube
B	2	Y616	Hollow Round Steel Pipe
C	2	Y615	Wide Flange I-Beam Column
D	2	N759	Beams between Columns

Interior Finishes

The interior finish requirements defined and evaluated in this report are per the LSC; however, the requirements in the LSC align with requirements in Chapter 803 of the IBC for this particular application.

According to the LSC Section 13.3.3, regarding existing assembly occupancies, the interior finish of the building's exit enclosures must be a Class A finish. Corridors and all other spaces shall be a Class A or B finish. However, according to Section 10.2.8, since the building has an automatic fire sprinkler system installed throughout in accordance with NFPA 13, where a Class A finish is required a Class B finish is acceptable and where a Class B finish is required a Class C finish is acceptable.

In reference to the finish schedule in the construction documents, the interior walls and partitions throughout the building are finished in a minimum of one layer of 5/8 in. Type X gypsum board, clay brick, or CMU brick. According to the Louisiana State Fire Marshal's Explanatory Information on Construction Requirements, regarding flame-spread ratings, the gypsum board, the clay bricks, and the CMU bricks are Class A finishes [4].

Separation

Since the building is classified as a non-separated mixed occupancy, per IBC Section 508.3, there are no separation requirements between the different occupancies. Therefore, this section addresses the means of egress separation requirements defined in the LSC.

The means of egress separation pertains to the constructed assembly forming a protective barrier between the means of egress and another space. The following outlines the fire-resistance rating requirements for exit access corridors and exits defined in Section 7.1.3.

Exit Access Corridors – generally require minimum 1-hour fire-resistance rated walls for occupant loads exceeding 30; however, since the building is existing, the occupancy classification did not change, and Chapter 13 does not stipulate any separation requirements for corridors, the corridor walls do not require a minimum fire-resistance rating.

Exits – require a minimum 1-hour fire resistance rating where the exits connect a maximum of three floors. Considering the building's exits connect only two floors, the minimum required fire-resistance rating of the exit enclosures is 1-hour. According to the construction documents, the exit enclosures are shown to be 1-hour fire barriers, as indicated in Figure 7 and Figure 8 with the bold red dash-dot lines.

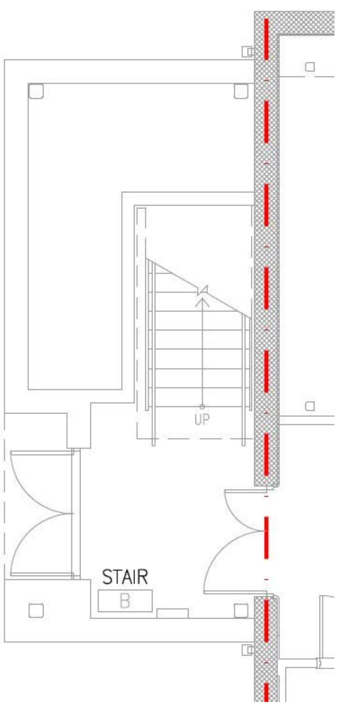

Figure 7 Stair B Fire Barrier

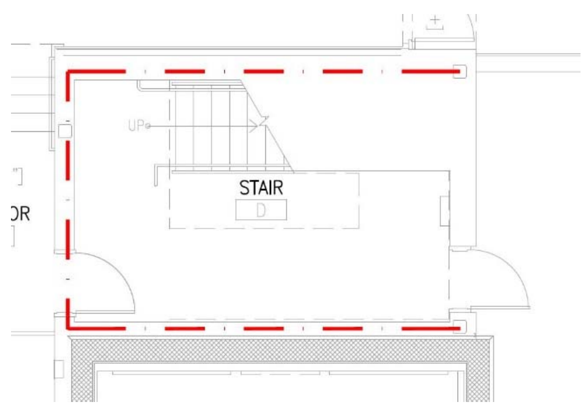

Figure 8 Stair D Fire Barrier

In addition, smoke partitions are used throughout the building separating vertically communicating spaces from the exit access corridors on each floor. The smoke partitions are applied as a means of passive smoke control intended to limit the spread of smoke between stories. The spaces separated with smoke partitions are the Planetarium, the Cafeteria, the Auditorium, and the Lobby, shown in Figure 9.

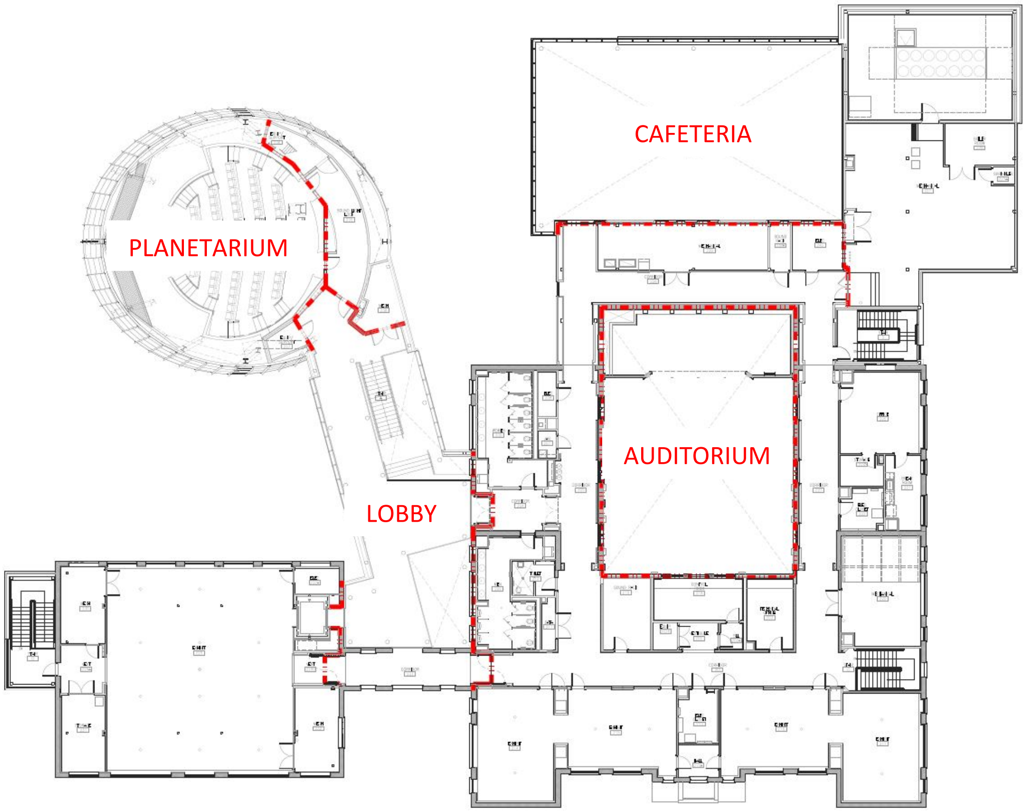

Figure 9 Smoke Partitions

The smoke partitions comply with the LSC Section 8.4 providing the required continuity and protection to limit smoke spread. In addition, the doors connecting the Lobby to the existing building structures are automatic-closing doors, magnetically held open and connected to the building fire alarm system, addressed further in the Fire Alarm section of this report.

The construction of the building in regards to fire protection satisfies the prescriptive requirements defined in the IBC and LSC in respect to fire rated construction, interior finishes, and separation.

Means of Egress

The means of egress provides occupants with "a continuous and unobstructed way of travel from any point in a building or structure to a public way consisting of three separate and distinct parts: (1) the exit access, (2) the exit, and (3) the exit discharge," as stated in Section 3.3.170 of the LSC. All three parts are described below and shown in Figures 10, 11, and 12.

Exit Access – consists of all occupied spaces and elements traveled to reach an exit, including corridors, unprotected stairs and ramps, open spaces, and rooms.

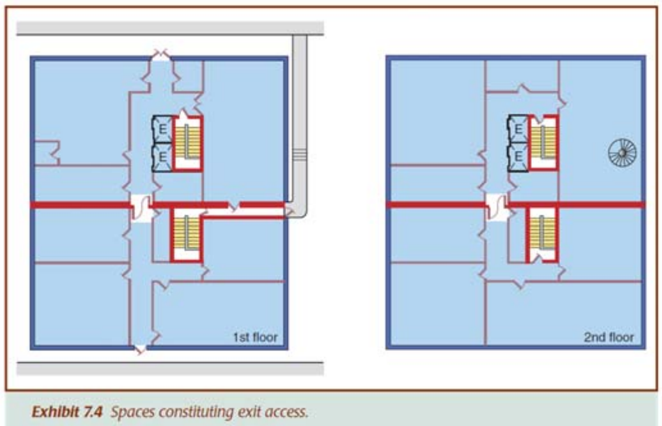

Figure 10 Exit Access [7]

Exit – a door, doorway, stair, or passage providing a protected means of travel to the exit discharge. Examples of exits are doors and fire resistance rated passageways discharging to the exterior of the building and fire resistance rated enclosures providing protected travel from a floor to the level of discharge or to an area of refuge.

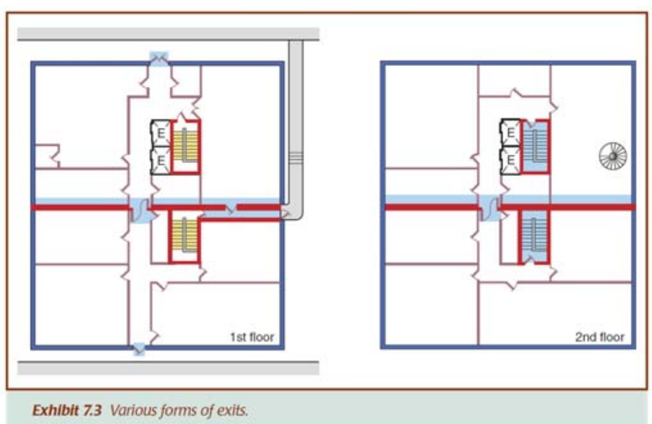

Figure 11 Exit [7]

Exit Discharge – the path of occupant travel from an exit to the public way, including sidewalks, steps, or ramps providing an accessible means to the public way.

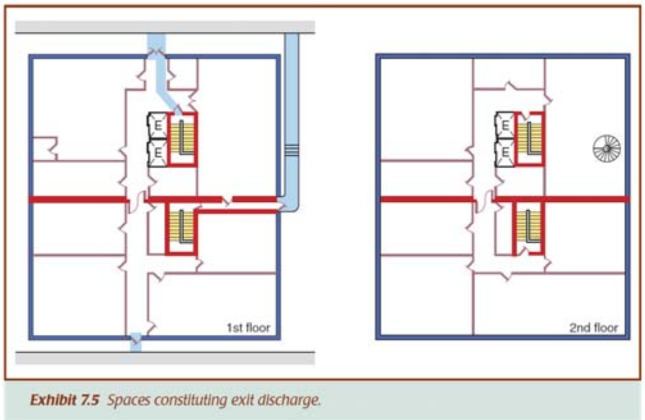

Figure 12 Exit Discharge [7]

Figures 13 and 14, identify the means of egress parts for the Maumus Center.

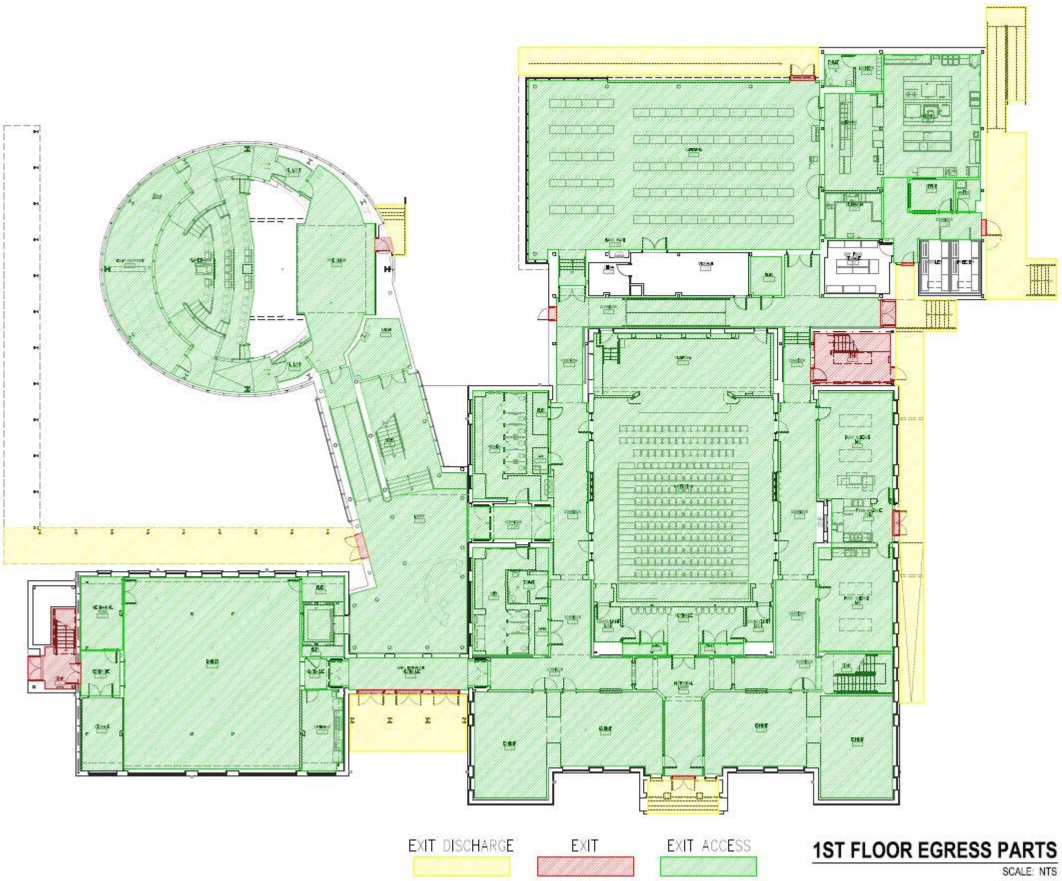

Figure 13 1st Floor Means of Egress Parts

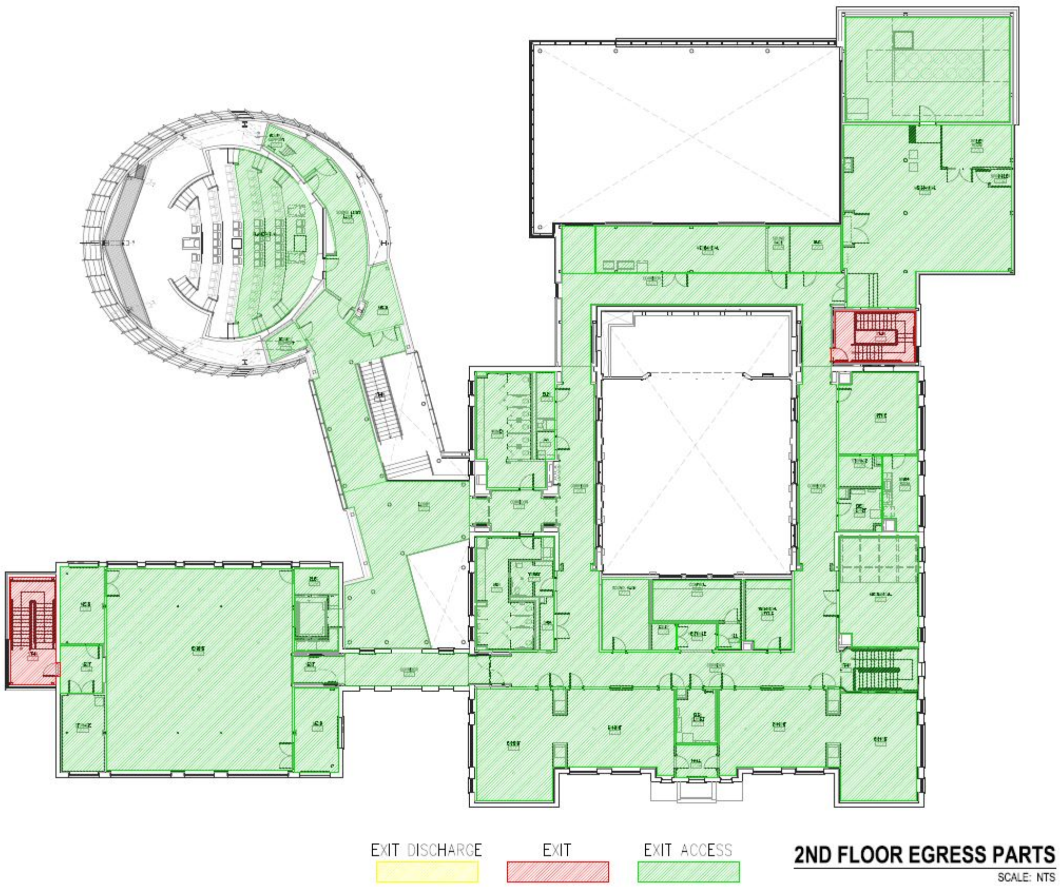

Figure 14 2nd Floor Means of Egress Parts

The following sections address each part and corresponding component of the building's means of egress, all in accordance with the general and occupancy specific prescribed codes found in Chapter 7 (General) and Chapter 13 (Existing Assembly Occupancy) of the LSC.

General

There are general egress requirements that must be applied to the building. These general egress requirements include the separation from other areas of the building, interior finishes, headroom, walking surfaces, changes in level, guards, impediments, and reliability.

Separation

The separation analysis is addressed in the Construction Section on Page 6.

Interior Finishes

The separation analysis is addressed in the Construction Section on Page 5.

Headroom

A minimum clearance above finish floor must be maintained along the means of egress in accordance with Section 7.1.5. The fact that existing building requirements are applicable to the building, the ceiling height in all occupiable spaces must be a minimum 7 ft. above finish floor with a minimum 4 in. vertical allowance for projections, projecting down below the ceiling. The headroom for stairs must be

maintained at a minimum 6 ft. 8 in. clearance measured vertically from a parallel plane to the most forward projection of a stair tread.

According to the reflected ceiling plans, the minimum common ceiling height is 7 ft. 10 in. above finish floor, allowing for an acceptable 14 in. of clear space for projections such as, ceiling mounted notification appliances and exit signs. The ceiling at the entrance to the elevator, on both floors, is 7 ft. 2 in. and is less likely to have a projection from the ceiling greater than the maximum allowable 6 in. Last, according to the reflected ceiling plans and the stair sections, the stairs maintain the minimum 6 ft. 8 in. clearance, even at the second-floor landing where the ceiling height is shown to be 8 ft.

Walking Surfaces

The means of egress walking surfaces must meet the requirements defined in Section 7.1.6 to prevent impeding the movement of occupants and injuring occupants due to tripping or slipping. The walking surfaces must not have abrupt changes in elevation that exceed ¼ in. Elevation changes that due exceed ¼ in. and are less than ½ in. must be beveled with a slope of 1 and 2. Any change greater than ½ in. is considered a change of level subject to Section 7.1.7.

Surfaces must be nominally level with a slope not exceeding 1 in 20 in the direction of travel and 1 in 48 perpendicular to the direction of travel, and they must be uniformly slip resistant under foreseeable conditions.

Change of Level

When there is an elevation change greater than ½ in. per Section 7.1.7, the change of level must be attained with a ramp, in accordance with Section 7.2.5, or a stair, in accordance with Section 7.2.2. In addition, when the change of level does not exceed 21 in., then the presence and location of ramps and stair treads must be readily apparent to occupants, and the stair treads must be no less than 13 in.

Guards

Guards must be installed along open sides of means of egress that are elevated more than 30 in. above finish floor or finish ground level.

Impediments

Devices and alarms installed to restrict the improper use of a means of egress must be designed and installed to prevent impeding the use of the means of egress in the event of an emergency.

Reliability

It is required that the means of egress must be maintained free of obstructions or impediments that would adversely affect the reliability during fire or other emergency conditions.

Components

The requirements specific to the components of the means of egress are found in Section 7.2 and Section 13.2.2 of the LSC. The component requirements applicable to the Maumus Center include door openings, stairs, and ramps. There are other components addressed in the LSC; however, are not applicable to this building and are not cited in this report (e.g., horizontal exits and exit passageways).

Door Openings

The door openings found throughout the building are swinging door assemblies. Addressed below, are the applicable requirements regarding door leaf width, floor level, door swing, and the hardware.

Door Leaf Width – is an important element of the means of egress, especially when determining the egress capacity of a given doorway. Figures 15 and 16 illustrate where the egress capacity width shall be measured and where the 3½ in. by 38 in. projection allowance is located.

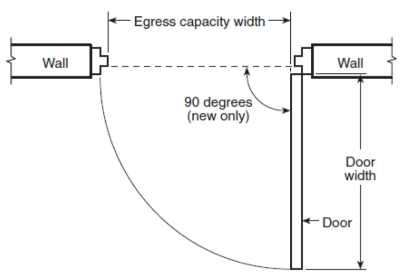

Figure A.7.2.1.2.2(a) Door Width — Egress Capacity.

Figure 15 Egress Capacity Width [7]

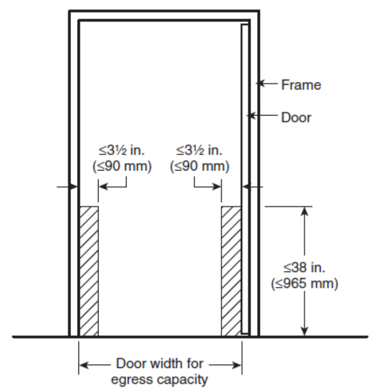

Figure A.7.2.1.2.2(b) Door Width — Egress Capacity with Permitted Obstructions.

Figure 16 Permitted Door Obstructions [7]

The minimum allowable egress capacity width is determined by the required egress capacity, based on the occupant load intended to pass through a door opening, addressed in the Egress Capacity section; however, the door leaf width shall not be less than 32 in., in new buildings, and 28 in., in existing buildings. Also, swinging door assemblies must maintain a clear height of no less than 6 ft. 8 in.

According to the door schedule, all of the doors have a minimum 7 ft. vertical clearance and a minimum clear (egress) width no less than 34 in., except one pair of doors accessing a small equipment closet, which each have a clear width of 30 in. Since the equipment closet is less than 70 ft.^{2} and is not intended to be accessed by persons with severe mobility impairments and the building is existing, the 30 in. clear width is acceptable.

Floor Level – on both sides of a door opening are required to maintain a relatively even surface with a maximum elevation change of no more than ½ in. and where the elevation change is between ¼ in. and ½ in., the transition must be beveled with a maximum slope of 1 in 2.

According to the threshold details, the thresholds transition acceptably per the noted requirements.

Door Swing – is required to be capable of swinging from any position to the full required width of the opening, must swing in the direction of egress travel (unless serving a room with an occupant load less than 50), and must not obstruct more than one-half of and project more than 7 in. into, the required width of an aisle, corridor, passageway, or a landing.

The Life Safety Plans, found in the Appendix, clearly shows the door swings and the widths of the aisles, corridors, passageways, and landings, confirming the building meets the door swing requirements for the means of egress. Figure 17 is the main entrance vestibule showing the doors swing in the direction of egress travel and the corridor doors are recessed, not projecting into the corridor.

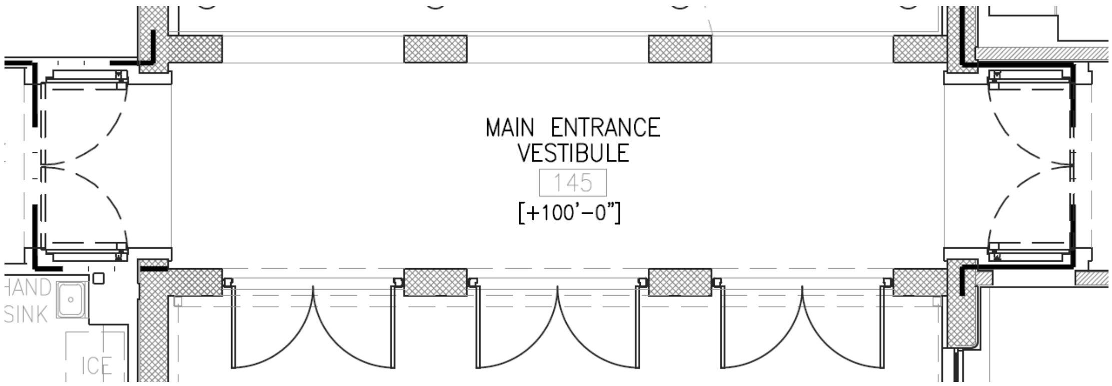

Figure 17 Main Entrance Vestibule – Door Swing [20]

Force to Open – must not exceed 15 lbf to release the latch, 30 lbf to set the leaf in motion, and 15 lbf to open the leaf to the minimum required width; however, since the building is existing the maximum allowable force to open door leaves is 50 lbf. These requirements are found in the LSC Section 7.2.1.4.5.

Relying only on the project building construction documents, and not having the specifications or the submittal data pertaining to the egress doors, the forces to open were not evaluated.

Hardware – there are extensive hardware options and applications to consider when evaluating the egress doors. Considering the limited information, provided in the construction documents, regarding the door hardware, this section only addresses the general requirements specific to the building without providing an evaluation.

Door leaves must be arranged to be opened readily from the egress side whenever the building is occupied, and latches or locks are permitted, for existing assembly occupancies, only if the latch or lock is panic hardware or fire exit hardware. The panic or fire exit hardware must consist of a cross bar or push pad extending no less than half of the door leaf, located between 34 in. and 48 in. above finish floor, and actuates with a force not exceeding 15 lbf.

The doors included the smoke partitions must be self-closing or automatic-closing in accordance with Section 8.4.3.5. The self-closing and automatic door operation must comply with Section 7.2.1.8. Self-closing doors must remain in the closed position, except as occupants pass through the door; therefore, these doors shall not be secured in the open position.

Automatic-closing doors must be held open by a mechanism that is electronically controlled by approved smoke detectors, installed in accordance with NFPA 72 for door leaf release service. Upon initiation of an associated smoke detector the hold-open mechanism must release the door leaf, the leaf then becomes self-closing. The hold-open device must release the door leaf upon loss of power, as well.

Stairs

Stairs are found throughout the project building used as components of exit access, exits, and exit discharge. The applicable required concepts regarding stair dimensions, guards and handrails, and enclosures are addressed, as follows.

Dimensions – must comply with the minimum requirements for new and existing stairs, as defined in Table 4 and Table 5.

Table 4 New Stairs [7]

Table 7.2.2.2.1.1(a) New Stairs

Feature	Dimensional Criteria	
	ft/in.	mm
Minimum width	See 7.2.2.2.1.2.	
Maximum height of risers	7 in.	180
Minimum height of risers	4 in.	100
Minimum tread depth	11 in.	280
Minimum headroom	6 ft 8 in.	2030
Maximum height between landings	12 ft	3660
Landing	See 7.2.1.3, 7.2.1.4.3.1, and 7.2.2.3.2.	

Table 5 Existing Stairs [7]

Table 7.2.2.2.1.1(b) Existing Stairs

Feature	Dimensional Criteria	
	ft/in.	mm
Minimum width clear of all obstructions, except projections not more than 4½ in. (114 mm) at or below handrail height on each side	36 in.	915
Maximum height of risers	8 in.	205
Minimum tread depth	9 in.	230
Minimum headroom	6 ft 8 in.	2030
Maximum height between landings	12 ft	3660
Landing	See 7.2.1.3 and 7.2.1.4.3.1.	

Section 7.2.2.2.1.2 requires new stairs serving an occupant load less than 2000 occupants to have a minimum width of 44 in. Stairs and intermediate landings must maintain a uniform width along the direction of egress travel, and all new stair landings must have a minimum dimension, measured in the direction of travel, equal to the stair width.

Figure 18 and Figure 19 indicate the building's two main exit stairs meet or exceed the minimum dimension requirements.

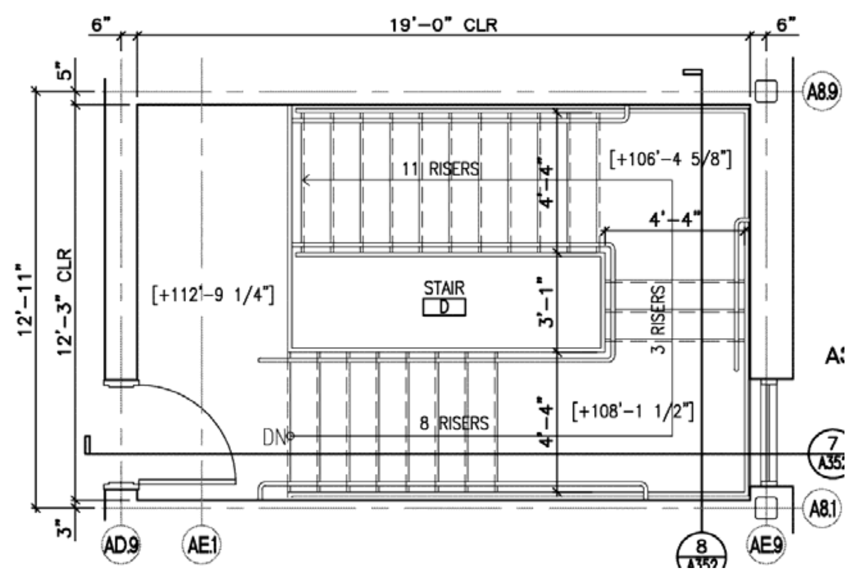

Figure 18 South Exit Stair D [20]

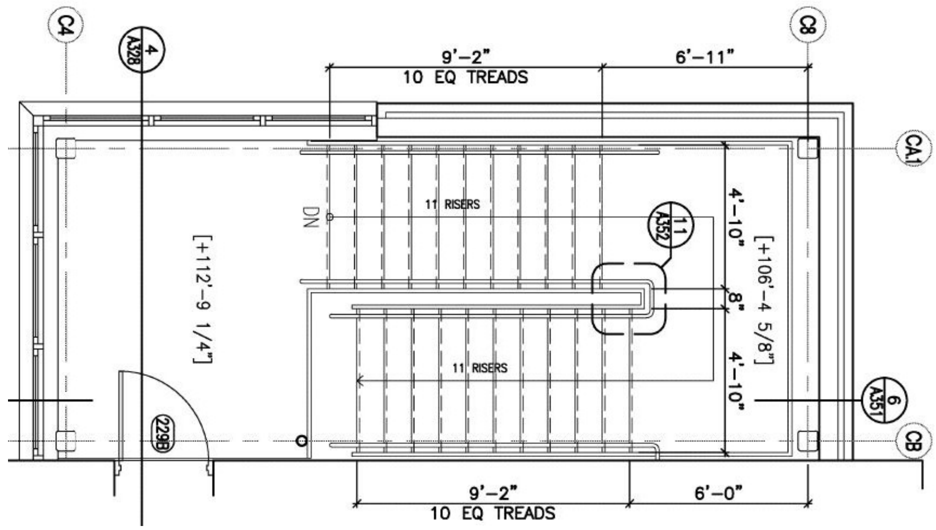

Figure 19 North Exit Stair B [20]

Guards and Handrails – must be installed in accordance with the minimum requirements in Section 7.2.2.4, to provide safe egress through a building where there are elevated floor levels. The requirements applicable to the Maumus Center are:

- Handrails must be on both sides of stairs.
- Handrails must be provided within 30 in., for new stairs, or 44 in., for existing stairs, of the required egress width.
- Guards and handrails must be continuous, smooth, without projections, and graspable along the full length of stair travel, including along landings.
- Handrails must be a minimum of 34 in., for new stairs, or 30 in., for existing stairs, and a maximum 38 in. measured vertically from the leading edge of the tread. Handrails that form part of a guard are allowed a maximum 42 in. above the leading edge of the tread.
- Guards must be minimum height of 42 in. above finish floor.
- Guards are not required on platforms in an assembly occupancy.

Figure 18 and Figure 19 indicate the handrails are provided along the full length of the exit stairs, in accordance with Section 7.2.2.4. Figure 20 and Figure 21 represent two examples of guards and handrails found in the building complying with the LSC. Figure 20 shows the guard surrounding the Lobby is 42 in. above finish floor, and Figure 21, shows the handrail serving the two exit stairs is 34 in. above finish floor.

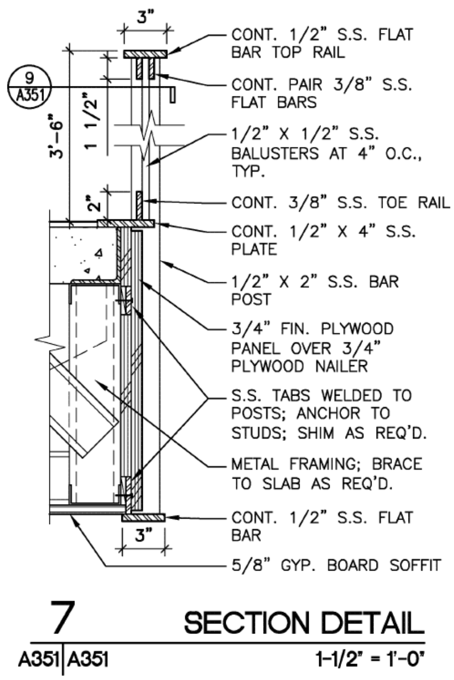

Figure 20 Lobby Guard [20]

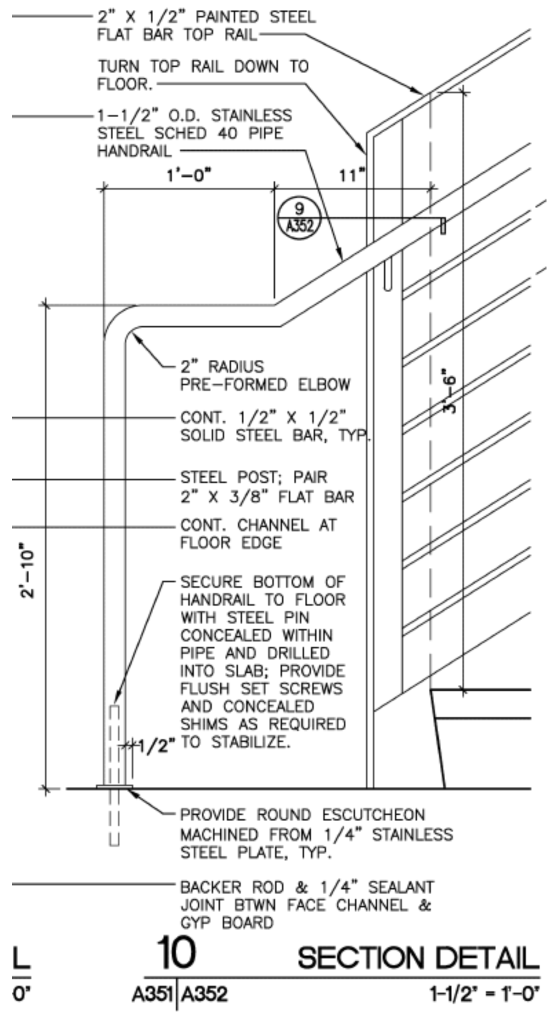

Figure 21 Exit Stair Handrail [20]

Stair Enclosures – must be protected in accordance with Section 7.1.3 for exit stairs and Section 8.6 and 13.3.1 for all other vertical openings.

As noted in the Construction Section, the two exit stairs meet the 1-hour fire-resistance rated separation requirements for an exit enclosure.

The new exit access stairs serving the Planetarium and the Lobby are not enclosed; however, this arrangement is acceptable per Section 13.3.1(4) considering the building is completely protected with an automatic fire sprinkler system, in accordance with Section 9.7.

The stairs located in the Southwest corner of the existing two-story structure are considered as a two-story opening with a partial enclosure per Section 8.6.8. The stairs are only enclosed on the 2nd floor with a 1-hour fire-resistance rated separation; however, the 2nd floor is only accessible under normal conditions. The 2nd story opening to the stair is equipped with an overhead roll-down fire door that actuates upon initiation of one of two smoke detectors located on either side of the opening. These stairs are not an exit, but may be used as exit access when accessible.

Ramps

There are four ramps on the level of discharge, two are exit access ramps and two are exit discharge ramps. Below addresses the applicable required concepts regarding ramp dimensions, guards, and enclosures.

Dimensions – must comply with the minimum requirements for new and existing ramps, as defined in Table 6 and Table 7.

Table 6 New Ramps [7]

Table 7.2.5.2(a) New Ramps

Feature	Dimensional Criteria	
	in.	mm
Minimum width clear of all obstructions, except projections not more than 4½ in. (114 mm) at or below handrail height on each side	44	1120
Maximum slope	1 in 12	
Maximum cross slope	1 in 48	
Maximum rise for a single ramp run	30	760

Table 7 Existing Ramps [7]

Table 7.2.5.2(b) Existing Ramps

Feature	Dimensional Criteria	
	ft/in.	mm
Minimum width	30 in.	760
Maximum slope	1 in 8	
Maximum height between landings	12 ft	3660

Figure 22 and Figure 23 indicate the two interior exit access ramps exceed the minimum dimension requirements; therefore, complying with the LSC.

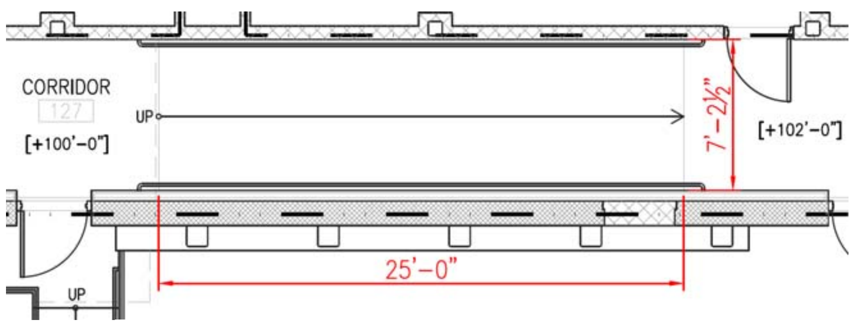

Figure 22 Ramp West of Platform – Slope 1:12½

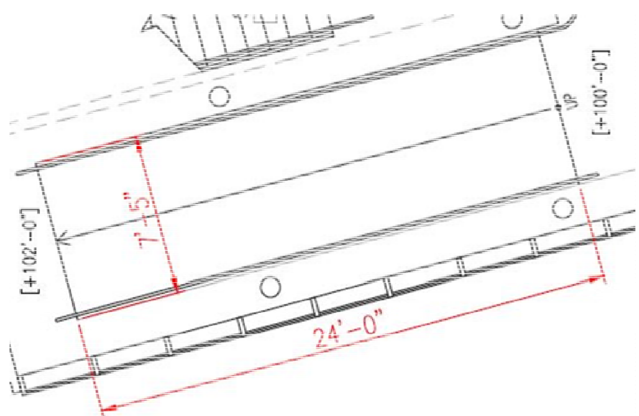

Figure 23 Lobby Ramp – Slope 1:12

Guards and Handrails – must be installed in accordance with the minimum requirements in Section 7.2.2.4, as noted in the Stair section.

Figure 22 and Figure 23 indicate the handrails are provided along the full length of the ramps, in accordance with Section 7.2.2.4.

Ramp Enclosures – must be protected as a stair in accordance with Section 7.1.3 for exit stairs and Section 8.6 and 13.3.1 for all other vertical openings.

Considering the ramps are only exit access or outside as a component of the exit discharge, the ramps are unenclosed and acceptable per Section 13.3.1(4) considering the building is completely protected with an automatic fire sprinkler system.

Capacity

The requirements outlined in Section 7.3 and Section 13.2.3 of the LSC address the means of egress capacity. Section 13.2.3 is specific to theater-type seating in existing assembly occupancies and Section 7.3 covers all other applications applicable to the building. In the following section, the occupant load is calculated and the available egress capacity is determined. This is to evaluate if the designed egress capacity is capable of providing a sufficient means of egress for the occupant load.

Occupant Load

The calculation of the occupant load is imperative to evaluating the overall effectiveness of the means of egress. The occupant load determines the minimum allowable egress capacity, the minimum number of exits, and other specific limitations noted in the LSC.

The occupant load for a space is calculated using the occupant load factor, found in Table 7.3.1.2 (Table 8) specific to the use of the space, multiplied by either the space's gross area or net area. Table 7.1.3.2 (Table 8) indicates when the gross or net area is required.

The primary use of the Maumus Center is as a place of assembly with incidental spaces used for business, storage, and support.

Assembly Use – consists of a combination of occupant load factors specific to the use within a defined space or room. Below are the occupant load factors applied to the places of assembly:

- Concentrated Use, without fixed seating: 7 (net) $ft.^2$/person
  - Planetarium Lobby (1st and 2nd floor)
  - Planetarium Pre-Show Space
- Less Concentrated Use, without fixed seating: 15 (net) $ft.^2$/person
  - Exhibit Spaces
  - Cafeteria (the seating arrangement indicated on the floor plan indicates folding tables, with integral seating, will be used and the seating exceeds the 15 (net) $ft.^2$/person load; therefore, in this instance the number of seats is used for the occupant load.)
- Fixed Seating: use number of fixed seats
  - Auditorium
  - Planetarium

- Kitchens: 100 (gross) ft.^{2}/person
  - Kitchen and supporting spaces: Serving, Dishwash, Lockers, and Toilet
  - Catering
  - Food Science Prep
  - Food Science Labs (space used as a kitchen; however, occupants gather as spectators to watch a chef/instructor cook. Though, the space is not classified as educational on the original fire protection life safety plan, the use and name indicates this space is a lab used to educate people; therefore, an educational use laboratory occupant load factor is used for this report, 50 (net) ft.^{2}/person.)
- Stages (i.e., platforms): 15 (net) ft.^{2}/person
  - Platform

Business Use – occupant load factor, 100 (gross) ft^2/person, is used for the following locations:

- 1st Floor
  - Kitchen Office
- 2nd Floor
  - Control Room
  - Technical Office
  - Office

Table 8 Occupant Load Factor [7]

Table 7.3.1.2 Occupant Load Factor

Use	(ft^2/person)[a]
Assembly Use	
Concentrated use, without fixed seating	7 net
Less concentrated use, without fixed seating	15 net
Bench-type seating	1 person/ 18 linear in.
Fixed seating	Use number of fixed seats
Waiting spaces	See 12.1.7.2 and 13.1.7.2.
Kitchens	100
Library stack areas	100
Library reading rooms	50 net
Swimming pools	50 (water surface)
Swimming pool decks	30
Exercise rooms with equipment	50
Exercise rooms without equipment	15
Stages	15 net

Storage Use – occupant load factor, 500 (gross) ft.^{2}/person, is used for all of the storage rooms throughout the building, considering the primary occupancy is assembly, and not, storage or mercantile.

Incidental Support Spaces – include the mechanical rooms, electrical rooms, elevator machine rooms, and restrooms. These spaces are considered not to be normally occupied and the occupants intended to use these spaces are included in the calculations above, for assembly, business, and storage use.

The calculated occupant load and area (ft.^{2}) for each space is shown on the Life Safety Plans, found in the Appendix, and indicated as shown in Figure 24 and Figure 25.

Figure 24 Room Occupant Load

Figure 25 Fixed Seating Occupant Load

Means of Egress Capacity

The means of egress capacity is determined by the minimum egress width for the components along the path of egress, including: door openings, stairs, and exit access corridors. The minimum required widths were mentioned above in the Components section; however, the actual minimum allowable width is dependent on the occupant load required to egress through the component. Below addresses how to calculate the available egress capacity for each component and evaluates the actual available egress capacity for the building, ultimately determining if the means of egress meets the minimum requirements for the anticipated occupant load.

The capacity calculations must first take into consideration the building is a place of assembly; therefore, a main entrance capable of accommodating one-half of the total occupant load for the entire building is required, see Figure 26. All of the other exits must have a combined capacity capable of accommodating one-half of the total occupant load served by that level.

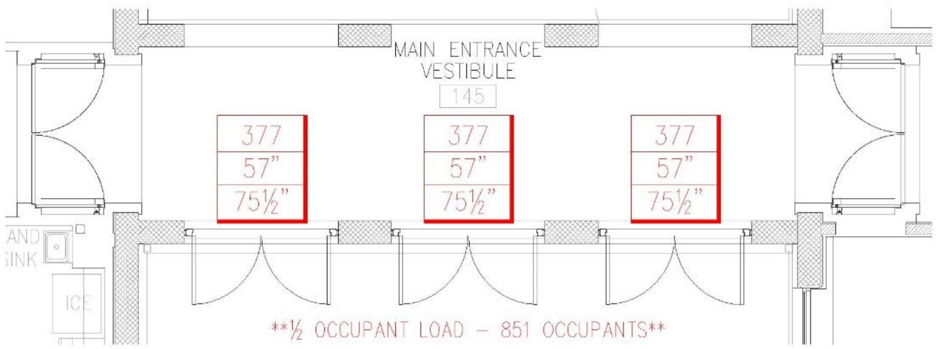

Figure 26 Main Entrance Capacity

To calculate the means of egress capacity, Table 7.3.3.1 (Table 9) must be referenced for the required capacity factors. The applicable factor for stairs is 0.3 and for level components and ramps it is 0.2. The capacity factor is multiplied by the measured egress capacity width, in inches, of the specific component, to find the actual capacity of the component.

Table 9 Capacity Factors [7]

Table 7.3.3.1 Capacity Factors

	Stairways (width/person)		Level Components and Ramps (width/person)	
Area	**in.**	**mm**	**in.**	**mm**
Board and care	0.4	10	0.2	5
Health care, sprinklered	0.3	7.6	0.2	5
Health care, nonsprinklered	0.6	15	0.5	13
High hazard contents	0.7	18	0.4	10
All others	0.3	7.6	0.2	5

The egress capacity width must be measured in the clear at the narrowest point of the egress component. Projections are allowed to project 4½ in. on each side and 38 in. above the finish floor. Exit access components in an existing building must have a minimum egress width of 28 in., existing stairs must have a minimum egress width of 36 in., and new stairs must have a minimum egress width of 44 in.

For stairs with a width that exceeds 44 in., the egress capacity must be calculated using the following equation:

$C = 146.7 + [(w_n - 44)/0.218]$

C = capacity, in persons, rounded to the nearest integer
W_n = nominal width of the stair as permitted by 7.3.2.2 (in.)

The Planetarium and the Auditorium seating areas must comply with Section 13.2.3.2 regarding theater-type seating. All aisles and other means of egress serving these two seating areas must use the capacity factors in Table 13.2.3.2 (Table 10).

Table 10 Theater Seating Capacity Factors [7]

Table 13.2.3.2 Capacity Factors

	Clear Width per Seat Served			
	Stairs		Passageways, Ramps, and Doorways	
No. of Seats	in.	mm	in.	mm
Unlimited	0.3 *AB*	7.6 *AB*	0.22 *C*	5.6 *C*

The egress capacity for each component of the project building is shown on the Egress Capacity Plans found in the Appendix. Each door opening and exit stair is marked with the block shown in Figure 27, indicating the actual egress capacity, the minimum required egress width, and the actual egress width.

Figure 27 Capacity Block

According to the Life Safety Plans, the egress components adequately accommodate the occupant loads required for each specific component.

