LOS ANGELES AIR FORCE BASE FITNESS CENTER

A Comprehensive Fire and Life Safety Analysis

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Executive Summary

The purpose of this report is to evaluate the life safety features of the Los Angeles Air Force Base Fitness Center, located on Los Angeles Air Force Base in El Segundo, California. This report is produced in partial fulfillment of the requirements of a Master's of Science in Fire Protection Engineering from the Fire Protection Engineering Program at California Polytechnic State University's San Luis Obispo Campus.

This analysis approaches life safety in the fitness center from two angles. First, a prescriptive approach is used to evaluate the building's compliance with current codes and standards that govern construction and maintenance of federal facilities. Four major areas are evaluated prescriptively. Each area is represented by a core code or standard against which the building is measured.

Structural fire protection systems are evaluated first. Standards for structural fire protection are codified in the International Building Code and other various standards. Next, life safety is evaluated using NFPA 101 – Life Safety Code as the standard. Third, fire detection and notification systems are evaluated against NFPA 72 – National Fire Alarm and Signaling Code as well as NFPA 70 – National Electric Code. Finally, fire suppression systems are evaluated against the provisions of NFPA 13- Standard for the Installation of Sprinkler Systems.

The next portion of this report evaluates the building from a performance-based standpoint using the provisions of Chapter 5 of NFPA 101 – Life Safety Code and supplemented by the SFPE Handbook of Fire Protection Engineering and the NFPA Fire Protection Handbook.

This performance-based approach evaluates the building against two fire scenarios designed to challenge all of the buildings fire protection elements. A medium growth sauna fire and an ultra-fast growth polyurethane foam fire are used as scenarios.

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1 PROJECT SCOPE

The scope of this report is to provide a comprehensive fire and life safety analysis in accordance with the codes and standards of the National Fire Protection Association (NFPA) and other applicable regulations in partial fulfillment of the requirements of the Fire Protection Engineering program at California Polytechnic State University at San Luis Obispo. Structural fire protection, occupant safety and egress, fire detection and notification, fire suppression, and smoke control systems were analyzed using a prescriptive approach based on current codes and standards. Additionally, a performance-based analysis was conducted in accordance with the provisions in Chapter 5 of NFPA 101 – Life Safety Code© (LSC), the NFPA Fire Protection Handbook, and the Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering. The results of this analysis are provided herein.

1.1 Life Safety Goals and Objectives

1.1.1 Life Safety Goals

The goal of the LSC is to provide reasonable safety from fire through a twofold effort to protect the occupants not intimate with the initial fire development and to improve the survivability of those occupants who are intimate with the initial fire development. These goals are met through the application of the life safety objectives.

1.1.2 Life Safety Objectives

1.1.2.1 Occupant Protection

The building must be designed, constructed, and maintained in such a way that, in the event of a fire, there is sufficient time for occupants to evacuate, relocate, or defend against the fire.

1.1.2.2 Structural Integrity

Structural integrity of the building must be maintained for the duration of the time mentioned above so that the efforts of occupants to evacuate, relocate, or defend are not thwarted by structural failure.

1.1.2.3 System Effectiveness

All the systems which are used to meet the goals mentioned above must be effective in mitigating hazards and conditions for which they are being used. Thus ensuring that such systems are reliable, remain operational, and are maintained in such a fashion as to guarantee the intended operation.

These life safety goals and objectives are applicable for both the prescriptive design approach and the performance-based design approach.

1.2 Existing Documentation

Where possible every effort was made to gather reliable documentation concerning the existing building. Where such information was not available assumptions were made in order to complete the analysis. The following documents and resources were made available for the purpose of this analysis.

- Partially complete, as-built construction drawings from the original construction of the facility
- Operations and Maintenance Manuals for various components which were part of the original installation
- Facility Specifications
- Maintenance and inspection reports, photographs, and construction blue books
- System testing results and reports
- Building user inputs

1.3 Applicable Codes and Standards

Applicable codes and standards for this project are listed below:

UFC 1-200-01 – DOD Building Code
UFC 3-410-01 – Mechanical Engineering
UFC 3-420-01 – Plumbing Systems
UFC 3-501-01 – Electrical Engineering
UFC 3-600-01 – Fire Protection Engineering for Facilities
UFC 4-740-02 – Design of Fitness Centers
International Building Code (IBC)
International Mechanical Code (IMC)
International Plumbing Code (IPC)
NFPA 1 – Fire Code
NFPA 13 – Standard for the Installation of Sprinkler Systems
NFPA 25 – Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Systems
NFPA 70 – National Electrical Code
NFPA 72 – National Alarm and Signaling Code
NFPA 101 – Life Safety Code
NFPA 5000 – Building Construction and Safety Code
LA AFB FC – Los Angeles Air Force Base Fire Code

2 BUILDING OVERVIEW

The Los Angeles Air Force Base Fitness Center is a single-story, mixed occupancy physical fitness facility located on Los Angeles Air Force Base (LA AFB) in El Segundo, California. The building is part of a larger recreational area which includes an outdoor basketball court, sand volleyball court, artificial grass sports field, rubberized running track, and picnic area with tables and a barbeque pit. The facility, which serves as the installation's primary fitness center, serves active-duty, government civilians, contractors and retired military personnel in the LA metropolitan area. The fitness center houses an indoor sports court/multi-purpose area, racquetball courts, various exercise rooms, restrooms and changing areas, and laundry and office space. The building also houses the Health and Wellness Center (HAWC) which has additional office space, a small conference room and a small demonstration kitchen.

The building, which was constructed in 2002 under a Naval Facilities Command (NAVFAC) contract, is organized around a central corridor with a finished plaster celling over the main reception area that transitions to an exposed raised ceiling with natural light provide by clerestories. The structure can be broken down into three major areas with differing construction type and occupancy classifications. The gymnasium is an 8,476 sq. ft. pre-engineered building. The HAWC, which is more administrative in nature, is 4,514 sq. ft. and includes office space for fitness evaluations, health and wellness education, and relaxation and therapy. The remainder of the facility, 21,526 sq. ft., is typical of other fitness clubs with weight rooms, cardio areas, and an aerobics floor. Particulars of the facility are listed below.

Occupancy:	A-2.1 (Gymnasium) A-3 (Remainder of the Facility) B (Office and Laundry)
Construction Type:	II (1-hr for 2.1 Occupancy) II (N for A-3 Occupancy)

Note: 2-hr. fire wall separates A-2.1 from A-3 and B occupancies

Number of Stories:	1
Building Height:	32 ft.
Total Area:	34,512 sq. ft.
Total Occupancy:	1,055

2.1 Building Location and Orientation

The fitness center is located on Los Angeles Air Force Base. Access to the base is via the main gate south of the fitness center on Douglas Ave. The main entrance to the facility is located on the east side of the building as indicated with a yellow arrow on Figure 1 below. The building is accessible via the base road which runs along the east side of the building.

Figure 1 – Building Location

2.2 Building Layout

An overall floor plan showing the building layout is shown in Figure 2 below. Detailed sections are provided in Figure 3 thru Figure 5. Figure 6 depicts the front of the building (east elevation), showing the main entrance to the facility. The fitness center is a controlled access facility so this entrance serves as the single entry/exit point to the gym. All other exits are for use in emergencies only. Figure 7 shows the entrance to the gym as seen from the main entrance looking west. Figure 8 is a view of the gym from its southeast corner. Figure 9 is looking down the main, north-south corridor at the weight room and the cardio room. Figure 10 shows the entrance to the weight and cardio rooms. Figure 11 shows the east-west corridor on the north side of the building. Figure

12 shows the aerobics room opposite the locker rooms. A depiction of the egress area of the men's locker room is shown in Figure 13.