Number

Sections 7.4 and 13.2.4 of the LSC define the number of means of egress required for an assembly occupancy. Below are the required number of means of egress for each level, mezzanine, and catwalk of the building:

- 2nd floor must have a minimum of two exits considering the total occupant load for the second floor is less than 600 occupants per Section 13.2.4.2. Figure 14, found at the beginning of the Means of Egress Section, show the two exits serving the second floor along with the exit access stairs leading from the Lobby to the main entrance.
- 1st floor must have a minimum of four exits considering the total occupant load for the 1st floor is greater than 1000 occupants per Section 7.4.1.2(2). Figure 13, found at the beginning of the Means of Egress Section, show the twelve exits serving the 1st floor.
- The mechanical mezzanine in the Planetarium is allowed to have only one means of egress considering the occupant load for the mezzanine is less than 50 occupants per Section 13.2.4.5.
- The catwalks serving the Planetarium are allowed to have only one means of egress considering there is a means of escape to a floor using an accessible escape ladder per Section 13.2.4.8.

Arrangement

The means of egress must be arranged to provide occupants with a safe passage to safety during a fire or emergency scenario. Section 7.5 establishes the requirements regarding the egress arrangement and Section 13.2.5 further defines the requirements specific to an existing assembly occupancy.

In general, exits must be located and exit access must be arranged so that exits are accessible at all times per Section 7.5.1.1 and 7.5.1.3.1. The accessibility must be attained by locating exits, exit access, and exit discharge remotely from one another and arranged to minimize the potential for more than one to be rendered inaccessible by any one emergency scenario. Section 7.5.1.3.2 and 7.5.1.3.3 require exits to be separated by a minimum distance depending on the diagonal dimension of the space the exits serve; however, per Section 7.5.1.3.4, existing buildings do not have to comply with the diagonal measurement separation distance criteria.

In an existing assembly occupancy, such as the Maumus Center, Section 13.2.5 defines the maximum distances for common paths of travel and dead-end corridors, and the areas that are not permissible for egress access.

Common Path of Travel – is a component of exit access that must be traveled before reaching a point where two separate and distinct means of egress to two separate exits are available. This path of travel is limited to the following distances:

- 20 ft. when serving any number of occupants
- 75 ft. when serving no more than 50 occupants

Figure 28 and Figure 29 illustrate the two longest common paths of travel in the building confirming the requirements defined in Section 13.2.5 are met.

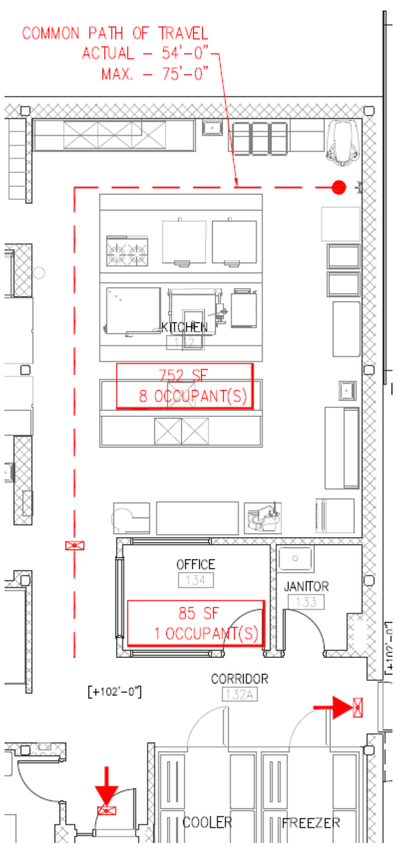

Figure 28 Common Path – Kitchen

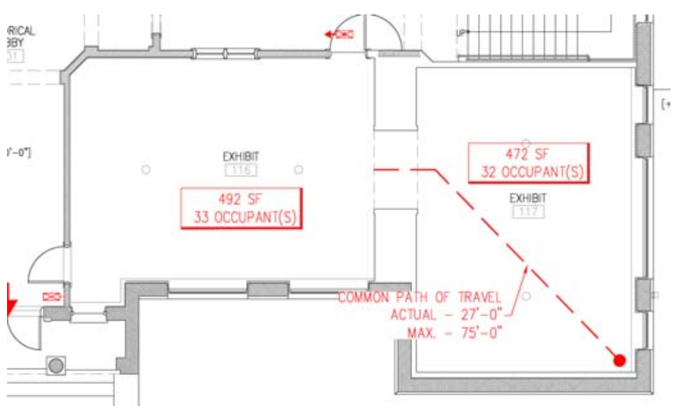

Figure 29 Common Path – Exhibit

Dead-End Corridor – is a portion of an exit access corridor that only allows one direction of travel and there is not a path of travel from an occupied space. A dead-end corridor requires that anyone that enters it must turnaround and retrace their entry to leave the corridor. All dead-end corridors are limited to a maximum distance of 20 ft.

The project building has only one dead-end corridor and its actual dimension is 11 ft. 3½ in., this is less than the required 20 ft. maximum.

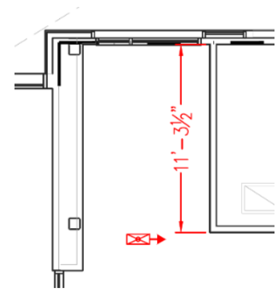

Figure 30 Dead-End

Not Permissible for Egress Access – the following areas are not permissible for egress access: kitchens, storerooms, restrooms, platforms, and hazardous areas.

The Occupancy Plans in the Appendix, illustrate the location and arrangement of the exits, exit access, and the exit discharge indicating a remote arrangement that is sufficient for compliance with Section 7.2.1.3.1.

Travel Distance

Section 13.2.6 defines the travel distance from the most remote point of occupancy within an existing building, with an assembly occupancy, that is protected by an approved automatic sprinkler system throughout, must not exceed 250 ft. This measurement must consider the following criteria defined in Section 7.6.1:

- Must be measured along the centerline of the natural path of travel.
- Allow a 12 in. clearance around corners and obstructions.
- Terminate at the center of an exit doorway.
- Must be measured along the plane of tread nosing of an exit access stair.

Figure 31 shows the greatest distance to travel in the building is from the 2nd floor dead-end corridor to the exit stairs located at the northern most part of the building, at a distance of 228 ft.; therefore, the longest travel distance is 22 ft. less than the maximum allowable distance. This measurement is conservative assuming the southwest exit stairs are inaccessible and the exit access stairs in the Lobby would not be used.

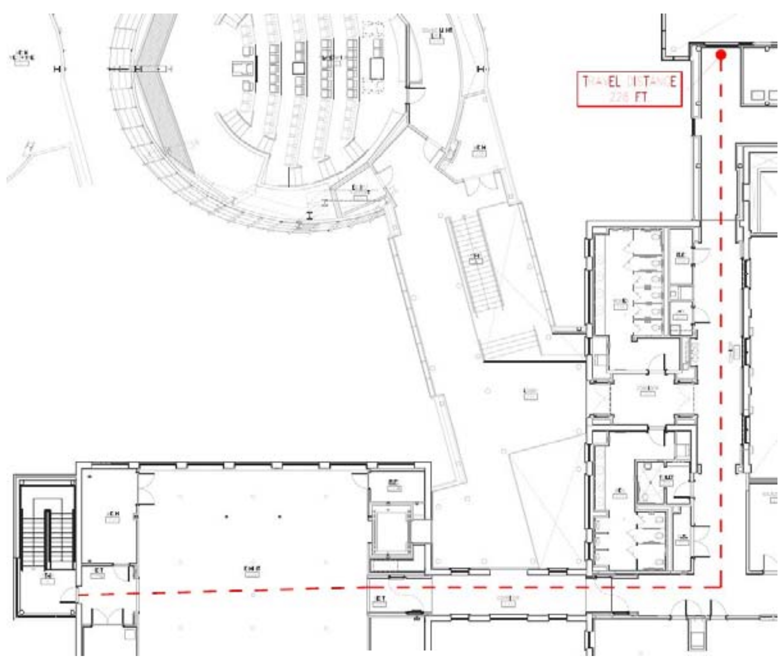

Figure 31 Travel Distance

Exit Discharge

In accordance with Section 7.7.1, exits must terminate directly at a public way or at an exterior exit discharge. The building's exit discharges are remotely located along the exterior perimeter of the building allowing safe egress to the public way. The exit discharges include components of means of egress, such as stairs and ramps. These are all indicated in Figure 13, found at the beginning of the Means of Egress Section.

Illumination

Section 7.8 defines the requirements for illuminating the means of egress. The building satisfies the requirements using the equipment installed to meet the requirements of Section 7.10 Marking of Means of Egress.

Emergency Lighting

Emergency lighting is required for existing assembly occupancies per Section 13.2.9.1 and must be in accordance with Section 7.9. The emergency lighting system must provide a minimum of 1½ hours of service in the event of a normal failure and the transition from one energy source to another must not delay longer than 10 seconds.

As indicated in the detail below, the building is equipped with an emergency backup generator and an automatic transfer switch to provide uninterrupted redundant power to continue lighting operations in the event the primary power source fails. The emergency generator must be installed, tested, and maintained in accordance with NFPA 110 Standard for Emergency and Standby Power Systems.

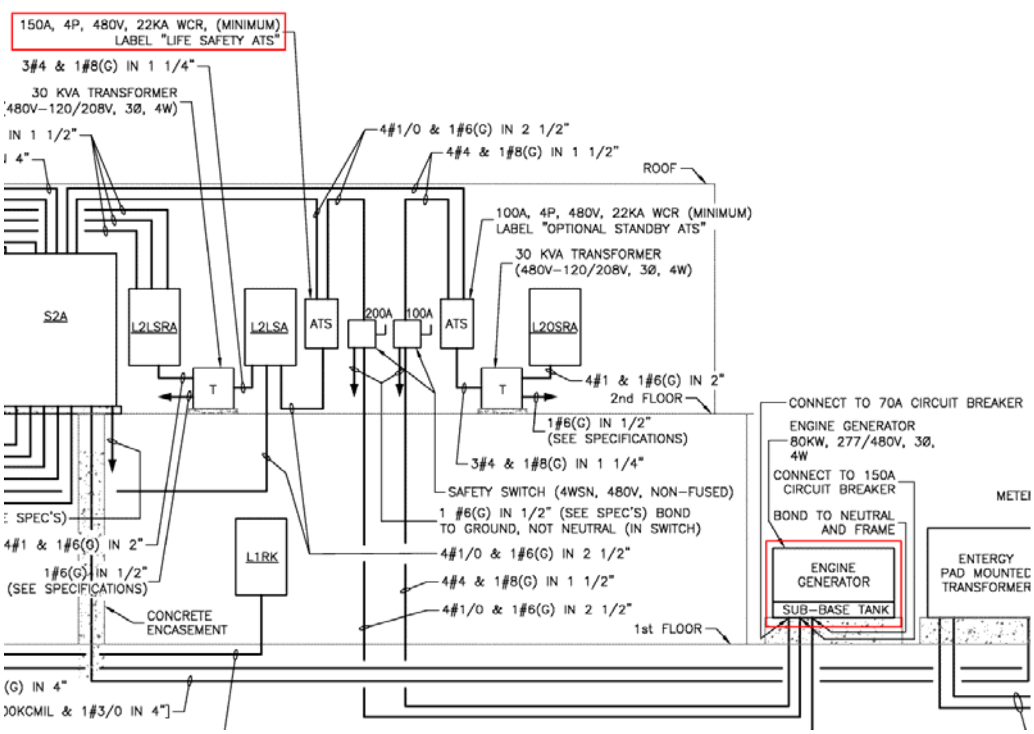

Figure 32 Emergency Lighting Power [20]

Marking

The means of egress for existing assembly occupancies must be marked with signs per Section 13.2.10 and in accordance with Section 7.2.10. Section 7.2.10 states, that all exits must be marked with an approved sign that

is visible from any direction of exit access, and exit access must have readily visible signs along the path of egress where exits or the way to exits is not clearly apparent. Also, the exit signs must be spaced along an exit access corridor no more than 100 ft., must be mounted no more than 6 ft. 8 in. above the top of an egress opening measured from the bottom of the sign, must have directional indicators where the direction to the nearest exit is not apparent, and must be continuously illuminated in the event of low light conditions.

The building's exits are marked in accordance with Section 7.2.10. Each sign location, along with a corresponding directional arrow, where applicable, is indicated on the Egress Capacity Plans, found in the Appendix. Also, the exit signs are illuminating signs connected to the primary power and the emergency backup power, for uninterrupted operation during a loss of power situation.

Figure 33 and Figure 34 illustrate the exit signs as shown on the Life Safety Plans.

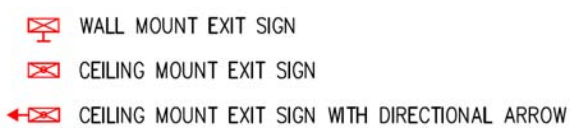

Figure 33 Exit Sign Legend

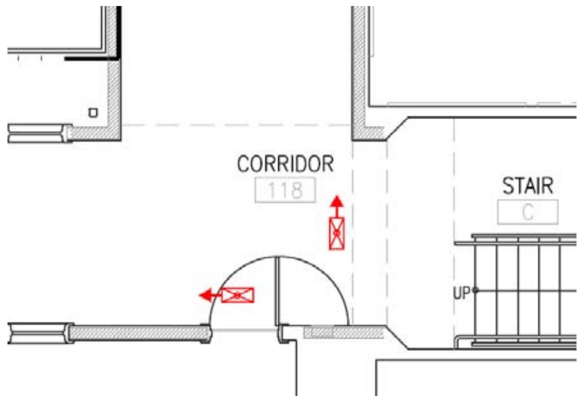

Figure 34 Exit Signs in Corridor

The building's means of egress satisfies the prescribed design found in the LSC regarding the general and existing assembly occupancy specific requirements. Now that the egress requirements are addressed, the fire sprinkler system requirements must be analyzed.

Fire Sprinkler System

An automatic fire sprinkler system is a means of active fire protection intended to provide fire suppression in the event of a fire that is significant enough to generate the necessary heat to activate a sprinkler or sprinklers to deliver a sufficient amount of water to the burning fuel surface, in attempt to reduce the heat release rate of the fire and to prevent the regrowth of the fire [10].

The LSC defines where automatic fire sprinkler systems are to be installed, specific to the use of the building. Considering the building is an existing assembly occupancy, Section 13.3.5 does not require the installation of a fire sprinkler system; however, Section 12.3.5, for new assembly occupancies, requires the installation since the occupant load exceeds 300. A fire sprinkler system was designed and installed in the Maumus Center during the revitalization project due to the extent of the renovations and the addition of new floor area, despite the allowance in Section 13.3.5.

This section analyzes the building's fire sprinkler system beginning with the system water supply, leading into the overhead fire sprinkler system, then the hydraulic calculations, and ending with the inspection, testing, and maintenance (ITM) requirements specific to the system. The analysis references NFPA 24 regarding the water supply, NFPA 13 in respect to the design and installation of the system, and NFPA 25 for the ITM requirements.

Water Supply

The fire sprinkler system is connected to a continuous automatic water supply provided by the local municipality's water distribution system. To determine the capability of the municipal water supply at the point of connection, a flow test was conducted in accordance with NFPA 291 Recommended Practice for Fire Flow Testing and Marking of Hydrants.

Two test hydrants were selected. The most remote test hydrant is the flow hydrant, located approximately 300 ft. to the north of the system connection, see Figure 36. The flow hydrant is used to measure the available volume flow rate, by fully opening the hydrant valve to discharge water from one 2½ in. outlet. The residual hydrant is located near the system connection, see Figure 36, and is used to measure the static and residual pressure along the circulating city water main by reading a pressure gauge installed on the hydrant.

The following results from the hydrant flow test are plotted on the graph found in Figure 35.

Date/Time: March 8, 2013 at 12:30 PM
Location: Corner of LeBeau Ave. and Royal St.
Static Pressure: 62 PSI
Residual Pressure: 35 PSI
Residual Flow: 790 GPM

The pressure drop exceeds 25% and the test was conducted during a period of ordinary consumption; therefore, the requirements in NFPA 291 are satisfied. However, the time of the test was likely not the most optimum time to perform the test considering early morning or later in the evening are statistically higher water consumption times.

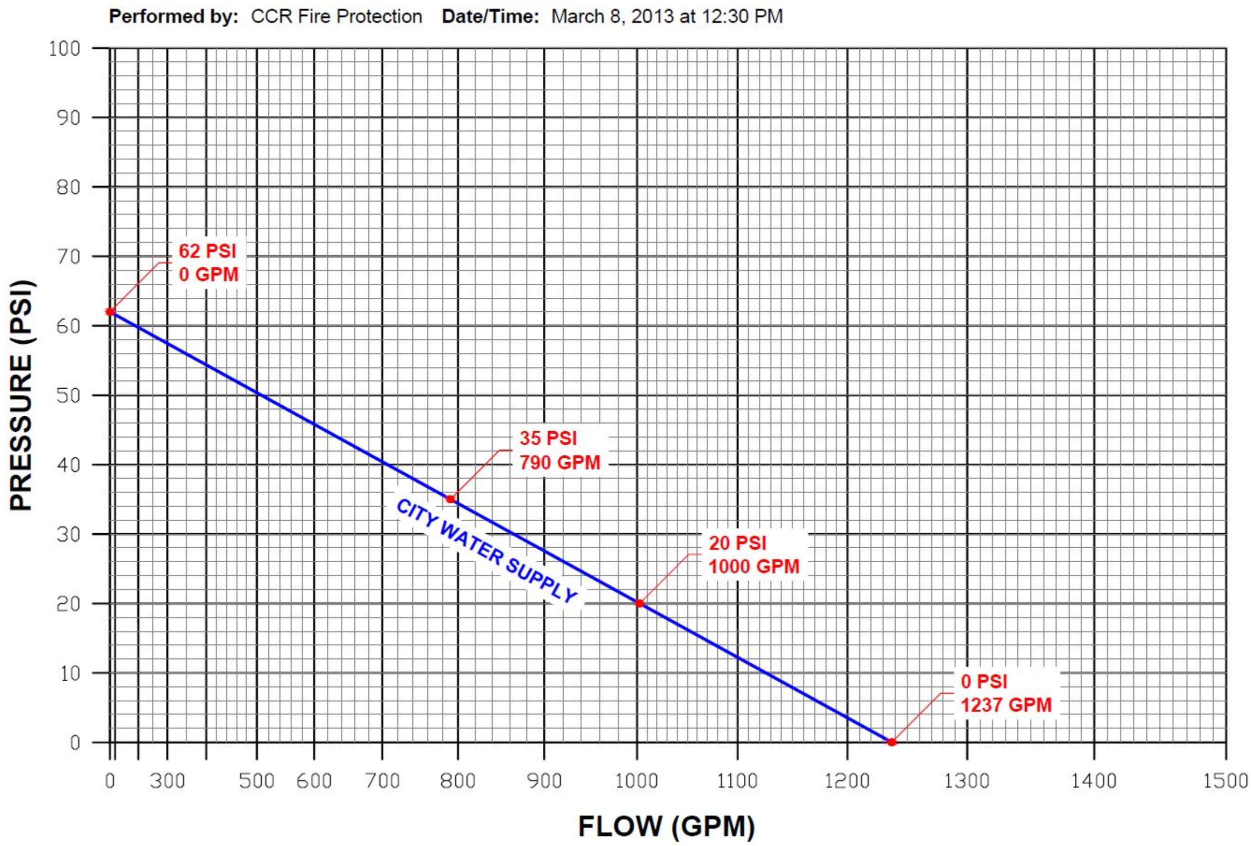

Figure 35 Hydrant Flow Test

Water is delivered from the city water main to the base of the fire sprinkler riser with a 6 in. PVC private fire service main, installed below grade, with a 36 in. minimum depth of cover, all in accordance with the requirements defined in NFPA 24. It is important to note, a 6 in. double check valve assembly is installed, above grade, in the private fire service main. The double check valve assembly is required by the local municipalities water department to prevent the stagnant water found in the fire sprinkler system from cross contaminating the public water supply.

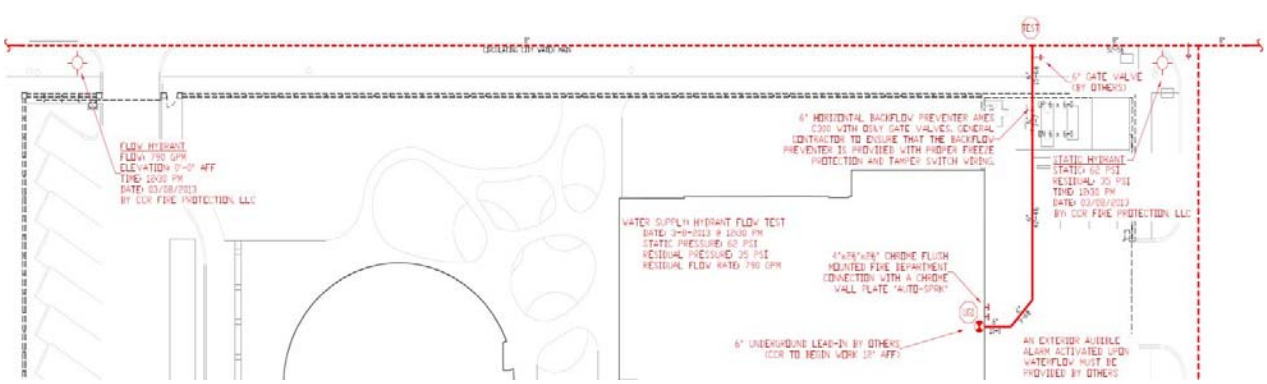

Figure 36 Water Supply

System

The building is equipped throughout with an automatic wet-pipe fire sprinkler system, designed and installed per NFPA 13. According to Section 4.1, the building must be provided with sprinklers in all areas, except where omissions are permitted by NFPA 13, to maintain an acceptable level of protection.

To provide adequate protection, the hazard occupancy classifications found in the building must be defined. Understanding the building is primarily an assembly occupancy with supporting spaces, the building is largely a Light Hazard (LH) occupancy with select supporting areas defined as Ordinary Hazard Group I (OHI) occupancies. The occupancy classifications are referenced throughout the standard to define occupancy specific installation and hydraulic calculation requirements.

Area Limitations

Section 8.2 addresses the protection area limitation for one system riser. It states that a Light Hazard or an Ordinary Hazard occupancy system is limited to a maximum protection area, on any one floor, to be 52,000 ft.^{2}. The greatest floor area of the building is 29,600 ft.^{2}; therefore, the building is acceptably protected with one fire sprinkler system.

Sprinklers

The sprinkler is the most important component of the system. It has two key roles, as a discharge device and a heat detector. The sprinkler operates automatically when its fusible element reaches its rated temperature, allowing water to discharge in an engineered spray pattern over an area defined by the sprinklers specific characteristics.

Characteristics

The sprinkler characteristics are defined by the discharge, temperature rating, thermal sensitivity, orientation, and spray pattern.

Figure 37 Sprinkler Legend

Figure 37, shows a sample of the sprinklers installed throughout the building. Each unique sprinkler was selected based on its characteristics to provide acceptable protection explicit to its associated application.

Discharge – of sprinklers is determined by the orifice size of the sprinkler and defined as a k-factor (gpm/psi$^{1/2}$). As shown in Figure 37, the most common k-factor is K5.6. The K5.6 sprinklers are found throughout the building, except in locations required to meet a specific performance criteria. For instance, the sprinklers noted in Figure 37 with k-factors 8.0 and 11.2 are extended coverage sprinklers required to deliver water over a greater area. The Section 23.4.4.10 requirement for the minimum operating pressure for all sprinklers, unless specifically defined in another section or in the manufacturer's datasheet, is 7 psi. Thus, the K5.6 sprinklers will discharge water at a minimum rate of

14.8 gpm. The K8.0 and the K11.2 have minimum flow and pressure requirements defined by the manufacturer's datasheet. The K8.0 sprinkler's minimum operating pressure is also 7 psi and the discharge rate is 21 gpm. However, the K11.2 has a minimum operating pressure of 7.2 psi and the discharge rate is 30 gpm. The actual operating pressure and the discharge rate are also dependent on the required hazard occupancy discharge density relative to the area of coverage. The Hydraulic Calculations section of this report addresses the sprinkler discharge characteristics further.

Temperature Rating – refers to the temperature the sprinkler must be exposed to in order to activate. Because the principal hazard occupancy is LH the sprinklers must have an ordinary temperature rating, 135°F - 170°F, or an intermediate temperature rating, 175°F - 225°F, except where susceptible to high temperature exposure. According to fire sprinkler plans, most of the sprinklers have a temperature rating of 165°F or 155°F. Both temperatures are within the ordinary temperature range. There are locations where Intermediate temperature sprinklers are installed, such as the mechanical rooms and the unventilated concealed spaces where the ambient temperatures are slightly higher. The only locations requiring high temperature sprinklers, with a temperature rating of 286°F, are the cooler and freezer, because of the automatic defrosting system, which exposes the sprinkler to a high temperature generated by the heating process necessary for defrosting.

Thermal Sensitivity – is in regard to the speed the thermal element operates once the temperature rating of the sprinkler is reached. The sensitivity is measured as the response time index (RTI). According to Section 8.3.3, sprinklers installed in LH occupancies must be quick-response sprinklers with an RTI of 50 $(m\text{-}s)^{1/2}$ or less. All sprinklers installed throughout the building are quick-response adhering to the requirement of Section 8.3.3.

Orientation – of the sprinklers is dependent on the construction and the desired results of an application. There are three common orientations used in the building. Upright sprinklers are installed on the top of the sprinkler system piping with the frame arms pointing up vertically and the deflector located on top, and is used in locations without a suspended ceiling below the ceiling deck. The pendent sprinklers point down vertically towards the floor area below and are installed below smooth ceilings. There are areas that the pendent and upright sprinklers are not the best solution, and horizontal sidewalls are required to be installed against a vertical wall, placed down from the ceiling within a prescribed distance.

Spray Pattern – is the water discharge pattern developed by the sprinkler deflector. The pendent and upright sprinklers create an umbrella pattern that wets a circular area on the floor below and the adjacent walls within the area of coverage. The horizontal sidewall sprinklers have special deflector that develops a quarter sphere pattern. The sidewall pattern covers a half circle area below the sprinkler extending a radial length on either side of the sprinkler along the wall and 90° to the front of the sprinkler with some of the water deflected against the wall below and adjacent to the sprinkler.

Location

Sprinklers must be located near the ceiling or deck of the protected area. The sprinklers used throughout the building must have the deflector between 1 in. and 12 in. below the ceiling or deck. However, if the sprinkler is installed exposed to obstructed construction the deflector may be installed 1 in. to 6 in. below the bottom of a beam, but cannot exceed 22 in. below the deck.

Protection Area and Spacing

The sprinkler protection areas and spacing are dependent on the occupancy classification and the construction type. Table 11 indicates the spacing and protection area requirements for LH occupancies, with the combinations specific to the Maumus Center marked in red.

Table 11 Light Hazard Spacing & Area [10]

Table 8.6.2.2.1(a) Protection Areas and Maximum Spacing of Standard Pendent and Upright Spray Sprinklers for Light Hazard

Construction Type	System Type	Maximum Protection Area		Maximum Spacing	
		ft²	m²	ft	m
Noncombustible unobstructed	Hydraulically calculated	225	20.9	15	4.6
Noncombustible unobstructed	Pipe schedule	200	18.6	15	4.6
Noncombustible obstructed	Hydraulically calculated	225	20.9	15	4.6
Noncombustible obstructed	Pipe schedule	200	18.6	15	4.6
Combustible unobstructed with no exposed members	Hydraulically calculated	225	20.9	15	4.6
Combustible unobstructed with no exposed members	Pipe schedule	200	18.6	15	4.6
Combustible unobstructed with exposed members 3 ft (0.91 m) or more on center	Hydraulically calculated	225	20.9	15	4.6
Combustible unobstructed with exposed members 3 ft (0.91 m) or more on center	Pipe schedule	200	18.6	15	4.6
Combustible unobstructed with members less than 3 ft (0.91 m) on center	All	130	12.1	15	4.6
Combustible obstructed with exposed members 3 ft (0.91 m) or more on center	All	168	15.6	15	4.6
Combustible obstructed with members less than 3 ft (0.91 m) on center	All	130	12.1	15	4.6
Combustible concealed spaces in accordance with 8.6.4.1.4	All	120	11.1	15 parallel to the slope 10 perpendicular to the slope*	4.6 parallel to the slope 3.05 perpendicular to the slope*

In addition, OHI occupancies have a maximum protection area of 130 ft.^{2}, with an allowed maximum spacing of 15 ft. Also, the extended coverage sprinklers have an increased maximum area and spacing defined by explicit parameters determined by manufacturer testing and outlined in the manufacturer datasheet. The extended coverage sprinklers used in the building have a maximum 16 ft. spacing and a maximum protection area of 256 ft.^{2} based on the associated hydraulic design data found in the manufacturer datasheets.

The sprinklers also have a minimum spacing requirement to prevent cold soldering. Cold soldering is the cooling of the air around the adjacent sprinklers delaying or even preventing their activation. The standard spray sprinklers must maintain a minimum 6 ft. between sprinklers and the extended coverage sprinklers must be spaced a minimum of 8 ft. between sprinklers to prevent any negative effects.

Obstructed construction has additional implications that may affect the sprinkler spacing in certain applications. The Maumus Center applications affected by obstructed construction are the combustible concealed spaces and the rooms with exposed structural steel at the ceiling. The roof structure in the combustible concealed spaces extends less than 12 in. below the roof deck; therefore, the structural elements near the deck do not affect the sprinkler performance, and special spacing requirements are not applied. Though, in the Planetarium, the sprinklers installed at the deck are affected by the steel beams supporting the roof. The beams in this area exceed 22 in. in depth. As a result, sprinklers cannot be installed beneath the beams and must be installed in each beam pocket within 1 in. to 22 in. from the deck.

Chapter 8 further addresses obstruction rules that must be applied in applications where components of the building are installed near the ceiling interrupting the discharge pattern of the sprinkler or modifying the heat plume characteristics. Majority of the sprinklers throughout the building are installed beneath smooth unobstructed ceilings with little or no obstructions located near the ceiling; for this reason, the obstruction rules are not addressed in this report.

Components

The sprinkler system is constructed of a network of components needed to effectively deliver water to the sprinklers. The key components are the piping and fittings, hanging and supporting material, and the elements of the riser.

Piping & Fittings

The system piping and fittings must conform to the standards in Sections 6.3 and 6.4. The fire sprinkler system Equipment Data Submittal was evaluated to determine the pipe and fittings are acceptable with the requirements outlined in the NFPA 13.

Piping – used throughout the system is ferrous black welded steel pipe manufactured in accordance with the guidelines defined in the ANSI/ASTM A53 standard. Instances where the pipe extends through an exterior wall of the building, the pipe is hot-dipped zinc-coated, in other words galvanized, to extend the life of the pipe by delaying corrosion from exposure to the outside atmosphere. The steel pipe has either a schedule 10 wall thickness for pipe with grooved ends or a schedule 40 wall thickness for pipe with threaded ends.

Fittings – used to join pipe, connecting the system together to create a complete network, must conform to ASME B16.4 for cast iron threaded fittings meeting a minimum pressure classification of 125, and to Section 6.4.4 and the manufacturer's listing for cast iron and ductile iron grooved fittings.

Hanging & Supporting

The system piping must be supported from the structure in accordance with Chapter 9. The pipe support and hanger types for the building do not require special applications; therefore, engineered alternatives are not addressed. The hanger components that attach directly to the building structure or to the fire sprinkler pipe must be listed or approved for the intended use, and this is confirmed by referencing the manufacturers equipment datasheet for the attachments. Figure 38 illustrates the typical hangers supporting the sprinkler system. Each hanger type shown is specific to the structural element it is attached to.

The piping hangers are mostly assembled with three parts. First, is the pipe attachment, which is a swivel ring sized according to the pipe it is supporting and UL Listed and FM Approved for fire protection pipe support. Second, is the structural attachment, which varies depending on the structural component it is attaching to. For example, the attachments found in the building are wood screws that screw into the wooden elements, concrete anchors inserted in concrete decks, and top beam clamps (c-clamps) that attach to the top flange of a steel beam or joist. These are also listed and approved for their specific application. Third, is commonly all thread rod that extends between the pipe attachment and the structural attachment to suspend the pipe at a specified elevation. The all thread rod is not required to be listed or approved. However, the diameter of the rod must conform to the minimum requirements defined in NFPA 13 Table 9.1.2.1. All pipe 4 in. or less in diameter must be supported with a rod diameter no less than 3/8 in., and all 6 in. pipe must be supported with a rod diameter no less than 1/2 in.

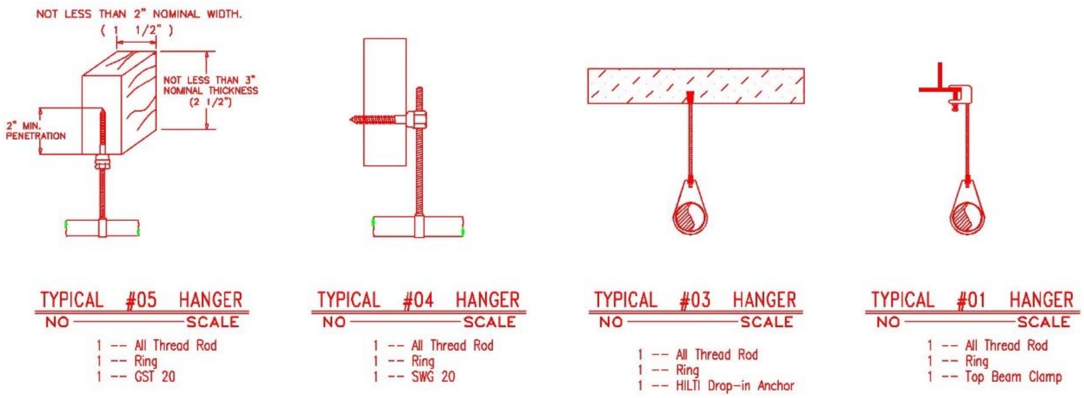

Figure 38 Hanger Details

The hangers are limited to a maximum spacing distance dependent on the pipe size being supported. All pipe 1¼ in. or less in diameter must not exceed 12 ft. between hangers and all pipe 1½ in. or larger in diameter must not exceed 15 ft. between hangers. Figure 39 illustrates two hangers within 12 ft. the spacing limitation, along an 1¼ in. branch line.

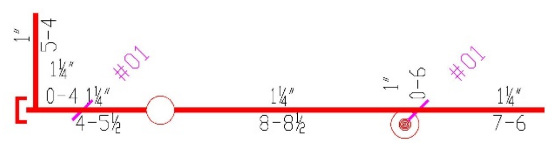

Figure 39 Hanger Spacing

Riser

The system riser is considered the control center of the system. The water supply must pass through the riser before entering the system piping network. For a wet-pipe sprinkler system the riser consists of a control valve used to turn the supply on or off, a check valve to minimize system pressure fluctuations, pressure gauges reading the supply water pressure and the system water pressure, a 2 in. main drain used to drain the system when needed, a waterflow switch attached to the building fire alarm system to report an alarm signal when a sprinkler activates allowing water to flow through the system, and a connection to a fire department connection used by the responding fire department to supplement the fire sprinkler system with additional flow and pressure. The noted components are indicated in the riser detail found in Figure 40.

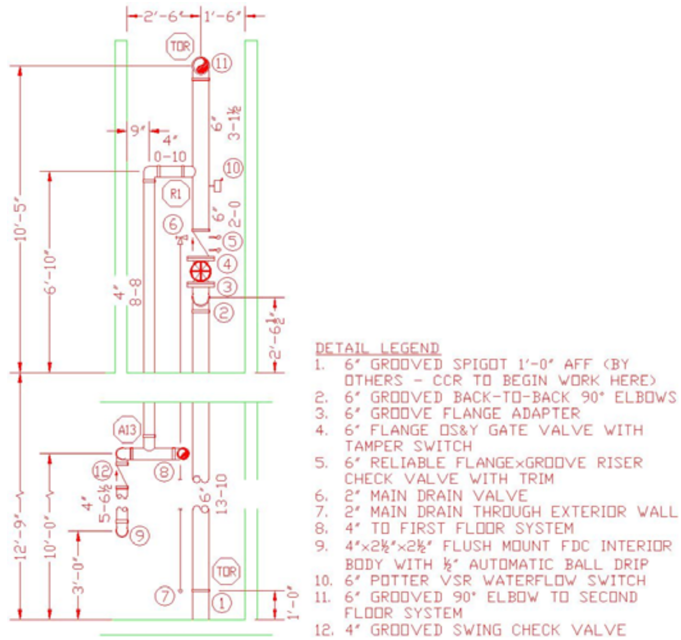

Figure 40 Riser Detail

At times the inspector's test connection is installed on the riser, downstream of the water flow switch, and is equipped with a discharge orifice equivalent to the smallest sprinkler orifice found in the system to simulate one sprinkler flowing, to test the responsiveness of the water flow switch. Upon opening of the test valve an alarm signal must activate within 90 seconds. The inspector's test for this system is located remotely, and is an integral test and drain valve with a K5.6 orifice located in the valve, see Figure 41.

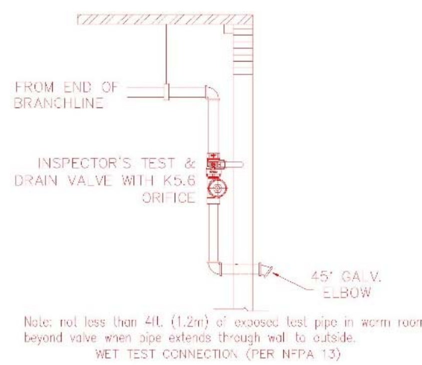

Figure 41 Inspector's Test

Special Situations

The Maumus Center has three special situations regarding the fire sprinkler system that require further review.

Planetarium Projection Screen

The Planetarium has a perforated aluminum dome projection screen located over the entire seating area. Projection screens for this application are perforated and approximately 22 percent open. The screen's effect on the sprinkler system was not considered in the fire sprinkler design based on the fire sprinkler construction documents. The screen poses a concern regarding the sprinkler activation time and the ability for the sprinkler discharge to reach the hazard in the event of a fire beneath the screen.

Telescopic Seating

The Auditorium has theater-type seating that is designed to fold up against the wall or telescope out over the floor area, creating a shielded space beneath the seating. Because of the two

opposing positions of the seating system, there is not a practical fire sprinkler application to protect both positions. Due to this application, the AHJ requested extended coverage horizontal sidewall sprinklers to be installed along the wall behind the elevated end of the seating system. The intended result of the extended coverage sprinklers is to provide coverage below the seating in the event a fire were to occur in this space. Figure 42 illustrates the location of the extended coverage sprinklers in plan view.

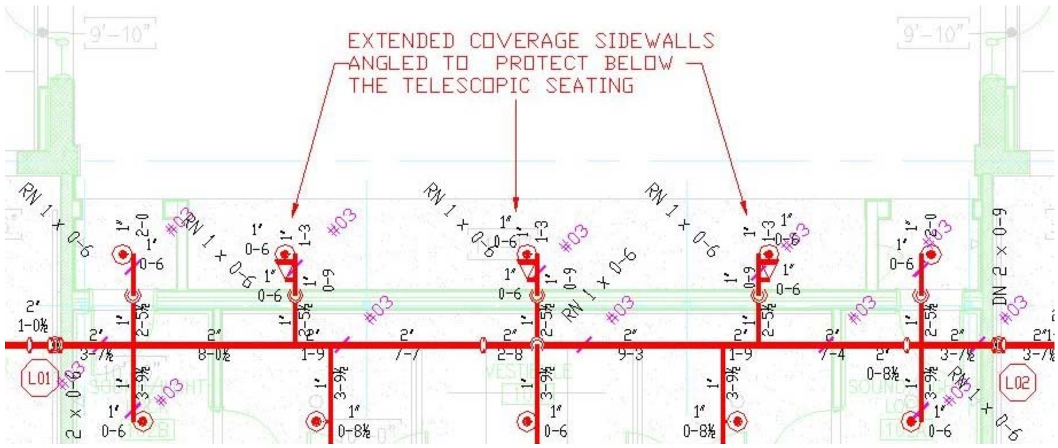

Figure 42 Extended Coverage Sidewall Sprinklers

The concept of the added sprinklers may work; however, the telescopic seating, when fully extended, begins at the edge of the ceiling fur down, shown in Figure 42, and there are pendent sprinklers installed in the bottom of the fur down, located above the extended coverage sidewall sprinklers. Because of the pendent sprinklers' location directly above the horizontal sidewall sprinklers, the pendent sprinklers are likely to activate before the sidewall sprinklers. If this were to occur, the horizontal sidewalls would likely cold solder because of the pendent sprinklers spray. This application is beyond the capabilities of the fire sprinkler system.

Combustible Concealed Spaces

Section 8.15.1.1 requires fire sprinklers to be installed in concealed spaces with exposed combustible construction, unless explicitly defined as an exception found in Section 8.15.1.2.

The original two-story section of the building built in 1929 was constructed with wood floor joists and wood trusses. The wood floor joists are concealed in an interstitial space between the first story ceiling and the second story floor with gypsum board attached directly to the bottom of the joists. According to Section 8.15.1.2.5, this scenario is defined as an exception, not requiring fire sprinkler protection. However, the wood trusses found in the attic, supporting the building roof, are required to be protected.

The combustible attic space is an inaccessible space satisfying Section 8.15.1.3 allowance as a LH occupancy, and as noted in Table 11, requiring a maximum coverage area of 120 ft.^{2} with a maximum spacing parallel to the roof slope of 15 ft. and perpendicular to the roof slope of 10 ft. Further, the depth of the attic cavity exceeds 36 in. allowing the use of standard spray sprinklers and not special application sprinklers.

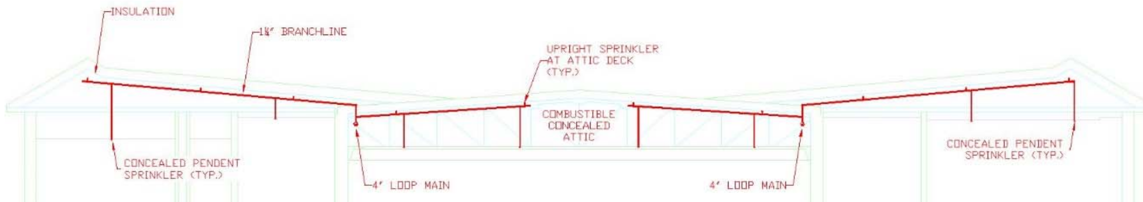

Figure 43 Combustible Concealed Attic Section

Hydraulic Calculations

The fire sprinkler system is a hydraulically designed system, and was designed by following the hydraulic calculation procedures defined in Section 23.4 to determine the most effective pipe sizes capable of delivering a prescribed water density over a specified area utilizing the available water supply. The hydraulic calculations were performed with a computer-based hydraulic calculation software (HydraCALC) applying the Hazen-Williams friction loss equation to calculate an accumulative pressure and flow demand for each defined design area.

There are eight design areas evaluated to confirm the pipe diameters are capable of delivering the required water with a demand less than the available water supply.

Design Area 1

- Hazard Occupancy
  - Light Hazard: Planetarium 148
  - Ordinary Hazard Group I: Mechanical Mezzanine 301
  - Principal Hazard Occupancy (Section 11.1.5.2): Light Hazard
- Density: 0.10 gpm/ft.^{2} (Light Hazard) | 0.15 gpm/ft.^{2} (Ordinary Hazard Group I)
- Design Area: 1,538 ft.^{2}
- Adjustments: None
- Sprinklers
  - Number Flowing: 23
  - K-Factor: 5.6
- System Demand (at City Connection)
  - Flow: 381.91 gpm
  - Pressure: 44.60 psi
  - Hose Stream Allowance: 100 gpm

Design Area 2

- Hazard Occupancy
  - Light Hazard: Stair B/Vestibule 229A/Exhibit 229
  - Ordinary Hazard Group I: Mechanical 230/Storage 231
  - Principal Hazard Occupancy (Section 11.5.1.2): Light Hazard
- Density: 0.10 gpm/ft.^{2} (Light Hazard) | 0.15 gpm/ft.^{2} (Ordinary Hazard Group I)
- Design Area: 1,003 ft.^{2}
- Adjustments: 38% Allowable Design Area Reduction for Quick-Response Sprinklers (Section 11.2.3.2.3.1)
- Sprinklers
  - Number Flowing: 9
  - K-Factor: 5.6
- System Demand (at City Connection)

  - Flow: 152.99 gpm
  - Pressure: 35.82 psi
  - Hose Stream Allowance: 100 gpm

Design Area 3

- Hazard Occupancy
  - Light Hazard: Hall 215A/Exhibit 216/Exhibit 217
  - Ordinary Hazard Group I: Electrical Closet 213
  - Principal Hazard Occupancy (Section 11.5.1.2): Light Hazard
- Density: 0.10 gpm/ft.^{2} (Light Hazard) | 0.15 gpm/ft.^{2} (Ordinary Hazard Group I)
- Design Area: 990 ft.^{2}
- Adjustments: 38.5% Allowable Design Area Reduction for Quick-Response Sprinklers (Section 11.2.3.2.3.1)
- Sprinklers
  - Number Flowing: 9
  - K-Factor: 5.6
- System Demand (at City Connection)
  - Flow: 209.76 gpm
  - Pressure: 43.64 psi
  - Hose Stream Allowance: 100 gpm

Design Area 4

- Hazard Occupancy
  - Light Hazard: Cafeteria 131
- Density: 0.10 gpm/ft.^{2} (Light Hazard)
- Design Area: 1,635 ft.^{2}
- Adjustments: None
- Sprinklers
  - Number Flowing: 14
  - K-Factor: 11.2
  - Minimum Operating Pressure: 7.2 PSI
- System Demand (at City Connection)
  - Flow: 450.18 gpm
  - Pressure: 36.80 psi
  - Hose Stream Allowance: 100 gpm

Design Area 5

- Hazard Occupancy
  - Ordinary Hazard Group I: Mechanical 227/Boiler Room 228
- Density: 0.15 gpm/ft.^{2} (Ordinary Hazard Group I)
- Design Area: 1,051 ft.^{2}
- Adjustments: 38% Allowable Design Area Reduction for Quick-Response Sprinklers (Section 11.2.3.2.3.1)
- Sprinklers
  - Number Flowing: 11
  - K-Factor: 5.6
- System Demand (at City Connection)
  - Flow: 326.89 gpm
  - Pressure: 33.44 psi
  - Hose Stream Allowance: 250 gpm

Design Area 6

- Hazard Occupancy
  - Light Hazard: Exhibit 141
  - Ordinary Hazard Group I: Storage 143
  - Principal Hazard Occupancy (Section 11.5.1.2): Light Hazard
- Density: 0.10 gpm/ft.^{2} (Light Hazard) | 0.15 gpm/ft.^{2} (Ordinary Hazard Group I)
- Design Area: 1,003 ft.^{2}
- Adjustments: 38.75% Allowable Design Area Reduction for Quick-Response Sprinklers (Section 11.2.3.2.3.1)
- Sprinklers
  - Number Flowing: 8
  - K-Factor: 5.6
- System Demand (at City Connection)
  - Flow: 165.07 gpm
  - Pressure: 42.44 psi
  - Hose Stream Allowance: 100 gpm

Design Area 7

- Hazard Occupancy
  - Light Hazard: Pre-Show 147/SL-Lock 151
  - Ordinary Hazard Group I: Mechanical 152
  - Principal Hazard Occupancy (Section 11.5.1.2): Light Hazard
- Density: 0.10 gpm/ft.^{2} (Light Hazard) | 0.15 gpm/ft.^{2} (Ordinary Hazard Group I)
- Design Area: 991 ft.^{2}
- Adjustments: 39.38% Allowable Design Area Reduction for Quick-Response Sprinklers (Section 11.2.3.2.3.1)
- Sprinklers
  - Number Flowing: 11
  - K-Factor: 5.6
- System Demand (at City Connection)
  - Flow: 215.16 gpm
  - Pressure: 38.46 psi
  - Hose Stream Allowance: 100 gpm

Design Area 8

- Hazard Occupancy
  - Light Hazard: Exhibit 114/Exhibit 115
- Density: 0.10 gpm/ft.^{2} (Light Hazard)
- Design Area: 983 ft.^{2}
- Adjustments: 38.75% Allowable Design Area Reduction for Quick-Response Sprinklers (Section 11.2.3.2.3.1)
- Sprinklers
  - Number Flowing: 9
  - K-Factor: 5.6
- System Demand (at City Connection)
  - Flow: 296.13 gpm
  - Pressure: 46.92 psi
  - Hose Stream Allowance: 100 gpm

It was necessary to calculate each design area because of the building layout, the system configuration, and the various hazard applications to prove the piping supplying each area is sized adequately. Though, there are eight

design areas, the most demanding area is Design Area 1 found in the Planetarium; thus, further evaluation is advised.