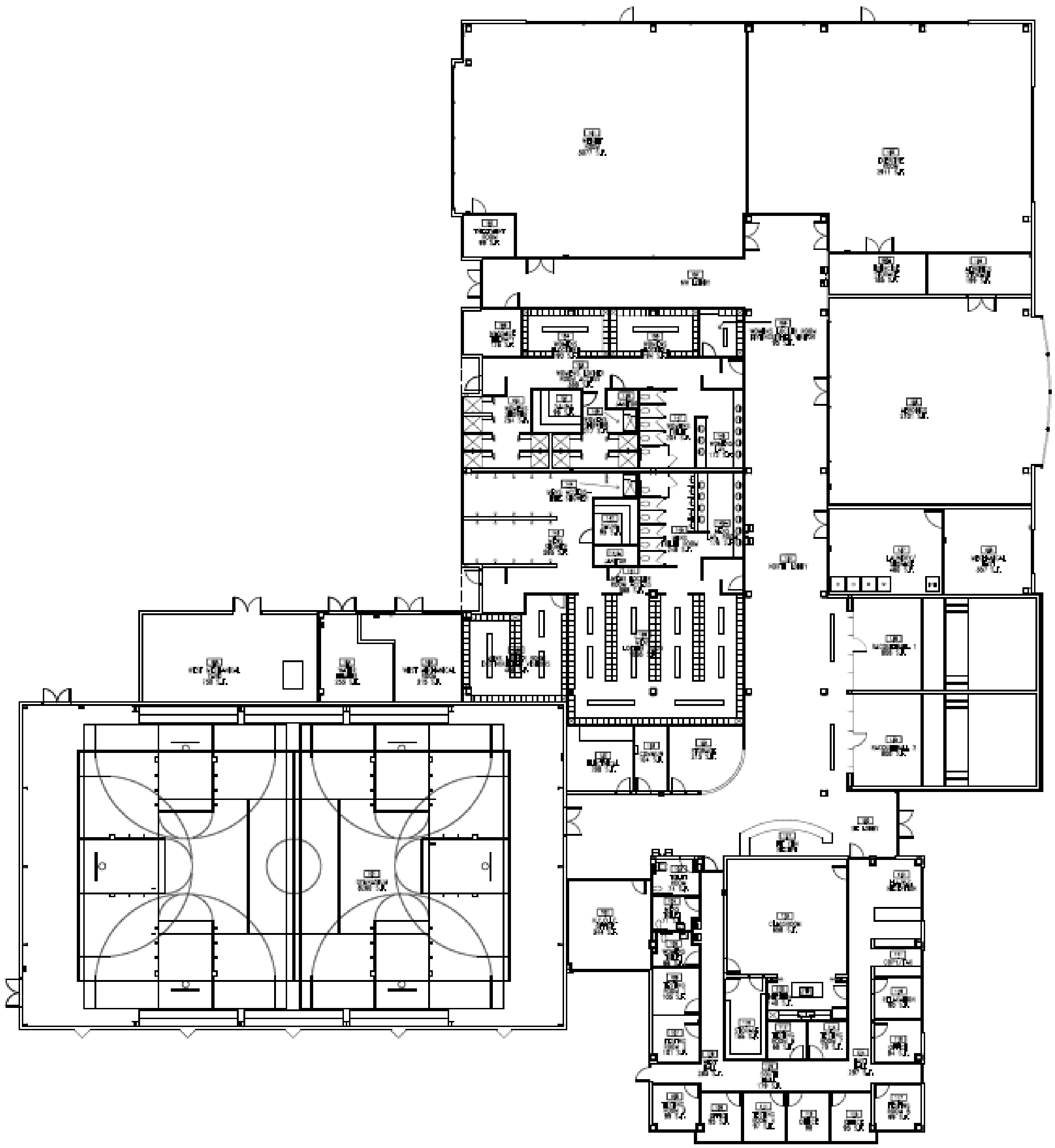

Figure 2 – Overall Building Floor Plan

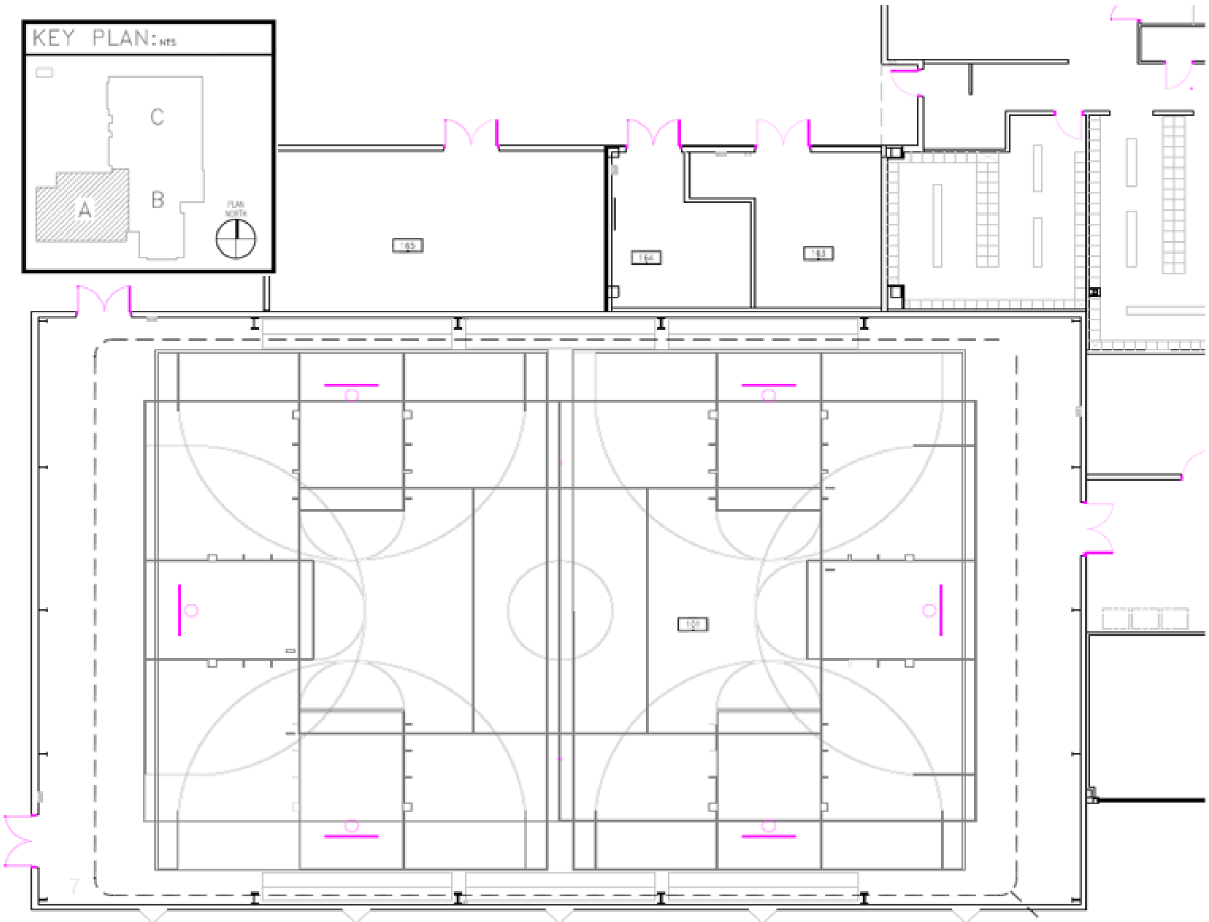

Figure 3 – Gymnasium Floor Plan

Figure 4 – HAWC Floor Plan

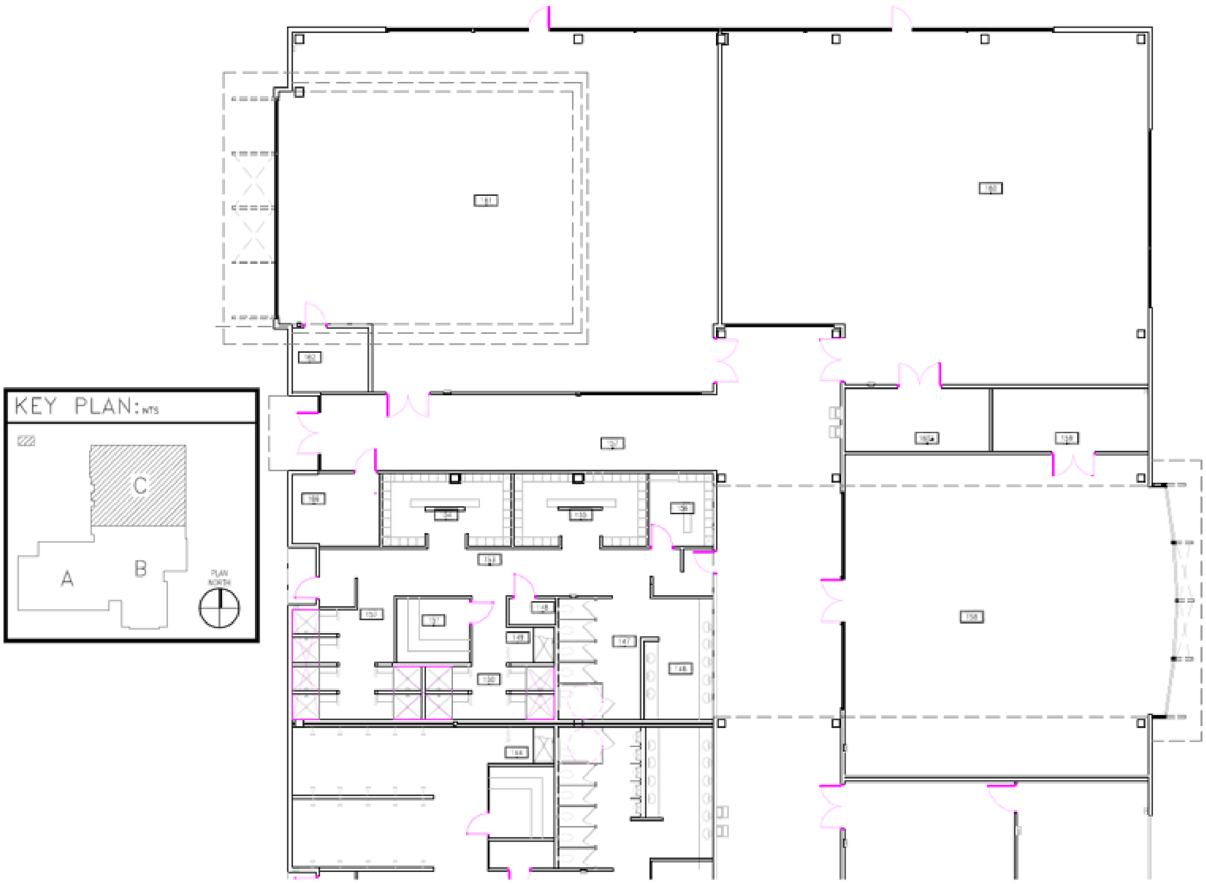

Figure 5 – Fitness Center Floor Plan

Figure 6 – Main Entrance (East Elevation) Looking West

Figure 7 – Interior Entrance to Gymnasium

Figure 8 – Gymnasium from Southeast Corner

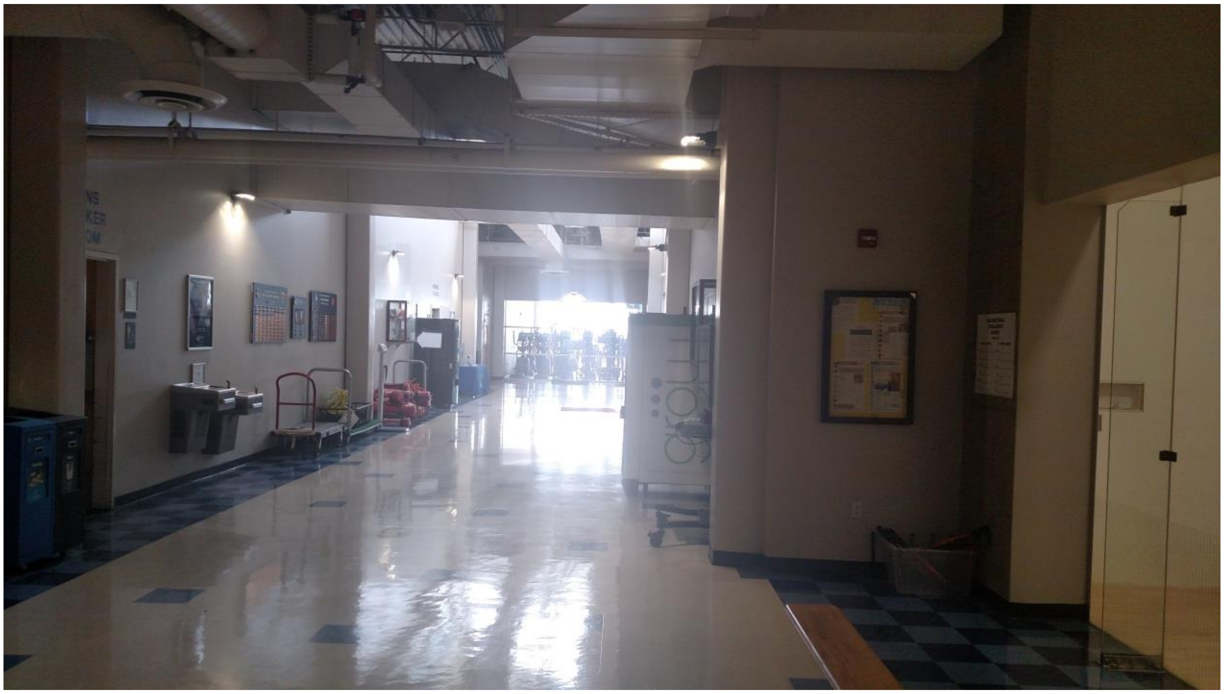