Design Area 1

Design Area 1 is the most remote area from the system riser, has sprinklers discharging at the highest elevation above the city connection, and a large number of sprinklers flowing because of the obstructed construction.

The remoteness of the design area necessitates the need for a greater linear footage of pipe between the area and the riser involving an enhanced potential for additional fittings. To comprehend the implications of the extended distance from the riser, an understanding of the Hazen-Williams formula is recommended. The formula calculates the friction loss per foot of a section of pipe, dependent on the internal roughness factor (C-Factor) of the pipe, the internal pipe diameter, and the volume flow rate of water through the pipe. The results are then summed for every linear foot of pipe from the source to the point of discharge. Therefore, as the distance increases the friction loss increases. Also, each fitting has an equivalent pipe length, adding to the overall friction loss. The total friction loss for Design Area 1 resulting from the remoteness of the area is 13.58 psi. The friction loss was controlled, to minimize the impact, by using large diameter pipe, see Figure 44.

The pressure loss due to elevation is the greatest loss affecting Design Area 1. The highest discharging sprinkler above grade is 41'-2½" above grade; consequently, the total pressure loss due to this elevation is 17.85 psi. This pressure is calculated by multiplying the elevation change between the source and the discharge outlet by 0.433.

There is a total number of 23 flowing sprinklers that were calculated for a LH remote area of 1538 ft.^{2}. The excessive number of sprinklers flowing is because the sprinklers have a reduced spacing perpendicular to the deep roof beams. The roof beams extend further than 22 in. below the roof deck requiring sprinklers to be installed in the beam pockets. This arrangement results in a greater system flow demand. The resultant flow demand is 381.9 gpm. The calculated system demand is 40 percent greater than the minimal flow required for a LH occupancy with the same design area.

An additional factor affecting the pressure demand is the actual operating pressure of the most demanding sprinkler. The actual operating pressure is derived from the actual flow and the sprinkler's k-factor. For instance, sprinkler node S16 (shown in Figure 44 and Table 12) has a 5.6 k-factor and is over discharging with a flow rate of 20.32 gpm, resulting in an operating pressure of 13.17 psi. This pressure is 188 percent greater than the minimum required operating pressure of 7 psi.

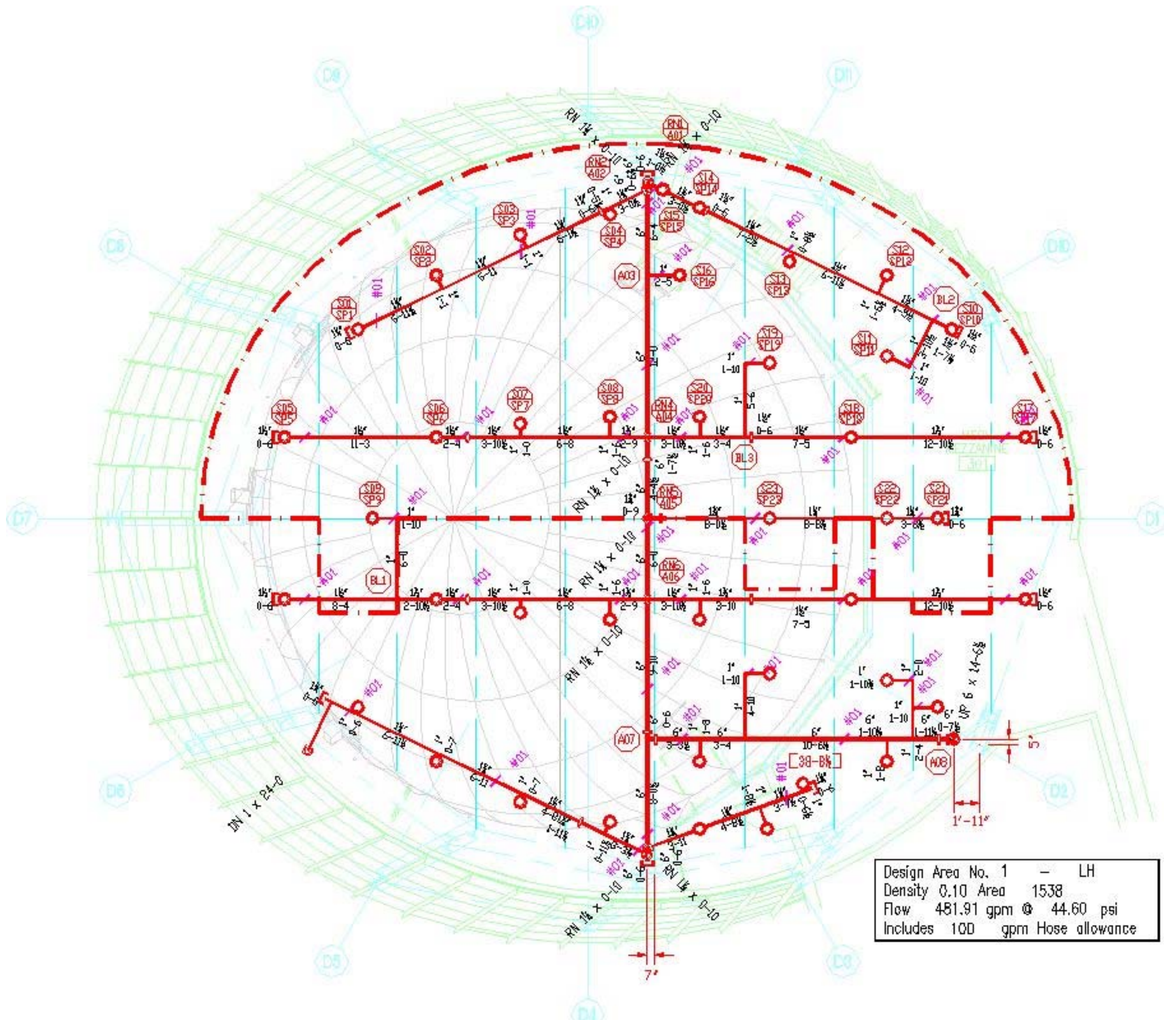

Figure 44 Design Area 1

Table 12 Design Area 1 Flow Summary

Node No.	Elevation	K-Fact	Pt Actual	Pn	Flow Actual	Density	Area	Press Req.
S01	41.208	5.6	8.2	na	16.03	0.1	81	7.0
S02	41.208	5.6	8.1	na	15.93	0.1	70	7.0
S03	41.208	5.6	8.61	na	16.43	0.1	81	7.0
S04	41.208	5.6	9.74	na	17.48	0.1	87	7.0
S05	41.208	5.6	7.56	na	15.4	0.1	154	7.0
S06	41.208	5.6	7.67	na	15.51	0.1	87	7.0
S07	41.208	5.6	7.65	na	15.49	0.1	81	7.0
S08	41.208	5.6	8.08	na	15.92	0.1	87	7.0
S09	41.208	5.6	12.01	na	19.4	0.1	112	7.0
S10	41.208	5.6	7.69	na	15.53	0.15	81	7.0
S11	41.208	5.6	7.02	na	14.84	0.15	92	7.0
S12	41.208	5.6	7.58	na	15.42	0.15	46	7.0
S13	41.208	5.6	8.12	na	15.96	0.15	81	7.0
S14	41.208	5.6	9.28	na	17.06	0.15	60	7.0
S15	41.208	5.6	9.87	na	17.59	0.1	20	7.0
S16	41.208	5.6	13.17	na	20.32	0.1	97	7.0
S17	41.208	5.6	8.48	na	16.3	0.15	87	7.0
S18	41.208	5.6	8.61	na	16.43	0.1	26	7.0
S19	41.208	5.6	8.01	na	15.85	0.1	126	7.0
S20	41.208	5.6	8.86	na	16.67	0.1	100	7.0
S21	41.208	5.6	9.4	na	17.17	0.15	112	7.0
S22	41.208	5.6	9.49	na	17.25	0.15	48	7.0
S23	41.208	5.6	10.25	na	17.93	0.1	112	7.0

The demand at the city connection for Design Area 1 is 381.91 gpm flowing with a pressure of 44.60 psi plus 100 gpm outside hose allowance. This demand is within the limits of the available water supply resulting in a 6.6 psi safety margin, as shown in Figure 45.

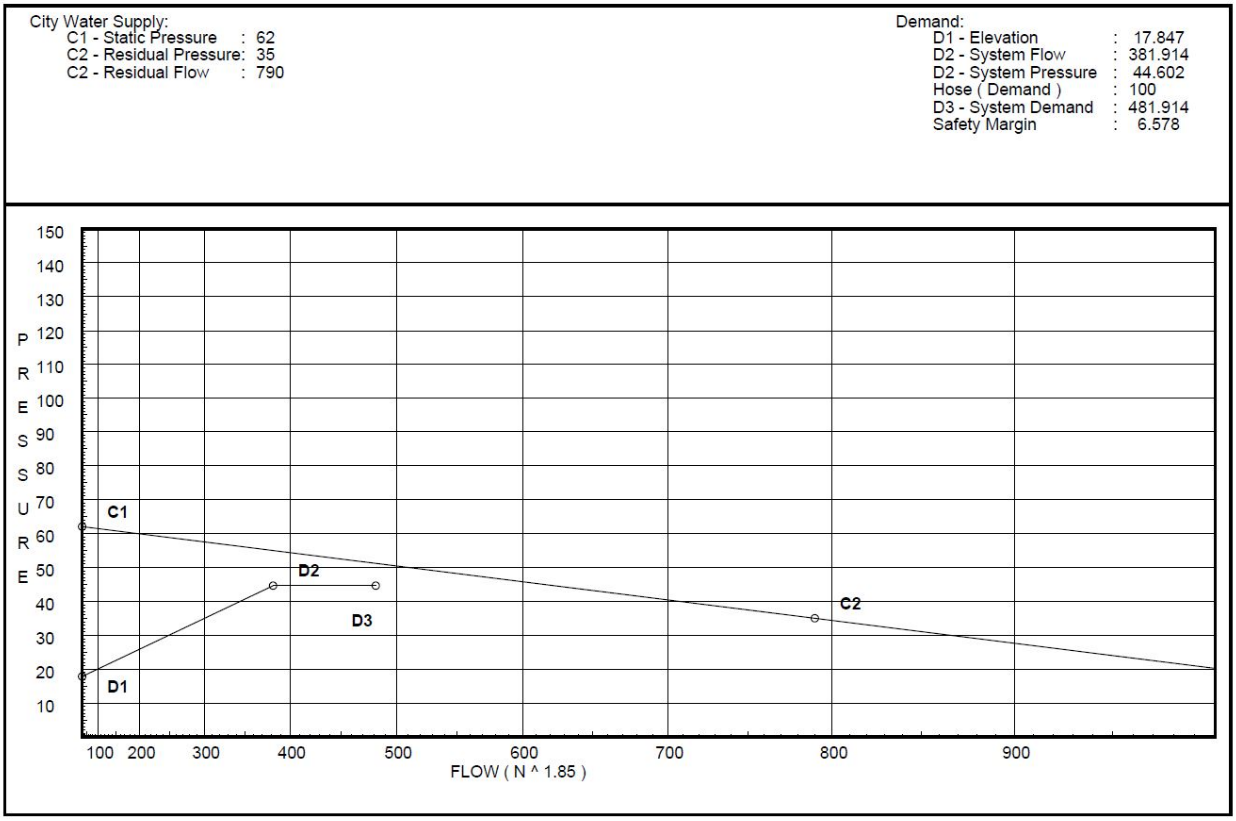

Figure 45 Design Area 1 Hydraulic Graph

Inspections, Testing, & Maintenance

The fire sprinkler system must be inspected, tested, and maintained in accordance with NFPA 25 to assure the system will operate as designed. The building owner is responsible for maintaining and inspecting the system, and in most cases, the building owner will contract the system maintenance out to a licensed fire sprinkler contractor. The sprinkler contractor will perform quarterly and annual inspections, test the system, perform routine maintenance, and repair any system impairments. The building owner or an owner's representative generally performs the weekly visual inspections.

It is important to coordinate specific inspections prior to the pivotal season changes. Specifically, in the Fall, before freezing conditions begin, and in the Spring, after the last freeze. These inspections are to assure the system is prepared for the changing of the seasons; pertaining mainly to dry-pipe fire sprinkler systems and anti-freeze systems. In addition, it is recommended to inspect the building envelope for openings that may allow freezing air into the building and to assure the heating system is in operation to prevent wet-pipe fire sprinkler systems from freezing during the Winter months.

It is also imperative that the building owner takes caution when renovating the building, changing occupancies, and/or modifying storage arrangements. These changes can affect the sprinkler system negatively, and may

require modifying or replacing the existing system. The following examples further describe how these scenarios can negatively affect the fire sprinkler system:

- Renovations can create obstructions that may impair a fire sprinkler system.
- An occupancy change may invoke additional storage and building allowances that may require additional fire sprinkler protection beyond what is existing.
- A change in the storage arrangement may require a more strenuous design criteria that is beyond the capability of the existing system.

If the building owner intends on making any of these changes, the owner is responsible for commissioning a professional to evaluate the design implications to the fire sprinkler system. Also, if a third-party inspector notices these changes the inspector must address their concerns to the building owner. In either event, the AHJ must be notified of any changes to evaluate and enforce the required modifications to the system.

The inspection, testing, and maintenance frequency requirements outlined in NFPA 25 and specific to the Maumus Center's fire sprinkler system, are shown in Table 13 on the following page.

Table 13 NFPA 25 Table 5.1 | Table 13.1 [12]

Item	Frequency
Inspection	
Control Valve	Monthly
Check Valve - Interior	5 Years
Waterflow Device	Quarterly
Valve Supervisory Device	Quarterly
Gauges	Quarterly
Hydraulic Name Plate	Quarterly
Building	Annually
Hangers	Annually
Pipe and Fittings	Annually
Sprinklers	Annually
Spare Sprinklers	Annually
Fire Department Connection	Quarterly
Obstruction - Pipe Interior	5 Years
Test	
Waterflow Device	Semi-Annually
Waterflow Alarm	Semi-Annually
Valve Supervisory Device	Semi-Annually
Main Drain	Annually
Contol Valve - Position	Annually
Control Valve - Operation	Annually
Control Valve - Supervisory	Semi-Annually
Backflow Prevention Assembly	Annually
Gauges	5 Years
Sprinklers - Fast-Response	At 20 Years & Every 10 Years Thereafter
Sprinklers	At 50 Years & Every 10 Years Thereafter
Maintenance	
Control Valve	Annually or As Needed
Obstruction Investigation	5 Years or As Needed
Investigation	
Obstruction	As Needed

The fire sprinkler system satisfies the minimum requirements defined in the LSC and in NFPA 13; however, the special situations addressed, regarding the Planetarium and the Auditorium, are beyond the scope of NFPA 13. Therefore, further analysis is recommended to provide an acceptable solution specific to each situation. To continue, the fire alarm system requirements must be analyzed.

Fire Alarm System

A fire alarm system is a means of active fire protection designed to detect a fire condition, communicate the condition to the building occupants and the local first responders, and alarm the building occupants. Beyond the primary objective of detecting a fire scenario and initiating the evacuation sequence, the system provides supervision for other fire protection systems and communicates supervisory and trouble conditions when the system is not in a normal state. These additional features provide the building owner the information necessary to maintain the system in normal operation in the event the system is needed for an emergency.

The LSC defines where fire alarm systems are to be installed specific to the use of the building. The building is an existing assembly occupancy; therefore, Section 13.3.4 requires the installation of a fire alarm system in accordance with Section 9.6.1 and Section 13.3.4, considering the occupant load exceeds 300 occupants. A new fire alarm system was designed and installed in the Maumus Center during the revitalization project.

Unable to obtain the fire alarm construction documents for review, this analysis is based on the building electrical drawings and specifications, which provide a high-level reference for the general requirements specific to the building's fire alarm system. All fire alarm design drawings referenced were prepared by myself, as if I were contracted to prepare the fire alarm construction package; therefore, the design and the equipment referenced do not reflect the actual built conditions.

This section analyzes the building's fire alarm system beginning with the type of system required, the system's components and their operating requirements, and ending with general information outlining where to find the inspection, testing, and maintenance requirements.

System Type

The Maumus Center's fire alarm system is an In-Building Fire Emergency Voice/Alarm Communications System (EVAC). NFPA 72 defines an EVAC system as "dedicated manual or automatic equipment for originating and distributing voice instructions, as well as alert and evacuation signals pertaining to a fire emergency, to the occupants of a building" [14]. An EVAC system operates as a fire alarm system consisting "of components and circuits arranged to monitor and annunciate the status of fire alarm or supervisory signal-initiating devices and to initiate the appropriate response to those signals" [14] An EVAC system satisfies the objectives regarding the means of initiation and notification required for an assembly occupancy defined in the LSC Section 13.3.4.

The primary means of initiation for the system is an electronically supervised automatic fire sprinkler system per the LSC Section 13.3.4.2 and one manual pull station per the LSC Section 9.6.2.6.

The required means of notification is automatically transmitted or live voice evacuation instructions in accordance with the LSC Section 13.3.4.3.3. Though the building is an existing assembly occupancy, the fire alarm system is a new system; therefore, the LSC Section 12.3.4.3.4 is applied requiring visible notification along with the voice instructions.

System Operation

The system has a sequence of operations consisting of inputs and corresponding outputs to satisfy the requirements addressed throughout NFPA 72 for the integral components of the EVAC system. The sequence of operations matrix for the Maumus Center is shown in Figure 46.

MAUMUS CENTER FIRE ALARM SYSTEM SEQUENCE OF OPERATIONS	OUTPUTS: FACP ANNUNCIATION							OUTPUTS: NOTIFICATION							OUTPUTS: CONTROL						
INPUTS	COMMON ALARM SIGNAL INDICATOR	AUDIBLE ALARM SIGNAL	COMMON SUPERVISORY SIGNAL INDICATOR	AUDIBLE SUPERVISORY SIGNAL	COMMON TROUBLE SIGNAL INDICATOR	AUDIBLE TROUBLE SIGNAL	LOCATION INDICATOR MESSAGE	ACTUATES VISUAL NOTIFICATION APPLIANCES	ACTUATES AUDIBLE VOICE EVACUATION MESSAGE	ACTUATES EXT. AUDIO/VISUAL NOTIFICATION APPLIANCE	TRANSMIT ALARM SIGNAL TO SUPERVISING STATION	TRANSMIT SUPERVISORY SIGNAL TO SUPERVISING STATION	TRANSMIT TROUBLE SIGNAL TO SUPERVISING STATION	TRANSMIT WATER FLOW SIGNAL TO SUPERVISING STATION	ACTUATES FIRE DOOR RELEASE	ACTUATES SHUNT TRIP - ELEVATOR	ACTUATES VISUAL WARNING SIGNAL - ELEVATOR	RECALL ELEVATOR TO PRIMARY RECALL FLOOR (1st FLOOR)	RECALL ELEVATOR TO ALTERNATE RECALL FLOOR (2nd FLOOR)	ACTUATES SHUTDOWN OF AUDIO SYSTEM	ACTUATES SHUT DOWN OF CORRESPONDING AIR HANDLER
MANUAL PULL STATION	X	X					X	X	X		X									X	
SMOKE DETECTOR - ABOVE PANEL(S)	X	X					X	X	X		X									X	
SMOKE DETECTOR - ADJACENT TO SMOKE DOOR	X	X					X	X	X		X				X					X	
SMOKE DETECTOR - 1st FLOOR ELEVATOR LOBBY	X	X					X	X	X		X								X	X	
SMOKE DETECTOR - 2nd FLOOR ELEVATOR LOBBY	X	X					X	X	X		X							X		X	
SMOKE DETECTOR - ELEVATOR MACHINE ROOM	X	X					X	X	X		X						X		X	X	
SMOKE DETECTOR - TOP OF ELEVATOR SHAFT	X	X					X	X	X		X						X	X		X	
HEAT DETECTOR - ELEVATOR MACHINE ROOM	X	X					X	X	X		X					X	X		X	X	
HEAT DETECTOR - PIT OF ELEVATOR SHAFT	X	X					X	X	X		X					X	X		X	X	
DUCT SMOKE DETECTOR			X	X			X					X									X
KITCHEN HOOD SYSTEM	X	X					X	X	X		X									X	
WATER FLOW SWITCH	X	X					X	X	X	X				X						X	
VALVE SUPERVISORY (TAMPER) SWITCH			X	X			X				X										
FIRE ALARM AC POWER FAILURE					X	X							X								
FIRE ALARM BATTERY TROUBLE					X	X							X								
OPEN CIRCUIT					X	X							X								
SHORT CIRCUIT					X	X							X								
GROUND FAULT					X	X							X								

Figure 46 Sequence of Operations

Inputs

The system receives three different input conditions: trouble, supervisory, and alarm.

Trouble Conditions – are generated by conditions that affect the integrity of all input circuits, most output circuits (the control unit and remote power supplies have one unsupervised auxiliary power circuit), and the systems power sources. The following trouble conditions are monitored by the building's control unit:

- Ground Fault
  - Internal – within the control unit or power supply's internal components
  - External – all field wiring connected to the control unit
- Open Circuit
  - Example Conditions: disconnected device or severed circuit
- Short Circuit
  - Example Conditions: the positive wire and the negative wire of a signaling line circuit or a notification appliance circuit are in contact due to a poor installation or damage to the circuit

- AC Power Failure (Primary Power)
  - Example Conditions: loss of building power or circuit breaker opened
- Battery Trouble (Secondary Power)
  - Example Conditions: bad battery (not holding a charge) or battery charger failure

Supervisory Conditions – are generated by field devices and other systems connected to the fire alarm system that require monitoring of abnormal conditions. The following supervisory conditions are monitored by the building's control unit:

- Fire Sprinkler System Control Valve Supervisory Switch
  - The fire sprinkler system control valve is a normally open valve allowing a constant supply of water to the network of sprinklers; therefore, it is in a normal state when open. If the valve is closed for any reason a supervisory signal is generated.
- HVAC Duct Smoke Detector
  - Automatically actuates upon detection of smoke moving through the HVAC ducts.

Alarm Conditions – are generated by devices in the field that are manually or automatically activated upon detection of a fire condition. The following alarm conditions are monitored by the building's control unit:

- Manual Pull Station
  - Manual switch that is activated by a building occupant upon detection of a fire condition.
- Smoke Detector
  - Automatically actuates upon detection of smoke.
- Heat Detector
  - Automatically actuates once a fixed temperature is reached.
- Kitchen Hood Suppression System
  - Automatically or manually activated upon detection of a fire condition below the commercial kitchen hood
- Fire Sprinkler Water Flow Switch
  - Automatically actuates after a fire sprinkler activates and begins discharging water; therefore, detecting the flow of water through the system riser piping.

System Outputs

The system outputs are annunciated signals, notification signals, and control functions that correspond directly with the associated input conditions.

Trouble Outputs – upon receipt of any trouble condition, signals are actuated and transmitted to notify designated personnel of a system impairment. The signal must be indicated within 200 seconds; however, the power failure signal may be delayed 60 minutes to 180 minutes in accordance with NFPA 72 Section 10.6.9.3. Trouble signals are received and responded to per the following:

- Audible annunciation at the system control unit and the remote annunciator generated by a local piezo at both locations. The piezo must sound intermittently until the signal has been silenced or the system has been repaired and restored to normal. If the signal is silenced it must reactivate every 24 hours until the system is restored to normal.
- Visual annunciation at the system control unit and the remote annunciator. The visual signal is identified by an active lamp, labeled as a trouble, and a description and error code

displayed on the LCD screen found at both locations. Unlike the audible signal, the visual signal remains active until the system is repaired and restored to normal.

- The Remote Supervising Station receives a signal transmission from the control unit requiring a response from the supervising station operator in accordance with NFPA 72.

Supervisory Outputs – upon receipt of any supervisory condition, signals are actuated and transmitted to notify designated personnel to investigate the condition and to restore the system to normal. There are situations where the supervisory signal is a latching signal that cannot be cleared at the control unit until the system is restored to normal and the control unit is reset. The signal must be indicated within 90 seconds after the activation of an initiating device. Supervisory signals are received and responded to per the following:

- Audible annunciation at the system control unit and the remote annunciator generated by a local piezo at both locations. The piezo must sound intermittently until the signal has been silenced or the system has been repaired and restored to normal. If the signal is silenced it must reactivate every 24 hours until the system is restored to normal.
- Visual annunciation at the system control unit and the remote annunciator. The visual signal is identified by an active lamp, labeled as a trouble, and a description and error code displayed on the LCD screen found at both locations. Unlike the audible signal, the visual signal remains active until the system is repaired and restored to normal.
- The Remote Supervising Station receives a signal transmission from the control unit requiring a response from the supervising station operator in accordance with NFPA 72.

In addition to the generated signals, there are control functions corresponding with an associated supervisory condition.

- Upon initiation of a duct smoke detector, the associated air handler fan must be shut down in accordance with NFPA 90A Section 6.4.3. This is a component of a passive smoke control system to prevent the redistribution of smoke throughout the building.

Alarm Outputs – upon receipt of any alarm condition, signals are actuated and transmitted to notify building occupants and emergency responders to take action. The signal must be indicated within 10 seconds after the activation of an initiating device. Alarm signals are received and responded to per the following:

- Audible annunciation at the system control unit and the remote annunciator generated by a local piezo at both locations. The piezo sounds continuously until the system is restored to normal and the control unit has been reset. This signal can be temporarily silenced after actively acknowledging and silencing the control unit. If the signal is silenced it must reactivate every 24 hours until the system is restored to normal or at any time a subsequent alarm initiates.
- Visual annunciation at the system control unit and the remote annunciator. The visual signal is identified by an active lamp, labeled as an alarm, and a description displayed on the LCD screen found at both locations. Unlike the audible signal, the visual signal remains active until the system is restored to normal and the panel has been reset.
- Audible evacuation signals are distributed throughout the building in accordance with NFPA 72 to notify the occupants of a fire condition and to evacuate the building. Audible notification is achieved by using speaker notification appliances distributing a prerecorded message. This signal can be temporarily silenced after actively acknowledging and silencing the control unit.

- Visual evacuation signals are distributed throughout all common areas of the building in accordance with NFPA 101 and NFPA 72 to notify occupants, especially hearing impaired occupants, of a fire condition and to evacuate the building. The visual signal is distributed with clear lens strobes which are marked "Fire". This signal can be temporarily silenced after actively acknowledging and silencing the control unit.
- The Remote Supervising Station receives a signal transmission from the control unit requiring a response from the supervising station operator in accordance with NFPA 72. The alarm signal is relayed to the designated fire department to actively respond to the alarm condition.

In addition to the alarm signals, there are control functions corresponding with an associated alarm condition.

- Upon initiation of a smoke detector located within 5 ft., on either side, of an automatic-closing door, per NFPA 72 Section 17.7.5.6, the magnetic hold-open device must release the associated doors.
- Upon receipt of an alarm condition, the building's audio system must be deactivated.
- Elevator Control per NFPA 72 Section 23.3 and Section 23.4
  - Upon initiation of the 2nd floor elevator lobby smoke detector or the smoke detector located at the top of the elevator shaft, the elevator shall be recalled to the 1st floor.
  - Upon initiation of the 1st floor elevator lobby smoke detector, the elevator machine room smoke and heat detector, or the heat detector located in the elevator pit, the elevator shall be recalled to the 2nd floor.
  - Upon initiation of the smoke and heat detectors located in the elevator shaft and the elevator machine room, a visual warning signal must be activated in the elevator.
  - Upon initiation of the heat detectors located in the elevator pit and the elevator machine room, installed within 24 in. of the associated spaces fire sprinkler, the elevator's power must be disconnected.

System Components

The EVAC system is composed of a network of communicating components to assure the system operates as required by NFPA 72 to achieve the objective of safely evacuating the occupants in the event of an emergency. The system consists of a central control unit, auxiliary power supplies, initiating devices, control devices, and notification appliances.

Refer to Figure 47, the system riser diagram, for an overview of the entire system. Figure 47 is a schematic diagram of all of the system components and how they are connected.

Control Unit

The system control unit is the command center, the computer that receives, transmits, and controls all of the information and signals related to the EVAC system. The EVAC control unit for the building is a Gamewell-FCI E3 intelligent addressable emergency communications control unit. It is equipped with all of the components and capabilities necessary to execute the required functions. The following component descriptions are regarding the functions important to meet the objectives of the Maumus Center's EVAC system; however, the Gamewell-FCI E3 panel has capabilities that far exceed those required for this building.

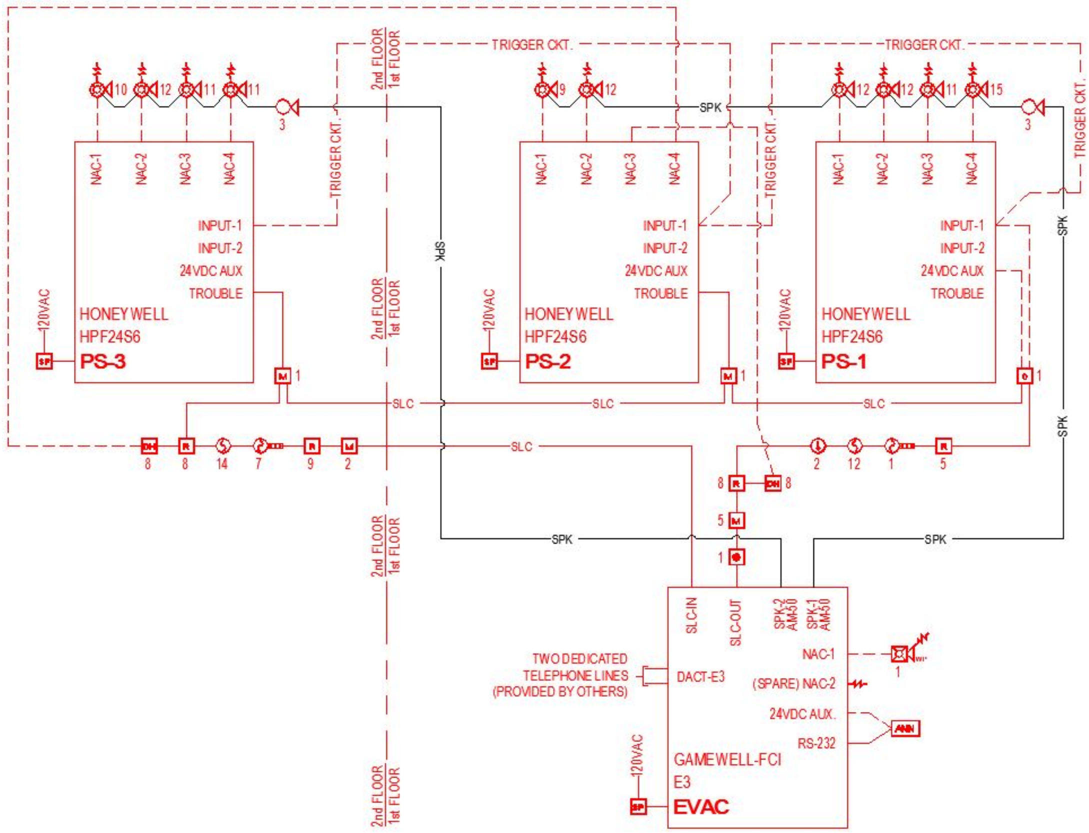

Figure 47 Riser Diagram

Power Supply – the panel is equipped with a 9A 24VDC internal power supply. The power supply acts as a power distribution module. It requires 120VAC at 3.5A from a dedicated branch circuit powered by the building's central power source. The power distribution module is the primary means of power for the control unit. The power supply converts the 120VAC input voltage to a 24VDC output voltage, powering the internal components of the control unit and the externally connected peripheral devices and appliances.

To continue, this module is connected to the secondary power source, two 12VDC lead-acid batteries. The connection between the power supply and the batteries provides two functions: charging the batteries, with a recharging capacity for two 12VDC batteries no greater than 55AH, and receiving power from the batteries in the event the primary power source fails.

To determine the required battery capacity to support the system upon loss of building power, battery calculations were performed in accordance with NFPA 72 Section 10.6.7.2. The calculations include the required alarm and standby power for the control unit's internal components and all connected peripherals. The battery capacity must be calculated using a minimum standby time of 24 hours. At the end of the 24 hours, the batteries must be able to power the control unit and peripherals in an alarm condition for a minimum of 15 minutes. The 15 minute alarm time is specifically required for EVAC systems. In addition, the final amp-hour rating for the batteries must include a 20 percent safety margin. See Figure 48 for the control unit battery calculations indicating the required minimum battery capacity of 17AH.

System Current Draw								
Gamewell-FCI E3 Series Control Panel								
	Total Standby			0.549 A	Total Alarm			3.314 A
Device	**Qty**		**Draw**	**Standby**	**Qty**		**Draw**	**Alarm**
1. System Device								
Intel. Loop Interface, Main Board (ILI-MB-E3)	1	x	0.08100	0.08100	1	x	0.15000	0.15000
2. E3 Optional Modules								
120V Power Supply Sub-Assembly (PM-9)	1	x	0.05000	0.05000	1	x	0.05000	0.05000
LCD Display & Switch Control (LCD-E3)	1	x	0.02400	0.02400	1	x	0.02800	0.02800
Digital Communicator (DACT-E3)	1	x	0.01800	0.01800	1	x	0.01800	0.01800
Optional Remote Serial Annunicator (LCD-7100)	1	x	0.05000	0.05000	1	x	0.07500	0.07500
3. INI-VGX Voice Gateway								
Intel. Network Voice Gateway (INI-VGX)	1	x	0.15000	0.15000	1	x	0.15000	0.15000
Amplifier Sub-assembly, 50 watt 25V (AM-50)	1	x	0.08600	0.08600	1	x	2.20600	2.20600
4. Smoke Detectors/Modules								
Addressable Photoelectric Smoke Detector (ASD-PL2F)	34	x	0.00030	0.01020	34	x	0.00650	0.22100
Addressable Double-Action Manual Pull (MS-7AF)	1	x	0.00030	0.00030	1	x	0.00300	0.00300
Addressable Monitor Module (AMM-4F)	9	x	0.00750	0.06750	4	x	0.00570	0.0228
Addressable Fixed Temp. Thermal Detector (ATD-L2F)	2	x	0.00030	0.00060	2	x	0.00650	0.01300
Addressable Form-C Relay (AOM-2RF)	30	x	0.00038	0.01125	30	x	0.00650	0.19500
Addressable Supervised Control Module (AOM-2SF)	1	x	0.00038	0.00038	1	x	0.00650	0.00650
5. Notification Appliances								
NAC-1	1	x	0.00000	0.00000	1	x	0.17600	0.17600
NAC-2	0	x	0.00000		0	x	0.00000	
			Total Standby Load:	0.549 A			Total Alarm Load:	3.314 A

Secondary Standby Load 0.549 A	x	Required Standby Time 24 hours	13.18
Secondary Alarm Load 3.314 A	x	Required Alarm Time (hours) 0.250 hours	0.83
		Total Secondary Load	14.01
		Derating factor	x 1.20
		Secondary Load Requirements	**16.81 AH**

Battery Selection	**17.00**	Amp Hours

Figure 48 Control Unit Battery Calculations

Digital Alarm Communicator Transmitter (DACT) – is a modular communicator installed in the control unit to transmit signals to the Remote Supervising Station via two supervised telephone lines, one primary and one backup. The DACT must have the capabilities to seize the telephone lines to deliver signals to the Remote Supervising Station within 90 seconds.

Annunciator – the panel is equipped with an integral LCD display screen and keypad as the primary control interface. A remote annunciator is also connected to the panel via the RS-232 serial terminal, to transmit and receive data, and the 24VDC auxiliary power circuit. The remote annunciator is located in the building Lobby near the Main Entrance. Each of these user interfaces allow trained personnel and first responders access into the system computer to control settings, program the panel, and to view the system history. Different levels of passcodes protect the access to various levels of controls.

Signaling Line Circuit (SLC) – the control unit is an intelligent addressable panel equipped with two SLCs. The circuits can be configured as Class A or Class B circuits depending on the system's survivability needs. The system is designed with one Class A SLC providing a redundant path of travel for data communication from the peripheral devices, located throughout the building, to the control unit. The Class A circuit provides secure system operation past a single open along the circuit. Another Class A requirement addresses the need for a separation between the outgoing and return circuits, per NFPA 72 Section 12.3.7. A minimum separation of 4ft. is recommended. Last, considering there are more than 50 addressable devices connected to the SLC, isolation modules must be installed every 50 addressable devices to prevent the loss of more than 50 devices as a result of a single fault.

Notification Appliance Circuit (NAC) – the panel is equipped with two NACs, and only utilizes one NAC to drive the exterior audio/visual notification appliance above the fire department connection, and used to indicate initiation of the water flow detector. This circuit is configured as a Class B circuit with an end-of-line resistor for circuit supervision.

Audio Distribution – the control unit contains the components required to distribute the audio communication and alarms throughout the building. The live voice messages, pre-recorded messages, and tones are generated from a voice command module that it is connected to a handheld microphone, for live voice messages, and two 50W 70.7Vrms amplifiers, for delivering the audio to the notification appliances throughout the building. The two amplifiers have the capability of distributing the audio power between two supervised Class B speaker circuits.

The system is designed with one amplifier and one Class B speaker circuit per story, distributing 45W to the 1st floor and 31.25W to the 2nd floor. The speaker circuits are non-shielded plenum rated cable with two twisted 14AWG conductors. Speaker Circuit 1 on the 1st floor is 1300 ft. and Speaker Circuit 2 on the 2nd floor is 1000 ft. According to the manufacturers installation manual, the distances and the corresponding power requirements are within the limitations of the amplifiers' speaker circuit capabilities.

Power Supplies

To efficiently and effectively distribute 24VDC power to the notification appliances and the electromagnetic door releases, remote auxiliary power supplies are installed strategically throughout the building. There are two providing power to the 1st floor and one providing power to the 2nd floor.

The power supplies used are Honeywell HPF24S6, capable of providing 24VDC at 6A across four supervised output circuits. Similar to the control unit's power supply, the remote power supplies require 120VAC at 3.2A from a dedicated branch circuit powered by the building's central power source, have two 12VDC lead-acid batteries for backup power, and the capability of charging batteries no greater than 18AH.

The required battery capacity is determined by calculating the total power load, in accordance with the same requirements defined for the control unit power supply. Figure 49 is the battery calculation for Power Supply 2, found on the 1st floor in Electrical Room 140, which provides supervised alarm power to two Class B NACs and supervised standby power to two Class B electromagnetic door release circuits.

Power Supply - PS-2					
Regulated Load in Standby					
Device Type	**Qty**		**Current**		**Total Current**
Main PC Board	1	X	0.065	=	0.065
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
NAC-3 (1st Floor - Door Holders)	8	X	0.020	=	0.16
NAC-4 (2nd Floor - Door Holders)	8	X	0.020	=	0.16
			Standby Load	=	**0.385**
Regulated Load in Alarm					
Device Type	**Qty**		**Current**		**Total Current**
Main PC Board without AC	1	X	0.145	=	0.145
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
NAC-1	9	X	0.089	=	0.798
NAC-2	12	X	0.114	=	1.364
			Alarm Load	=	**2.307**
Battery Amp Hour Calculation					
Standby Load (Amps)			Required Standby Time (Typically 24 or 60 Hours)		
0.385		X	24	=	9.24 AH
Alarm Load (Amps)			Required Alarm Time (Typically 5 or 10 Minutes)		
2.307		X	15	=	0.58 AH
Sub Total Standby / Alarm Amp Hours					9.82 AH
Multiply by the Derating Factor				X	1.2
Total Ampere Hours Required				=	**12 AH**

Figure 49 PS 2 Battery Calculations

The output circuits must be calculated for the voltage drop across an entire circuit based on the required amp draw and the resistance along the circuit. When performing the calculations, the starting voltage for an output circuit must be derated 15 percent and the voltage must not drop below the output device or appliance's minimum operating voltage. The calculations for the output circuits connected to Power Supply 2 are shown in Figure 50. According to the manufacturer's datasheets, the power supplies' rated voltage is 24VDC, providing 20.4VDC after derating 15 percent, and the minimum operating voltage for the electromagnetic door releases and the notification appliances is 16VDC.

VOLTAGE DROP CALCULATIONS - PS #2								
CIRCIUT #	PANEL	SUPPLY VOLTAGE	ALARM CURRENT	WIRE TYPE & SIZE	OHMS/1000 FT.	LENGTH (FEET)	RESISTANCE (OHMS)	VOLTAGE @ LAST DEVICE
NAC-1	PS #2	20.4	0.798	14 AWG SOLID	2.52	250	1.260	19.39
NAC-2	PS #2	20.4	1.364	14 AWG SOLID	2.52	400	2.016	17.65
NAC-3	PS #2	20.4	0.160	14 AWG SOLID	2.52	250	1.260	20.20
NAC-4	PS #2	20.4	0.160	14 AWG SOLID	2.52	300	1.512	20.16

Figure 50 PS 2 Voltage Drop Calculations

Each power supply is monitored, by the control unit, for trouble conditions with an addressable monitor module. Except, Power Supply 1, located on the 1st floor in Electrical Room 130, is supervised and activated with an addressable supervised control module, which communicates with the control unit. A trigger circuit is connected between all of the remote power supplies, beginning at Power Supply 1, to

activate the power supplies simultaneously and to assure the visual notification appliances are synchronized in accordance with NFPA 72 Section 18.5.5.4.2.

Initiating Devices

The system's initiating devices are addressable devices connected to the SLC, that communicate conditions, from various locations throughout the building back to the control unit. The initiating devices connected to the SLC are addressable photoelectric smoke detectors, addressable fixed-temperature heat detectors, an addressable manual pull station, and addressable monitor modules, which monitor the state of devices and equipment.

Smoke Detectors – there are two types of smoke detectors used in the building: spot-type photoelectric smoke detectors and air sampling photoelectric duct smoke detectors. Both types are automatic detectors initiated by detecting particles of combustion as they pass through a partially enclosed chamber, scattering a projected light beam.

The spot-type detectors are located adjacent to specific equipment or building components to initiate a signal and activate a control function, where defined by the LSC and NFPA 72. All locations where spot-type smoke detectors are required, they must be placed between the ceiling and 12 in. down from the ceiling per NFPA 72 Section 17.7.3.2.

System Protection – spot-type smoke detectors are installed above the EVAC control unit and the remote power supplies per NFPA 101 Section 9.6.1.8.1.

Elevator Recall – spot-type smoke detectors are installed at the 1st floor elevator lobby, the 2nd floor elevator lobby, the top of the elevator hoistway, considering a sprinkler is installed in the elevator pit, and in the elevator machine room, all to initiate the sequence of operations concerning elevator recall, in accordance with NFPA 72 Section 21.3.

Automatic-Closing Doors – spot-type smoke detectors are installed 5 ft. from the lintel of automatic-closing doors, on both sides, and at the ceiling per NFPA 72 Section 17.7.5.6. These detectors activate the release of the automatic-closing doors per the sequence of operations noted in the System Operation section. These detectors are a component of the passive smoke control system separating the Lobby from the remainder of the building.

The duct smoke detectors are used to monitor the distribution of smoke through the HVAC duct network. These detectors are located directly downstream of the filters and upstream of any branch connections in supply ducts of air handlers with a capacity greater than 2000 cfm, per NFPA 90A Section 6.4. These detectors are spot-type detectors installed in an enclosed housing on the exterior of the duct with a metal sampling tube extending from the detector housing through to the other side of the duct and a metal exhaust tube discharging back into the duct downstream of the sampling tube. The sampling tube is perforated with equally spaced holes directed upstream to collect samples of air. The duct detectors shut down the associated air handler upon initiation, and operate as a component of the passive smoke control system preventing redistribution of smoke throughout the building.

Heat Detectors – there are two addressable-fixed temperature heat detectors installed to shut down the elevator prior to sprinkler operation per NFPA 72 Section 21.4. The detectors have a fixed operating temperature of 135°F, and are installed in the elevator pit within 24 in. of the pit fire sprinkler and within 12 in. of the elevator machine room ceiling, no greater than 24 in. from the ceiling fire sprinkler. The fire sprinklers in the two areas have an operating temperature of 200°F, exceeding the operation temperature of the heat detectors; therefore, satisfying the requirement of NFPA 72 Section 21.4.1.

Manual Pull Station – as noted at the beginning of the System Type section, the LSC requires only one manual pull station to be installed, considering the building is equipped with an automatic fire sprinkler system throughout. Thus, one addressable double-action manual pull station is installed adjacent to the EVAC control unit in the Cafeteria. The fire alarm plans' equipment legend indicates the centerline of the manual pull station is to be installed no higher than 44 in. above the finish floor. The manual pull station installation height satisfies the NFPA 72 Section 17.14.5 requirement stating the operable part of the device must be no less than 42 in. and no more than 48 in. from the finish floor.

Monitor Modules – the addressable monitor modules found throughout the building monitor a Class B supervised initiating device circuit (IDC) that extends from the module to the following devices and equipment:

Kitchen Hood Suppression System – two monitor modules are used to detect the operation of the kitchen hood suppression system located in the commercial kitchen and in the kitchen lab, per NFPA 72 Section 17.13.

Fire Sprinkler Waterflow – one monitor module is used to detect the operation of the fire sprinkler system's waterflow switch. The waterflow switch must initiate an alarm condition within 90 seconds of water flow that is equal to or greater than the flow through a single sprinkler with the smallest orifice, installed in the system, per NFPA 72 Section 17.12.

Fire Sprinkler Control Valve – monitor modules are used to monitor the fire sprinkler system control valve located at the fire sprinkler riser and the two control valves located on the remote backflow preventer. These valves are normally open valves allowing an automatic and continuous water supply to the fire sprinkler system. A supervisory condition must be indicated at the control panel upon movement of the valve from its normal position, and upon return to the valves normal position, the condition must be restored. The valve supervisory operation is in accordance with NFPA 72 Section 17.16.1.

Elevator Power – a monitor module is used to monitor the control circuit, used to shut down the power to the elevator, for loss of voltage, creating a supervisory signal, per NFPA 72 Section 21.4.4.

Control Devices

The system is equipped with addressable relay modules and addressable supervised control modules used to activate output control functions defined in the System Operation section. These devices must be installed within 3 ft. of the equipment or device being controlled, per NFPA 72 Section 21.2.4.

Notification Appliances

The audible and visible notification appliances distributed throughout the building to alert the occupants of a fire or other emergency conditions, are speakers, alerting by sense of hearing, and strobes, alerting by sense of light. The speakers and strobes are combined into one integral appliance, except for the occasional speaker used to satisfy the audibility and intelligibility requirements. Though the appliances have combined functions, the appliances must meet to the individual performance requirements for each function.

Audible – NFPA 72 Section 18.4 defines the audible performance requirements regarding location and placement, sound pressure level of the evacuation signal, and intelligibility of the prerecorded and live voice messages.

Audible notification appliance placement must be in accordance with Section 18.4.8. Considering 95 percent of the building's notification appliances are combination audio/visual appliances, the location and placement of the combination appliances must comply with Section 18.5.5 regarding the location and placement of visible notification appliances; therefore, refer to the Visible section addressing the stipulated requirements. The remaining 5 percent are speaker only appliances mounted on the ceiling, which is permitted per Section 18.4.8.2, and located as necessary to improve the intelligibility of the voice messages.

To adequately analyze the audibility and the intelligibility requirements, the fire evacuation signal must be addressed. First, the signal must be distinctive from other similar appliances in the same area per Section 10.10. Second, the signal must meet the requirements for a public operating mode; meaning it is intended for the building occupants. Last, the signal is comprised of an initial tone and a following evacuation message that is continually repeated for an appropriate duration to sufficiently evacuate the building and for no less than 180 seconds. The initial tone prior to the message is a three-pulse temporal pattern, meeting the requirements defined in Section 18.4.2, and only generated once before the message begins. The tone's objective is to alert the occupants of the upcoming message. The message is to notify the occupants of the emergency and to provide explicit evacuation instructions.

The sound pressure level, general and public mode, requirements only pertain to the initial tone. The sound pressure level must not exceed 110 dBA at the minimum hearing distance, and in the same instance, it must be a minimum of 15 dBA above the average ambient sound pressure level. According to Table 14, found in the appendix of NFPA 72, the average ambient sound pressure level for an assembly occupancy is 55 dBA; therefore, a minimum sound pressure level of 70 dBA must be heard throughout all occupiable spaces in the building. The required sound output is achieved throughout the building using System Sensor speaker strobes. The System Sensor SPSCW ceiling mount speaker strobe is the

Table 14 Average Ambient Sound Levels [14]

Table A.18.4.3 Average Ambient Sound Level According to Location

Location	Average Ambient Sound Level (dBA)
Business occupancies	55
Educational occupancies	45
Industrial occupancies	80
Institutional occupancies	50
Mercantile occupancies	40
Mechanical rooms	85
Piers and water-surrounded structures	40
Places of assembly	55
Residential occupancies	35
Storage occupancies	30
Thoroughfares, high-density urban	70
Thoroughfares, medium-density urban	55
Thoroughfares, rural and suburban	40
Tower occupancies	35
Underground structures and windowless buildings	40
Vehicles and vessels	50

primary appliance used, and has a range of sound outputs dependent upon the selected power input. Table 15 shows the sound output capabilities of the speakers.

Table 15 System Sensor Speaker Sound Output

Sound Output				
UL Reverberant (dBA @ 10 ft.)	2W	1W	½ W	¼ W
Ceiling-Mount SPC Series	86	83	80	77
Ceiling-Mount SPCV Series	90	87	84	81
Ceiling-Mount SPSC Series	85	82	79	76
Ceiling-Mount SPSCV Series	89	86	83	80

The power input varies throughout the building between ¼ W to 1 W, and is selected based on the location of the speaker, the spacing between speakers, and the size of the enclosure the speaker is installed in. For example, the greatest distance between speakers is found in the Cafeteria, shown in Figure 51, at a distance of 34 ft., and the speakers are tapped with a 1 W power input. Using the Inverse Square Law, the starting sound output of 82 dBA at 10 ft. decreases 6 dBA every time the reference distance is doubled. Thus, the sound pressure level is maintained above the minimum required 70 dBA at a distance no greater than 40 ft. from the speaker. The speaker spacing is satisfactory to alert the occupants located in the Cafeteria.

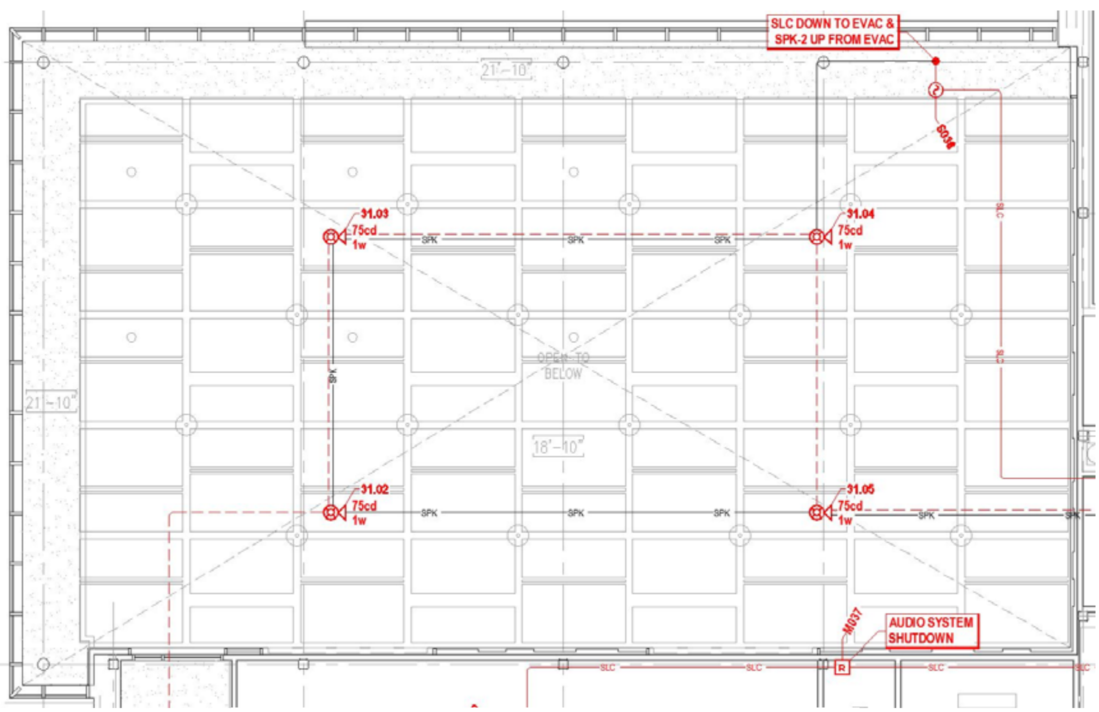

Figure 51 Cafeteria Fire Alarm Plan

In the 2010 edition of NFPA 72, an increased emphasis on voice intelligibility was introduced, requiring designers to design emergency communication systems to distribute intelligible or, in other words, distinguishable and comprehendible messages to the building occupants. This approach requires the building to be separated into acoustically distinguishable spaces (ADS). The division between an ADS and another ADS and whether or not an ADS is suitable for achieving intelligibility is dependent on construction differences regarding interior finishes, furnishings, and geometry. For instance, large open spaces and spaces with reflective surfaces

are affected by reverberation. Reverberation delays the delivery of sound, and in result, can distort the message received by a listener. According to the NEMA Emergency Communications Audio Intelligibility Applications Guide, by increasing the direct sound to a listener, reverberation is decreased; hence, improving the intelligibility. The NEMA applications guide provides approaches to increase the direct sound:

- Move the speaker closer to the listener and reduce the wattage of the speaker: This places the sound where it is needed and minimizes excitation of the room's reverberation, at the expense of additional speakers.
- Increase the speaker density and reduce the wattage to each speaker: This increases the direct sound heard by the listener by creating overlapping regions of coverage.
- In areas with high ceilings, specify a more directional speaker: A speaker that is more focused (has a higher "Q") concentrates most of the sound energy in a tighter beam than low "Q" devices. This is important in areas with high ceilings to reduce the effect of multiple late arriving sounds. [2]

To accurately locate speakers to deliver the optimum intelligibility, professional sound engineering software should be used. In most cases, fire alarm designers do not have this at their disposal. In this instance, it is suggested to apply the calculations found in the NEMA applications guide. This approach will require obtaining the 2 kHz (critical band for intelligibility) polar plot test data from the speaker manufacturer to determine the speakers Critical Polar Angle. "The Critical Polar Angle is the angle where the sum of the distance loss and the polar loss is 6 dB less than the on-axis sound pressure level" [2]. The Critical Polar Angle is then applied to determine the coverage circle diameter used to space the speakers.

Coverage Circle Diameter = $2D_2\tan(\theta/2)$

D_2 – Distance from the speaker to the listener
θ – Critical Polar Angle

For example, the 2nd floor Corridor 226 has an 8 ft. ceiling with speakers spaced 28 ft. apart, see Figure 52. Because of the low ceiling and the distance between speakers this corridor is a challenging ADS, in regards to providing voice intelligibility.

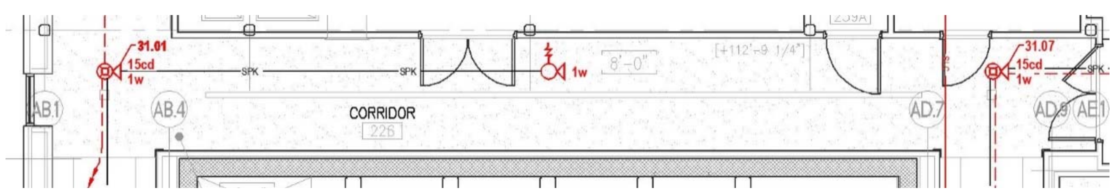

Figure 52 Corridor 226 Fire Alarm Plan

Referencing the 2 kHz polar plot from the System Sensor Loudspeaker Test Report for the SPSCW, Figure 53, the Critical Polar Angle is determined, see Table 16.

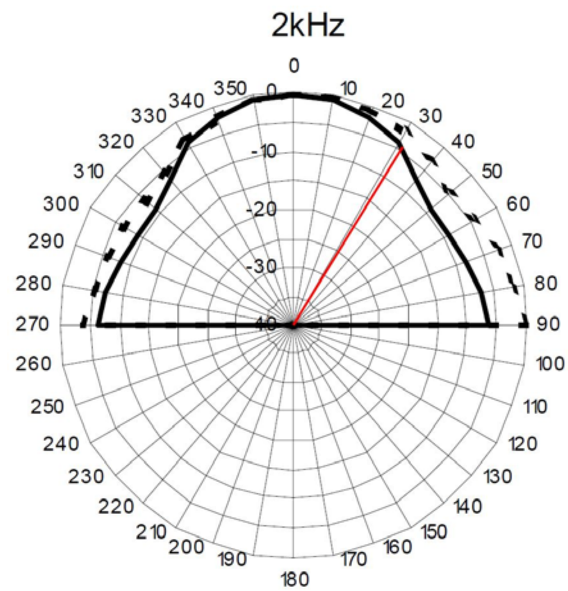

Figure 53 SPSCW 2 kHz Polar Plot

Table 16 Critical Polar Angle

Angle Off-Axis (θ)	**0°**	**10°**	**20°**	**30°**	**32°**	**40°**
Polar Loss[1] (dB)	0.5	1	2	4	4.5	7.5
Distance Loss[2] (dB)	0	0.1	0.5	1.2	1.43	2.3
Total	0.5	1.1	2.5	5.2	5.93	9.8
					~ 6 dB	
			Critical Polar Angle		**64°**	

[1] Polar Loss from Polar Plot

[2] Distance Loss = 20*Log(cos(θ))

The Critical Polar Angle is then applied to calculate the coverage circle diameter at 5 ft. above the finish floor, which is 3 ft. below the ceiling mounted speaker.

$$\text{Coverage Circle Diameter} = 2*3*\tan(64°/2) = 3.75 \text{ ft.}$$

Therefore, the suggested speaker spacing along the corridor is 3.75 ft. This spacing will require an excessive number of speakers to be installed along the corridor. Also, considering the corridor has an epoxy terrazzo floor, which is an acoustically reflective surface; reverberation will be a concern, resulting in a decreased capability of achieving intelligibility. This corridor should be presented to the AHJ as an ADS not requiring voice intelligibility per Section 18.4.10.2.

Visible – NFPA 72 Section 18.5 defines the public mode visible performance requirements regarding placement and location dependent on the visible notification appliance light output effective intensity, measured in candelas (cd).

Visible notification appliances must be either mounted vertically on a wall or horizontally on a ceiling, and the appliances must be listed for its installation orientation. 87 percent of the visible notification appliances for the building are ceiling mounted and are listed for this application, according to the manufacturer's data sheet. The 13 percent that are wall-mounted

appliances must be installed in accordance with Section 18.5.5.1. The appliance's entire lens must be not less than 80 in. and not more than 96 in. above the finish floor. In locations where the ceiling is less than 80 in. above the finish floor, the lens must be within 6 in. below the ceiling, and the effective coverage must be reduced per Section 18.5.5.2.

The appliance coverage and spacing is determined by referencing Table 18.5.5.4.1(a) for wall-mounted appliances and Table 18.5.5.4.1(b), Table 17, for ceiling-mounted devices. Focusing on ceiling-mounted appliances because of the large percentage installed in the building, the spacing for ceiling-mounted appliances is dependent on the appliances candela rating and the height of the lens above the finished floor.

Table 17 Ceiling-Mounted Visible Appliances [14]

Table 18.5.5.4.1(b) Room Spacing for Ceiling-Mounted Visible Appliances

Maximum Room Size		Maximum Lens Height*		Minimum Required Light Output (Effective Intensity); One Light (cd)
ft	m	ft	m	
20 × 20	6.1 × 6.1	10	3.0	15
30 × 30	9.1 × 9.1	10	3.0	30
40 × 40	12.2 × 12.2	10	3.0	60
44 × 44	13.4 × 13.4	10	3.0	75
20 × 20	6.1 × 6.1	20	6.1	30
30 × 30	9.1 × 9.1	20	6.1	45
44 × 44	13.4 × 13.4	20	6.1	75
46 × 46	14.0 × 14.0	20	6.1	80
20 × 20	6.1 × 6.1	30	9.1	55
30 × 30	9.1 × 9.1	30	9.1	75
50 × 50	15.2 × 15.2	30	9.1	95
53 × 53	16.2 × 16.2	30	9.1	110
55 × 55	16.8 × 16.8	30	9.1	115
59 × 59	18.0 × 18.0	30	9.1	135
63 × 63	19.2 × 19.2	30	9.1	150
68 × 68	20.7 × 20.7	30	9.1	177
70 × 70	21.3 × 21.3	30	9.1	185

*This does not preclude mounting lens at lower heights.

Appliances installed in corridors less than 20 ft. wide must have a minimum candela rating of 15 cd, and are allowed to be spaced according to Section 18.5.5.5.5. This section allows visible notification appliances to be installed up to 100 ft. apart and no more than 15 ft. from either end of a corridor. When applying this section, obstructions to the field of view such as doors and lentils must be taken into consideration. Instances where these obstructions are in place, they must be treated similar to a partition, requiring appliances on both sides. Refer to Figure 52 for an example of adequate corridor coverage.

Inspection, Testing, & Maintenance

The system must be inspected, tested, and maintained to ensure the system operates in accordance with the approved design documents and NFPA 72. Ensuring acceptable performance in the event of an actual emergency. The system must be inspected in accordance with Section 14.3, tested in accordance with Section 14.4, and maintained in accordance Section 14.5. These sections of NFPA 72 prescribe the test frequencies and the specific operations that must be inspected and tested. The installing contractor responsible for the acceptance testing and the party responsible for the periodic inspections must document their test and inspection results and findings in accordance with Section 7.8.

The documented design of the fire alarm system satisfies the minimum intent of the LSC and NFPA 72; however, based on the audible notification analysis the speaker spacing may or may not provide intelligible voice messages. The speaker performance must be evaluated during the system acceptance test to qualitatively determine the audio intelligibility.

Conclusion

In conclusion, the prescriptive design of the Maumus Center, in regards to fire protection, complies with the adopted codes and standards. There are special situations mentioned regarding shielding of the fire sprinkler system that would require a performance analysis to better understand the effects on occupant safety and to design alternative solutions. Concluding the prescriptive design analysis, now the performance-based design must be addressed.

Performance-Based Design

Introduction

The LSC allows a performance-based option as an alternative to the prescriptive requirements. This approach allows for greater flexibility for more complicated applications that are not clearly defined in the prescriptive requirements; however, this option does not sacrifice the goals and objectives needed to provide the required level of life safety. This section addresses the goals and objectives that must be attained, the performance criteria based on the goals and objectives, three design fire scenarios selected to test the building's performance, and ending with an analysis of one design scenario's performance results.

Goals & Objectives

The goals and objectives are explicitly defined in Sections 4.1 and 4.2 of the LSC.

Goals

- to provide an environment reasonably safe from fires
- life safety during emergencies using similar methods that would be used in the case of a fire
- to provide safe crowd movement

Objectives

- to provide protection for occupants that are not intimate with the initial fire for the time needed to seek safety
- structural integrity maintained for the time needed to seek safety
- effective systems used to mitigate the hazard [7]

The performance-based design option must be prepared by a registered design professional. This level of expertise is required to adequately determine the optimum performance-based design method to achieve the required goals and objectives, and to effectively execute the design considering the design fire scenarios, specifications, conditions, and assumptions. An effective design requires a complete understanding of all of the requirements and possibilities, along with the capability to accurately document the design.

Performance Criteria

The performance criterion defined in Section 5.2.2 states, "Any occupant who is not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions" [7]. The following are defined in the appendix of the LSC as methods to meet the performance criterion:

- **Method 1** – set performance criteria that will ensure the occupants are not incapacitated by the fire effects. Establishes the Available Safe Egress Time (ASET).
- **Method 2** – demonstrate an area will be fully evacuated before the occupants are exposed to the fire effects. The Required Safe Egress Time (RSET) must be less than the ASET.
- **Method 3** – demonstrate the smoke and toxic gas layer will not descend to a level lower than 6 ft. above finish floor in an occupied space ensuring the occupants are not exposed to the fire effects, no matter where the occupants are located or where they may move.
- **Method 4** – demonstrate that no fire effects will reach any occupied room; therefore, ensuring the occupants are not exposed to the fire effects. [7]

Method 1 and Method 2 are used to establish the performance criteria for the Maumus Center's performance-based design.

Method 1

The performance criteria for Method 1 is regarding tenability for occupants exposed to the fire effects. The fire effects that inhibit occupants from effectively escaping a fire scenario are smoke obscuration and irritants impeding an occupant's visibility, asphyxiant gases that are inhaled by occupants, and depending on the concentration and exposure time, can lead to incapacitation and death, and heat exposure that can also lead to incapacitation and death, depending on heat flux and temperatures.

The methodology often used to evaluate the effects of smoke, toxic gases, and heat is the Fractional Effective Dose (FED) method. According to the SFPE Handbook 5th Edition, "the concept of FED is used whereby the exposure concentration or dose at any point during a fire is expressed as a fraction of the exposure concentration or dose predicted for a given endpoint" [17] The time it takes a space to become untenable is the time each endpoint reaches an FED of 1, and the FED is an accumulative calculation of fractional effective concentrations at one-minute time intervals over the duration of a fire scenario. The threshold FED values used in performance-based designs to determine the ASET are 0.3 for the prevention of incapacitating exposure and 0.8 for the prevention of lethal exposure. An FED not exceeding 0.8 virtually assures the survivability of all occupants.

Below are the specific byproducts of combustion calculated in the FED method and their effects on tenability:

- **Smoke Optical Density** – impairs an occupant's vision resulting in slower movement speeds and wayfinding ability.
- **Irritant Gas Concentrations** – impairs an occupant's vision and causes painful effects on the eyes and respiratory tract resulting in slower movement speeds and wayfinding ability. Common irritant gases are hydrogen chloride, hydrogen bromide, and sulfur dioxide.
- **Toxic Gas Concentrations** – as occupants are exposed to increasing concentrations and exposure times, the effects escalate from a normal state of coherence, to confusion, to loss of consciousness, and eventually resulting in death. The two common toxic gases are carbon monoxide and hydrogen cyanide.
- **Carbon Dioxide Concentrations** – primary effect is on an occupant's respiration rate and increased rate of absorption of toxic gases, accelerating the effects of the toxic gases, and at raised levels it can cause loss of consciousness and eventually death.
- **Anoxia** – is the significantly decreased level of oxygen that causes loss of consciousness and eventually death.
- **Heat** – as occupants are exposed to increasing values of temperature and radiative heat flux, they experience hyperthermia, body surface burns, respiratory tract burns, and high levels death can occur.

The performance criteria used to generate the ASET for the design fire scenario analyzed in this report is a set of tenability thresholds pertaining to visibility, heat, thermal radiation, and the exposure to carbon monoxide.

Visibility

The fact the building is classified as an assembly occupancy, used as a place of gathering for the community and the local school district, the occupants are transient and are not expected to be familiar with the building floor plan and the various obstructions that may impede their egress through the

building. Also, the building is a complex two-story building consisting of long corridors with illuminated exit signs. The exit signs are only located at the ends of the corridors and at transition points. Therefore, visibility is crucial to an occupant attempting to navigate the building during a fire scenario. According to Klote, the criterion for visibility is suggested to range from 13 ft. to 46 ft., depending on the occupants' familiarity with the building, the room sizes, and the complexity of the building [6]. The fact the exit signs are located at the ends of the long corridors, the distance between an occupant and the exit sign will, in many cases, exceed the maximum suggested visibility distance; thus, the exit signs are not considered in determining the visibility criterion. Based on the building's characteristics and occupancy classification a conservative visibility criterion of 46 ft. (14 m) is selected as an appropriate threshold.

Heat

Occupants exposed to high temperatures can experience hyperthermia (heat stroke) with symptoms of incapacitation or death. The normal core human body temperature range is 98.6°F to 102.2°F, and once it is raised to 104°F, consciousness is influenced and the exposed become seriously ill [17]. Any further increase in temperature the damage becomes irreversible, and at 108.5°F the exposure becomes lethal, unless treated within minutes [17]. Purser, further defines a tenability limit of 140°F for 100 percent saturated air at a minimum exposure time of 30 minutes. Considering the building is located in a high humidity climate and to be conservative, 140°F (60°C) is the selected tenability criterion for heat.

Thermal Radiation

Thermal radiation can result in skin burns that can lead to incapacitation due to psychological shock, and loss of blood effecting the circulatory system can cause unconsciousness and eventually death. According to the SFPE Handbook 5th Edition, thermal radiation of 2.5 kW/m^2 or less can be tolerated 5 minutes or more, and any heat flux greater than 2.5 kW/m^2 results in tolerance times of 30 seconds or less [17]. Therefore, the selected thermal radiation tenability criterion is a heat flux of 2.5 kW/m^2.

Carbon Monoxide

The toxic effects of Carbon Monoxide (CO) and the hyperventilating effects of Carbon Dioxide (CO_2) must be calculated into the tenability criterion for toxic gases. CO is dangerous at high concentrations over a short time period and at small concentrations over an extended time period. The hyperventilating effects of CO_2 accelerates the absorption of CO decreasing the time to incapacitation. The time to incapacitation is calculated using the Fractional Effective Dose (FED) Model, found in the SFPE Handbook 5th Edition, by calculating the additive effect of the toxic gases over an exposure time for a specific design fire scenario. Without calculating the FED for a design fire scenario, the incapacitating threshold for CO has been determined. Harzell states that a CO concentration, in respect to time, of 35,000 ppm-min has the potential for serious harm to many occupants [17]. Therefore, at an exposure time of 30 minutes the tenability criterion for CO is a concentration of 1167 ppm.

The four selected thresholds forming the tenability criteria for Method 1 are:

- Visibility – 46 ft. (14 m) at 6 ft. (1.8 m) above the highest walking surface
- Heat – 140°F (60°C)
- Thermal Radiation (Heat Flux) – 2.5 kW/m^2
- Toxicity – 1167 ppm (CO)

The selected fire scenario is modeled using the NIST Fire Dynamic Simulator (FDS) to determine the estimated time the first threshold is reached establishing the ASET.

Method 2

Method 2 uses the ASET, determined in Method 1, and egress performance calculations to demonstrate a means of egress is capable of providing an RSET in less time than the ASET. To accurately evaluate the safe egress time, an engineering timeline must be created, see Figure 54.

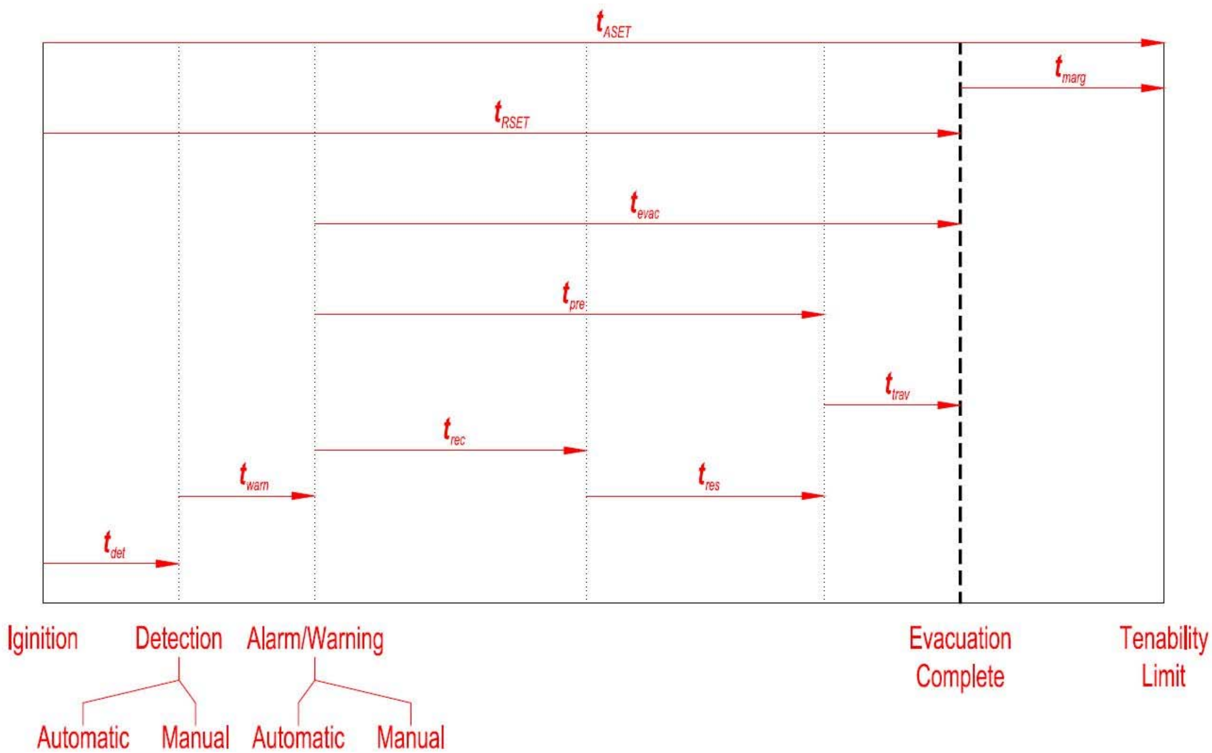

Figure 54 Engineering Timeline

Below are the components of the engineering timeline, as defined in Chapter 64 of the SFPE Handbook 5th Edition:

- Detection time (t_{det}) – The interval between fire ignition and the first detection of the fire by a device or an individual.
- Warning time (t_{warn}) – The interval between detection of the fire and the time at which an alarm signal is activated or notification of occupants takes place.
- Pre-evacuation time (t_{pre}) – The interval between the time at which a general alarm signal or warning is given and the time at which the first deliberate evacuation movement is made. This interval consists of two components: recognition time and response time.
  - Recognition time (t_{rec}) – The interval between the time at which the alarm signal is perceived and the time at which the occupant interprets this signal as indicating a fire/emergency event. This time includes investigation and milling, for example, to determine the situation.
  - Response time (t_{res}) – The interval between recognition time and the time at which the first move is made to evacuate the building. This time includes activities such as firefighting, warning

others, gathering family members and pets, dressing, retrieving personal belongings, calling the fire department, and so on.

- Travel time (t_{trav}) – The time needed, once movement toward an exit has begun, for all occupants to reach a place of safety.
- Evacuation time (t_{evac}) – The time from the alarm signal to the time at which the occupants reach a place of safety. This is the sum of the pre-evacuation time (t_{pre}) and the travel time (t_{trav}).
- Required Safe Escape Time (t_{RSET}) – The calculated time necessary between ignition of a fire and the time at which all occupants can reach an area of safety. t_{RSET} is the sum of the detection time (t_{det}), the warning time (t_{warn}) and the evacuation time (t_{evac}).
- Available Safe Egress Time (t_{ASET}) – The calculated time available between ignition of a fire and the time at which tenability criteria are exceeded in the means of egress. t_{ASET} should be longer than t_{RSET} by an acceptable margin of safety. [17]

The components of the engineering timeline relevant to the Method 2 performance criteria is the detection time, warning time, pre-evacuation or pre-movement time, and the travel or movement time.

Detection Time (T_{det})

The detection time is specific to each design fire scenario; therefore, the detection time for the selected design scenario is addressed in the Analysis and Results section.

Warning Time (T_{warn})

The warning time is specific to each design fire scenario; therefore, the warning time for the selected design scenario is addressed in the Analysis and Results section.

Pre-Movement Time (T_{pre})

To effectively determine a valid pre-movement time, the following must be assessed: the expected characteristics of the intended occupants, the human behavior which influences the intended occupants' activities, and the historical data regarding pre-movement times associated with the intended occupants' characteristics and behaviors. This process must be adequately documented to validate the pre-movement time selected for a given scenario. The following is a general assessment of the building's pre-movement time.

Considering the Maumus Center is intended to be used as an interactive science center focused on educating children, yet also used as an assembly space for the local community, the following are the expected occupant characteristics and their associated human behaviors used to determine the pre-movement time, categorized into the characteristic categories, described in Chapter 57 of the SFPE Handbook 5th Edition:

Permanent/Transitory – the building staff is considered permanent and is expected to be familiar with the building and its systems allowing them the ability to recognize alarm signals, identify alternate escape routes, or have a familiarity with the building's emergency management plan. The staff is also expected to assist the transitory occupants proactively or by example.

The building attendants are considered transitory; therefore, unfamiliar with the building and its systems. The attendants are anticipated to rely on the life safety systems and the staff to safely escape.

Trained/Untrained – the building staff may or may not be trained; however, if the staff is trained, they should be familiar with the emergency management plan, the alarm signals, procedures, and emergency exits.

The building attendants will be expected to be untrained; therefore, lacking the knowledge expected of the trained.

Potential Age Ranges – the building occupants will have a wide age range based on the intended use. Children of all ages are expected occupants, and are assumed to be unable to make independent decisions that will lead to self-rescue; thus, requiring assistance to safely evacuate the building. Children are expected to be accompanied by an adult with the capability to assist them during an escape, such as, a building staff member, a guardian, or a teacher. The children along with the associated adult attendants are the most common anticipated occupants; however, community events held in the building would likely bring in elderly occupants that may also need assistance evacuating.

Cognitive, Sensory, or Mobility Issues – some occupants may be expected to have disabilities, not related to age, that may negatively affect their ability to evacuate the building efficiently. These disabilities may be mental or physical requiring assistance to evacuate or slower movement times.

Potential Vulnerabilities – there will be a range of vulnerabilities among the occupants, not all of the occupants will be able tolerate the same level of smoke and products of combustion.

Awake/Asleep/Unconscious/Intoxicated – considering the building is an interactive place of assembly, it is assumed the occupants will be awake. Also, since the common intended occupants are children and associated adults, the occupants are assumed to be not intoxicated.

Social Groupings or Not – families and groups of children lead by an instructor or other such leader tend to group together prior to moving towards an exit. This assembling can be expected in the building.

Role – an individual's role affects how one reacts to specific events. For instance, subordinates tend to look to their leader for guidance assuming their normal roles in the building. This characteristic can be expected in the building. For example, instructors or guardians not familiar with the building will look to the permanent/trained staff for guidance, and the students/children will look to whomever is leading them, for guidance.

Now that the occupant characteristics and behaviors have been identified, they are used along with the associated historical data found in Tables 64.9 and 64.11, of the SFPE Handbook 5th Edition, to select an acceptable expected pre-movement time. When using the tables to select an applicable pre-movement time the following aspects are considered:

Occupancy – Table 64.9 is data collected from educational occupancies. This information is considered, despite the building having an assembly occupancy, because of its intended use as a learning center for children. It is assumed the most common design scenario would resemble a population typically found in a school. Though, the occupants are not expected to be familiar

with the building. On the other hand, the building is classified as a place of assembly; therefore, Table 64.11, regarding data collected from assembly occupancies, is used, as well.

Observational Conditions – the observational conditions were evaluated in the following sequence: participants, spatial configuration, variable, and location. The conditions closely resembling the building were applied to the pre-movement time selection.

Procedure – the only strategy considered is full evacuation, the intended strategy for the building. The staff is observed to resemble a scenario that would be found in the building, such as, staff members outnumbered by children.

Sample – the population sample size relatively similar to the building is used.

Results – the pre-movement time chosen is the most conservative time applicable to the building based on the evaluation of the parameters referenced above.

Referencing the data in Tables 64.9, regarding educational occupancies, and Table 64.11, regarding assembly occupancies, a pre-movement time is calculated. Two sources, from each occupancy classification, that relatively resemble the conditions applicable to the building were selected, see Table 18. Using the maximum pre-movement times noted for each source, a mean pre-movement time is calculated. The suggested value estimated for this analysis is 44 seconds.

Table 18 Pre-Movement Times [17]

SFPE HB Table	Occupancy	Source	Time (s)
Table 64.9	Educational	Kholshevnikov	30
Table 64.9	Educational	Galea	98
Table 64.11	Assembly	Tancogne-Dejean	10
Table 64.11	Assembly	Purser	36
		Mean Pre-Movement Time	**44**

Movement Time (T_{trav})
The travel time or movement time must be calculated using an empirical timed egress analysis or a computer-based evacuation simulation. Computer-based simulations are commonly used for their flexibility and complexity; however, must be reviewed thoroughly for validation. Empirical timed egress analyses tend to be more simplified calculations that can be executed in a spreadsheet software or by hand. For this report, the building's movement time for the selected design scenario is analyzed using the computer-based egress simulation software, Pathfinder.

Retained Prescriptive Requirements

It must be mentioned, in addition to the performance criteria defined, the requirements defined in the Prescriptive Design section must be retained and applied to the performance-based design, per Section 5.3. Any shortcomings of the retained systems are respectfully addressed, where necessary, for the specific design scenarios.

Design Fire Scenarios

The design fire scenarios are selected as realistic, yet conservative, fires used to evaluate the building's fire protection systems' performance in respect to the defined objectives and goals. There are three scenarios selected to address the unique characteristics, in three different spaces, affecting a significant population of occupants. The following defines the building characteristics, the design fire, and the assumptions and limitations for each scenario.

Design Fire Scenario 1 – Auditorium

The Auditorium is selected because of the potential for a significant fire affecting a large population of occupants with accessibility to elevated floor levels. This scenario is susceptible to an increased possibility of the occupants interfacing with the products of combustion. As defined below, this scenario aligns closely with the LSC Design Fire Scenario 4 and 6 in Chapter 5.

Building Characteristics

Other than the building characteristics noted in the Prescriptive Design section, the following building features are important in addressing the selected design fire scenario. The Auditorium space is composed of two adjoining spaces, the Auditorium, the spectator seating area with telescopic seating, and the Platform, the presentation area beyond the proscenium opening. Figure 55 is the floor plan illustrating the layout of the two communicating spaces.

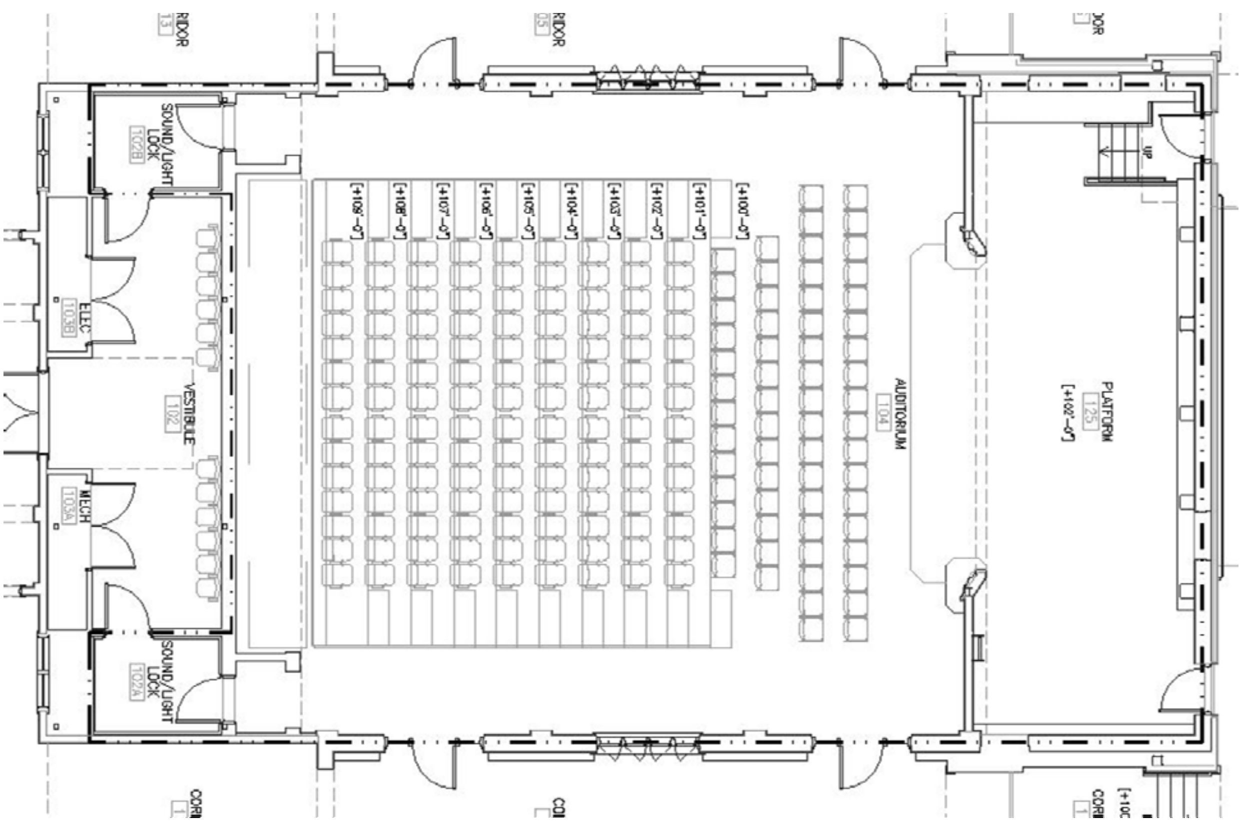

Figure 55 Auditorium Floor Plan [20]

- **Platform**
  - Geometry – 15'-6"W x 42'-0"L x 23'-0" to 24'-6"H with a proscenium opening 22'-0"W x 14'-6"H
  - Ceiling – open to roof deck and exposed existing 2"x12" wood beams with additional steel I-beams used to support curtains
  - Walls – existing masonry brick walls with finished with 2-layers of 5/8" Type X gypsum wall board with decorative wood trim baseboards and proscenium opening
  - Floor – elevated concrete slab supported with CMU brick knee walls and with a ¾" plywood finish
  - Drapery – seven layers of 25 oz. inherent fire retardant (IFR) cotton velour and one layer of muslin, all have varying lengths and are hung from separate riggings
- **Auditorium**
  - Geometry – 45'-0"W x 51'-0"L x 21'-6"H
  - Ceiling – existing plaster and gypsum board
  - Walls – existing plaster and gypsum board with decorative wood trim base boards
  - Floor – epoxy Terrazzo
  - Telescopic Seating – steel and aluminum frame, a min. ¾" plywood deck walking surface covered in nylon carpet, and 25 oz. IFR cotton velour drapery along the elevated sides. The seats are constructed of blow-molded linear polyethylene with a maximum burn rate of 1 in. per minute, tested in accordance with ASTM D635, and open cell polyurethane foam padding and standard fabric upholstery complying with California Technical Bulletin 117.
- **HVAC – Auditorium/Platform**
  - Dedicated 6,000 cfm AHU
  - Return air louver located below the Platform, at the proscenium, with 11 $ft.^2$ of free vent area, serving the Auditorium. One opposed blade damper return register located on the West side of the Platform 10'-0" AFF, capable of 1,830 cfm, serving the platform. Return air plenum below the Platform. Return air fire dampers located at the platform smoke partition duct penetration and at the second-floor duct penetrations.
  - Three supply air plate diffusers spaced evenly across the center of the Platform, providing 1,830 cfm to the Platform. Six, 12'-0" long, linear supply air diffusers located along the perimeter of the Auditorium, supplying 4,170 cfm to the Auditorium.
- **Fire Protection Systems**
  - Automatic Wet-Pipe Fire Sprinkler System throughout in accordance with NFPA 13, with extended coverage sidewall fire sprinklers providing limited protection below the telescopic seating.
  - In-Building Fire Emergency Voice/Alarm Communications System throughout the building.
  - Smoke Control System, passive with duct smoke detectors for AHU shutdown.

Design Fire

An appropriately conservative design fire is selected to evaluate a realistic fire risk by considering the location of the fire, the possible fuels, ignition sources, and flame spread possibilities.

Location of Fire – Initially the Platform area was considered because of the enhanced possibility of a significant fuel load due to the innate use of the Platform for a variety of presentations. However, the Platform fuel loads are limited to 100 kW in accordance with the LSC Section 13.4.5.11, the presence of fire sprinklers, the size of the proscenium opening, the results from

full-scale tests conducted by Yamada [17] indicating fire-retardant cotton velour drapery failed to sustain burning, and the fact the majority of the occupants will be located in the Auditorium. The Platform was eliminated from the selection due to the prescriptive requirements minimizing the apparent risk and the possibility of a more conservative fire scenario at another location.

After assessing the conditions in the Auditorium, it was determined a fire originating below the telescopic seating, outside of the fire sprinkler coverage and located at the edge of the seating area, would be an appropriate location. This selection is based on the fire sprinkler system's ineffectiveness due to the lack of fire sprinkler coverage below the seating area, the potential for stored materials, the probability of ignition due to electrical failure associated with the electrically powered retraction system or intentional ignition, the proximity to the occupants, and the nature of the concealed space allowing a fire to grow unnoticed.

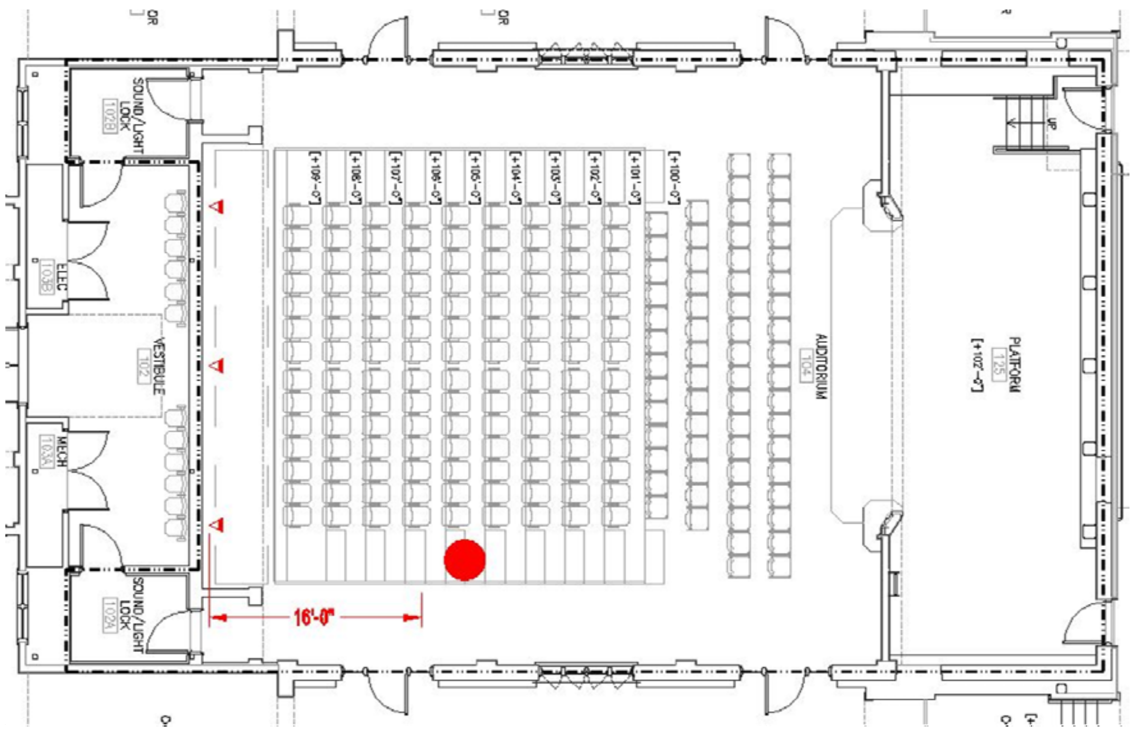

Figure 56 Auditorium Fire Location

Fuel – The possibility of the area below the telescopic seating could be mistakenly used for storage, due to its accessibility and ability to conceal, items such as, chairs, boxes, or trash should be considered as initial fuel sources. Based on the use of the building, it is typical for such facilities to maintain quality housekeeping; therefore, the possibility of trash collection and the storing of boxes is not as probable as the temporary storage of surplus chairs. The fuel selected for this design fire is a stack of eight upholstered, stackable chairs with metal frames. Due to the concealed nature of the selected location, the fire is likely to grow unnoticed igniting adjacent fuels, such as, the cotton velour curtains along the edge of the seating and possibly the plywood deck below the elevated walking surface.

Fuel Characteristics – Table 19 shows the fuel characteristics that would be used as inputs in the FDS model, to accurately simulate the fire scenario.