Figure 9 - Looking North down Main North-South Corridor

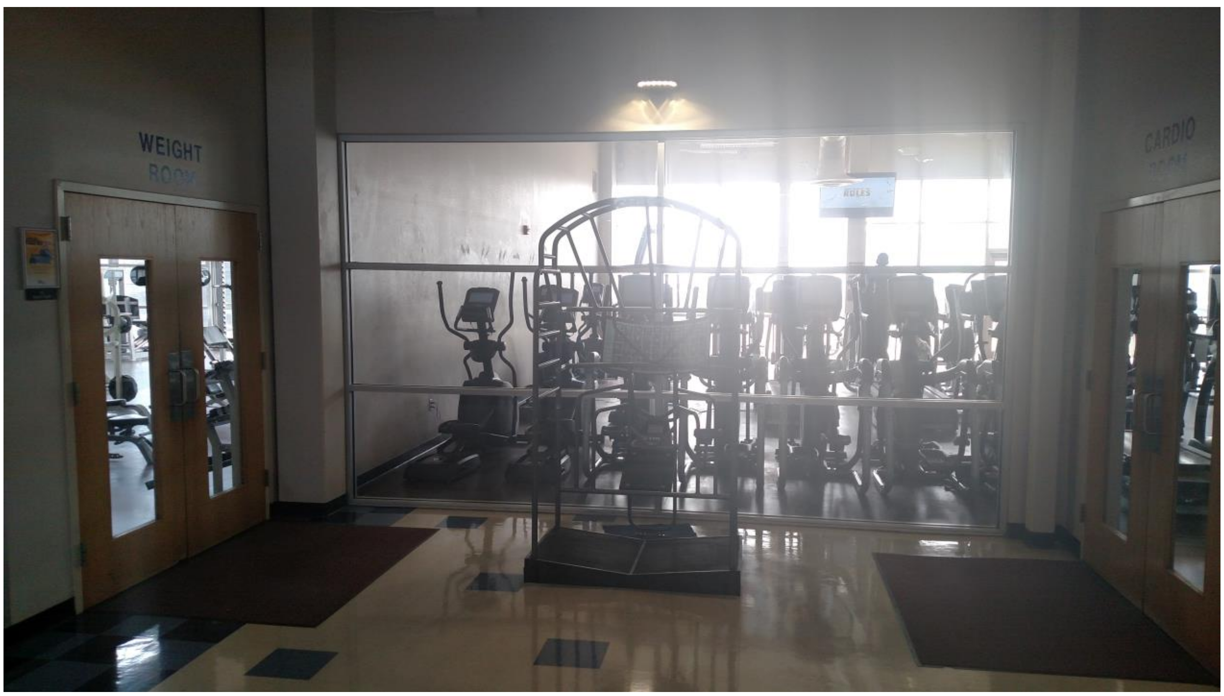

Figure 10 – Entrance to the Weight and Cardio Rooms

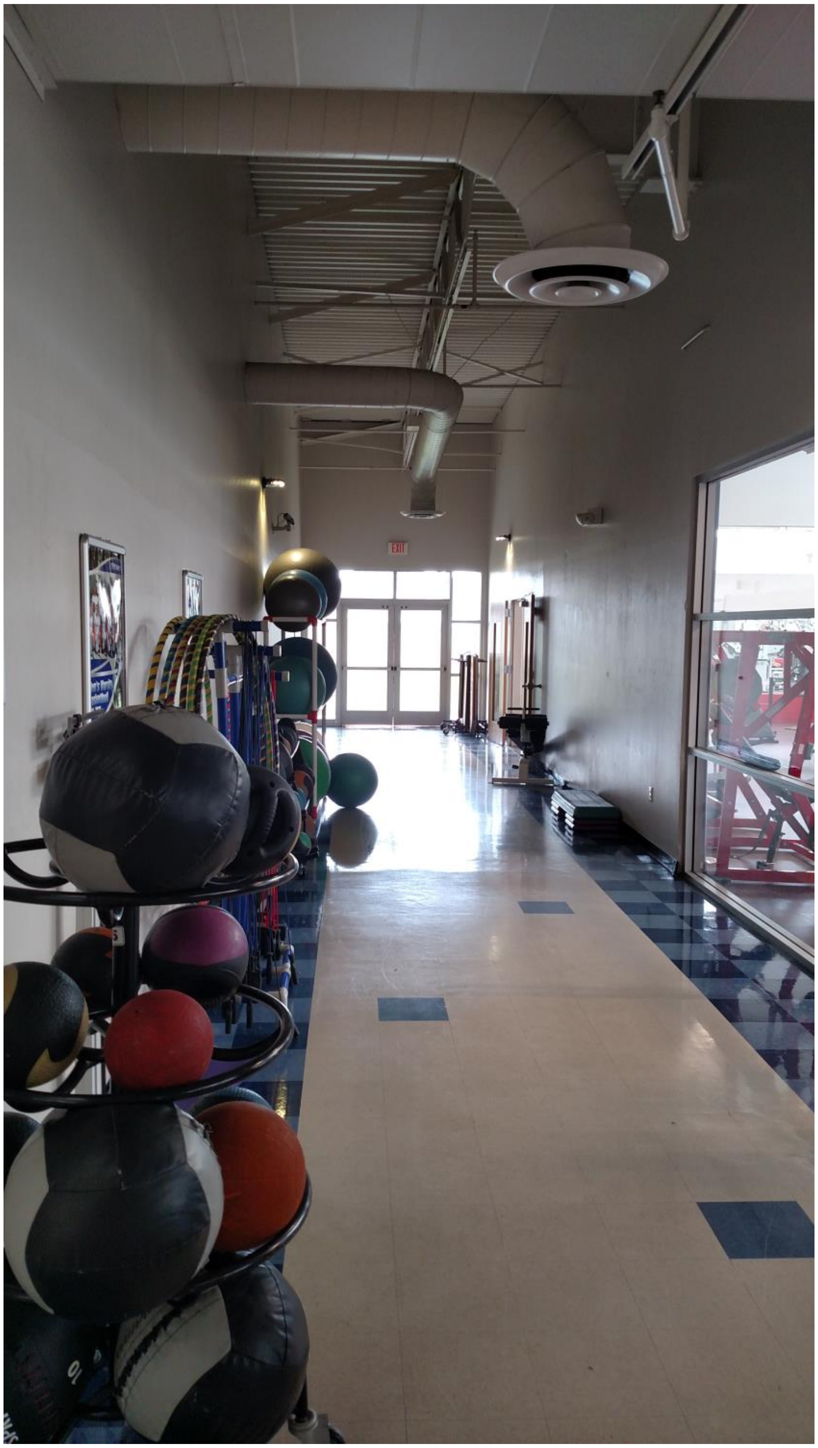

Figure 11 – East-West Corridor

Figure 12 - Aerobics Room

Figure 13 - Men's Locker Room Egress

2.3 Building Use

The primary function of the fitness center is to promote a healthy and active lifestyle by providing access to fitness equipment and educational programs. The gymnasium in the fitness center serves as a multi-purpose area where occasional events are held. In the past these have included dances/balls, conference meetings, fairs, and assemblies. The gym also hosts competitive sporting events where spectators are present. In the event of a natural disaster or other similar emergency the fitness center can serve as a staging/quarantine area.

3 PRESCRIPTIVE ANALYSIS

3.1 Structural Fire Protection

The safety of building occupants during a fire depends on the expectation that a building will not collapse or that the fire will not be allowed to spread significantly. To meet this goal the fire rating needs of various assemblies in the structure need to be determined and assessed to ensure that they remain intact throughout the duration of a building evacuation or indefinitely, depending on the design objectives. This section will address the type and nature of the various construction elements of the fitness center. This information will be compared with fire resistance requirements to determine compliance with existing building codes.

3.1.1 Construction Type

The gymnasium was designed as a Type II-I Hour facility under the 1997 Uniform Building Code (UBC). This is equivalent to Type IIA in the current International Building Code (IBC). Section 602.2 of the IBC specifies that Type II construction is generally made of non-combustible materials with specific exceptions listed in Section 603. The remainder of the facility is designed as Type II-N construction under the 1997 UBC. This type of construction is equivalent to Type IIB in the current code. Type IIB construction does not require a specific fire rating. Table 1 shows a comparison of construction types from various classification sources.

Table 1 – Comparisons of Various Classification Sources

TYPES OF CONSTRUCTION
Comparisons of Various Classification Sources

IBC/IFC:	UBC/UFC:	NFPA:	NFIRS:	BOCA:	SBC:	COMMON TERMINOLOGY:
-----	-----	I (443)	1	1-A	I	Fire Resistive, Non-combustible
Type I-A	Type I-FR	I (332)	1	1-B	II	Fire Resistive, Non-combustible
Type I-B	Type II-FR	II (222)	1	2-A	-----	Fire Resistive, Non-combustible
Type II-A	Type II-1 Hr.	II (111)	3	2-B	IV-1 Hr.	Protected Non-combustible
Type II-B	Type II-N	II (000)	4	2-C	IV-unp.	Unprotected Non-combustible
Type III-A	Type III-1 Hr	III (211)	5	3-A	V-1 Hr.	Protected Ordinary
Type III-B	Type III-N	III (200)	6	3-B	V-unp.	Unprotected Ordinary
Type IV	Type IV (H.T.)	IV (2HH)	2	4	III	Heavy Timber
Type V-A	Type V-1 Hr	V (111)	7	5-A	VI-1 Hr.	Protected Combustible
Type V-B	Type V-N	V (000)	8	5-B	VI-unp.	Unprotected Combustible

IBC/IFC – International Building Code / International Fire Code
UBC/UFC – Uniform Building Code / Uniform Fire Code
NFPA – National Fire Protection Association
NFIRS – National Fire Incident Reporting System
BOCA – BOCA / National Building Code
SBC – Standard / Southern Building Code

A 1-Hour fire wall separates the A-2.1 and B occupancies and a 2-Hour fire wall separates A-2.1 from A-3 and B. Details of each of the fire walls are shown in Figure 14. It's noteworthy that these walls as drawn would not meet the criteria for firewalls. A note was included in the drawings to indicate that the gypsum board was Type X and needed to continue up to the deck as opposed to stopping 6" above the dropped ceiling as indicated on the drawings below.