Table 19 Design Scenario 1 - Fuel Characteristics

FUEL CHARACTERISTICs		
FIRE CHARACTERISTICs		
Description	Units	Input Data
Product		Stack of 8 Chairs
Composition		Steel Frame | Plywood Backing | Polyurethane Padding | Vinyl Covering
Configuration		Corner
Peak HRR	kW	900
Growth Rate (α)	kW/s^2	0.1878
Width	m	0.50
Length	m	0.50
Area	m^2	0.25
Base Height	m	0.50
***SFPE Handbook 5th Edition - Chapter 26 "Heat Release Rates", Babrauksas [17]*		

SMOKE CHARACTERISTICs				
Materials	ΔH_c (kJ/g)	CO Yield (g/g)	Soot Yield (g/g)	% Composition
Flexible Polyurethan Foam	17.80	0.010	0.131	70.0%
Vinyl (PVC)	5.70	0.063	0.172	5.0%
Plywood	12.40	0.004	0.015	25.0%
Chairs	**15.85**	**0.011**	**0.104**	**100.0%**
***SFPE Handbook 5th Edition - Table A.39 [17]*				

Assumptions & Limitations

The following assumptions are applied to this design scenario:

- Ambient Conditions
  - Temperature: 295K (22°C | 72°F)
  - Atmospheric Pressure: 101325 Pa
- Ignition
  - Initial: the stack of chairs ignite
- Chair Composition
  - Padding: Polyurethane
  - Covering: Polyvinylchloride
  - Backing: Plywood (e.g., Red Oak)
- Curtains adjacent to the initial fire, quickly burnout allowing the plume to spill beyond the concealed space below the telescopic seating; however, beyond the curtained area nearest to the flaming fire does not sustain burning. The curtain burning characteristics are according to the full-scale tests conducted by Yamada [17, FR cotton curtains failed to sustain burning. Therefore, curtain burnout adjacent to the fire is implicitly modeled as a 2 m wide hole, representing a 2 m wide vertical strip of curtain.

- The fire sprinklers at the Auditorium ceiling activate. (Not explicitly modeled)
- The fire is allowed to grow until the activation of the first ceiling fire sprinkler, at this time the heat release rate (HRR) is sustained at a steady rate and does not grow further.
- The fire alarm activates 90 seconds after the initial activation of the first fire sprinkler.
- Fuel burnout is not accounted for.
- The fire is allowed to grow unnoticed.
- HVAC remains active throughout duration.
- The Auditorium is fully occupied.
- The Auditorium doors are closed.
- The Auditorium lights are dimmed.
- Occupants avoid using the walking surface directly above the fire.
- Occupants beyond the room of origin are capable of evacuating within the time it takes to evacuate the Auditorium.
- The Auditorium is only modeled.

Design Fire Scenario 2 – Planetarium

The Planetarium was selected because of the potential for a fire to occur with occupants relatively close to the origin, and because of the room's unique use and geometry. This scenario is necessary to model how the smoke and fire will interact with the projection dome. As defined below, this scenario aligns closely with the LSC Design Fire Scenario 5 in Chapter 5.

Building Characteristics

Other than the building characteristics noted in the Prescriptive Design section, the following building features are important in addressing the selected design fire scenario. Figure 57 is the section view of the planetarium illustrating how the projection dome interacts with the space.

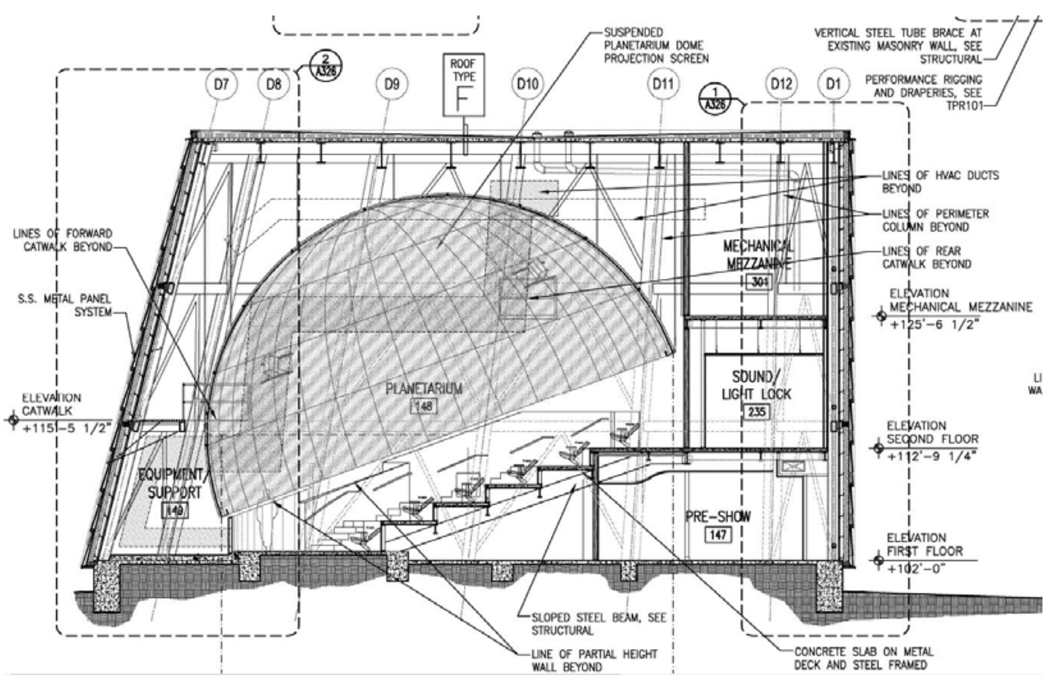

Figure 57 Planetarium Section [20]

- **Planetarium**
  - Description – irregular, oval geometry connecting two floor levels along with elevated catwalks. Also, a domed projection screen that will influence the smoke layer and the fire sprinkler coverage.
  - Geometry – 48'-6"L x 62'-0"S x 41'-4"H
  - Ceiling – open to the metal roof deck and structure.
  - Projection Screen – perforated (~22% open) aluminum dome with an epoxy powder coated finish, encompassing the entire occupant seating area.
  - Walls – metal structural components with a minimum single layer of 5/8" Type X gypsum board or black fiberglass acoustical panels.
  - Floor – concrete slabs covered in nylon carpet.
- **Fire Protection Systems**
  - Automatic Wet-Pipe Fire Sprinkler System throughout in accordance with NFPA 13.
  - In-Building Fire Emergency Voice/Alarm Communications System throughout the building.
  - Smoke Control System, passive with duct smoke detectors for AHU shutdown.

Design Fire

An appropriately conservative design fire is selected to evaluate a realistic fire risk by considering the location of the fire, the possible fuels, ignition sources, and flame spread possibilities.

Location of Fire – The Planetarium was selected based on the unique use and geometry, more specifically, to simulate how the projection screen influences the fire scenario. Therefore, the location of the fire must be located beneath the screen. The exact location is identified in the Fuel paragraph below and shown in Figure 58.

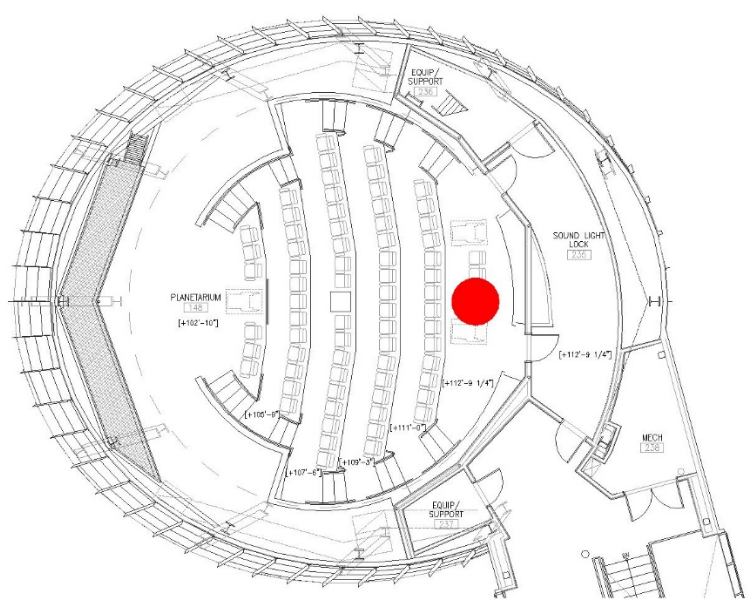

Figure 58 Planetarium Fire Location

Fuel – The fuel selected for this fire scenario is the projector operator's workstation. The workstation is the greatest fuel load below the projector screen with the highest probability of ignition. The high ignition probability is due to the accumulation of electrical equipment and

wiring surrounding and integrated into the workstation along with the likely presence of a small trash bin located beneath the control console.

The composition of the workstation is not explicitly defined; however, based on the review of an existing image of the workstation, Figure 59, it appears to be constructed of metal, fiberboard lined in a plastic veneer, and trimmed in plastic. Along with construction of the console, the contents of the workstation must be considered. The contents include a computer, a monitor, a keyboard, cables, and a possible control board.

Figure 59 Workstation Image [3]

In addition, the proximity of the surrounding spectator seating to the initial fire increases the probability of a second ignition of an upholstered seat, spreading the fire beyond the workstation. The spectator seats have an identical composition to the telescopic seating seats. The seats are constructed of blow-molded linear polyethylene with a maximum burn rate of 1 in. per minute, tested in accordance with ASTM D635, open cell polyurethane foam padding, and standard fabric upholstery complying with California Technical Bulletin 117

Fuel Characteristics – Table 20 shows the fuel characteristics that would be used as inputs in the FDS model, to accurately simulate the fire scenario.

Table 20 Design Scenario 2 - Fuel Characteristics

FUEL CHARACTERISTICs		
FIRE CHARACTERISTICs		
Description	Units	Input Data
Product		Workstation
Composition		Metal Frame | Fiberboard | PVC
Peak HRR	kW	1900 (Rounded up to nearest 100)
Growth Rate (α)	kW/s^2	0.1878
Width	m	0.75
Length	m	2.00
Area	m^2	1.50
Base Height	m	10.00
***SFPE Handbook 5th Edition - Chapter 26 "Heat Release Rates", Babrauksas [17]*		

SMOKE CHARACTERISTICs				
Materials	ΔH_c (kJ/g)	CO Yield (g/g)	Soot Yield (g/g)	% Composition
PVC	5.70	0.063	0.172	40.0%
Fiberboard	14.00	0.015	0.008	60.0%

Workstation	10.68	0.03	0.07	100.0%
***SFPE Handbook 5th Edition - Table A.39 & Handbook of Smoke Control Engineering - Table 6.5 [17]*				

Assumptions & Limitations

The following assumptions are applied to this design scenario:

- Ambient Conditions
  - Temperature: 295K (22°C | 72°F)
  - Atmospheric Pressure: 101325 Pa
- Ignition
  - Initial: the workstation ignites
- The fire sprinklers at the ceiling activate; however, due to the shielding from the dome projection screen, the fire sprinklers are assumed to be ineffective in controlling the fire. Thus, the fire is able to grow to its peak HRR.
- The fire alarm activates 90 seconds after the initial activation of the first fire sprinkler.
- AHU is shut down due to initiation of duct detectors. (Not explicitly modeled)
- Fuel burnout is not accounted for.
- The Planetarium is fully occupied.
- Occupants avoid egress adjacent to fire.
- Occupants beyond the room of origin are capable of evacuating within the time it takes to evacuate the Planetarium.
- The Planetarium is only modeled, considering the Planetarium is relatively isolated from the remaining building.

Design Fire Scenario 3 – Lobby (Main Entrance)

The Lobby was selected because of the potential for a significant fire impeding the primary means of egress on the first floor and second floor, with an enhanced possibility of occupants interfacing with the products of combustion. This scenario aligns with the LSC Design Fire Scenario 2 in Chapter 5.

Building Characteristics

The overall building characteristics were addressed, regarding the entire building and the prescriptive requirements, in the prescriptive section of this report. The following building features are important in addressing the selected design fire scenario:

- **Lobby**
  - Description – irregular geometry connecting two floors and three building sections, with the first floor open to the second floor. The elevator lobby is within this space, as well.
  - Geometry – ~30’-0”W x ~86’-0”L
  - Height
    - 1^{st} Floor – 12’-9” (1^{st} Floor Finish Floor to 2^{nd} Floor Finish Floor)
    - 2^{nd} Floor – 10’-4” (2^{nd} Floor Finish Floor to 2^{nd} Floor Ceiling)
  - Ceiling – Acoustical plaster
  - Walls – Metal studs with 5/8” Type X gypsum board, metal studs with wood paneling, masonry, and aluminum and glass curtain wall extending between the 1^{st} and 2^{nd} floor.
  - Floor – Epoxy Terrazzo
- Fire Protection Systems

- Automatic Wet Pipe Fire Sprinkler System throughout in accordance with NFPA 13.
- In-Building Fire Emergency Voice/Alarm Communications System throughout the building with smoke detectors located at each level of the elevator lobby, to activate elevator recall.
- Smoke Control System, passive with duct smoke detectors for AHU shutdown and automatic-closing doors. Automatic-closing doors are located at the first and second floor entrances to the Lobby from the East and the West.

Design Fire

An appropriately conservative design fire is selected to evaluate a realistic fire risk by considering the location of the fire, the possible fuels, ignition sources, and flame spread possibilities.

Location of Fire – Considering the space is primarily used for egress and standing room only, the permanent entry desk is the most likely fuel source for this fire scenario, and is located as shown in Figure 60. The desk consists of multiple storage compartments and has data and power integrated into the desk construction. Items stored in the compartments, an electrical failure, or the presence of a small trash bin are potential ignition sources.

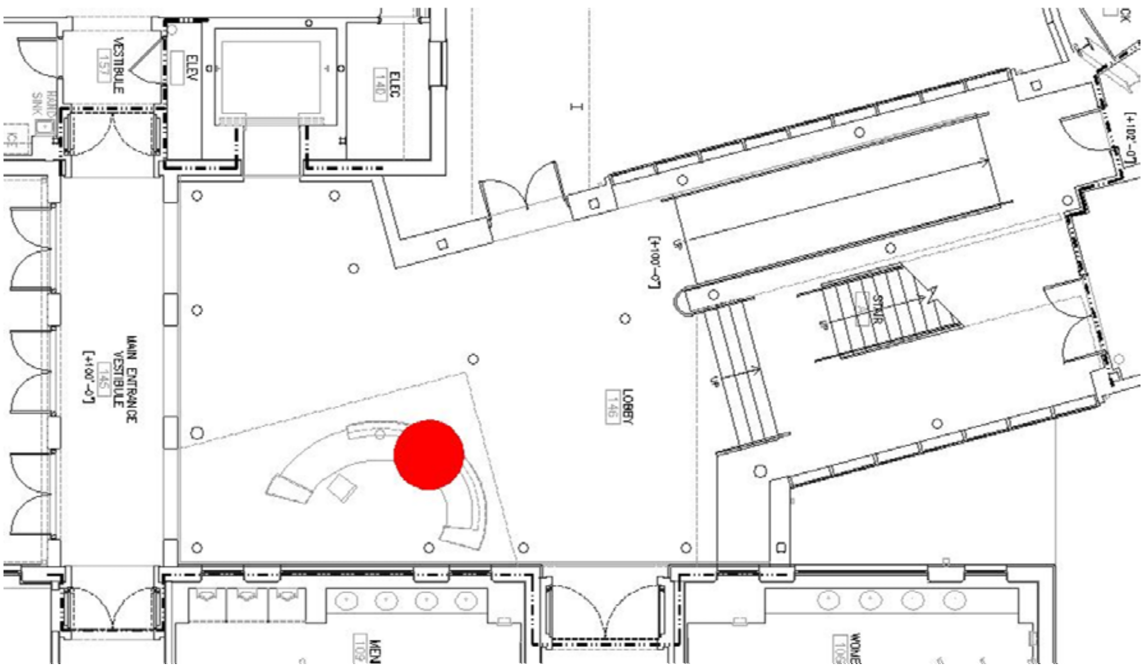

Figure 60 Lobby Fire Location

Fuel – As noted above, the selected fuel source for this scenario is the entry desk. The desk is constructed of mostly plywood with a finish wood paneling along the vertical exterior and an epoxy Terrazzo top. Figure 61, 62, and 63 detail the desk construction.

Figure 61 Entry Desk Image [9]

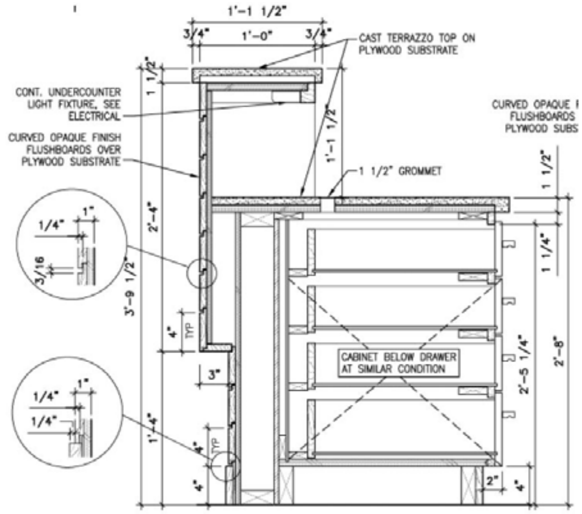

Figure 62 Entry Desk Section [20]

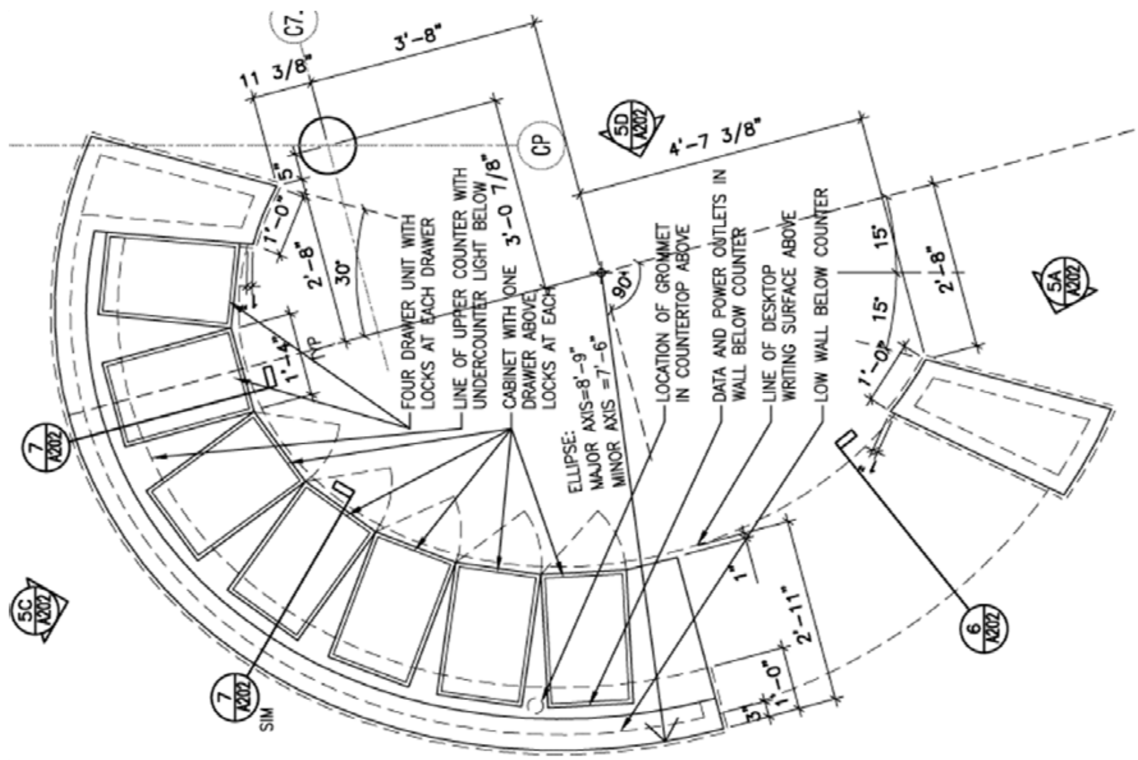

Figure 63 Entry Desk Plan [20]

Fuel Characteristics – Table 21 shows the fuel characteristics that are used as inputs in the FDS model, to accurately simulate the fire scenario.

Table 21 Design Scenario 3 - Fuel Characteristics

FUEL CHARACTERISTICs		
FIRE CHARACTERISTICs		
Description	Units	Input Data
Product		Dresser (Actual - Entry Desk)
Composition		Wood | Terrazzo Work Surface
Peak HRR	kW	1800
Growth Rate (α)	kW/s^2	0.0183
Width	m	1.00
Length	m	3.00
Area	m^2	3.00
Base Height	m	0.00
***Heat Release Rates of Burning Items in Fires - Table C, Kim and Lilley [5]*		

SMOKE CHARACTERISTICs				
Materials	ΔH_c (kJ/g)	CO Yield (g/g)	Soot Yield (g/g)	% Composition
Wood	12.40	0.004	0.015	100.0%
***SFPE Handbook 5th Edition - Table A.39 [17]*				

Assumptions & Limitations

The following assumptions are applied to this design scenario:

- Ambient Conditions
  - Temperature: 295K (22°C | 72°F)
  - Atmospheric Pressure: 101325 Pa
- Ignition
  - Initial: the desk ignites
- The fire sprinklers at the ceiling, directly above the desk, activate. (Not explicitly modeled)
- The fire is allowed to grow until the activation of the first fire sprinkler, at this time the HRR is sustained at a steady rate.
- Occupants detect fire prior to any fire alarm initiating devices.
- The automatic doors activate upon detection of smoke.
- The fire alarm activates upon first detection of smoke.
- AHUs are shut down due to initiation of duct detectors. (Not explicitly modeled)
- Fuel burnout is not accounted for.
- The building is fully occupied.
- Occupants avoid egress adjacent to fire.
- The Lobby is only modeled FDS, considering the automatic doors operate as designed, preventing the products of combustion from spreading throughout the building.

Analysis & Results – Design Scenario 3

To continue with Design Fire Scenario 3 (DS3), the following is an analysis of the RSET and ASET regarding a potential fire in the Lobby.

RSET

Using the information presented in the Performance Criteria section, regarding Method 2, the engineering timeline is completed by simulating an occupant evacuation using Pathfinder to approximate a conservative travel time, along with the estimation of the detection and warning time specific to DS3. Last, all of the times are added together and a 50% safety factor is applied resulting in the estimated RSET for DS3, to be compared with the ASET evaluated in the following section. The safety factor is equivalent to the RSET applied to an atrium per the LSC Section 8.6.7(5) to account for the applied assumptions and estimates.

$T_{RSET} = (T_{det} + T_{warn} + T_{pre} + T_{trav}) \times 1.5$ (Safety Factor)

Detection Time (T_{det})

The detection time for this scenario is from the time of ignition until the first sign of visible smoke. It is assumed the fire is initially detected by building occupants in the Lobby, considering the proximity of the desk to the occupants when the Lobby is at the maximum occupant load, defined in the Prescriptive Design section.

The initial detection time is determined by evaluating the incipient stages of the fire modeled in the FDS simulation. FDS is explained further in the ASET section. Using the NIST Smokeview simulator, a visualization tool integral to FDS, to visually identify the time the smoke plume is substantial enough to obtain the attention of the nearby occupants. Considering there is no empirical data to reference that is applicable to the design scenario, a qualitative visual observation is used to approximate the detection time, see Figure 64.

Figure 64 FDS – 30 s

The approximated detection time is 30 seconds.

Warning Time (T_{warn})

The warning time is the time the fire is initially detected by a building occupant leading to the time the pre-evacuation process begins. Considering the fire is detected by an occupant prior to the initiation of a smoke detector or a fire sprinkler, the warning time is difficult to accurately determine because of unpredictable variables based on human behavior. The warning time can be predicted based on historical data; however, data representative of DS3 was not found. Therefore, the warning time must be approximated according to the characteristics of DS3 resulting in an engineering judgement.

The fact the Lobby has an open design and the scenario assumes the maximum occupant load, the Lobby occupants will likely be able to witness the fire cues personally. Therefore, the occupants are able to communicate the alarm condition to one another in a quick manner and prior to the activation of the building fire alarm system.

The approximated warning time used for the occupants within the Lobby is 20 seconds.

The occupants outside of the Lobby have a delayed warning time dependent on the time it would take a trained staff member to travel from the Lobby to the EVAC control unit in the Cafeteria to deliver a live voice message. In addition to the warning time for the Lobby occupants, an additional 68 seconds must be added for the remaining building occupants' warning time. This time was calculated using the following equation for pedestrian speed, found in Chapter 59 of the SFPE Handbook 5th Edition:

$$S = k - akD = (275 - 2.86*275*0.05)/60 = 3.90 \text{ ft./s}$$

S = Speed along the line of travel
D = Population density (0.05 persons/ft.^{2} is used assuming the pedestrian is minimally impeded)
k = Constant (275 is used for level components, considering there are no stairs along the path)
a = Speed (2.86 ft./min.)

Occupants in spaces adjacent to the Lobby that are along the path of egress, begin evacuating as the Lobby occupants egress through the space. This is modeled in the Movement Time simulation.

Pre-Evacuation Time (T_{pre})

The pre-evacuation time based on the building and occupancy characteristics, determined in the Performance Criteria section, is 44 seconds.

Movement Time (T_{trav})

The movement time is calculated using the Pathfinder egress software. According to the Pathfinder User Manual, "Pathfinder is an agent based egress and human movement simulator" [18]. The software has two simulation modes, Steering and SFPE. The Steering mode, per the user manual, attempts to emulate human behavior and movement by steering the occupants to move and interact with others [18] The SFPE mode is based on the assumptions and hand-calculations found in the SFPE Handbook. The mode used for this analysis to simulate the evacuation of the Maumus Center, and more specifically, the Lobby, is the Steering mode. The Steering mode is chosen for the additional effect of human interaction, versus only calculating the queuing that occurs as occupants interface with egress components. Thus, the human interaction aspect adds to the realism of the simulation results.

The egress model is setup to evaluate the Lobby evacuation and subsequently, the entire building. The occupant population is distributed through the building at the maximum occupant load defined in the Prescriptive Design section and the LSC, for all occupiable spaces. All exit components are accessible to all occupants; however, the doors surrounding the Lobby are limited to one-way, exiting the Lobby only. The door limitations are based on the assumption the occupants outside of the Lobby are warned via a live voice message identifying the need to avoid the Lobby fire conditions.

The following figures, 65 through 70, illustrate the occupant evacuation at key time intervals. The red cylinders indicate the 1st floor occupants and the blue cylinders indicate the 2nd floor occupants.

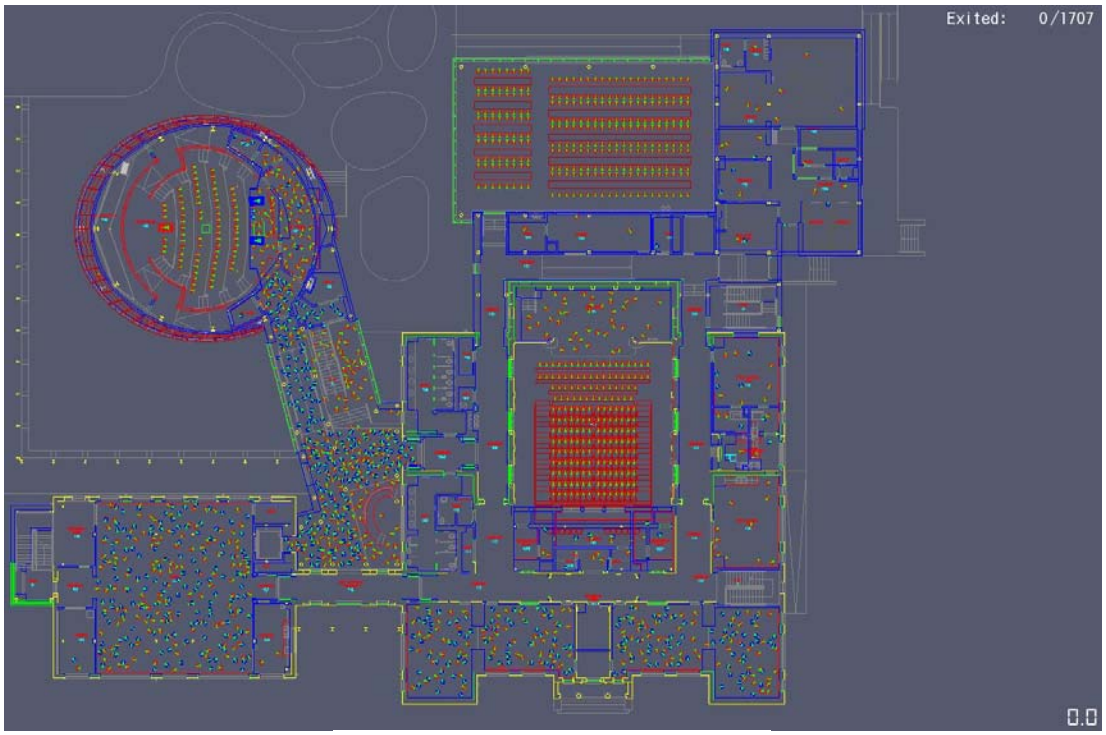

Figure 65 Pathfinder – 0 s

Figure 65 illustrates the distribution of occupants just before they begin evacuating.

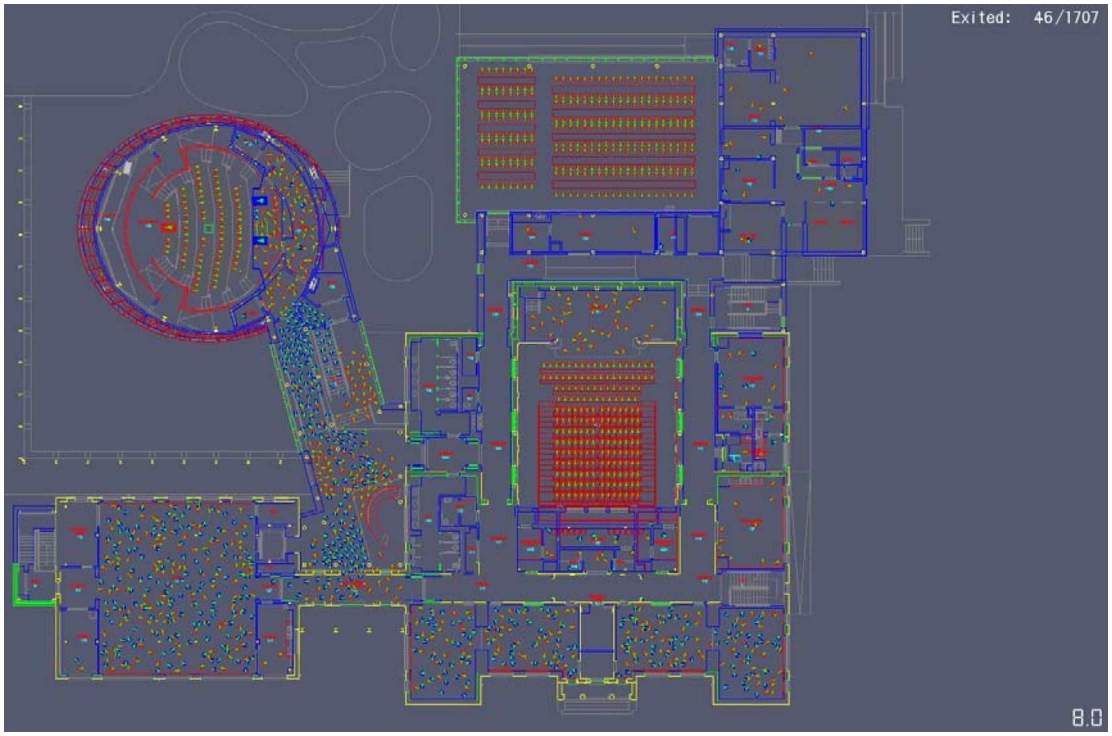

Figure 66 Pathfinder – 8 s

Figure 66 is a snapshot of the time the adjacent spaces interact with the evacuating Lobby occupants.

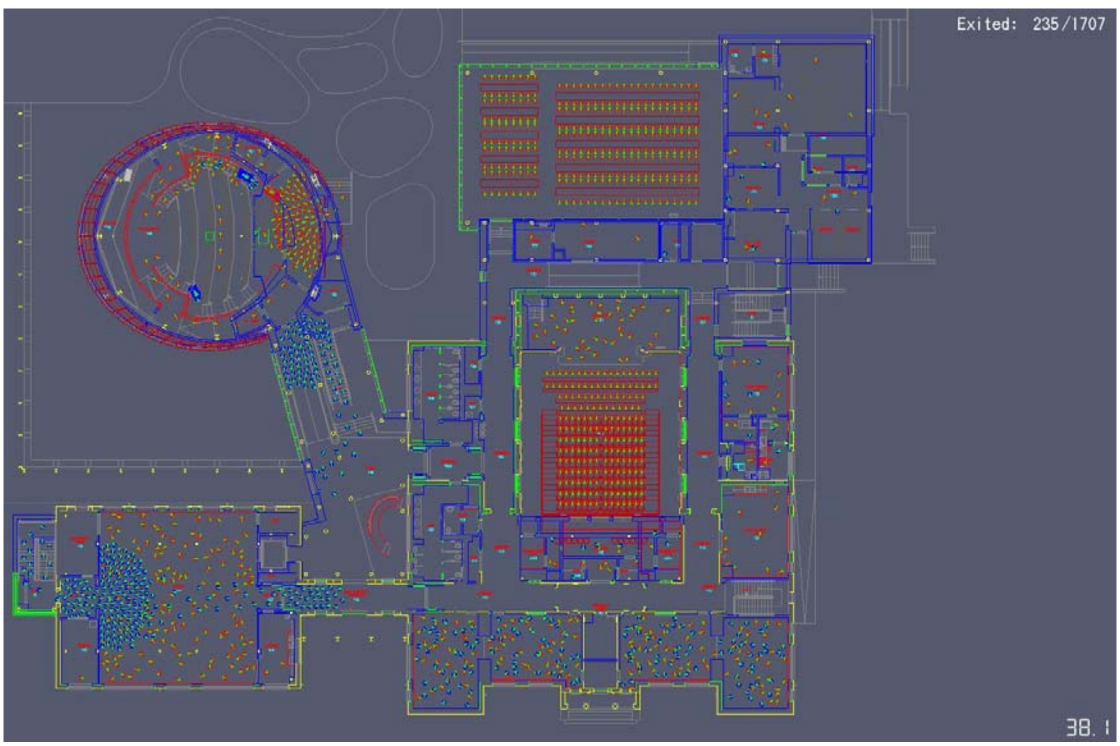

Figure 67 Pathfinder – 38 s

Figure 67 illustrates the moment the last 1st floor occupant evacuates the Lobby.

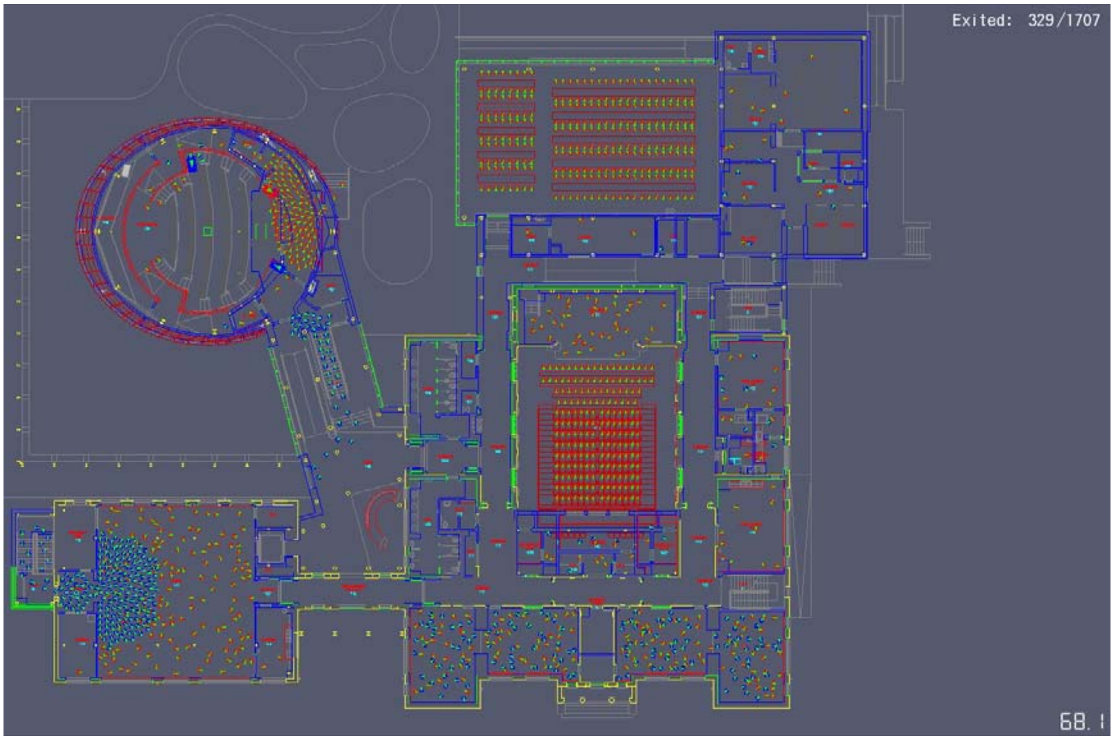

Figure 68 Pathfinder – 68 s

Figure 68 illustrates the moment the remaining building occupants begin moving.

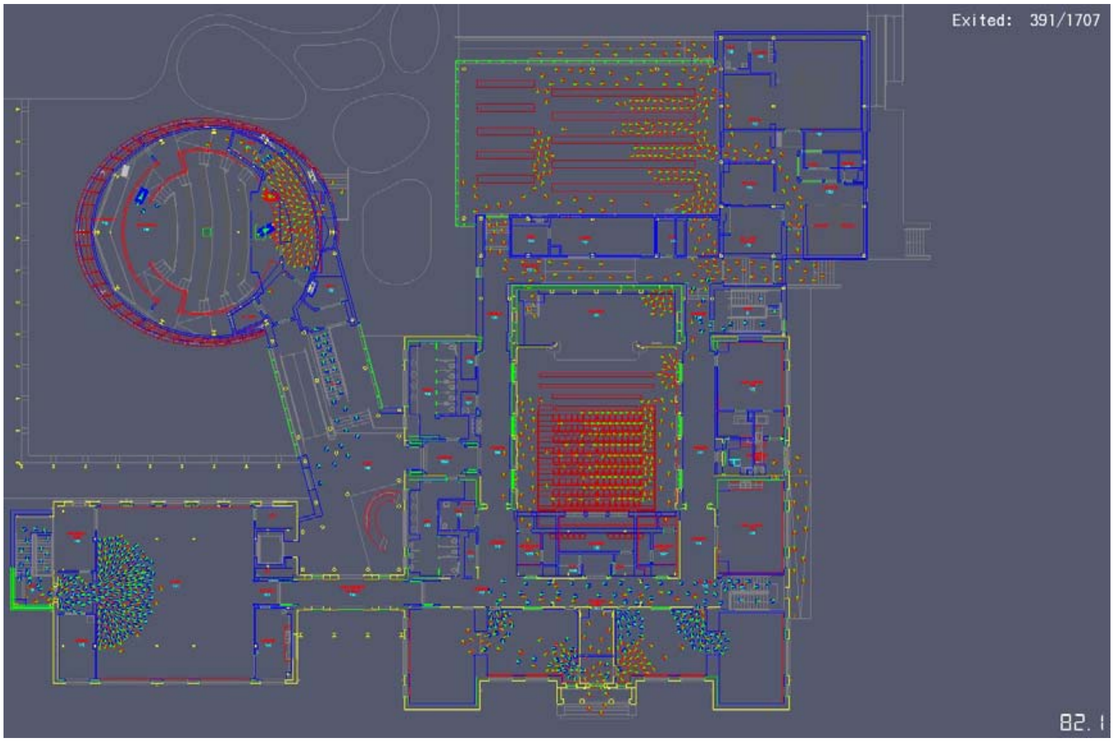

Figure 69 Pathfinder – 82 s

Figure 69 illustrates the moment the last 2nd floor Lobby occupant accesses the Lobby stairs.

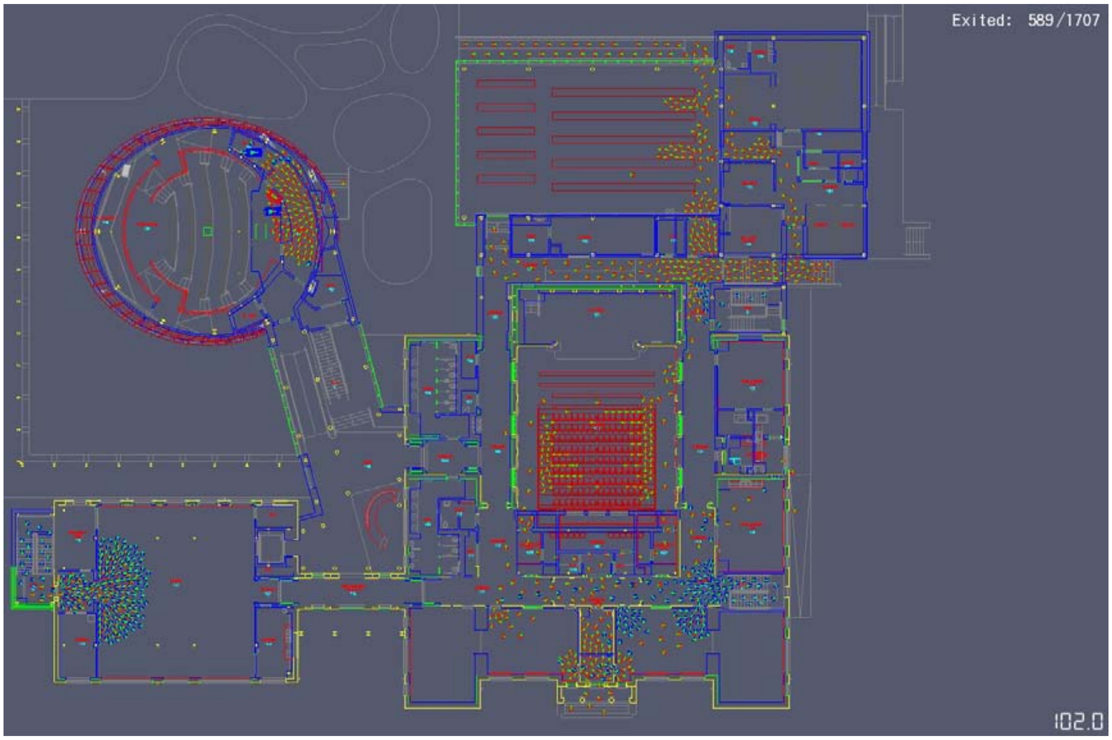

Figure 70 Pathfinder – 102 s

Figure 70 illustrates the moment the Lobby is fully evacuated.

According to the Pathfinder simulation, the time it takes to evacuate all of the Lobby occupants from the Lobby is 102 seconds. Therefore, the movement time for DS3 is 102 seconds.

In addition, it is important to note the entire building is evacuated in 268 seconds, and there were occupants queued on the 2nd floor at 248 seconds. These 2nd floor occupants were only separated from the room of origin by one set of automatic-closing doors. If for any reason, the automatic-closing doors do not operate as designed, these occupants may be exposed to untenable conditions.

Now that the time intervals leading to complete evacuation of the Lobby have been determined, the RSET to completely evacuate the Lobby can be calculated.

$\mathbf{T_{RSET} = (T_{det} + T_{warn} + T_{pre} + T_{trav}) \times 1.5 = (}30 + 20 + 44 + 102) \times 1.5 \mathbf{= 294\ s}$

$T_{det} = 30$ s | $T_{warn} = 20$ s | $T_{pre} = 30$ s | $T_{trav} = 102$ s

Furthermore, it is necessary to calculate the RSET for the 2nd floor of the Lobby, as well; considering untenable conditions are likely to be reached on the 2nd floor prior to any other location.

$\mathbf{T_{RSET2} = (T_{det} + T_{warn} + T_{pre} + T_{trav2}) = (}30 + 20 + 44 + 82) \times 1.5 \mathbf{= 264\ s}$

$T_{det} = 30$ s | $T_{warn} = 20$ s | $T_{pre} = 30$ s | $T_{trav2} = 82$ s

ASET

The ASET is derived by inputting the information found in the Design Fire Scenario section into an FDS model, which simulates the fire conditions, to determine the time the visibility performance criterion is reached.

According to the FDS user guide:

> Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. FDS solves numerically a form of the Navier-Stokes equations appropriate for low-speed (Ma < 0.3), thermally-driven flow with an emphasis on smoke and heat transport from fires. [8]

The key features of the FDS software are the Hydrodynamic Model, used to model the fire flows, the Combustion Model, used to model the chemical reactions related to combustion necessary to simulate the products of combustion, and the Radiation Transport, used to model radiative heat transfer [8]. Accompanied with the FDS software, is Smokeview, a separate program used to visualize the FDS results.

The parameters required to model the fire were addressed previously in the Design Fire Scenario section; however, prior to performing the final simulation, the time at which the first fire sprinkler operates must be established to accurately demonstrate the fire sprinkler controlling affects to the fire heat release rate. The fire sprinkler operation time is empirically calculated using a DETACT spreadsheet and modeled using FDS. Table 21 shows the time results from the DETACT calculation and the FDS model.

Table 22 Sprinkler Activation Time

Source	Time (s)	HRR (kW)
DETACT	218	870
FDS	219	878

As indicated in Table 22, there is minimal variation between the two methods used to estimate the activation time. Thus, the HRR is controlled 219 seconds after ignition, sustaining a HRR at approximately 878 kW. Figure 71 is the charted HRR modeled in FDS.

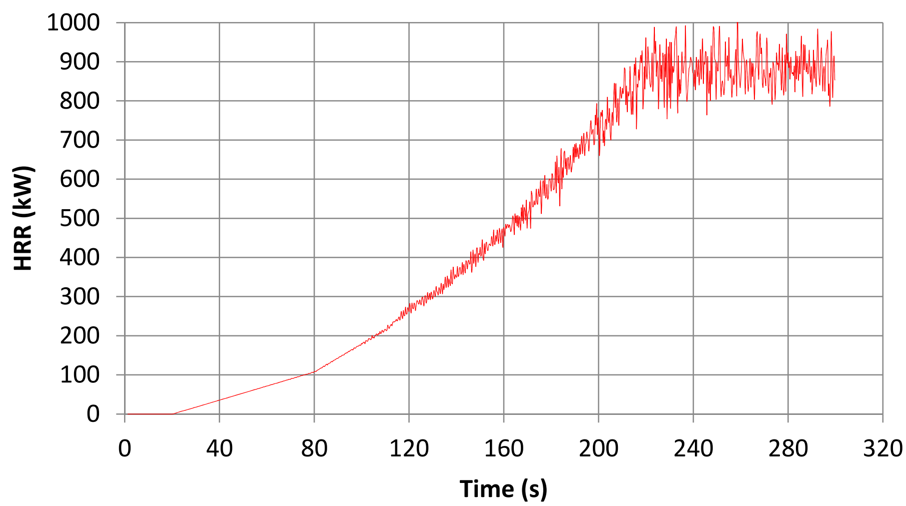

Figure 71 FDS HRR Chart

The following is a review of the FDS simulation results in regards to the DS3 ASET performance criteria.