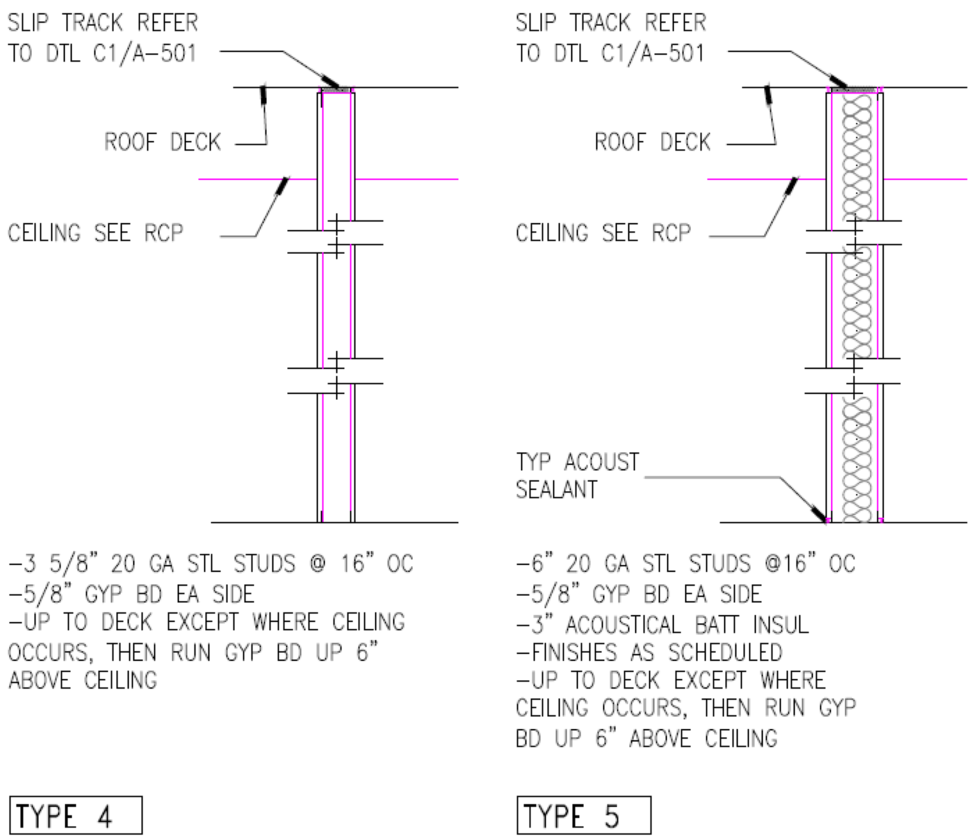

Figure 14 – Representative 1-hr (Type 4) and 2-hr (Type 5) Fire Walls

3.1.2 Occupancy Type

Under the 1997 UBC the occupancy types for the fitness center were slightly different than under the 2015 IBC. Under the UBC the gymnasium was classified as an A-2.1 occupancy. Based on section 303.5 of the current IBC the gymnasium would be classified as an A-4 occupancy, since the gymnasium includes spectator seating for 180 people. The occupancy types depicted in Figure 15 are based on the current IBC which would be identical to the UBC with the exception of the name change for the gymnasium occupancy.

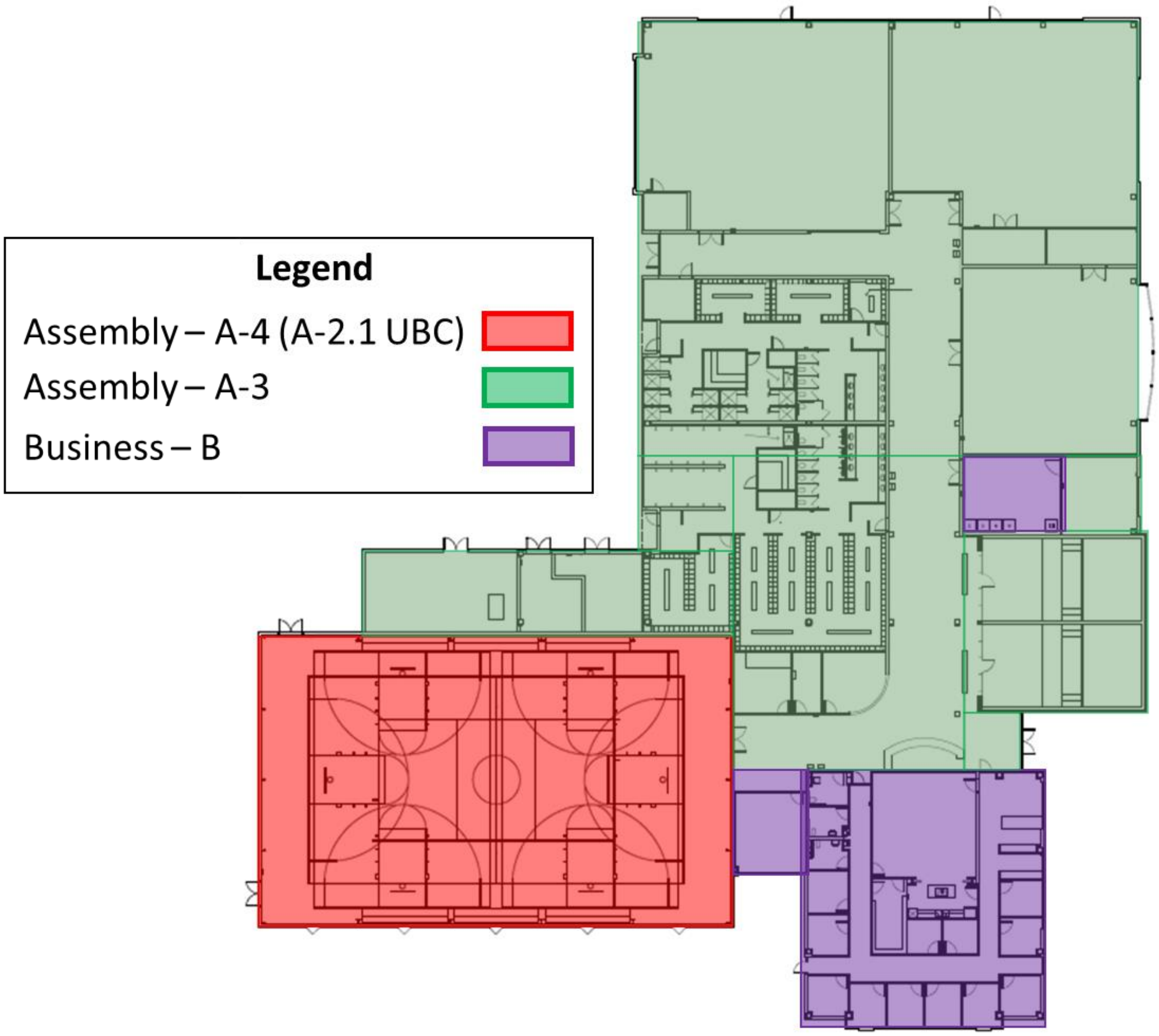

Figure 15 – IBC Building Occupancy Types

3.1.3 Building Height, Area, and Required Occupancy Separation

Provisions of Chapter 5 of the IBC control the maximum height and area of structures. IBC Table 504.3, shown below as Table 2 indicates that Type IIA and Type IIB structures which are sprinklered can be no higher than 85 and 75 feet respectively.