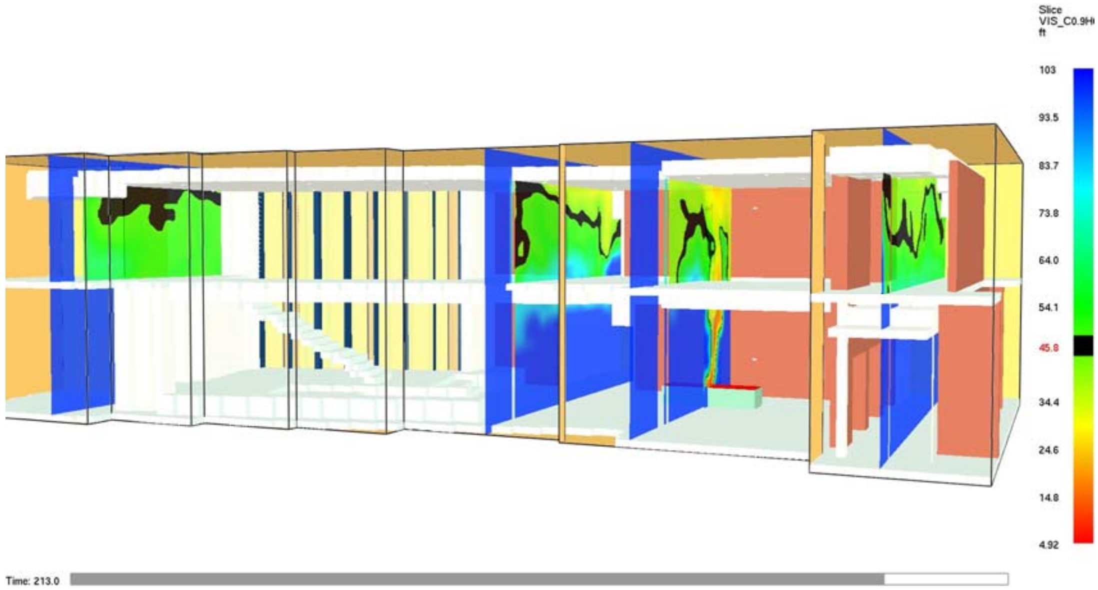

Figure 72 FDS Visibility – 213 s

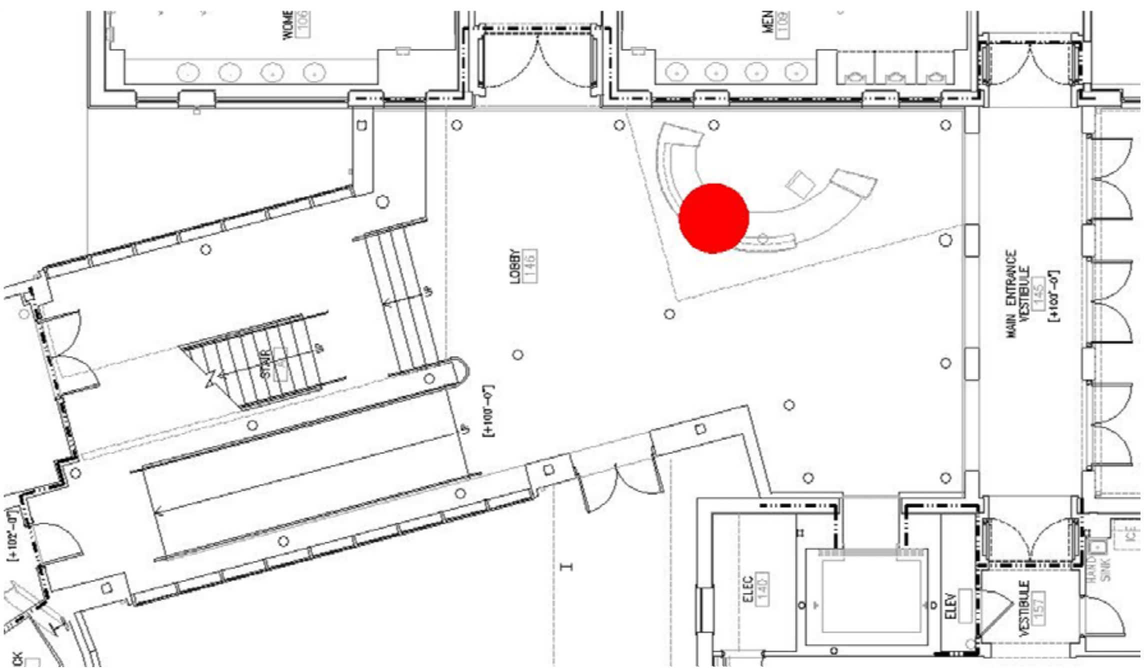

Figure 73 Fire Plan View

Figure 72 illustrates the visibility for four different slices throughout the Lobby, 213 seconds after ignition. Figure 73 is a plan view of the Lobby, provided to further communicate the fire scenario shown in Figure 72. The black regions shown, indicate the visibility criterion, a visibility distance of 46 ft. (14 m). Figure 72 shows the occupants remaining on the 2nd floor, 213 seconds after ignition will be exposed to untenable conditions. Comparing this to the 2nd floor Lobby RSET of 264 seconds, there is a difference of 51 seconds. The Lobby RSET exceeds the ASET; therefore, the building's prescriptive design is unable to achieve the defined goals and

objectives. Furthermore, a visibility factor of 8 was used based on the building being equipped with illuminated exit signs.

To continue, beyond the visibility threshold the temperature, heat flux, and carbon monoxide levels were evaluated for a duration of 300 seconds. The heat flux and the carbon monoxide levels never reached the tenability threshold defined. However, the temperature of 140°F is exceeded on the 2nd floor of the Lobby at approximately 210 seconds after ignition; hence, the ASET in regards to temperature is exceeded by the Lobby RSET 3 seconds prior to the visibility threshold being reached. The temperature profile at 210 seconds is shown in Figure 74. In Figure 74, the temperature threshold is noted as the black regions in the temperature slices. The untenable temperature exposure to the 2nd floor occupants further proves the prescriptive design is unable to achieve the defined goals and objectives.

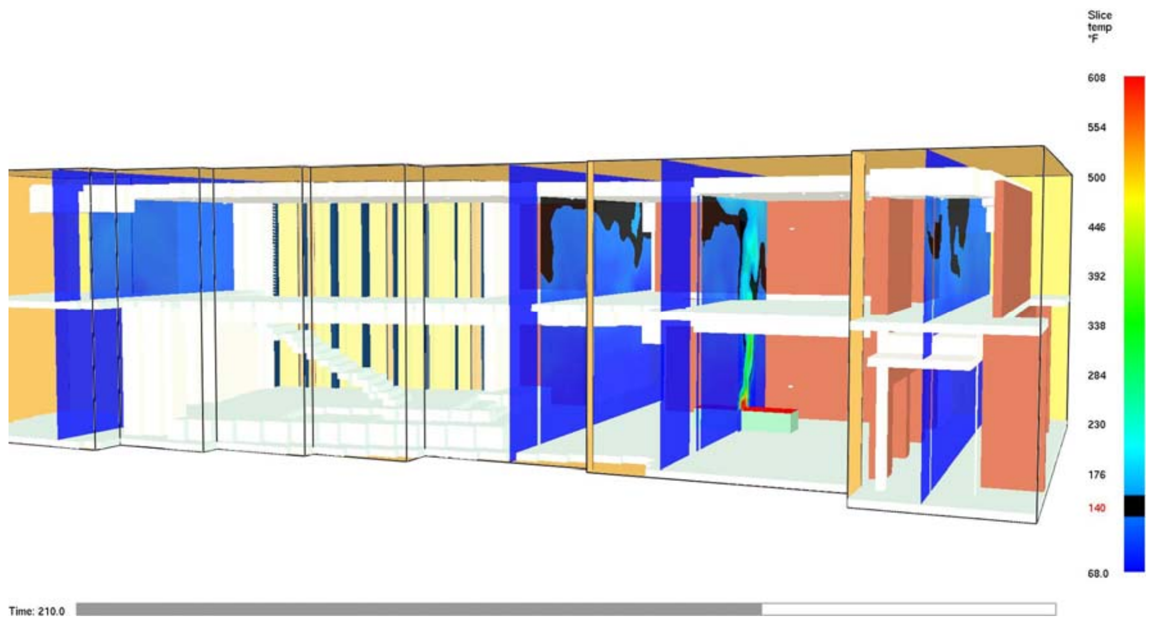

Figure 74 FDS Temperature – 210 s

Conclusion

To conclude, the performance analysis of the Lobby design scenario proved the building fire protection systems were unable to provide an adequate level of protection for the Lobby occupants. Further analysis is recommended to provide an adequate design capable of meeting the performance criteria. Two suggested solutions to be explored are to apply administrative controls that limit the Lobby occupant load or limit the fuels acceptable in the Lobby. It is also worth mentioning, the fire sprinkler performance was not modeled, other than the effect of controlling the HRR at an already elevated state. It is likely, due to the location of the desk in relation to the ceiling fire sprinklers, that the fire sprinklers would be able to suppress the fire to a lower HRR potentially reducing the temperature effects and delaying the time to reach the visibility threshold.

In addition, the two scenarios defined, but not analyzed would also require a performance analysis to confirm the building design is suitable for providing a safe environment for the associated occupants.

Conclusion

Concluding Summary

The Maumus Center's fire protection prescriptive design satisfies the adopted codes and standards. However, there are design situations that are not addressed in the codes or standards, that may have negative consequences for the building and the occupants. Along with these situations, the performance analysis proved the building design has the potential to expose occupants to untenable conditions. The following recommendations address these shortcomings and provide possible solutions that may require further analysis.

Recommendations

The following are recommendations based on the prescriptive and performance-based analysis:

- The hydrant flow test was performed at 12:30 pm. This time is acceptable per NFPA 291. Although, it is recommended that the test be performed at a more conservative time; either, early in the morning or later in the evening when there is statistically higher water consumption.
- The domed projector screen in the Planetarium is likely to have a negative effect on the fire sprinkler system, if a fire were to originate beneath it. It is recommended that a performance analysis be performed to determine how the system may be negatively affected and what design revisions are required to provide an acceptable level of safety.
- The telescopic seating, in the Auditorium, creates a combustible concealed space with partial and potentially ineffective fire sprinkler protection. It is recommended that a performance analysis be performed to determine how the system may be negatively affected and what design revisions are required to provide an acceptable level of safety.
- The fire sprinkler system Design Area 1, has a length along the branch lines of 64'-6". The required minimum length for the 1500 ft.^{2} design area is 47'-0", per NFPA 13. It is recommended to modify the design area by shortening the length closer to 47'-0", while maintaining the 1500 ft.^{2}. This modification to the design area may or may not have a negative effect on the hydraulic demand.
- The analysis of the voice evacuation system proved that the speaker spacing may not be capable of achieving intelligibility. It is recommended that a computer-based audibility model be used to evaluate the performance of the speaker arrangement, additional speakers should be installed, or other applicable speakers with specific performance capabilities should be considered.
- The fire alarm system control unit is located in the Cafeteria, a remote corner of the building. Because of the complex building layout, it is recommended that the control unit be relocated to the Lobby near the main entrance. This placement is a more centralized location along the main path of egress providing increased accessibility to staff and occupants in an emergency scenario.
- The Lobby design scenario proved to have the potential to expose occupants to untenable conditions. It is recommended that further analysis of this scenario be performed to determine suitable design revisions or administrative controls that would improve the outcome for the building occupants.

References

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6 Klote, John H., et al. *Handbook of Smoke Control Engineering.* ASHRAE, 2012.

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10 *NFPA 13: Standard for the Installation of Sprinkler Systems*. 2013 Ed., NFPA, 2012.

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12 *NFPA 25: Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*. 2014 Ed., NFPA, 2013.

13 *NFPA 70: National Electric Code*. 2014 Ed., NFPA, 2013.

14 *NFPA 72: National Fire Alarm and Signaling Code*. 2013 Ed., NFPA, 2012.

15 *NFPA 90A: Standard for the Installation of Air-Conditioning and Ventilating Systems*. 2012 Ed., NFPA, 2011.

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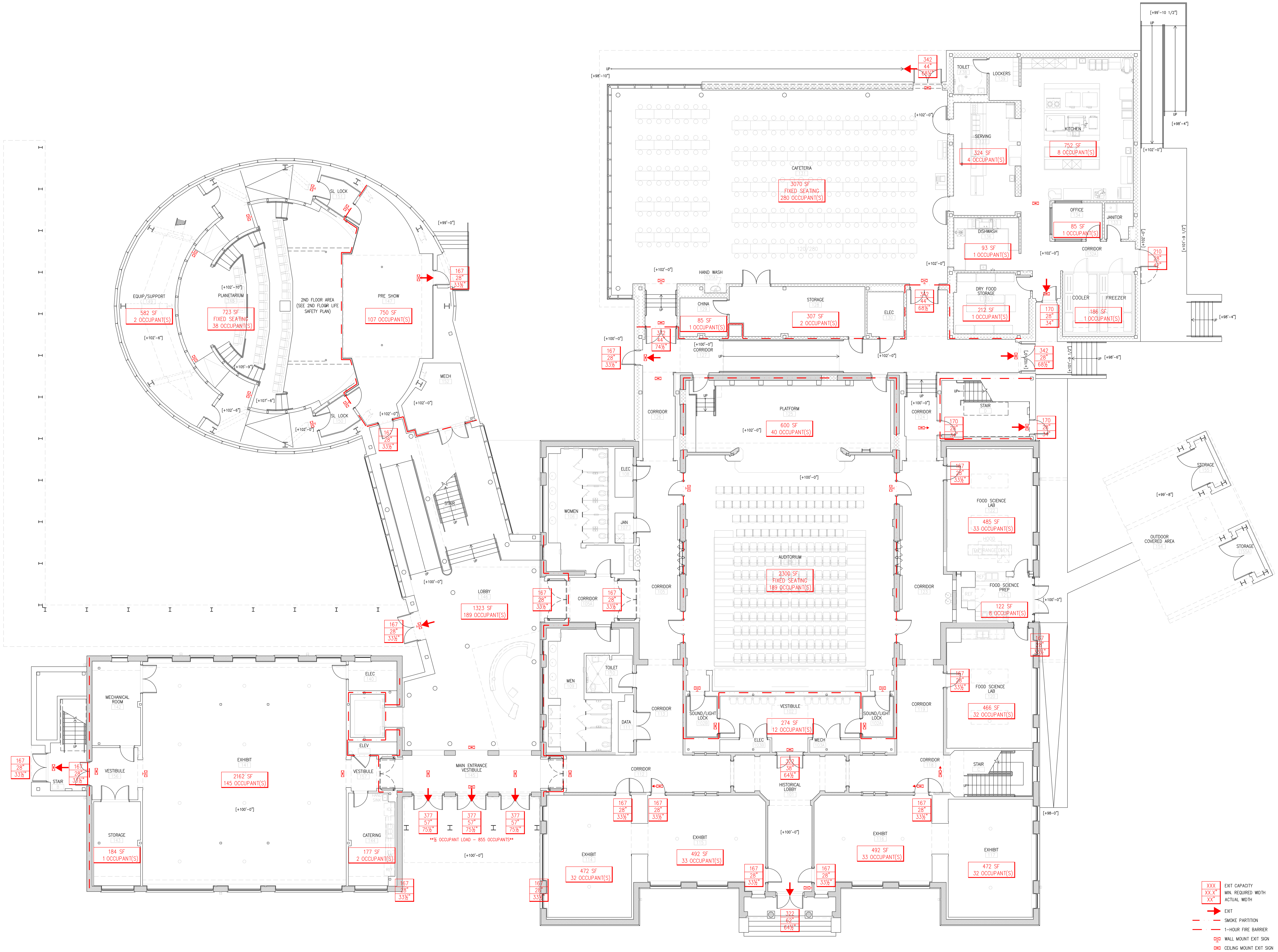
18 Thunderhead Engineering. *Pathfinder: User Manual*. 2017 Ed., Thunderhead Engineering, 2017.

19 Waggonner and Ball Architects. *Maumus Center*. http://www.wbarchitects.com/projects/maumus_center/. Accessed 28 May 2017.

20 Waggonner and Ball Architects. *Maumus Center: Construction Documents.* 2012.

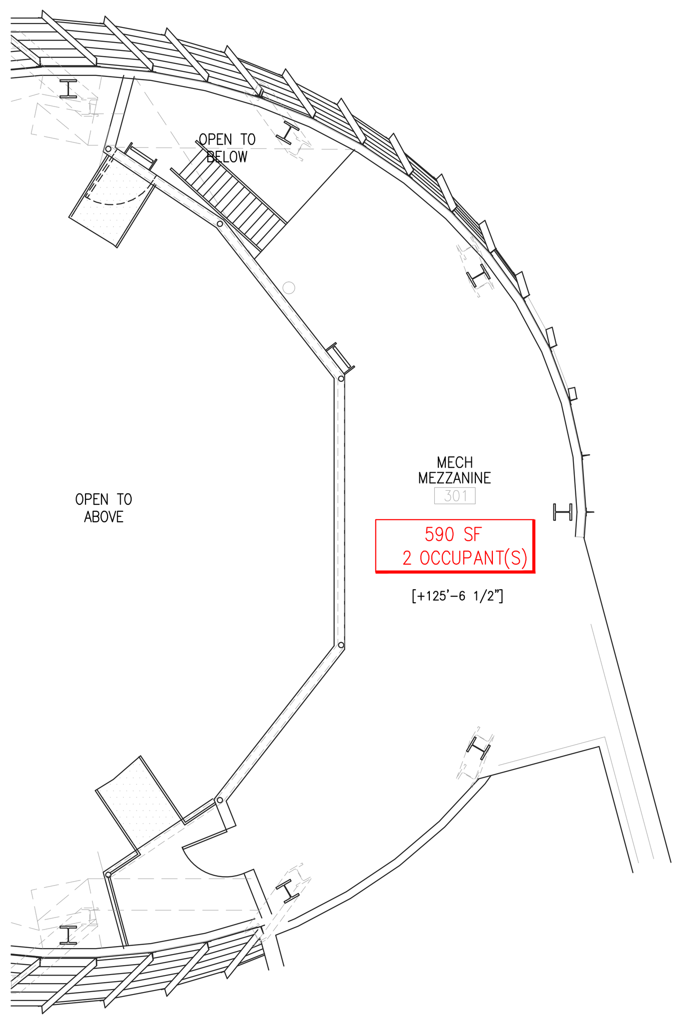
Appendix

- Life Safety Plans
- Egress Parts Plans
- Occupancy Plans
- Fire Sprinkler Plans
- Design Area 1 – Hydraulic Calculations
- Fire Alarm Plans



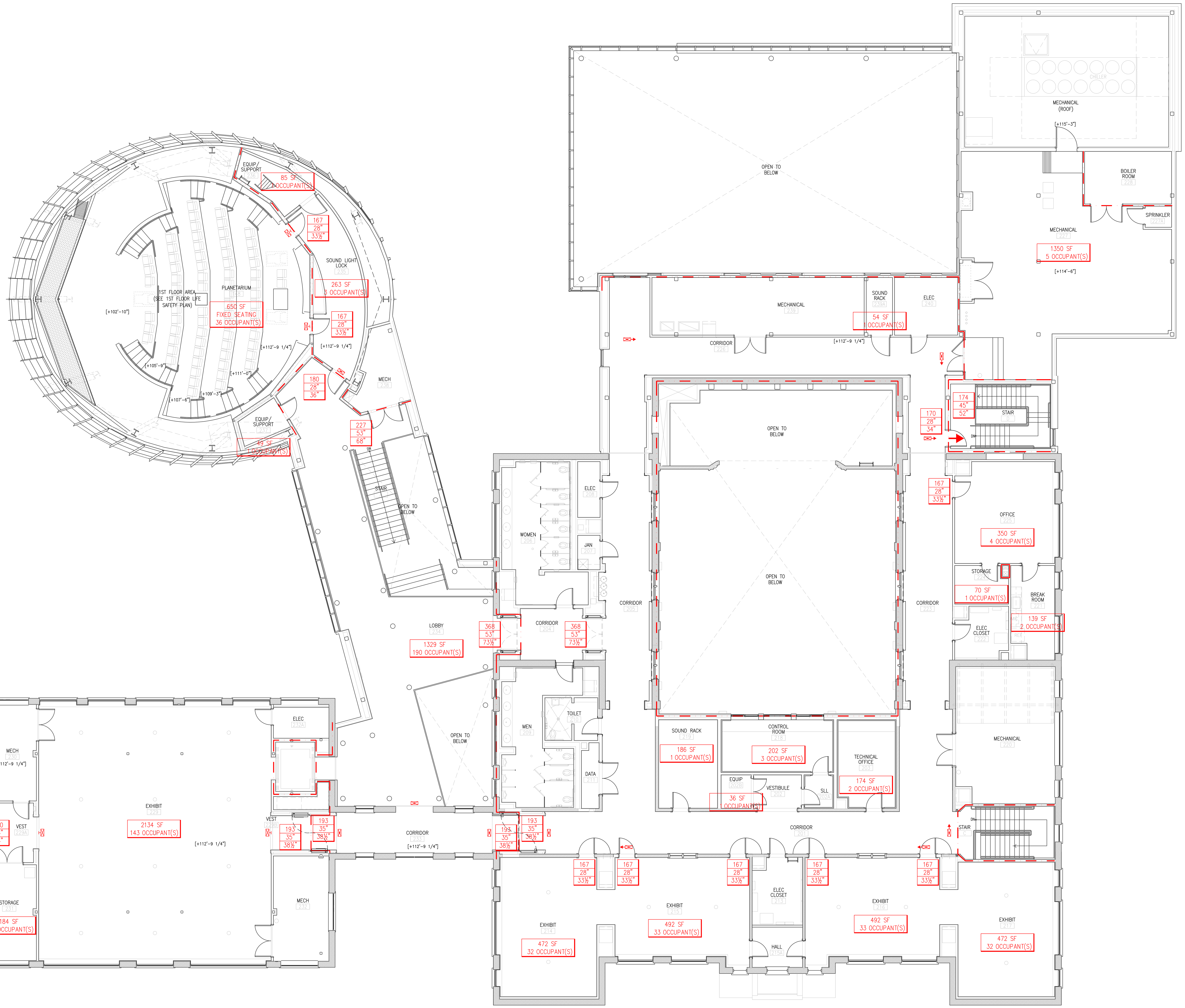
1ST FLOOR LIFE SAFETY PLAN

SCALE 1/16"=1'-0"



MECHANICAL MEZZANINE

SCALE 1/8"=1'-0"

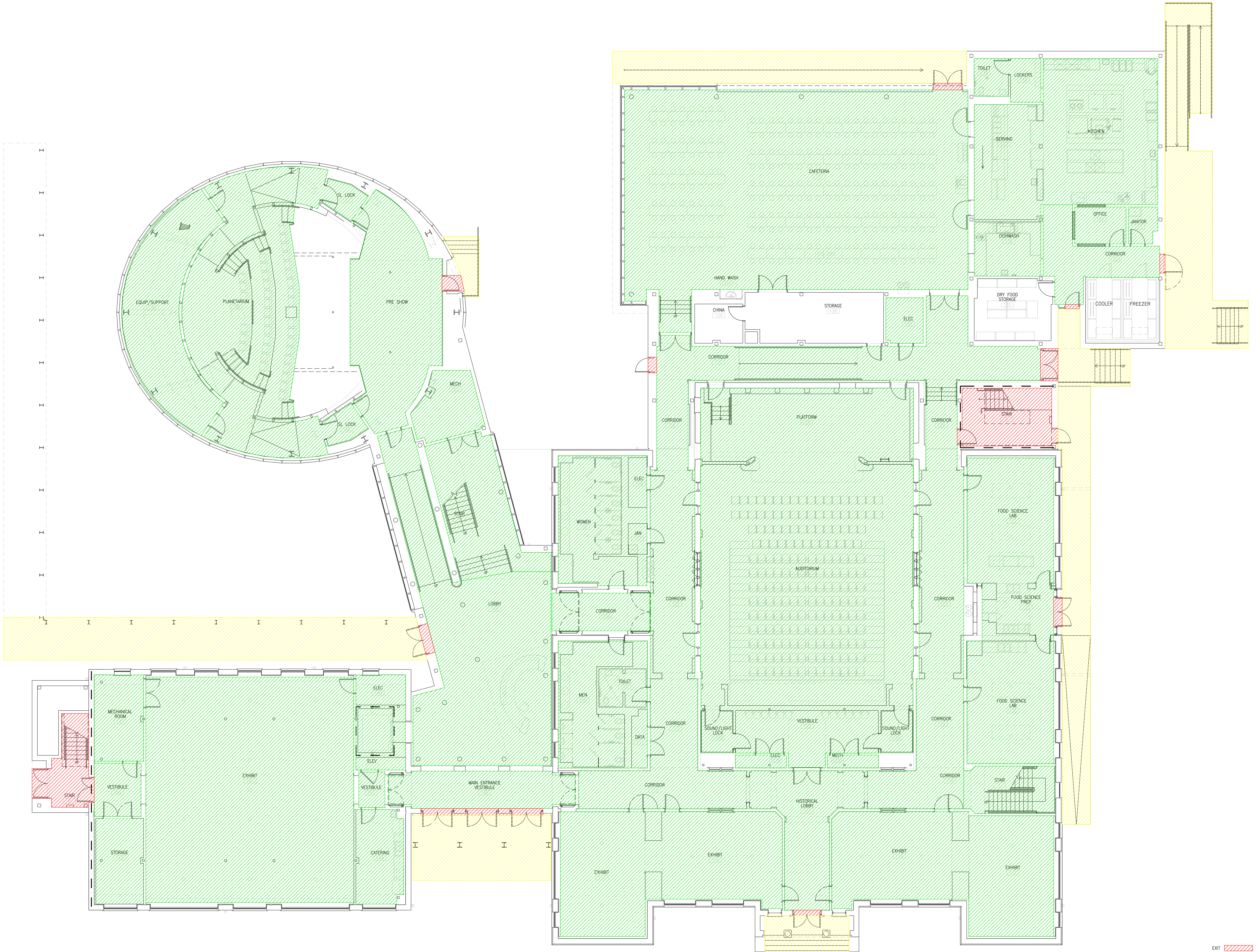


XXX EXIT CAPACITY
XX.X" MIN. REQUIRED WIDTH
XX" ACTUAL WIDTH
EXIT
SMOKE PARTITION
1-HOUR FIRE BARRIER
WALL MOUNT EXIT SIGN
CEILING MOUNT EXIT SIGN

16,680 SF
526 OCCUPANT(S)

2ND FLOOR LIFE SAFETY PLAN

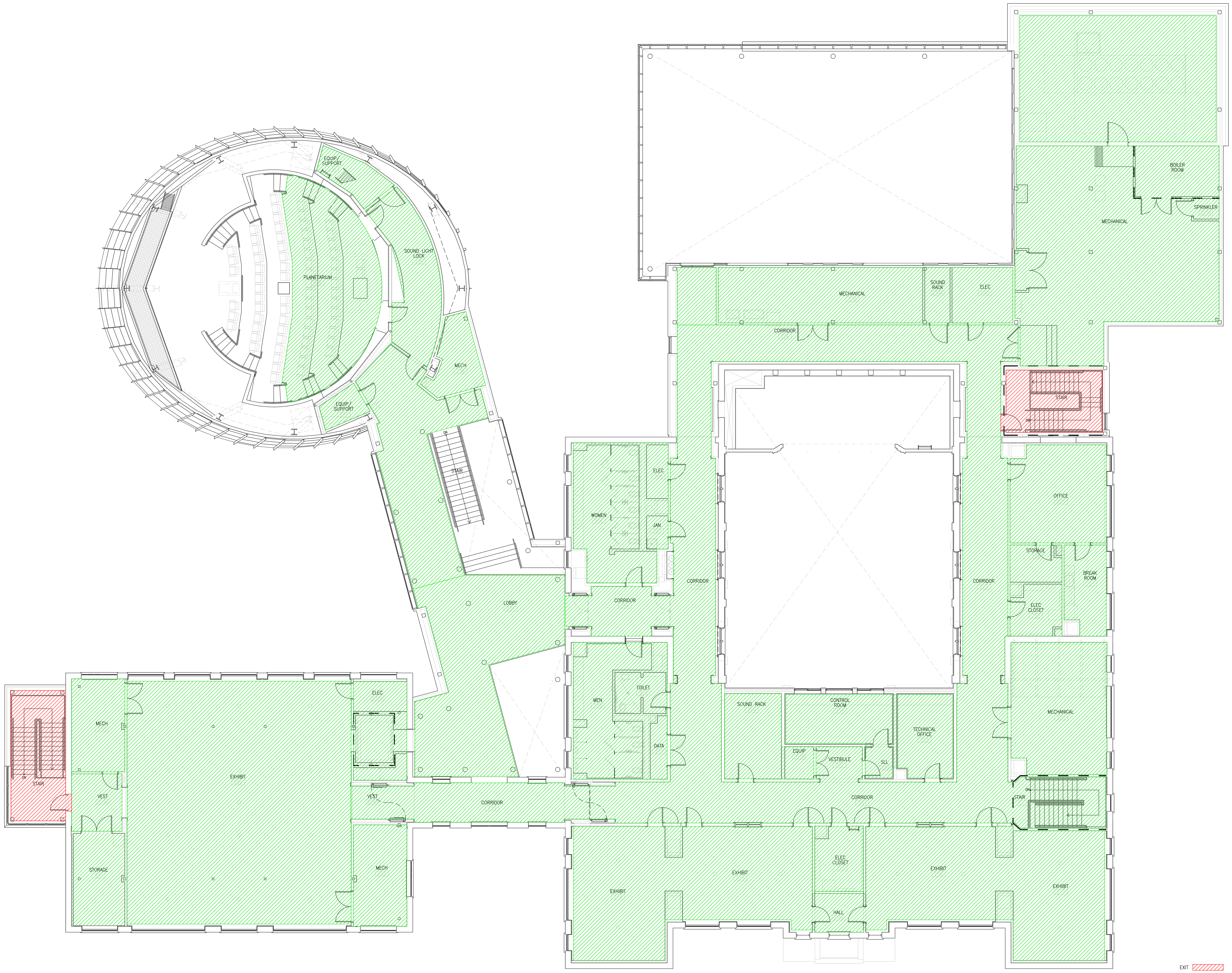
SCALE 1/8"=1'-0"



EXIT
EXIT ACCESS
EXIT DISCHARGE

1ST FLOOR EGRESS PARTS PLAN

SCALE ⅛"=1'-0"

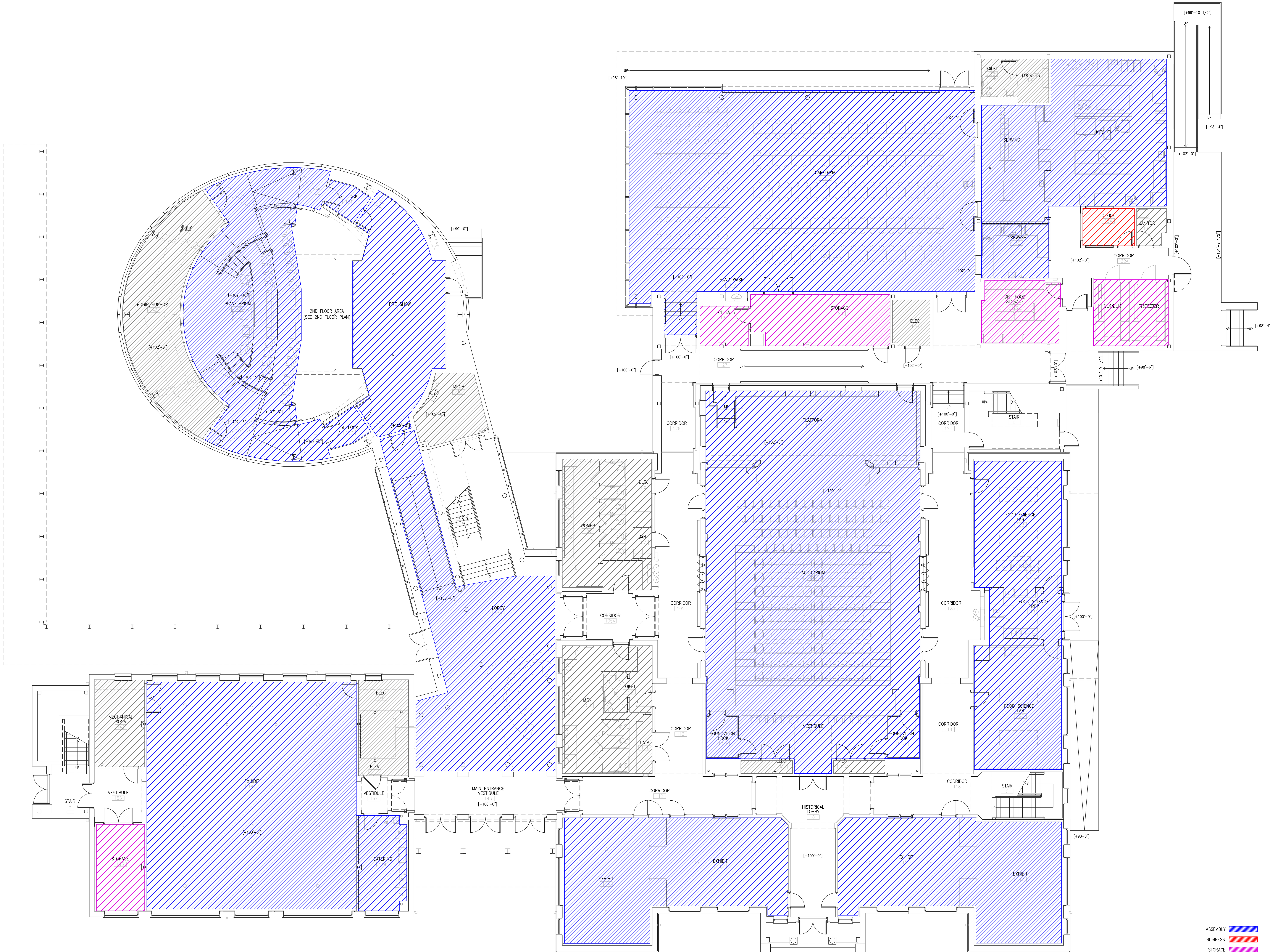


EXIT

EXIT ACCESS

2ND FLOOR EGRESS PARTS PLAN

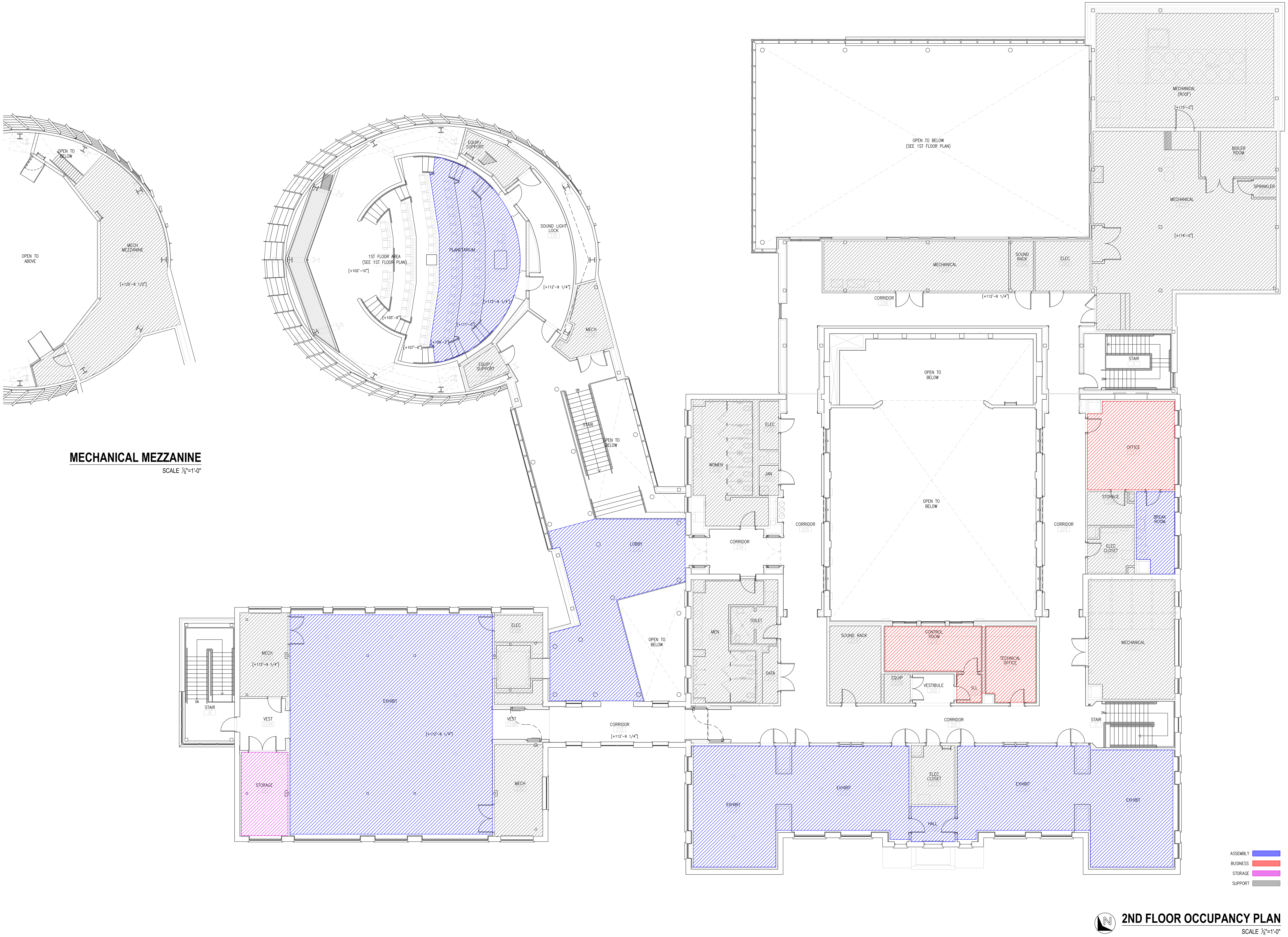
SCALE 1/8"=1'-0"



ASSEMBLY
BUSINESS
STORAGE
SUPPORT

1ST FLOOR OCCUPANCY PLAN

SCALE 1/8"=1'-0"

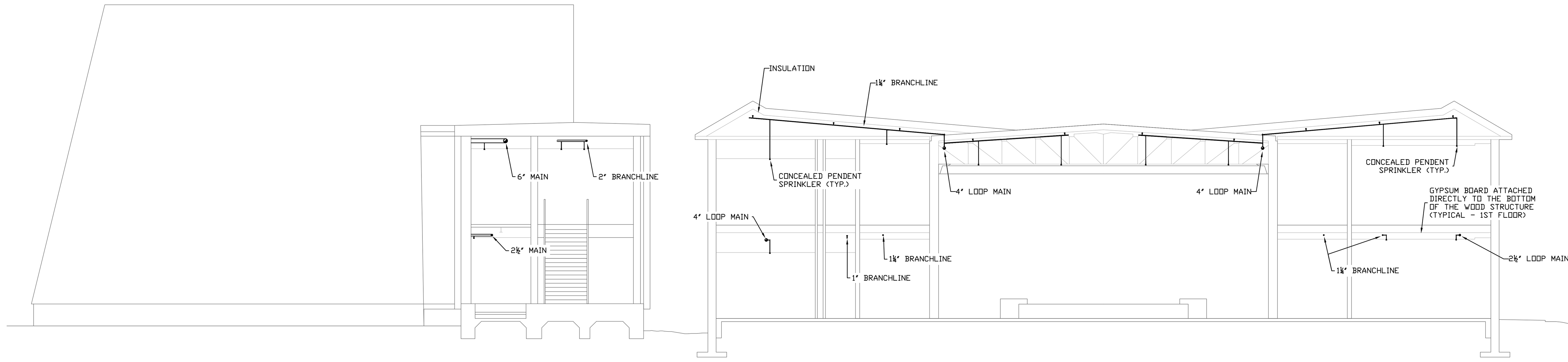


MECHANICAL MEZZANINE

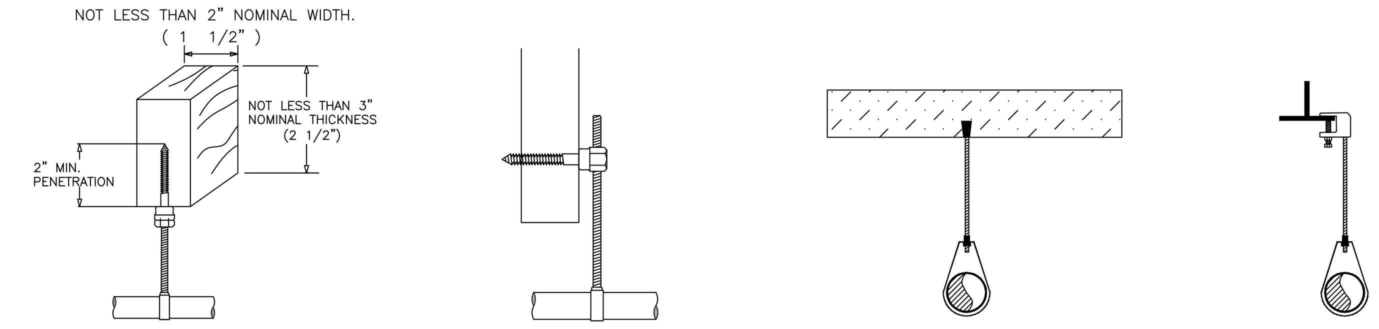
SCALE 1/8"=1'-0"

2ND FLOOR OCCUPANCY PLAN

SCALE 1/8"=1'-0"



FIRE SPRINKLER SECTION A
SCALE: ⅛" = 1'-0"

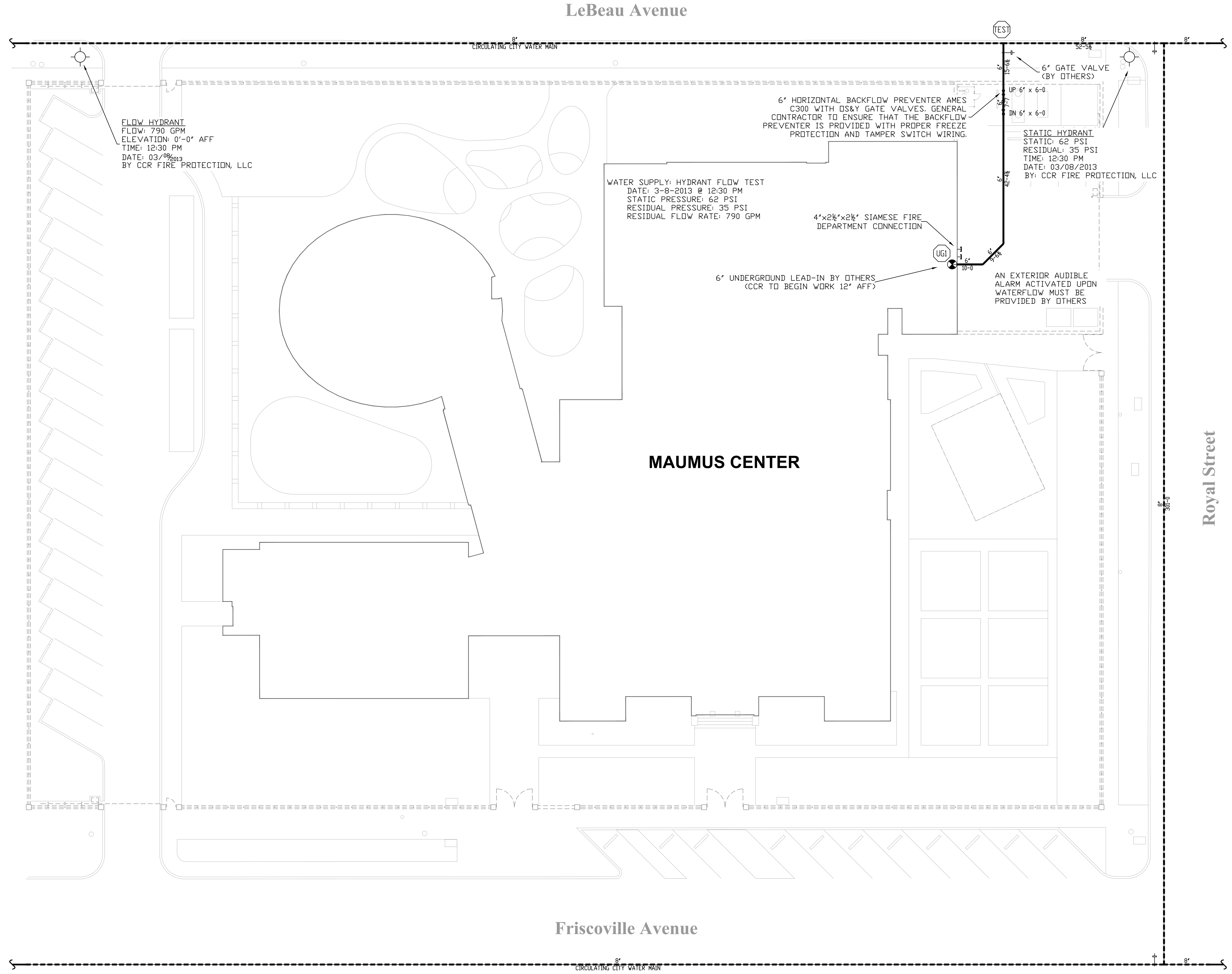


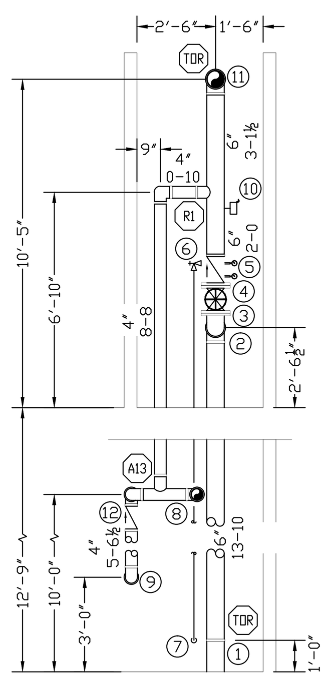
TYPICAL #05 HANGER
NO SCALE
1 -- All Thread Rod
1 -- Ring
1 -- GST 20

TYPICAL #04 HANGER
NO SCALE
1 -- All Thread Rod
1 -- Ring
1 -- SWG 20

TYPICAL #03 HANGER
NO SCALE
1 -- All Thread Rod
1 -- Ring
1 -- HILTI Drop-in Anchor

TYPICAL #01 HANGER
NO SCALE
1 -- All Thread Rod
1 -- Ring
1 -- Top Beam Clamp

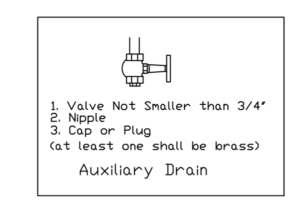


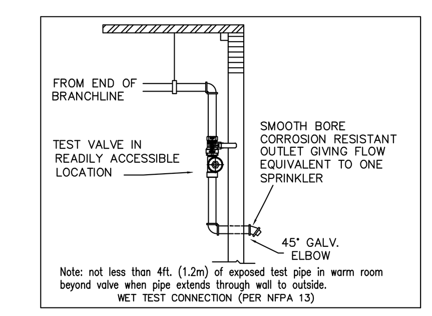


DETAIL LEGEND

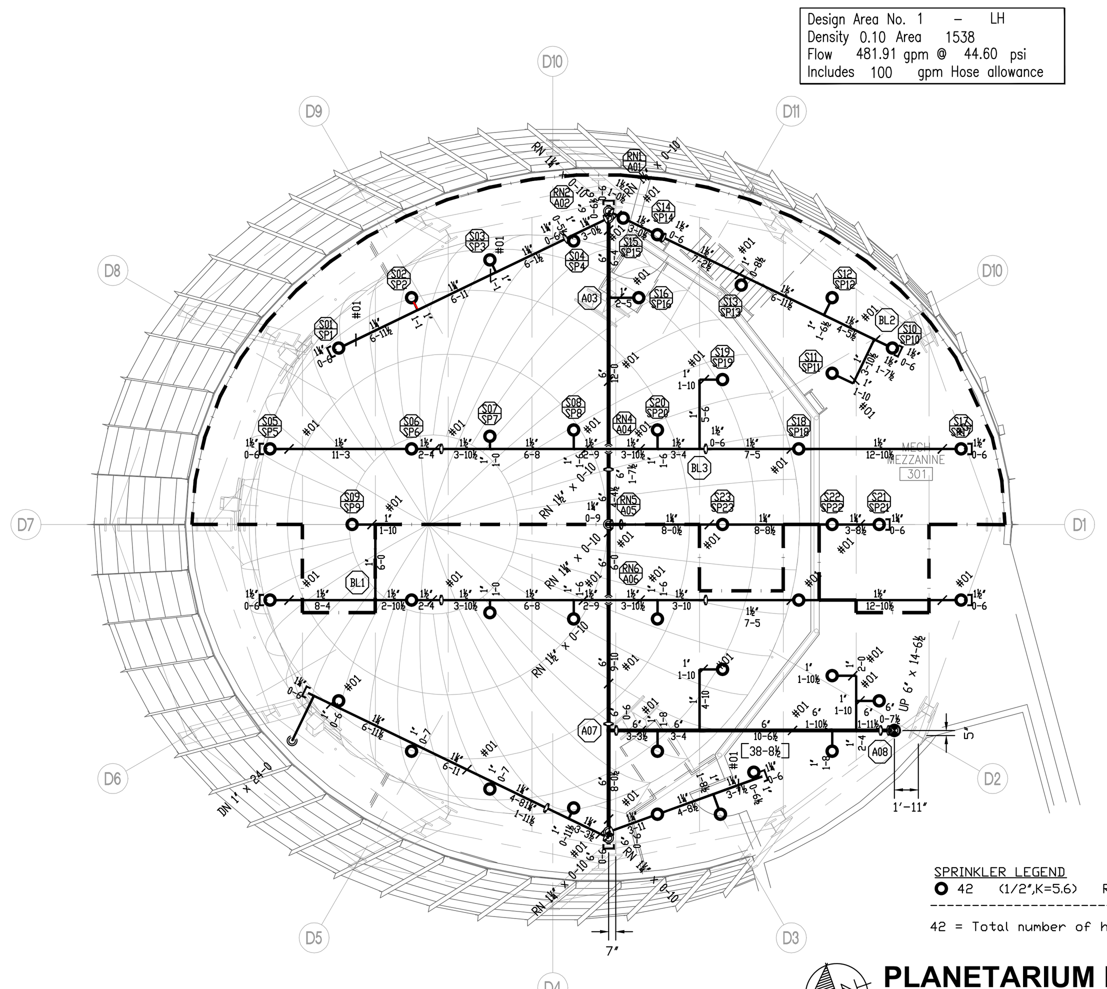
1. 6" GROOVED SPIGOT 1'-0" AFF (BY OTHERS - CCR TO BEGIN WORK HERE)
2. 6" GROOVED BACK-TO-BACK 90° ELBOWS
3. 6" GROOVE FLANGE ADAPTER
4. 6" FLANGE OS&Y GATE VALVE WITH TAMPER SWITCH
5. 6" RELIABLE GROOVED RISER CHECK VALVE WITH TRIM
6. 2" MAIN DRAIN VALVE
7. 2" MAIN DRAIN THROUGH EXTERIOR WALL
8. 4" TO FIRST FLOOR SYSTEM
9. 4"x2½"x2½"SIAMESE FDC WITH ½" AUTOMATIC BALL DRIP
10. 6" POTTER VSR WATERFLOW SWITCH
11. 6" GROOVED 90° ELBOW TO SECOND FLOOR SYSTEM
12. 4" GROOVED SWING CHECK VALVE

FIRE SPRINKLER RISER DETAIL
SCALE: ¼"=1'-0"





Design Area No. 1 – LH
Density 0.10 Area 1538
Flow 481.91 gpm @ 44.60 psi
Includes 100 gpm Hose allowance



SPRINKLER LEGEND
42 (1/2")(K=5.6) RA1425 1/2 QR 200 BRONZE UPRIGHT ON SPRIG
42 = Total number of heads this floor

PLANETARIUM FIRE SPRINKLER PLAN
SCALE: ⅛" = 1'-0"

SITE PLAN (FOR REFERENCE ONLY)
SCALE: 1" = 20'-0"

SCOPE OF WORK

CCR FIRE PROTECTION IS CONTRACTED BY GIBBS CONSTRUCTION TO INSTALL A NEW FIRE SPRINKLER SYSTEM IN A TWO-STORY SCHOOL BUILDING, ALL IN ACCORDANCE WITH NFPA 101 (2009), NFPA 13 (2007), AND THE STATE OF LOUISIANA DEPARTMENT OF PUBLIC SAFETY OFFICE OF THE STATE FIRE MARSHAL.

DESIGN CRITERIA

FIRE SPRINKLER SYSTEM IS DESIGNED IN ACCORDANCE WITH NFPA 13 (2007).
OCCUPANCY: B-BUSINESS / A-ASSEMBLY
HAZARD CLASSIFICATION: LIGHT HAZARD / ORDINARY HAZARD GRP. I
CONSTRUCTION: TYPE IIIB
CEILING: LAY-IN TILE / GYPSUM BOARD / OPEN TO THE DECK
HYDRAULIC REQUIREMENTS: LH-0.10/1500 SQ. FT. / OHI-0.15/1500 SQ. FT. (REMOTE AREA MAY BE REDUCED PER NFPA 13 WHEN USING QUICK RESPONSE SPRINKLERS)
WATER SUPPLY: HYDRANT FLOW TEST
DATE: 3-8-2013 @ 12:30 PM
STATIC PRESSURE: 62 PSI
RESIDUAL PRESSURE: 35 PSI
RESIDUAL FLOW RATE: 790 GPM

GENERAL NOTES

1. ALL MATERIAL AND INSTALLATION SHALL MEET THE REQUIREMENTS OF NFPA 13 (2007).
2. THE UNDERGROUND INSTALLED BY OTHERS IS TO BE IN STRICT ACCORDANCE WITH NFPA 24.
3. ALL PIPE 1" AND LARGER IS SCHEDULE 40 BLACK STEEL PIPE WITH EITHER C.I. 125# THREADED FITTINGS OR GROOVED FITTINGS LISTED FOR FIRE PROTECTION SERVICE, ANVIL OR EQUAL.
4. INSTALLATION OF QUICK RESPONSE SPRINKLERS, STANDARD SPRAY BRASS UPRIGHT SPRINKLERS IN AREAS OPEN TO THE DECK AND STANDARD SPRAY CONCEALED PENDENT SPRINKLERS IN AREAS WITH A CEILING.
5. ALL SPRINKLERS ARE TO BE INSTALLED IN CENTER OF A CEILING TILES.
6. ALL FIRE SPRINKLER PIPE SHALL BE SUPPORTED WITH HANGERS AND HANGER MATERIAL LISTED AND INSTALLED IN ACCORDANCE WITH NFPA 13.
7. OWNER MUST PROVIDE ADEQUATE HEATING (MIN. 40° F) TO PREVENT PIPE FROM FREEZING.
8. HYDROSTATICALLY TEST NEW SPRINKLER SYSTEM PIPING AT MIN. 200 PSI FOR 2 HOURS AS REQUIRED BY NFPA 13.

REVISIONS			
NO.	DATE	DESCRIPTION	BY
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CCR FIRE PROTECTION
PO BOX 669
DENHAM SPRINGS, LA 70727
PH: (225) 756-4300
FAX: (225) 756-4301
LASFM LIC. # F1199

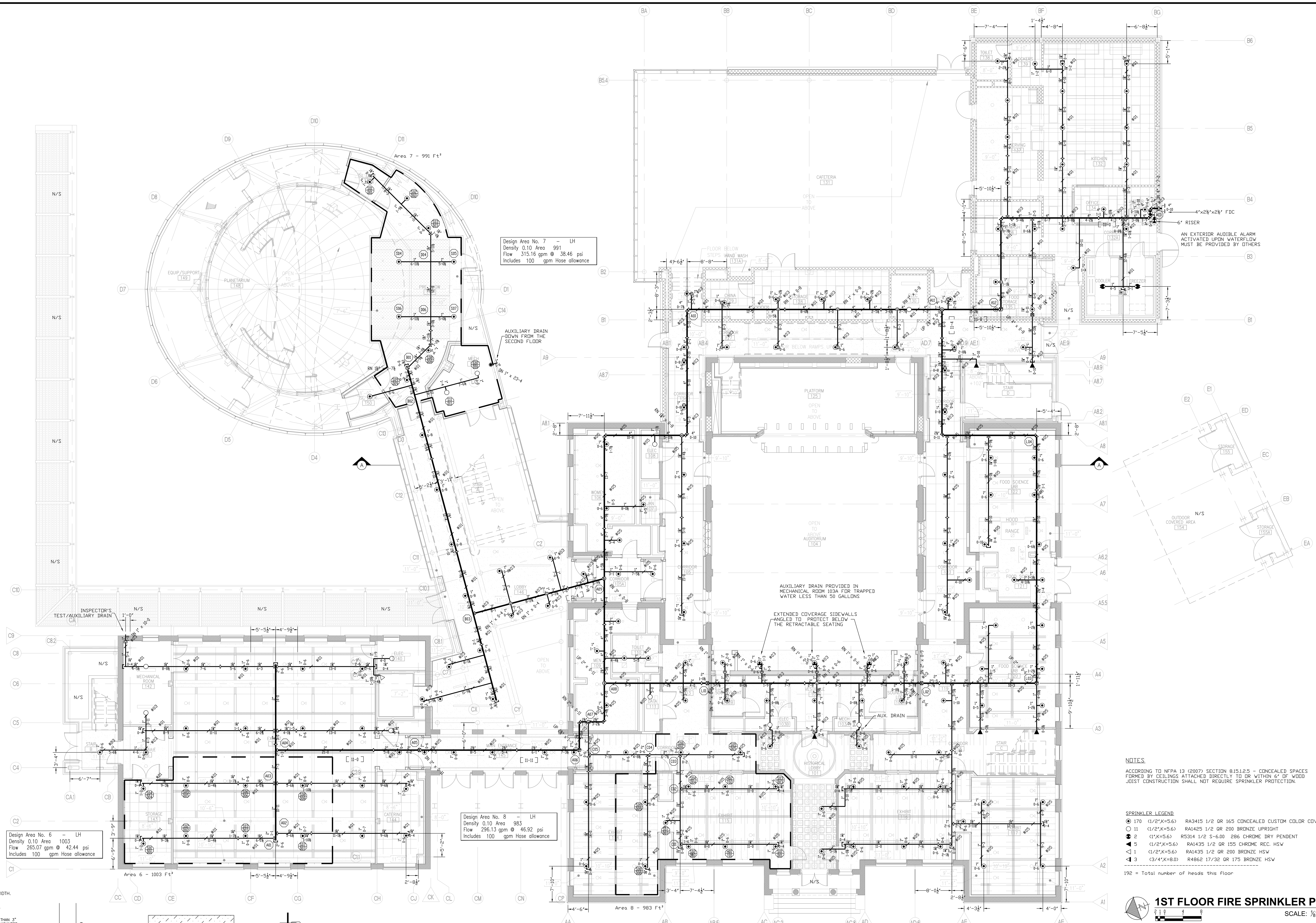
CONTRACT WITH: GIBBS CONSTRUCTION, LLC.
5736 CITRUS BOULEVARD, SUITE 200
NEWORLEANS, LOUISIANA 70123
PH: (504) 733-4336 FAX: (504) 734-0389

APPROVALS BY: LOUISIANA STATE FIRE MARSHAL
8181 INDEPENDENCE BOULEVARD
BATON ROUGE, LOUISIANA 70806

PROJECT
Maumus Center
St. Benard Parish School Board
721 Friscoville Avenue
Arabi, Louisiana 70032

TITLE NOTES, SITE PLAN, DETAILS, & SECTION

DRAWN	TDM	DATE	05/14/2013	CONTRACT	2013–200
CHKD.	KWB	SCALE	1/8" = 1'-0"	DWG.NO.	FP-1



NOTES

ACCORDING TO NFPA 13 (2007) SECTION 8.15.1.2.5 - CONCEALED SPACES FORMED BY CEILINGS ATTACHED DIRECTLY TO OR WITHIN 6" OF WOOD JOIST CONSTRUCTION SHALL NOT REQUIRE SPRINKLER PROTECTION.

SPRINKLER LEGEND

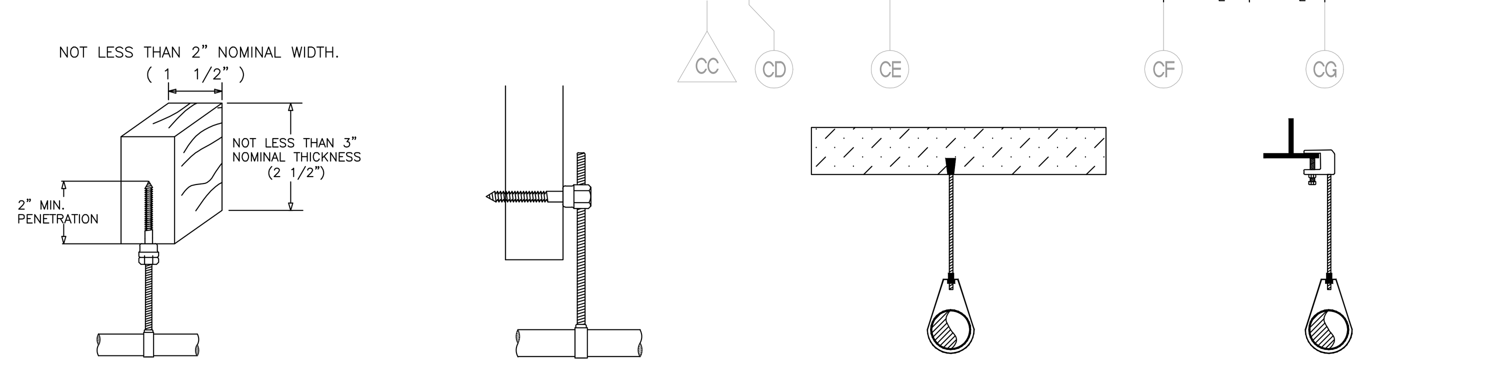
◉	170	(1/2",K=5.6)	RA3415 1/2 QR 165 CONCEALED CUSTOM COLOR COVER PLATE
○	11	(1/2",K=5.6)	RA1425 1/2 QR 200 BRONZE UPRIGHT
⊗	2	(1",K=5.6)	R5314 1/2 S-6.00 286 CHROME DRY PENDENT
◀	5	(1/2",K=5.6)	RA1435 1/2 QR 155 CHROME REC. HSW
◁	1	(1/2",K=5.6)	RA1435 1/2 QR 200 BRONZE HSW
◁	3	(3/4",K=8.0)	R4862 17/32 QR 175 BRONZE HSW

192 = Total number of heads this floor

1ST FLOOR FIRE SPRINKLER PLAN

SCALE: ⅛" = 1'-0"

SCALE 1/8"=1'-0"



TYPICAL #05 HANGER	TYPICAL #04 HANGER	TYPICAL #03 HANGER	TYPICAL #01 HANGER
NO — SCALE	NO — SCALE	NO — SCALE	NO — SCALE
1 -- All Thread Rod 1 -- Ring 1 -- GST 20	1 -- All Thread Rod 1 -- Ring 1 -- SWG 20	1 -- All Thread Rod 1 -- Ring 1 -- HILTI Drop-in Anchor	1 -- All Thread Rod 1 -- Ring 1 -- Top Beam Clamp

REVISIONS

NO.	DATE	DESCRIPTION	BY
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CCR FIRE PROTECTION
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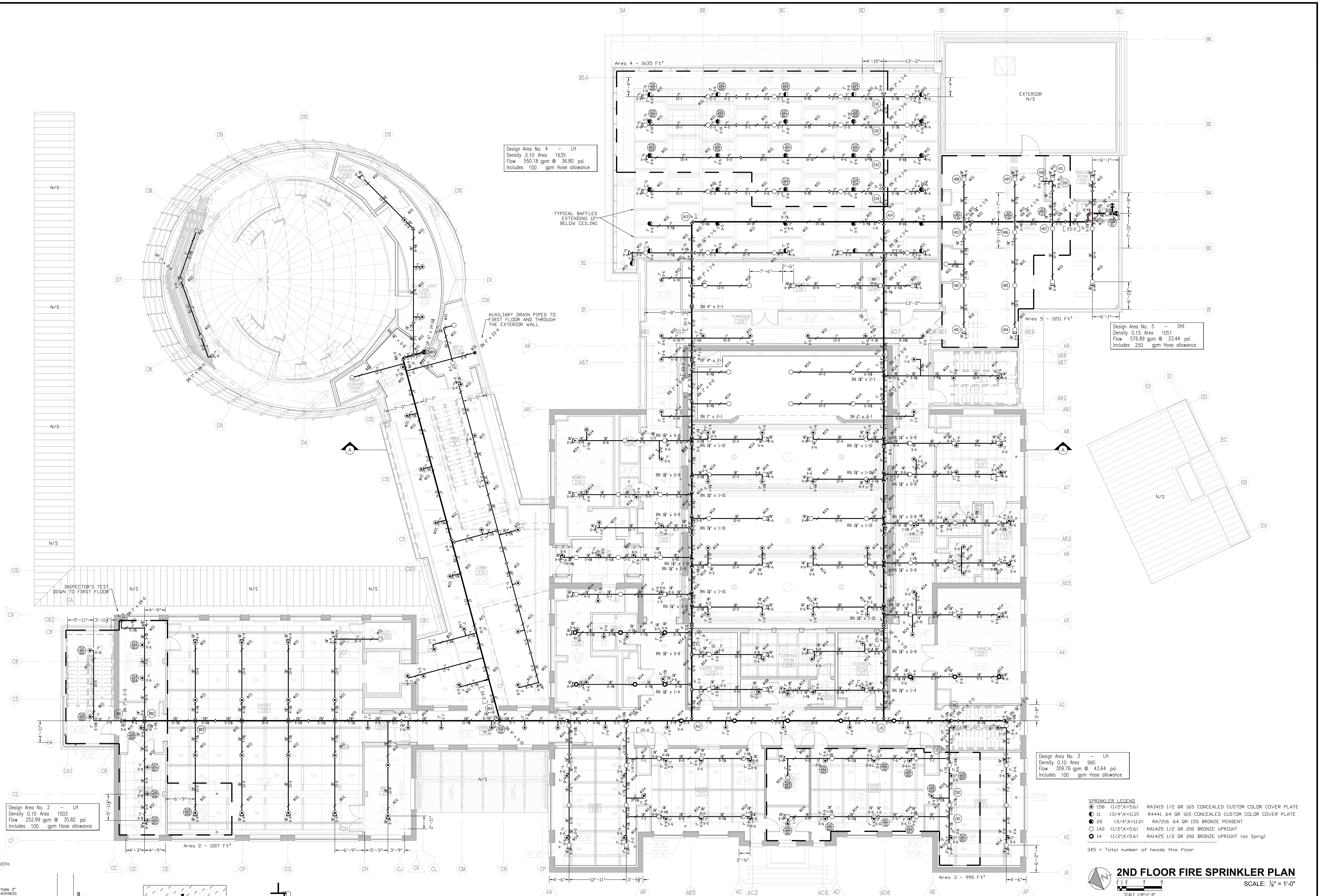
APPROVALS BY: LOUISIANA STATE FIRE MARSHAL
8181 INDEPENDENCE BOULEVARD
BATON ROUGE, LOUISIANA 70806

PROJECT
Maumus Center
St. Benard Parish School Board
721 Friscoville Avenue
Arabi, Louisiana 70032

TITLE 1st FLOOR PLAN

DRAWN	TDM	DATE	05/14/2013	CONTRACT	2013-200
CHKD.	KWB	SCALE	1/8" = 1'-0"	DWG.NO.	FP-2



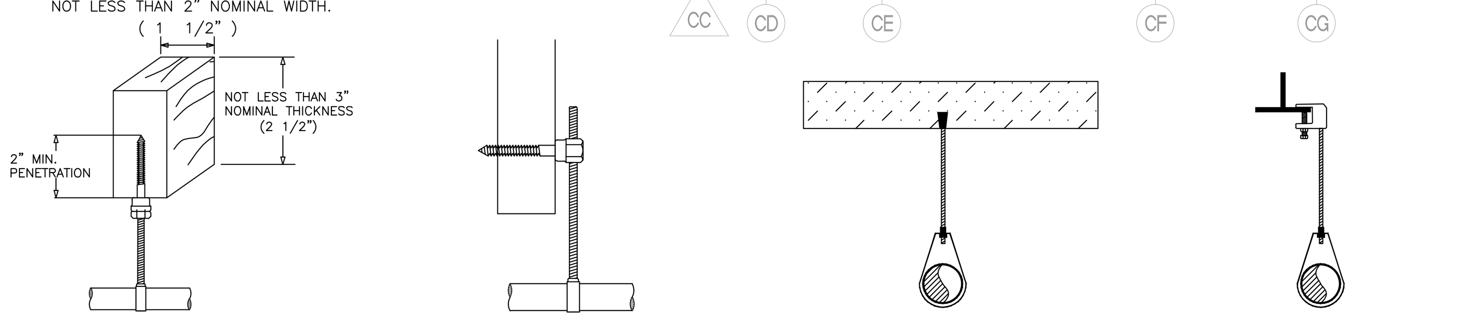
SPRINKLER LEGEND

- 158 (1/2",K=5.6) RA3415 1/2 QR 165 CONCEALED CUSTOM COLOR COVER PLATE
- 11 (3/4",K=11.2) R4441 .64 QR 165 CONCEALED CUSTOM COLOR COVER PLATE
- 20 (3/4",K=11.2) RA7216 .64 QR 155 BRONZE PENDENT
- 142 (1/2",K=5.6) RA1425 1/2 QR 200 BRONZE UPRIGHT
- 14 (1/2",K=5.6) RA1425 1/2 QR 200 BRONZE UPRIGHT (on Sprig)

345 = Total number of heads this floor

2ND FLOOR FIRE SPRINKLER PLAN

SCALE: 1/8" = 1'-0"



TYPICAL #05 HANGER	TYPICAL #04 HANGER	TYPICAL #03 HANGER	TYPICAL #01 HANGER
NO SCALE	NO SCALE	NO SCALE	NO SCALE
1 -- All Thread Rod	1 -- All Thread Rod	1 -- All Thread Rod	1 -- All Thread Rod
1 -- Ring	1 -- Ring	1 -- Ring	1 -- Ring
1 -- GST 20	1 -- SWG 20	1 -- HILTI Drop-in Anchor	1 -- Top Beam Clamp

REVISIONS

NO.	DATE	DESCRIPTION	BY
--	---	---	---

CCR FIRE PROTECTION
PO BOX 669
DENHAM SPRINGS, LA 70727
PH: (225) 756-4300
FAX: (225) 756-4301
LASFM LIC. # F1199

CONTRACT WITH: GIBBS CONSTRUCTION, LLC. 5736 CITRUS BOULEVARD, SUITE 200 NEWORLEANS, LOUISIANA 70123 PH: (504) 733-4336 FAX: (504) 734-0389

APPROVALS BY: LOUISIANA STATE FIRE MARSHAL 8181 INDEPENDENCE BOULEVARD BATON ROUGE, LOUISIANA 70806

PROJECT
Maumus Center
St. Benard Parish School Board
721 Friscoville Avenue
Arabi, Louisiana 70032

TITLE 2nd FLOOR PLAN

DRAWN	TDM	DATE	05/14/2013	CONTRACT	2013-200
CHKD.	KWB	SCALE	1/8" = 1'-0"	DWG.NO.	FP-3

. . . Fire Protection by Computer Design

CCR
Baton Rouge, LA

Job Name	:	Maumus Center - Remote Area 1 Calc
Building	:	FP-1
Location	:	721 Friscoville Ave. Arabi, LA 70032
System	:	1
Contract	:	
Data File	:	Maumus Center - Remote Area 1 Calc.WXF

HYDRAULIC CALCULATIONS
for

Project name: Maumus Center St. Benard Parish School Board
Location: 721 Friscoville Ave. Arabi, LA 70032
Drawing no: FP-1
Date: 3-20-2013

Design

- ***Remote area number:*** 1
- ***Remote area location:*** Planetarium Roof
- ***Occupancy classification:*** LH
- ***Density:*** 0.10 - Gpm/SqFt
- ***Area of application:*** 1538 - SqFt
- ***Coverage per sprinkler:*** 154 - SqFt
- ***Type of sprinklers calculated:*** K5.6 SSU
- ***No. of sprinklers calculated:*** 23
- ***In-rack demand:*** - GPM
- ***Hose streams:*** 100 - GPM
- ***Total water required (including hose streams):*** 481.91 - GPM @ 44.60 - Psi
- ***Type of system:*** Wet
- ***Volume of dry or preaction system:*** - Gal

Water supply information

- ***Date:***
- ***Location:***
- ***Source:***

Name of contractor: CCR Fire Protection
Address: 6353 Equity Dr. Baton Rouge, LA 70809
Phone number: 225-756-4300
Name of designer: TDM
Authority having jurisdiction: Louisiana State Fire Marshal
Notes: (Include peaking information or gridded systems here.)

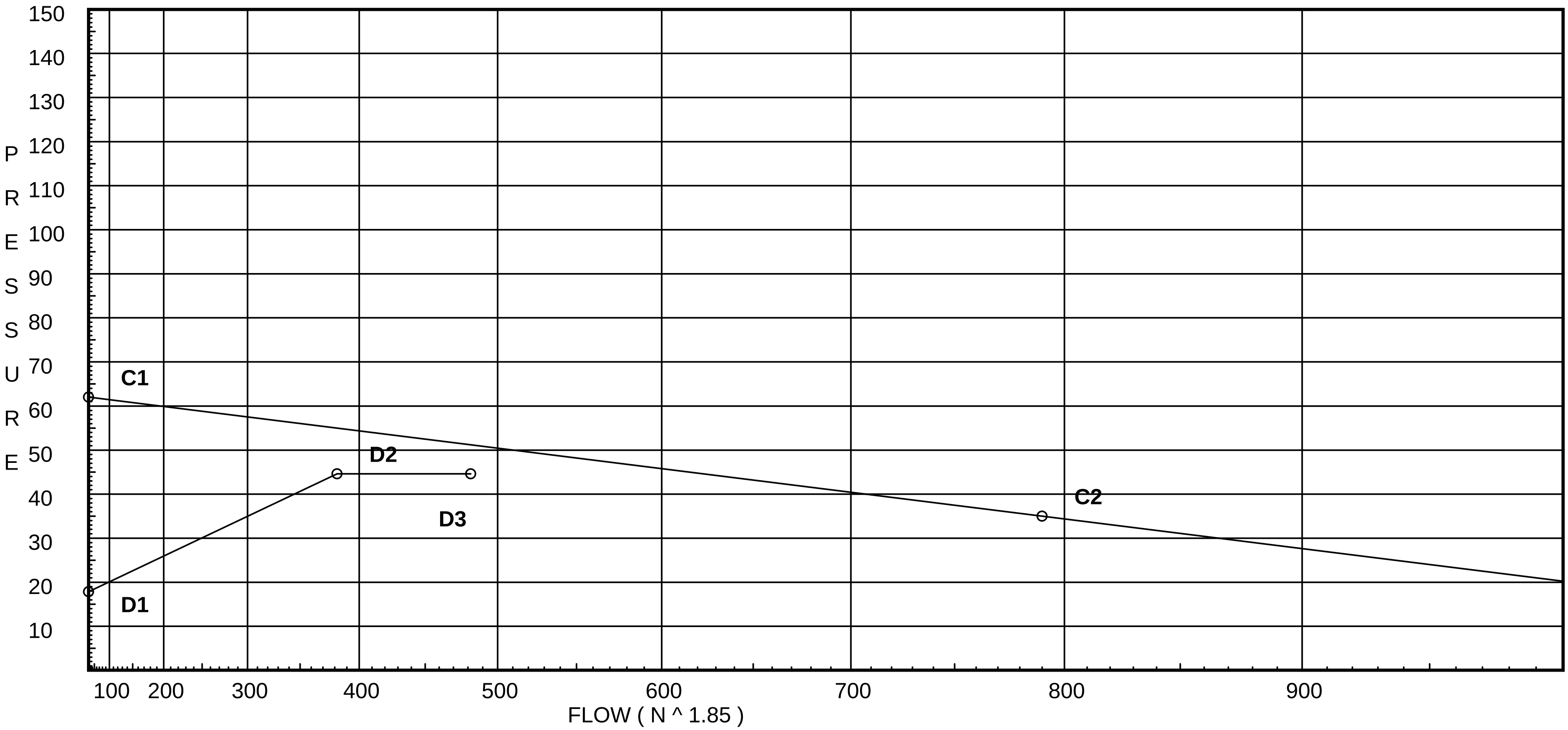
Water Supply Curve (C)

City Water Supply:

C1 - Static Pressure	:	62
C2 - Residual Pressure	:	35
C2 - Residual Flow	:	790

Demand:

D1 - Elevation	:	17.847
D2 - System Flow	:	381.914
D2 - System Pressure	:	44.602
Hose (Demand)	:	100
D3 - System Demand	:	481.914
Safety Margin	:	6.578



Fittings Used Summary

Fitting Legend

Abbrev.	Name	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12	14	16	18	20	24
E	NFPA 13 90' Standard Elbow	1	2	2	3	4	5	6	7	8	10	12	14	18	22	27	35	40	45	50	61
F	NFPA 13 45' Elbow	1	1	1	1	2	2	3	3	3	4	5	7	9	11	13	17	19	21	24	28
G	NFPA 13 Gate Valve	0	0	0	0	0	1	1	1	1	2	2	3	4	5	6	7	8	10	11	13
L	NFPA 13 Long Turn Elbow	0.5	1	2	2	2	3	4	5	5	6	8	9	13	16	18	24	27	30	34	40
S	NFPA 13 Swing Check	0	0	5	7	9	11	14	16	19	22	27	32	45	55	65					
T	NFPA 13 90' Flow thru Tee	3	4	5	6	8	10	12	15	17	20	25	30	35	50	60	71	81	91	101	121
V	90' Ell Firelock #001	0	0	0	0	0	3.5	4.3	5	0	6.8	8.5	10	13	0	0	0	0	0	0	0
Zac	Ames 2000SS	Fitting generates a Fixed Loss Based on Flow																			

Units Summary

Diameter Units	Inches
Length Units	Feet
Flow Units	US Gallons per Minute
Pressure Units	Pounds per Square Inch

Note: Fitting Legend provides equivalent pipe lengths for fittings types of various diameters. Equivalent lengths shown are standard for actual diameters of Sched 40 pipe and CFactors of 120 except as noted with *. The fittings marked with a * show equivalent lengths values supplied by manufacturers based on specific pipe diameters and CFactors and they require no adjustment. All values for fittings not marked with a * will be adjusted in the calculation for CFactors of other than 120 and diameters other than Sched 40 per NFPA.

Pressure / Flow Summary - STANDARD

Node No.	Elevation	K-Fact	Pt Actual	Pn	Flow Actual	Density	Area	Press Req.
S01	41.208	5.6	8.2	na	16.03	0.1	81	7.0
S02	41.208	5.6	8.1	na	15.93	0.1	70	7.0
S03	41.208	5.6	8.61	na	16.43	0.1	81	7.0
S04	41.208	5.6	9.74	na	17.48	0.1	87	7.0
S05	41.208	5.6	7.56	na	15.4	0.1	154	7.0
S06	41.208	5.6	7.67	na	15.51	0.1	87	7.0
S07	41.208	5.6	7.65	na	15.49	0.1	81	7.0
S08	41.208	5.6	8.08	na	15.92	0.1	87	7.0
S09	41.208	5.6	12.01	na	19.4	0.1	112	7.0
S10	41.208	5.6	7.69	na	15.53	0.15	81	7.0
S11	41.208	5.6	7.02	na	14.84	0.15	92	7.0
S12	41.208	5.6	7.58	na	15.42	0.15	46	7.0
S13	41.208	5.6	8.12	na	15.96	0.15	81	7.0
S14	41.208	5.6	9.28	na	17.06	0.15	60	7.0
S15	41.208	5.6	9.87	na	17.59	0.1	20	7.0
S16	41.208	5.6	13.17	na	20.32	0.1	97	7.0
S17	41.208	5.6	8.48	na	16.3	0.15	87	7.0
S18	41.208	5.6	8.61	na	16.43	0.1	26	7.0
S19	41.208	5.6	8.01	na	15.85	0.1	126	7.0
S20	41.208	5.6	8.86	na	16.67	0.1	100	7.0
S21	41.208	5.6	9.4	na	17.17	0.15	112	7.0
S22	41.208	5.6	9.49	na	17.25	0.15	48	7.0
S23	41.208	5.6	10.25	na	17.93	0.1	112	7.0
SP9	39.542		13.18	na				
SP11	39.542		8.02	na				
SP19	39.542		9.04	na				
SP1	39.542		9.49	na				
SP2	39.542		9.65	na				
SP3	39.542		10.22	na				
SP4	39.542		11.39	na				
RN2	39.542		13.34	na				
SP5	39.542		8.82	na				
SP6	39.542		8.93	na				
SP7	39.542		9.16	na				
SP8	39.542		9.67	na				
RN4	39.542		11.09	na				
BL1	39.542		15.0	na				
RN6	39.542		15.41	na				
SP10	39.542		8.95	na				
BL2	39.542		8.97	na				
SP12	39.542		9.12	na				
SP13	39.542		9.64	na				
SP14	39.542		10.65	na				
SP15	39.542		11.27	na				
RN1	39.542		12.84	na				
SP16	38.875		14.76	na				
SP17	39.542		9.79	na				
SP18	39.542		9.94	na				
BL3	39.542		10.25	na				
SP20	39.542		10.53	na				
SP21	39.542		10.77	na				
SP22	39.542		10.87	na				
SP23	39.542		11.68	na				
RN5	39.542		14.12	na				
A12	25.0		26.74	na				
L01	23.167		28.22	na				
A01	38.708		15.82	na				
A02	38.708		15.82	na				
A03	38.708		15.83	na				
A04	38.708		15.85	na				
A05	38.708		15.87	na				

Node No.	Elevation	K-Fact	Pt Actual	Pn	Flow Actual	Density	Area	Press Req.
A06	38.708		15.9	na				
A07	38.708		16.14	na				
A08	38.708		16.34	na				
A09	24.167		22.78	na				
A10	24.167		23.43	na				
A11	25.0		23.98	na				
A13	23.167		29.76	na				
A14	23.167		29.84	na				
TOR	23.167		30.34	na				
R1	18.792		32.26	na				
BASE	1.0		40.4	na				
UG1	-3.5		42.42	na				
TEST	0.0		44.6	na	100.0			

The maximum velocity is 20.1 and it occurs in the pipe between nodes RN4 and A04

Hyd. Ref. Point	Qa / Qt	Dia. "C" Pf/Ft	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	******* Notes ******
S01	16.03	1.049	1T	5.0	1.667	8.195		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP1	16.03	0.0864		0.0	6.667	0.576		Vel = 5.95
	0.0							
	16.03					9.493		K Factor = 5.20
S02	15.93	1.049	1E	2.0	2.750	8.096		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP2	15.93	0.0854		0.0	9.750	0.833		Vel = 5.91
	0.0							
	15.93					9.651		K Factor = 5.13
S03	16.43	1.049	1E	2.0	2.750	8.611		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP3	16.43	0.0905		0.0	9.750	0.882		Vel = 6.10
	0.0							
	16.43					10.215		K Factor = 5.14
S04	17.48	1.049	1E	2.0	2.125	9.739		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP4	17.48	0.1013		0.0	9.125	0.924		Vel = 6.49
	0.0							
	17.48					11.385		K Factor = 5.18
S05	15.40	1.049	1T	5.0	1.667	7.562		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP5	15.4	0.0802		0.0	6.667	0.535		Vel = 5.72
	0.0							
	15.40					8.819		K Factor = 5.19
S06	15.51	1.049	1T	5.0	1.667	7.668		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP6	15.51	0.0811		0.0	6.667	0.541		Vel = 5.76
	0.0							
	15.51					8.931		K Factor = 5.19
S07	15.49	1.049	1E	2.0	2.667	7.651		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP7	15.49	0.0811		0.0	9.667	0.784		Vel = 5.75
	0.0							
	15.49					9.157		K Factor = 5.12
S08	15.92	1.049	1E	2.0	3.167	8.079		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP8	15.92	0.0853		0.0	10.167	0.867		Vel = 5.91
	0.0							
	15.92					9.668		K Factor = 5.12
S09	19.40	1.049	1E	2.0	1.667	12.005		K Factor = 5.60
to		120.0		0.0	2.000	0.722		
SP9	19.4	0.1230		0.0	3.667	0.451		Vel = 7.20
	0.0							
	19.40					13.178		K Factor = 5.34
S10	15.53	1.049	1T	5.0	1.667	7.687		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP10	15.53	0.0814		0.0	6.667	0.543		Vel = 5.77

Final Calculations - Hazen-Williams

Hyd. Ref. Point	Qa / Qt	Dia. / "C" / Pf/Ft	Fitting or Eqv.	Ln.	Pipe / Ftng's / Total	Pt / Pe / Pf	Pt / Pv / Pn	******* Notes ******
	0.0							
	15.53					8.952		K Factor = 5.19
S11	14.84	1.049	1E	2.0	1.667	7.020		K Factor = 5.60
to		120.0		0.0	2.000	0.722		
SP11	14.84	0.0747		0.0	3.667	0.274		Vel = 5.51
	0.0							
	14.84					8.016		K Factor = 5.24
S12	15.42	1.049	1E	2.0	3.167	7.585		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP12	15.42	0.0804		0.0	10.167	0.817		Vel = 5.72
	0.0							
	15.42					9.124		K Factor = 5.10
S13	15.96	1.049	1E	2.0	2.375	8.120		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP13	15.96	0.0857		0.0	9.375	0.803		Vel = 5.92
	0.0							
	15.96					9.645		K Factor = 5.14
S14	17.06	1.049	1T	5.0	1.667	9.284		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP14	17.06	0.0969		0.0	6.667	0.646		Vel = 6.33
	0.0							
	17.06					10.652		K Factor = 5.23
S15	17.59	1.049	1T	5.0	1.667	9.868		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP15	17.59	0.1024		0.0	6.667	0.683		Vel = 6.53
	0.0							
	17.59					11.273		K Factor = 5.24
S16	20.32	1.049	1E	2.0	2.333	13.172		K Factor = 5.60
to		120.0		0.0	2.000	1.010		
SP16	20.32	0.1341		0.0	4.333	0.581		Vel = 7.54
	0.0							
	20.32					14.763		K Factor = 5.29
S17	16.30	1.049	1T	5.0	1.667	8.476		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP17	16.3	0.0891		0.0	6.667	0.594		Vel = 6.05
	0.0							
	16.30					9.792		K Factor = 5.21
S18	16.43	1.049	1T	5.0	1.667	8.610		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP18	16.43	0.0904		0.0	6.667	0.603		Vel = 6.10
	0.0							
	16.43					9.935		K Factor = 5.21
S19	15.85	1.049	1E	2.0	1.667	8.009		K Factor = 5.60
to		120.0		0.0	2.000	0.722		
SP19	15.85	0.0845		0.0	3.667	0.310		Vel = 5.88
	0.0							
	15.85					9.041		K Factor = 5.27

Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/Ft	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	******* Notes ******
S20	16.67	1.049	1E	2.0	3.167	8.865		K Factor = 5.60
to		120.0	1T	5.0	7.000	0.722		
SP20	16.67	0.0928		0.0	10.167	0.944		Vel = 6.19
	0.0							
	16.67					10.531		K Factor = 5.14
S21	17.17	1.049	1T	5.0	1.667	9.396		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP21	17.17	0.0981		0.0	6.667	0.654		Vel = 6.37
	0.0							
	17.17					10.772		K Factor = 5.23
S22	17.25	1.049	1T	5.0	1.667	9.486		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP22	17.25	0.0988		0.0	6.667	0.659		Vel = 6.40
	0.0							
	17.25					10.867		K Factor = 5.23
S23	17.93	1.049	1T	5.0	1.667	10.250		K Factor = 5.60
to		120.0		0.0	5.000	0.722		
SP23	17.93	0.1063		0.0	6.667	0.709		Vel = 6.66
	0.0							
	17.93					11.681		K Factor = 5.25
SP9	19.40	1.049	1E	2.0	7.833	13.178		
to		120.0	1T	5.0	7.000	0.0		
BL1	19.4	0.1230		0.0	14.833	1.825		Vel = 7.20
	0.0							
	19.40					15.003		K Factor = 5.01
SP11	14.84	1.049	1E	2.0	5.708	8.016		
to		120.0	1T	5.0	7.000	0.0		
BL2	14.84	0.0749		0.0	12.708	0.952		Vel = 5.51
	0.0							
	14.84					8.968		K Factor = 4.96
SP19	15.85	1.049	1E	2.0	7.333	9.041		
to		120.0	1T	5.0	7.000	0.0		
BL3	15.85	0.0846		0.0	14.333	1.212		Vel = 5.88
	0.0							
	15.85					10.253		K Factor = 4.95
SP1	16.03	1.38		0.0	6.958	9.493		
to		120.0		0.0	0.0	0.0		
SP2	16.03	0.0227		0.0	6.958	0.158		Vel = 3.44
SP2	15.94	1.38		0.0	6.917	9.651		
to		120.0		0.0	0.0	0.0		
SP3	31.97	0.0815		0.0	6.917	0.564		Vel = 6.86
SP3	16.43	1.38		0.0	6.667	10.215		
to		120.0		0.0	0.0	0.0		
SP4	48.4	0.1755		0.0	6.667	1.170		Vel = 10.38
SP4	17.47	1.38	1E	3.0	3.292	11.385		
to		120.0		0.0	3.000	0.0		
RN2	65.87	0.3106		0.0	6.292	1.954		Vel = 14.13
RN2	0.0	1.38	1T	6.0	0.833	13.339		
to		120.0		0.0	6.000	0.361		
A02	65.87	0.3106		0.0	6.833	2.122		Vel = 14.13

Hyd. Ref. Point	Qa / Qt	Dia. / "C" / Pf/Ft	Fitting or Eqv.	Ln.	Pipe / Ftng's / Total	Pt / Pe / Pf	Pt / Pv / Pn	******* Notes ******
	0.0							
	65.87					15.822		K Factor = 16.56
SP5	15.40	1.61		0.0	11.250	8.819		
to		120.0		0.0	0.0	0.0		
SP6	15.4	0.0100		0.0	11.250	0.112		Vel = 2.43
SP6	15.51	1.61		0.0	6.250	8.931		
to		120.0		0.0	0.0	0.0		
SP7	30.91	0.0362		0.0	6.250	0.226		Vel = 4.87
SP7	15.49	1.61		0.0	6.667	9.157		
to		120.0		0.0	0.0	0.0		
SP8	46.4	0.0766		0.0	6.667	0.511		Vel = 7.31
SP8	15.91	1.61	1T	8.0	2.750	9.668		
to		120.0		0.0	8.000	0.0		
RN4	62.31	0.1323		0.0	10.750	1.422		Vel = 9.82
RN4	65.26	1.61	1T	8.0	0.833	11.090		
to		120.0		0.0	8.000	0.361		
A04	127.57	0.4978		0.0	8.833	4.397		Vel = 20.10
	0.0							
	127.57					15.848		K Factor = 32.05
BL1	19.40	1.61	1T	8.0	18.542	15.003		
to		120.0		0.0	8.000	0.0		
RN6	19.4	0.0153		0.0	26.542	0.405		Vel = 3.06
RN6	0.0	1.61	1T	8.0	0.833	15.408		
to		120.0		0.0	8.000	0.361		
A06	19.4	0.0153		0.0	8.833	0.135		Vel = 3.06
	0.0							
	19.40					15.904		K Factor = 4.86
SP10	15.53	1.61		0.0	1.625	8.952		
to		120.0		0.0	0.0	0.0		
BL2	15.53	0.0098		0.0	1.625	0.016		Vel = 2.45
BL2	14.83	1.61		0.0	4.458	8.968		
to		120.0		0.0	0.0	0.0		
SP12	30.36	0.0350		0.0	4.458	0.156		Vel = 4.78
SP12	15.43	1.61		0.0	6.958	9.124		
to		120.0		0.0	0.0	0.0		
SP13	45.79	0.0749		0.0	6.958	0.521		Vel = 7.22
SP13	15.95	1.61		0.0	7.750	9.645		
to		120.0		0.0	0.0	0.0		
SP14	61.74	0.1299		0.0	7.750	1.007		Vel = 9.73
SP14	17.07	1.61		0.0	3.042	10.652		
to		120.0		0.0	0.0	0.0		
SP15	78.81	0.2041		0.0	3.042	0.621		Vel = 12.42
SP15	17.59	1.61	1E	4.0	1.292	11.273		
to		120.0		0.0	4.000	0.0		
RN1	96.4	0.2965		0.0	5.292	1.569		Vel = 15.19
RN1	0.0	1.61	1T	8.0	0.833	12.842		
to		120.0		0.0	8.000	0.361		
A01	96.4	0.2965		0.0	8.833	2.619		Vel = 15.19

Hyd. Ref. Point	Qa / Qt	Dia. / "C" / Pf/Ft	Fitting or Eqv.	Ln.	Pipe / Ftng's / Total	Pt / Pe / Pf	Pt / Pv / Pn	******* Notes ******
	0.0							
	96.40					15.822		K Factor = 24.24
SP16	20.32	1.049	1T	5.0	2.417	14.763		
to		120.0		0.0	5.000	0.072		
A03	20.32	0.1342		0.0	7.417	0.995		Vel = 7.54
	0.0							
	20.32					15.830		K Factor = 5.11
SP17	16.30	1.61		0.0	12.875	9.792		
to		120.0		0.0	0.0	0.0		
SP18	16.3	0.0111		0.0	12.875	0.143		Vel = 2.57
SP18	16.44	1.61		0.0	7.917	9.935		
to		120.0		0.0	0.0	0.0		
BL3	32.74	0.0402		0.0	7.917	0.318		Vel = 5.16
BL3	15.84	1.61		0.0	3.333	10.253		
to		120.0		0.0	0.0	0.0		
SP20	48.58	0.0834		0.0	3.333	0.278		Vel = 7.66
SP20	16.68	1.61		0.0	3.875	10.531		
to		120.0		0.0	0.0	0.0		
RN4	65.26	0.1443		0.0	3.875	0.559		Vel = 10.28
	0.0							
	65.26					11.090		K Factor = 19.60
SP21	17.17	1.38		0.0	3.708	10.772		
to		120.0		0.0	0.0	0.0		
SP22	17.17	0.0256		0.0	3.708	0.095		Vel = 3.68
SP22	17.24	1.38		0.0	8.708	10.867		
to		120.0		0.0	0.0	0.0		
SP23	34.41	0.0935		0.0	8.708	0.814		Vel = 7.38
SP23	17.93	1.38	1E	3.0	9.042	11.681		
to		120.0		0.0	3.000	0.0		
RN5	52.34	0.2029		0.0	12.042	2.443		Vel = 11.23
RN5	0.0	1.38	1T	6.0	0.833	14.124		
to		120.0		0.0	6.000	0.361		
A05	52.34	0.2030		0.0	6.833	1.387		Vel = 11.23
	0.0							
	52.34					15.872		K Factor = 13.14
A12	180.66	4.026	1T	20.0	43.333	26.740		
to		120.0		0.0	20.000	0.794		
L01	180.66	0.0109		0.0	63.333	0.691		Vel = 4.55
L01	0.0	4.026	2V	13.6	114.500	28.225		
to		120.0	1T	20.0	33.600	0.0		
A14	180.66	0.0109		0.0	148.100	1.617		Vel = 4.55
	0.0							
	180.66					29.842		K Factor = 33.07
A01	96.40	6.065		0.0	0.542	15.822		
to		120.0		0.0	0.0	0.0		
A02	96.4	0.0		0.0	0.542	0.0		Vel = 1.07
A02	65.87	6.065		0.0	6.333	15.822		
to		120.0		0.0	0.0	0.0		
A03	162.27	0.0013		0.0	6.333	0.008		Vel = 1.80

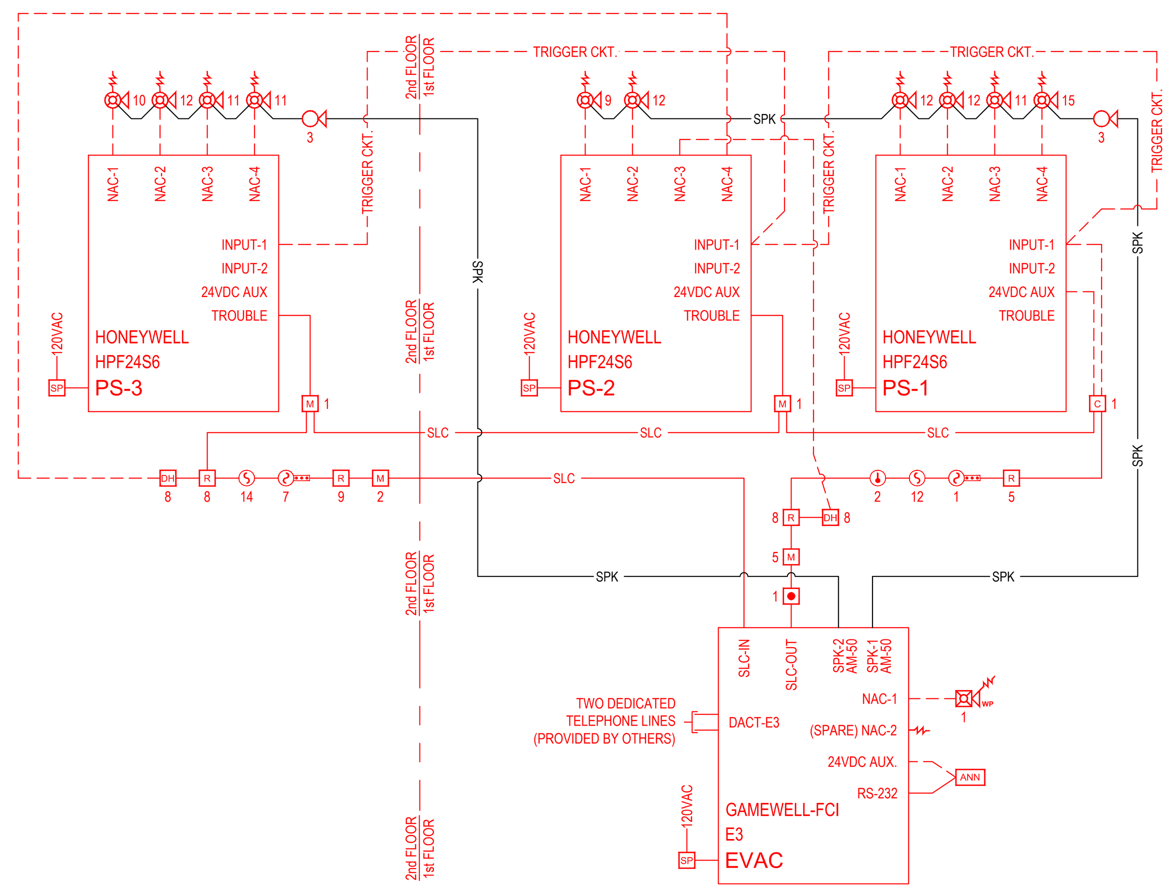
Final Calculations - Hazen-Williams

CCR
Maumus Center - Remote Area 1 Calc

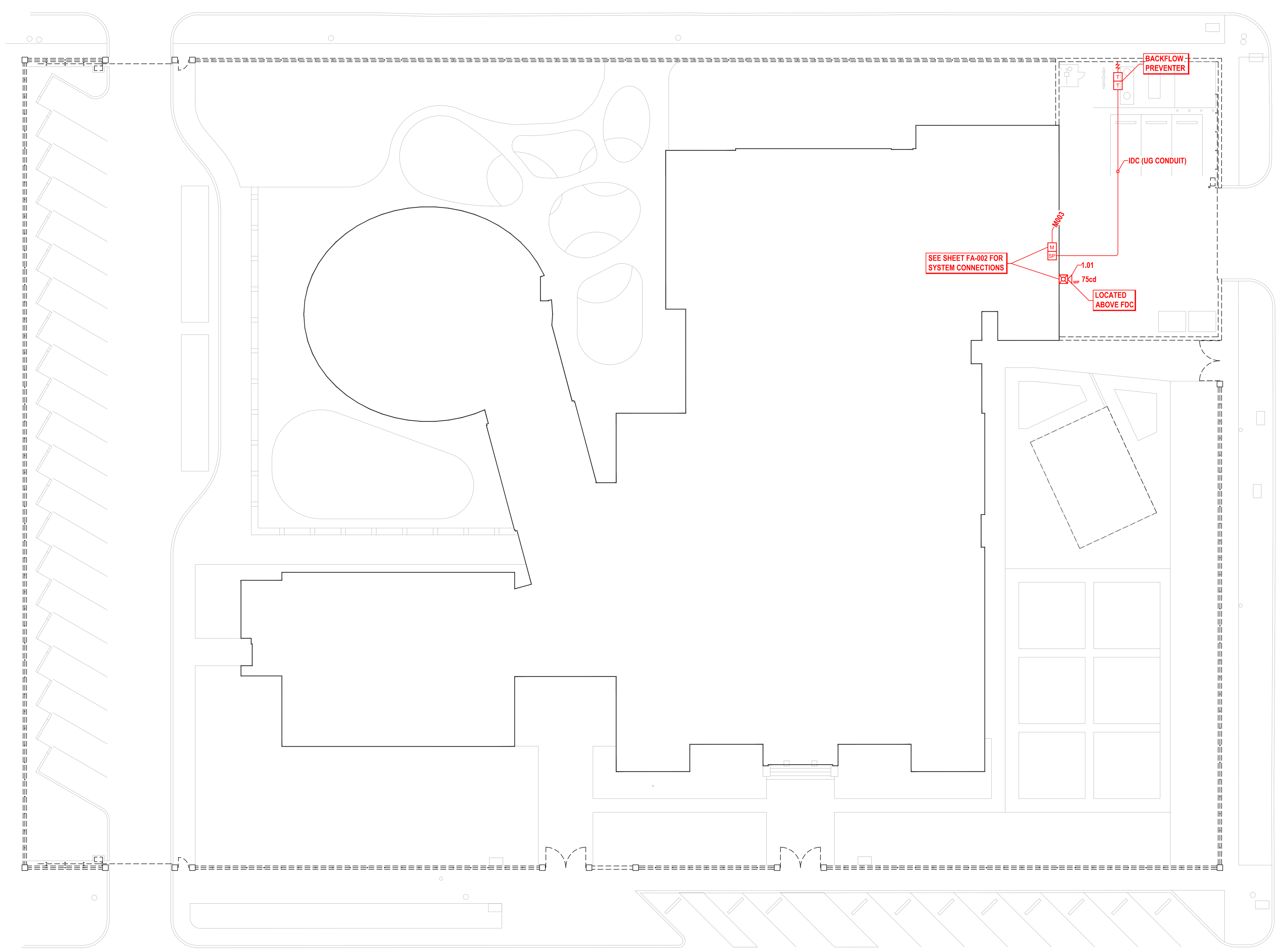
Page 11
Date 3-20-2013

Hyd. Ref. Point	Qa / Qt	Dia. / "C" / Pf/Ft	Fitting or Eqv.	Ln.	Pipe / Ftng's / Total	Pt / Pe / Pf	Pt / Pv / Pn	******* Notes ******
A03	20.33	6.065		0.0	12.000	15.830		
to		120.0		0.0	0.0	0.0		
A04	182.6	0.0015		0.0	12.000	0.018		Vel = 2.03
A04	127.57	6.065		0.0	6.000	15.848		
to		120.0		0.0	0.0	0.0		
A05	310.17	0.0040		0.0	6.000	0.024		Vel = 3.44
A05	52.34	6.065		0.0	6.000	15.872		
to		120.0		0.0	0.0	0.0		
A06	362.51	0.0053		0.0	6.000	0.032		Vel = 4.03
A06	19.40	6.065	1T	30.0	10.333	15.904		
to		120.0		0.0	30.000	0.0		
A07	381.91	0.0059		0.0	40.333	0.239		Vel = 4.24
A07	0.0	6.065	1V	10.0	22.708	16.143		
to		120.0		0.0	10.000	0.0		
A08	381.91	0.0059		0.0	32.708	0.194		Vel = 4.24
A08	0.0	6.065	1V	10.0	14.542	16.337		
to		120.0		0.0	10.000	6.298		
A09	381.91	0.0059		0.0	24.542	0.145		Vel = 4.24
A09	0.0	6.065	2V	20.0	89.875	22.780		
to		120.0		0.0	20.000	0.0		
A10	381.91	0.0059		0.0	109.875	0.652		Vel = 4.24
A10	0.0	4.026	1T	20.0	0.833	23.432		
to		120.0		0.0	20.000	-0.361		
A11	381.91	0.0436		0.0	20.833	0.909		Vel = 9.63
A11	0.0	4.026	1T	20.0	43.292	23.980		
to		120.0		0.0	20.000	0.0		
A12	381.91	0.0436		0.0	63.292	2.760		Vel = 9.63
A12	-180.66	4.026	7V	47.6	119.667	26.740		
to		120.0		0.0	47.600	0.794		
A13	201.25	0.0133		0.0	167.267	2.229		Vel = 5.07
A13	0.0	6.065		0.0	43.333	29.763		
to		120.0		0.0	0.0	0.0		
A14	201.25	0.0018		0.0	43.333	0.079		Vel = 2.23
A14	180.66	6.065	3V	30.0	53.500	29.842		
to		120.0		0.0	30.000	0.0		
TOR	381.91	0.0059		0.0	83.500	0.495		Vel = 4.24
TOR	0.0	6.065		0.0	4.375	30.337		
to		120.0		0.0	0.0	1.895		
R1	381.91	0.0057		0.0	4.375	0.025		Vel = 4.24
R1	0.0	6.065	1G	3.0	18.708	32.257		
to		120.0	1S	32.0	55.000	7.706		
BASE	381.91	0.0059	2V	20.0	73.708	0.437		Vel = 4.24
BASE	0.0	6.16	1L	12.911	4.500	40.400		
to		140.0		0.0	12.911	1.949		
UG1	381.91	0.0041		0.0	17.411	0.072		Vel = 4.11
UG1	0.0	5.86	2F	17.893	97.042	42.421		
to		150.0	4E	71.573	131.642	1.120		* Fixed loss = 2.636
TEST	381.91	0.0046	1G	3.834	228.684	1.061		Vel = 4.54

Hyd. Ref. Point	Qa Qt	Dia. "C" Pf/Ft	Fitting or Eqv.	Ln.	Pipe Ftng's Total	Pt Pe Pf	Pt Pv Pn	******* Notes ******
			1T 1Zac	38.342 0.0				
	100.00 481.91					44.602		Qa = 100.00 K Factor = 72.16



SYSTEM RISER DIAGRAM



SITE PLAN 1
SCALE: 1"=20'-0"

MAUMUS CENTER FIRE ALARM SYSTEM SEQUENCE OF OPERATIONS

	OUTPUTS																				
	FACP ANNUNCIATION							NOTIFICATION							CONTROL						
INPUTS	COMMON ALARM SIGNAL INDICATOR	AUDIBLE ALARM SIGNAL	COMMON SUPERVISORY SIGNAL INDICATOR	AUDIBLE SUPERVISORY SIGNAL	COMMON TROUBLE SIGNAL INDICATOR	AUDIBLE TROUBLE SIGNAL	LOCATION INDICATOR MESSAGE	ACTUATES VISUAL NOTIFICATION APPLIANCES	ACTUATES AUDIBLE VOICE EVACUATION MESSAGE	ACTUATES EXT. AUDIO/VISUAL NOTIFICATION APPLIANCE	TRANSMIT ALARM SIGNAL TO SUPERVISING STATION	TRANSMIT SUPERVISORY SIGNAL TO SUPERVISING STATION	TRANSMIT TROUBLE SIGNAL TO SUPERVISING STATION	TRANSMIT WATER FLOW SIGNAL TO SUPERVISING STATION	ACTUATES FIRE DOOR RELEASE	ACTUATES SHUNT TRIP - ELEVATOR	ACTUATES VISUAL WARNING SIGNAL - ELEVATOR	RECALL ELEVATOR TO PRIMARY RECALL FLOOR (1st FLOOR)	RECALL ELEVATOR TO ALTERNATE RECALL FLOOR (2nd FLOOR)	ACTUATES SHUTDOWN OF AUDIO SYSTEM	ACTUATES SHUT DOWN OF CORRESPONDING AIR HANDLER
MANUAL PULL STATION	X	X					X	X	X		X									X	
SMOKE DETECTOR - ABOVE PANEL(S)	X	X					X	X	X		X									X	
SMOKE DETECTOR - ADJACENT TO SMOKE DOOR	X	X					X	X	X		X				X					X	
SMOKE DETECTOR - 1st FLOOR ELEVATOR LOBBY	X	X					X	X	X		X								X	X	
SMOKE DETECTOR - 2nd FLOOR ELEVATOR LOBBY	X	X					X	X	X		X							X		X	
SMOKE DETECTOR - ELEVATOR MACHINE ROOM	X	X					X	X	X		X						X		X	X	
SMOKE DETECTOR - TOP OF ELEVATOR SHAFT	X	X					X	X	X		X						X	X		X	
HEAT DETECTOR - ELEVATOR MACHINE ROOM	X	X					X	X	X		X					X	X		X	X	
HEAT DETECTOR - PIT OF ELEVATOR SHAFT	X	X					X	X	X		X					X	X		X	X	
DUCT SMOKE DETECTOR			X	X			X					X									X
KITCHEN HOOD SYSTEM	X	X					X	X	X		X									X	
WATER FLOW SWITCH	X	X					X	X	X	X				X						X	
VALVE SUPERVISORY (TAMPER) SWITCH			X	X			X				X										
FIRE ALARM AC POWER FAILURE					X	X							X								
FIRE ALARM BATTERY TROUBLE					X	X							X								
OPEN CIRCUIT					X	X							X								
SHORT CIRCUIT					X	X							X								
GROUND FAULT					X	X							X								

WIRE LEGEND

CKT#	QTY.	AWG	LENGTH	CIRCUIT NAME	LINE TYPE
1	1	16/2	1,700'-0"	SLC (SIGNALING LINE CIRCUIT)	SLC
2	1	14/2	1,300'-0"	SPK-1 (SPEAKER CIRCUIT - 1st FLOOR)	SPK
3	1	14/2	1,000'-0"	SPK-2 (SPEAKER CIRCUIT - 2nd FLOOR)	SPK
4	1	14/2	200'-0"	FACP NAC-1	
5	1	14/2	280'-0"	PS-1 NAC-1	
6	1	14/2	300'-0"	PS-1 NAC-2	
7	1	14/2	280'-0"	PS-1 NAC-3	
8	1	14/2	450'-0"	PS-1 NAC-4	
9	1	14/2	250'-0"	PS-2 NAC-1	
10	1	14/2	400'-0"	PS-2 NAC-2	
11	1	14/2	250'-0"	PS-2 NAC-3 (1st FLOOR DOOR HOLDERS)	
12	1	14/2	300'-0"	PS-2 NAC-4 (2nd FLOOR DOOR HOLDERS)	
13	1	14/2	380'-0"	PS-3 NAC-1	
14	1	14/2	400'-0"	PS-3 NAC-2	
15	1	14/2	350'-0"	PS-3 NAC-3	
16	1	14/2	400'-0"	PS-3 NAC-4	
17	1	14/2	400'-0"	TRIGGER CIRCUIT (SYNC.)	
18	1	16/4	300'-0"	ANN	ANN

**ALL CABLE TO BE UNSHIELDED TWISTED PAIR (UTP)

EQUIPMENT LEGEND

SYMBOL	PART #	QTY.	DESCRIPTION	MOUNTING
EVAC	GAMEWELL-FCI E3 | DACT-E3	1	FIRE EMERGENCY VOICE/ALARM COMMUNICATIONS CONTROL PANEL	SURFACE MOUNT ENCLOSURE (MAX. HEIGHT TO TOP 5'-6")
PS-#	HONEYWELL HPF24S6	3	6-AMP REMOTE POWER SUPPLY	SURFACE MOUNT ENCLOSURE
ANN	GAMEWELL-FCI LCD-7100	1	REMOTE ANNUNCIATOR	FLUSH MOUNT 3-GANG BOX 54" AFF
	GAMEWELL-FCI ASD-PL2F	26	ADDRESSABLE PHOTOELECTRIC SMOKE DETECTOR	CEILING MOUNT 4" OCTAGON BOX 512 STD. CADDY BAR HANGER
	GAMEWELL-FCI DNR/ASD-PL2FR	8	ADDRESSABLE DUCT SMOKE DETECTOR REMOTE TEST READY	MOUNT TO SIDE OF MAIN RETURN DUCT UPSTREAM OF AHU
	GAMEWELL-FCI MS-7AF	2	ADDRESSABLE FIXED TEMP. 135° F THERMAL DETECTOR	CEILING MOUNT 4" OCTAGON BOX 512 STD. CADDY BAR HANGER
	GAMEWELL-FCI MS-7AF	1	ADDRESSABLE MANUAL PULL STATION	FLUSH MOUNT 4" SQUARE BOX ℄ 44" AFF
M	GAMEWELL-FCI AMM-4F	9	ADDRESSABLE MONITOR MODULE	SURFACE MOUNT DEEP 4" SQUARE BOX
R	GAMEWELL-FCI AOM-2RF	30	ADDRESSABLE RELAY MODULE	SURFACE MOUNT DEEP 4" SQUARE BOX
C	GAMEWELL-FCI AOM-2SF	1	ADDRESSABLE SUPERVISED CONTROL MODULE	SURFACE MOUNT DEEP 4" SQUARE BOX
A	GAMEWELL-FCI MR101	1	120VAC CONVENTIONAL CONTROL RELAY	SURFACE MOUNT DEEP 4" SQUARE BOX
DH	GAMEWELL-FCI FM-996	16	ELECTROMAGNETIC DOOR RELEASE	SURFACE MOUNT
	SYSTEM SENSOR SPCW	6	SPEAKER CEILING MOUNT (WHITE)	4" DEEP SQUARE BOX W/ EXT. RING 512HDEEP CADDY BAR HANGER
	SYSTEM SENSOR SPSCW	99	SPEAKER/STROBE CEILING MOUNT (WHITE)	4" DEEP SQUARE BOX W/ EXT. RING 512HDEEP CADDY BAR HANGER
W	SYSTEM SENSOR SPSW	16	SPEAKER/STROBE WALL MOUNT (WHITE)	RECESSED 4" DEEP SQUARE BOX ℄ 90" AFF
WP	SYSTEM SENSOR P2RK	1	WEATHERPROOF HORN/STROBE WALL MOUNT (RED)	SURFACE MOUNT WEATHERPROOF BACK BOX ℄ 90" AFF
SP	DITEK DTK-120HW DITEK DTK-2MHLP	4 1	HIGH VOLTAGE SURGE PROTECTOR LOW VOLTAGE SURGE PROTECTOR	SURFACE MOUNT 4" SQUARE BOX SURFACE MOUNT 4" SQUARE BOX
W	WATERFLOW SWITCH	1	WATERFLOW SWITCH (BY OTHERS)	
T	TAMPER SWITCH	3	TAMPER SWITCH (BY OTHERS)	
	END-OF-LINE RESISTOR			

SHEET LEGEND

SHEET #	DESCRIPTION
FA-001	GENERAL NOTES | EQUIPMENT LEGEND | WIRE LEGEND | RISER DIAGRAM | SEQUENCE OF OPERATIONS
FA-002	1st FLOOR FIRE ALARM PLAN
FA-003	2nd FLOOR FIRE ALARM PLAN
FA-004	BATTERY CALCULATIONS | LOW VOLTAGE DROP CALCULATIONS

SCOPE OF WORK

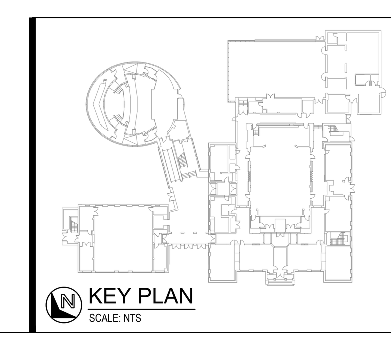
THE INSTALLATION OF AN IN-BUILDING FIRE EMERGENCY VOICE/ALARM COMMUNICATIONS SYSTEM DESIGNED & INSTALLED IN ACCORDANCE WITH NFPA 101 (2012 ED.), NFPA 72 (2012 ED.), & THE OFFICE OF THE LOUISIANA STATE FIRE MARSHAL.

PROJECT DATA

OCCUPANCY: A - ASSEMBLY
NUMBER OF FLOORS: 2
AREA OF WORK: 1st FLOOR - 29,600 SF | 2nd FLOOR - 16,680 SF
CEILING TYPE/HEIGHT: VARIES (SEE PLANS)

INSTALLATION NOTES

1. INSTALLING CONTRACTOR SHALL PROVIDE & INSTALL ALL CABLE, WIRES, MATERIALS, & DEVICES REFERENCED IN THE CONTRACT DOCUMENTS & ON THE SHOP DRAWINGS.
2. ALL ELECTRICAL WIRING MUST MEET THE REQUIREMENTS SET FORTH BY NFPA 70 ARTICLE 760 & ALL LOCAL CODES.
3. HIGH VOLTAGE & LOW VOLTAGE WIRES MUST BE RAN IN SEPARATE CONDUIT.
4. ALL WIRES MUST BE LABELED, NUMBERED, OR COLOR CODED.
5. ALL SIGNALING LINE CIRCUITS SHALL BE A CLASS A CONFIGURATION & A MINIMUM OF 16 AWG FPLP CABLE SHALL BE USED.
6. ALL INDICATING DEVICE CIRCUITS SHALL BE A CLASS B CONFIGURATION & A MINIMUM OF 18 AWG FPLP CABLE SHALL BE USED.
7. ALL NOTIFICATION APPLIANCE CIRCUITS SHALL BE A CLASS B CONFIGURATION & A MINIMUM OF 14 AWG FPLP CABLE SHALL BE USED.
8. ALL NOTIFICATION APPLIANCE CIRCUITS ARE TO BE SUPERVISED. (T-TAPPING AND BRANCHING IS NOT PERMITTED)
9. ALL CLASS A CIRCUITS MUST MAINTAIN A 4'-0" SEPARATION BETWEEN THE SUPPLY & THE RETURN CIRCUIT.
10. ALL CIRCUITS MUST BE ENCLOSED IN CONDUIT.
11. ALL CONDUIT MUST BE INSTALLED & SUPPORTED IN ACCORDANCE WITH THE NFPA 70.
12. ALL UNDERGROUND CONDUIT MUST BE IN ACCORDANCE WITH THE NFPA 70.
13. ALL PENETRATIONS MADE BY INSTALLING CONTRACTOR SHALL BE SEALED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
14. ALL PENETRATIONS IN FIRE OR SMOKE RATED ASSEMBLIES MUST BE SEALED IN ACCORDANCE WITH NFPA 101.
15. SMOKE DETECTORS SHALL BE LOCATED A MINIMUM OF 36" FROM ANY HVAC REGISTER OR DIFFUSER.
16. ALL EQUIPMENT LOCATIONS SHALL BE ASSURED NOT TO INTERFERE WITH OTHER EQUIPMENT AND/OR OTHER ELECTRICAL & MECHANICAL MATERIALS OR DEVICES.
17. UPON COMPLETION OF THE INSTALLATION, A COMPLETE SET OF MARKED-UP FIELD DRAWINGS SHALL BE GIVEN TO THE SYSTEM DESIGN CONTRACTOR FOR AS-BUILT DRAWING PREPARATION. ALL CHANGES SHALL BE SHOWN ON THESE DRAWINGS TO ASSURE ACCURACY FOR FUTURE REFERENCE.



KEY PLAN
SCALE: NTS

REVISIONS

NO.	DATE	BY	REVISION DESCRIPTION
0	---	TM	ORIGINAL-SUBMIT FOR APPROVAL
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
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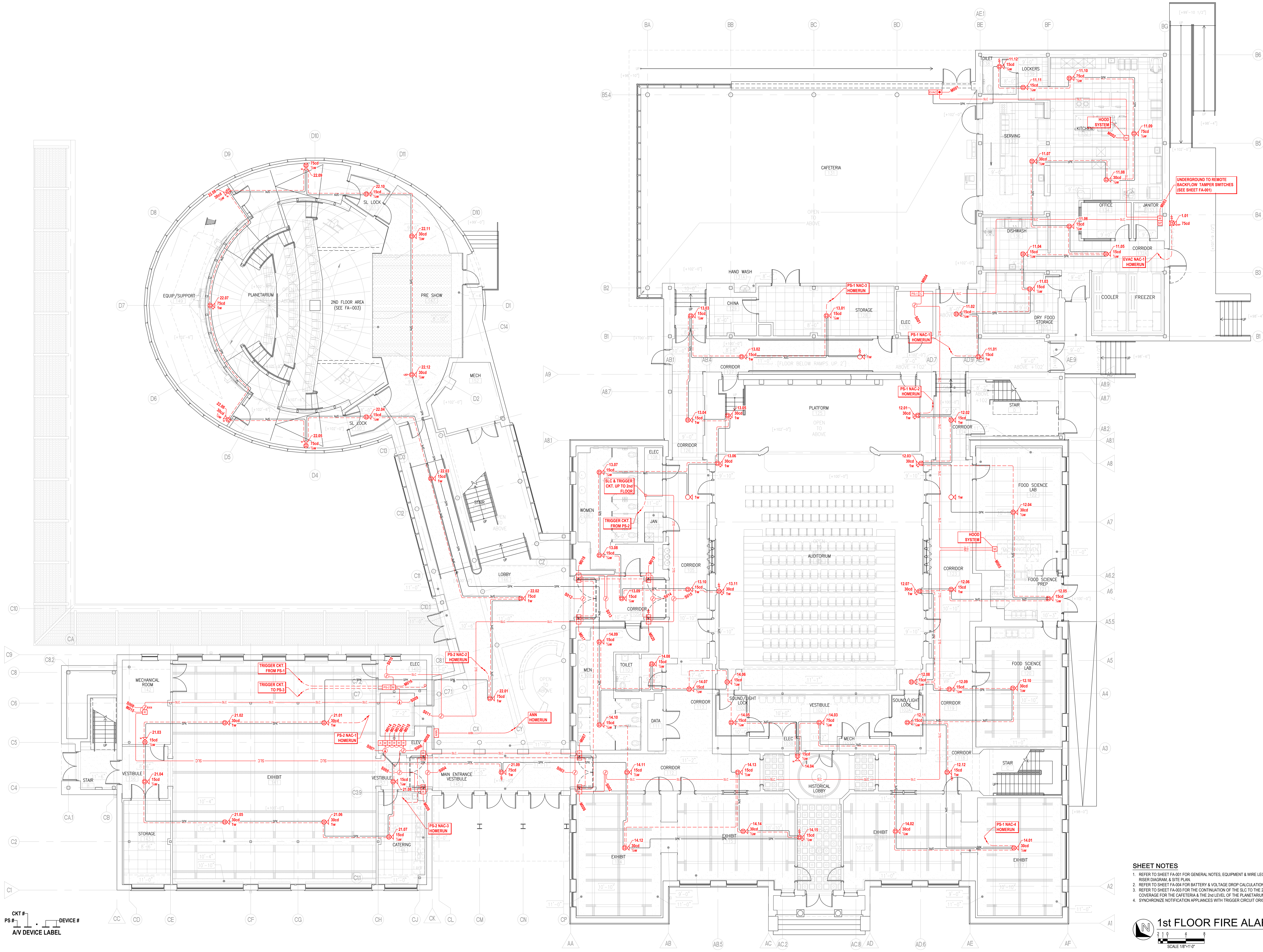
SCALE: AS NOTED
DRAWN BY: TDM
CHECKED BY: ---
CONTRACT WITH: ---
CONTRACT #: ---
DATE: --/--/----
REV. #: 0

MFP a Fire Protection Company

PROJECT NAME AND LOCATION
MAUMUS CENTER
ST. BERNARD PARISH SCHOOL BOARD
721 FRISCOVILLE AVE.
ARABI, LOUISIANA 70032

SHEET DESCRIPTION
GENERAL NOTES | LEGENDS | SITE PLAN | RISER | SOO

LATEST REV. DESCRIPTION: ORIGINAL-SUBMIT FOR APPROVAL
DRAWING #: FA-001



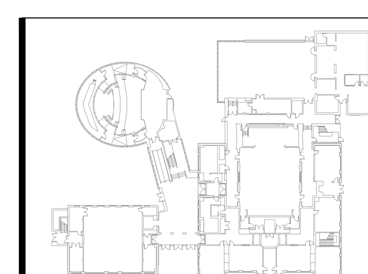
SHEET NOTES

1. REFER TO SHEET FA-001 FOR GENERAL NOTES, EQUIPMENT & WIRE LEGEND, SEQUENCE OF OPERATIONS, RISER DIAGRAM, & SITE PLAN.
2. REFER TO SHEET FA-004 FOR BATTERY & VOLTAGE DROP CALCULATIONS.
3. REFER TO SHEET FA-003 FOR THE CONTINUATION OF THE SLC TO THE 2nd FLOOR, NOTIFICATION COVERAGE FOR THE CAFETERIA & THE 2nd LEVEL OF THE PLANETARIUM.
4. SYNCHRONIZE NOTIFICATION APPLIANCES WITH TRIGGER CIRCUIT ORIGINATING AT PS-1.

1st FLOOR FIRE ALARM PLAN (1)

SCALE: 1/8"=1'-0"

SCALE 1/8"=1'-0"



KEY PLAN
SCALE: NTS

REVISIONS

NO.	DATE	BY	REVISION DESCRIPTION
0	---	TM	ORIGINAL-SUBMIT FOR APPROVAL
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---
-	---	--	---

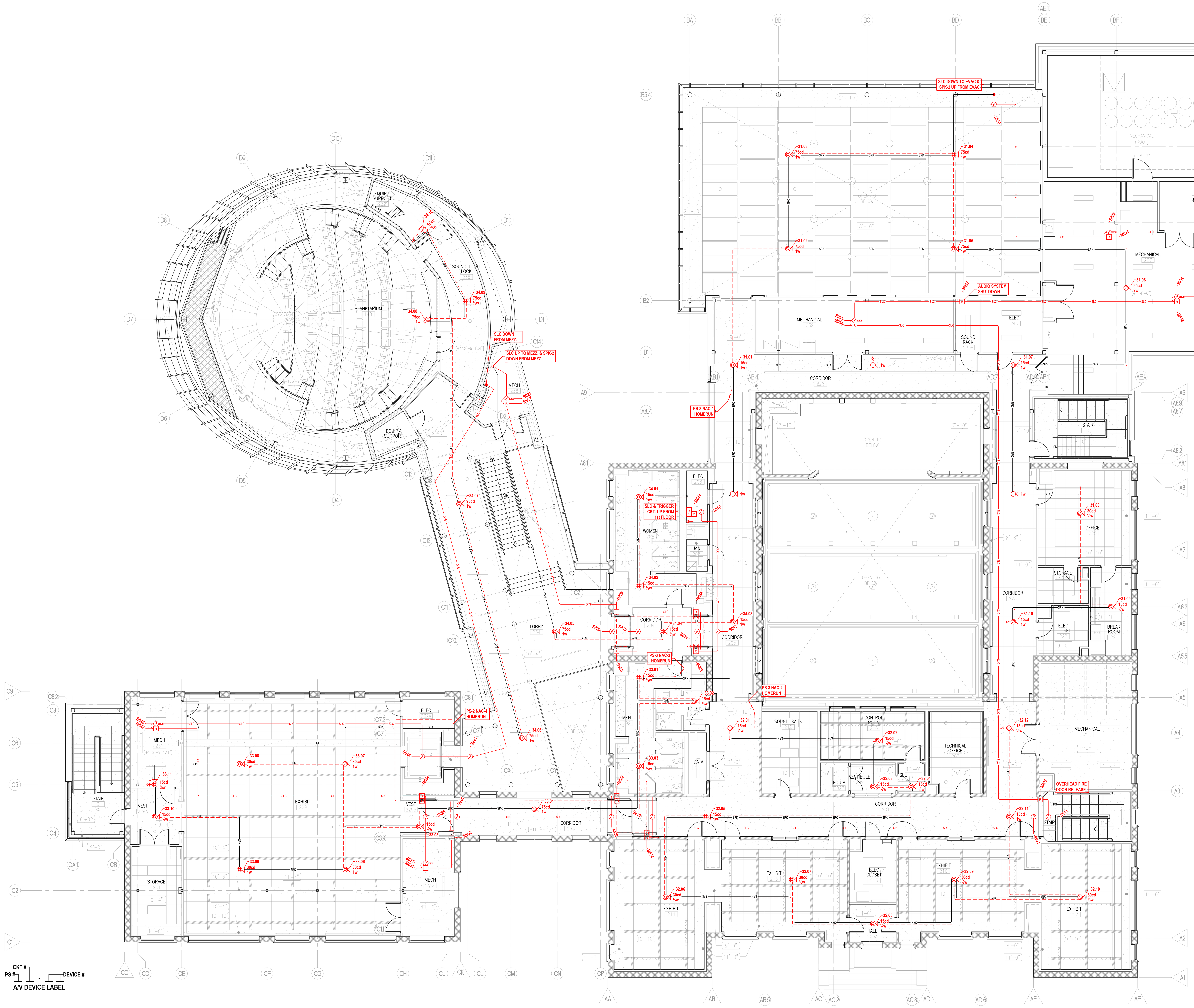
SCALE: AS NOTED
DRAWN BY: TDM
CHECKED BY: ---
CONTRACT WITH: ---
CONTRACT #: ---
DATE: --/--/----
REV. #: 0

MFP a Fire Protection Company

PROJECT NAME AND LOCATION
MAUMUS CENTER
ST. BERNARD PARISH SCHOOL BOARD
721 FRISCOVILLE AVE.
ARABI, LOUISIANA 70032

SHEET DESCRIPTION
1st FLOOR FIRE ALARM PLAN

LATEST REV. DESCRIPTION: ORIGINAL-SUBMIT FOR APPROVAL
DRAWING #: FA-002



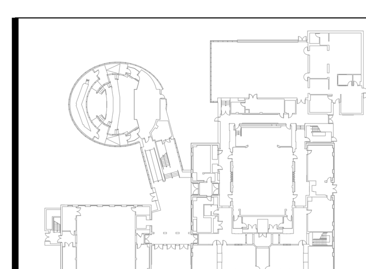
SHEET NOTES

1. REFER TO SHEET FA-001 FOR GENERAL NOTES, EQUIPMENT & WIRE LEGEND, SEQUENCE OF OPERATIONS, RISER DIAGRAM, & SITE PLAN.
2. REFER TO SHEET FA-004 FOR BATTERY & VOLTAGE DROP CALCULATIONS.
3. REFER TO SHEET FA-002 FOR THE CONTINUATION OF THE SLC FROM/TO THE 1st FLOOR.
4. SYNCHRONIZE NOTIFICATION APPLIANCES WITH TRIGGER CIRCUIT ORIGINATING AT PS-1.

2nd FLOOR FIRE ALARM PLAN (1)

SCALE: 1/8"=1'-0"

SCALE 1/8"=1'-0"



KEY PLAN
SCALE: NTS

REVISIONS

NO.	DATE	BY	REVISION DESCRIPTION
0	---	TM	ORIGINAL-SUBMIT FOR APPROVAL
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SCALE	AS NOTED
DRAWN BY	TDM
CHECKED BY	---
CONTRACT WITH	---
CONTRACT #	---
DATE	--/--/----
REV. #	0

MFP a Fire Protection Company

PROJECT NAME AND LOCATION

MAUMUS CENTER
ST. BERNARD PARISH SCHOOL BOARD
721 FRISCOVILLE AVE.
ARABI, LOUISIANA 70032

SHEET DESCRIPTION

2nd FLOOR FIRE ALARM PLAN

LATEST REV. DESCRIPTION: ORIGINAL-SUBMIT FOR APPROVAL

DRAWING # FA-003

VOLTAGE DROP CALCULATIONS - PS #3

CIRCUIT #	PANEL	SUPPLY VOLTAGE	ALARM CURRENT	WIRE TYPE & SIZE	OHMS/1000 FT.	LENGTH (FEET)	RESISTANCE (OHMS)	VOLTAGE @ LAST DEVICE
NAC-1	PS #3	20.4	1.171	14 AWG SOLID	2.52	380	1.915	18.16
NAC-2	PS #3	20.4	0.904	14 AWG SOLID	2.52	400	2.016	18.58
NAC-3	PS #3	20.4	0.560	14 AWG SOLID	2.52	350	1.764	19.41
NAC-4	PS #3	20.4	1.016	14 AWG SOLID	2.52	400	2.016	18.35

Power Supply - PS-3

Device Type	Qty		Current		Total Current
Regulated Load in Standby					
Main PC Board	1	X	0.065	=	0.065
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
			Standby Load	=	**0.065**
Regulated Load in Alarm					
Device Type	**Qty**		**Current**		**Total Current**
Main PC Board without AC	1	X	0.145	=	0.145
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
NAC-1	10	X	0.117	=	1.171
NAC-2	12	X	0.075	=	0.904
NAC-3	11	X	0.051	=	0.560
NAC-4	11	X	0.092	=	1.016
			Alarm Load	=	**3.796**
Battery Amp Hour Calculation					
Standby Load (Amps)			Required Standby Time (Typically 24 or 60 Hours)		
0.065		X	24	=	1.56 AH
Alarm Load (Amps)			Required Alarm Time (Typically 5 or 10 Minutes)		
3.796		X	15	=	0.95 AH
			Sub Total Standby / Alarm Amp Hours		2.51 AH
			Multiply by the Derating Factor	X	1.2
			Total Ampere Hours Required	**=**	**4 AH**

VOLTAGE DROP CALCULATIONS - PS #2

CIRCUIT #	PANEL	SUPPLY VOLTAGE	ALARM CURRENT	WIRE TYPE & SIZE	OHMS/1000 FT.	LENGTH (FEET)	RESISTANCE (OHMS)	VOLTAGE @ LAST DEVICE
NAC-1	PS #2	20.4	0.798	14 AWG SOLID	2.52	250	1.260	19.39
NAC-2	PS #2	20.4	1.364	14 AWG SOLID	2.52	400	2.016	17.65
NAC-3	PS #2	20.4	0.160	14 AWG SOLID	2.52	250	1.260	20.20
NAC-4	PS #2	20.4	0.160	14 AWG SOLID	2.52	300	1.512	20.16

Power Supply - PS-2

Device Type	Qty		Current		Total Current
Regulated Load in Standby					
Main PC Board	1	X	0.065	=	0.065
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
NAC-3 (1st Floor - Door Holders)	8	X	0.020	=	0.16
NAC-4 (2nd Floor - Door Holders)	8	X	0.020	=	0.16
			Standby Load	=	**0.385**
Regulated Load in Alarm					
Device Type	**Qty**		**Current**		**Total Current**
Main PC Board without AC	1	X	0.145	=	0.145
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
NAC-1	9	X	0.089	=	0.798
NAC-2	12	X	0.114	=	1.364
			Alarm Load	=	**2.307**
Battery Amp Hour Calculation					
Standby Load (Amps)			Required Standby Time (Typically 24 or 60 Hours)		
0.385		X	24	=	9.24 AH
Alarm Load (Amps)			Required Alarm Time (Typically 5 or 10 Minutes)		
2.307		X	15	=	0.58 AH
			Sub Total Standby / Alarm Amp Hours		9.82 AH
			Multiply by the Derating Factor	X	1.2
			Total Ampere Hours Required	**=**	**12 AH**

VOLTAGE DROP CALCULATIONS - PS #1

CIRCUIT #	PANEL	SUPPLY VOLTAGE	ALARM CURRENT	WIRE TYPE & SIZE	OHMS/1000 FT.	LENGTH (FEET)	RESISTANCE (OHMS)	VOLTAGE @ LAST DEVICE
NAC-1	PS #1	20.4	1.032	14 AWG SOLID	2.52	280	1.411	18.94
NAC-2	PS #1	20.4	0.932	14 AWG SOLID	2.52	300	1.512	18.99
NAC-3	PS #1	20.4	0.810	14 AWG SOLID	2.52	280	1.411	19.26
NAC-4	PS #1	20.4	1.194	14 AWG SOLID	2.52	450	2.268	17.69

Power Supply - PS-1

Device Type	Qty		Current		Total Current
Regulated Load in Standby					
Main PC Board	1	X	0.065	=	0.065
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
			Standby Load	=	**0.065**
Regulated Load in Alarm					
Device Type	**Qty**		**Current**		**Total Current**
Main PC Board without AC	1	X	0.145	=	0.145
Power Supervision Relays		X	0.025	=	0
Auxiliary Current Draw		X		=	0
NAC-1	12	X	0.086	=	1.032
NAC-2	12	X	0.078	=	0.932
NAC-3	11	X	0.074	=	0.81
NAC-4	15	X	0.080	=	1.194
			Alarm Load	=	**4.113**
Battery Amp Hour Calculation					
Standby Load (Amps)			Required Standby Time (Typically 24 or 60 Hours)		
0.065		X	24	=	1.56 AH
Alarm Load (Amps)			Required Alarm Time (Typically 5 or 10 Minutes)		
4.113		X	15	=	1.03 AH
			Sub Total Standby / Alarm Amp Hours		2.59 AH
			Multiply by the Derating Factor	X	1.2
			Total Ampere Hours Required	**=**	**4 AH**

VOLTAGE DROP CALCULATIONS - FACP

CIRCUIT #	PANEL	SUPPLY VOLTAGE	ALARM CURRENT	WIRE TYPE & SIZE	OHMS/1000 FT.	LENGTH (FEET)	RESISTANCE (OHMS)	VOLTAGE @ LAST DEVICE
NAC-1	FACP	20.4	0.176	14 AWG SOLID	2.52	200	1.008	20.22
NAC-2	FACP	20.4	0.000	14 AWG SOLID	2.52	0	0.000	20.40

System Current Draw

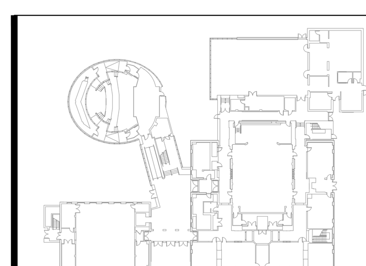
Gamewell-FCI E3 Series Control Panel

	Total Standby			**0.549 A**	**Total Alarm**		**3.314 A**

Device	Qty		Draw	Standby	Qty		Draw	Alarm
1. System Device								
Intel. Loop Interface, Main Board (ILI-MB-E3)	1	x	0.08100	0.08100	1	x	0.15000	0.15000
2. E3 Optional Modules								
120V Power Supply Sub-Assembly (PM-9)	1	x	0.05000	0.05000	1	x	0.05000	0.05000
LCD Display & Switch Control (LCD-E3)	1	x	0.02400	0.02400	1	x	0.02800	0.02800
Digital Communicator (DACT-E3)	1	x	0.01800	0.01800	1	x	0.01800	0.01800
Optional Remote Serial Annunicator (LCD-7100)	1	x	0.05000	0.05000	1	x	0.07500	0.07500
3. INI-VGX Voice Gateway								
Intel. Network Voice Gateway (INI-VGX)	1	x	0.15000	0.15000	1	x	0.15000	0.15000
Amplifier Sub-assembly, 50 watt 25V (AM-50)	1	x	0.08600	0.08600	1	x	2.20600	2.20600
4. Smoke Detectors/Modules								
Addressable Photoelectric Smoke Detector (ASD-PL2F)	34	x	0.00030	0.01020	34	x	0.00650	0.22100
Addressable Double-Action Manual Pull (MS-7AF)	1	x	0.00030	0.00030	1	x	0.00300	0.00300
Addressable Monitor Module (AMM-4F)	9	x	0.00750	0.06750	4	x	0.00570	0.0228
Addressable Fixed Temp. Thermal Detector (ATD-L2F)	2	x	0.00030	0.00060	2	x	0.00650	0.01300
Addressable Form-C Relay (AOM-2RF)	30	x	0.00038	0.01125	30	x	0.00650	0.19500
Addressable Supervised Control Module (AOM-2SF)	1	x	0.00038	0.00038	1	x	0.00650	0.00650
5. Notification Appliances								
NAC-1	1	x	0.00000	0.00000	1	x	0.17600	0.17600
NAC-2	0	x	0.00000		0	x	0.00000	
			Total Standby Load:	**0.549 A**			**Total Alarm Load:**	**3.314 A**

Secondary Standby Load 0.549 A	x	**Required Standby Time** 24 hours	13.18
Secondary Alarm Load 3.314 A	x	**Required Alarm Time (hours)** 0.250 hours	0.83
		Total Secondary Load	14.01
		Derating factor	x 1.20
		Secondary Load Requirements	**16.81 AH**

Battery Selection **17.00** Amp Hours



KEY PLAN
SCALE: NTS

REVISIONS

NO.	DATE	BY	REVISION DESCRIPTION
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SCALE: AS NOTED
DRAWN BY: TDM
CHECKED BY: ---
CONTRACT WITH: ---
CONTRACT #: ---
DATE: --/--/----
REV. #: 0

MFP a Fire Protection Company

PROJECT NAME AND LOCATION
MAUMUS CENTER
ST. BERNARD PARISH SCHOOL BOARD
721 FRISCOVILLE AVE.
ARABI, LOUISIANA 70032

SHEET DESCRIPTION
BATTERY CALCULATIONS

LATEST REV. DESCRIPTION: ORIGINAL-SUBMIT FOR APPROVAL
DRAWING #: FA-004