Table 2 – Allowable Building Height in Feet above Grade Plane (IBC Table 504.3)

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION									
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S									
H-4	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 2, I-2	NS[d, f, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85						
I-4	NS[d, g]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
R	NS[d, h]	UL	160	65	55	65	55	65	50	40
	S13R	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	85	70	60

For SI: 1 foot = 304.8 mm.

Note: UL = Unlimited; NS = Buildings not equipped throughout with an automatic sprinkler system; S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1; S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2.

a. See Chapters 4 and 5 for specific exceptions to the allowable height in this chapter.
b. See Section 903.2 for the minimum thresholds for protection by an automatic sprinkler system for specific occupancies.
c. New Group H occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.5.
d. The NS value is only for use in evaluation of existing building height in accordance with the *International Existing Building Code*.
e. New Group I-1 and I-3 occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.6. For new Group I-1 occupancies Condition 1, see Exception 1 of Section 903.2.6.
f. New and existing Group I-2 occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.6 and Section 1103.5 of the *International Fire Code*.
g. For new Group I-4 occupancies, see Exceptions 2 and 3 of Section 903.2.6.
h. New Group R occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.8.

Section 508.4.2 of the IBC requires that the allowable building area of a mixed-occupancy building will be such that the sum of the ratios of actual to allowable area of each separate occupancy not exceed 1. Table 3 shows the allowable building areas from Table 506.2 of the IBC, the actual building areas from the as-built drawings, and the ratio calculation which verify compliance of this section of the building code. Section 508 of the IBC dictates the required separation of occupancies. Table 508.4 indicates that A occupancies are required to have a 1-hour separation from B occupancies.

Table 3 – Fitness Center Allowable Area Calculations

Occupancy Type	Construction Type	Actual Area (SF)	Allowable Area (SF)	Ratio Actual to Allowable
Type A-4 (Gymnasium)	IIA	8,476	62,000	0.14
Type A-3 (Remainder of Building)	IIB	21,526	38,000	0.57
Type B (Office and Laundry)	IIB	4,514	92,000	0.05
	Total Area:	34,516	**Total Ratio:**	0.75

3.1.4 Construction Materials

3.1.4.1 Columns

The main building, constructed of steel decking over open web steel bar joists, is supported by steel girders and tube columns. The steel girders and columns form the moment resisting frames throughout the building, which is the primary lateral resisting system. The gymnasium is supported by 18 columns. Dimensions of these columns are listed in Table 4. RFI-1 refers to the 8 columns that line the north and south facing walls. RFI-3 refers to the 10 columns on both ends of the building.

Table 4 – Gymnasium Column and Beam Schedule

MEMBER SIZE TABLE (in)

PIECE	WEB DEPTH START/END	WEB PLATE THICK	WEB PLATE LENGTH	OUTSIDE FLANGE W x T x LEN	INSIDE FLANGE W x T x LEN
RF1–1	16.0/28.3	0.250	144.0	10 x 3/8" x 350.3	10 x 3/8" x 305.1
	28.3/40.6	0.250	144.0	10 x 3/8" x 49.4	
	40.6/41.0	0.250	63.2		
RF1–2	44.0/36.0	0.250	137.1	8 x 1/4" x 377.1	8 x 1/4" x 377.2
	36.0/27.6	0.188	144.0		
	27.6/22.0	0.188	96.0		
RF1–3	41.0/40.6	0.250	63.2	10 x 3/8" x 49.4	10 x 3/8" x 305.1
	40.6/28.3	0.250	144.0	10 x 3/8" x 350.3	
	28.3/16.0	0.250	144.0		

The structural load for the office area of the fitness center is carried by 12 main columns lining the west and east faces of the building. Additionally, five minor columns support an extended wall on the south side of the building. There are also two columns in the middle of the floorplan providing additional support for the roof. Structural loads for the remainder of the facility are carried primarily by 21 ¼" thick hollow structural steel columns measuring 6" square. In addition there are four thicker hollow structural steel columns also 6" square, but 3/8" thick. Finally, five 4X4X5/16 steel columns support a glass façade on the east side of the aerobics room.

All columns in the facility have no fire protection. With the exception of the gymnasium, all the columns are either partially or fully concealed behind drywall. These coverings provide some fire protection by preventing direct contact between the steel and the fire. This extra measure is aesthetic in nature, however, and not required by the code.

3.1.4.2 Beams

A wide variety of wide-flange structural steel I-beams are used throughout the facility to support the loads on the roof. In most cases these beams are exposed and have no fire protection. In the restrooms, offices, and racquetball courts these structural elements are covered by non-structural ceiling assemblies. While not a requirement per the code these non-structural assemblies provide some fire protection.

3.1.4.3 Floor and Roof Assemblies

The foundation for the fitness center is 5” thick slab on grade concrete with steel reinforcement. Throughout most of the fitness portion of the facility, flooring is rubber sport flooring laid over rubber sub flooring which rests directly on the concrete slab. In the gymnasium, aerobics room, and racquetball courts the floor is maple wood with a cushioning system recommended for the specific application of the room. In the offices flooring is carpet over rubber, while in the bathrooms ceramic tile is used as flooring.

The roof assembly over the aerobics room and office portion of the facility consists of a standing seam metal roof system over R-19 ridged insulation and corrugated steel deck. This assembly rests on steel bow trusses and wide-flange beams. The gymnasium roof includes a roofing system over ½” protection board and R-19 rigid insulation. This roof assembly rests on metal decking and metal support purlins. The remainder of the facility is covered by a rubberized roofing system over ½” protection board. Under the protection board lays R-19 rigid insulation over a metal deck.

3.1.4.4 Exterior Walls

Portions of most of the facility—including the fitness rooms, aerobic rooms, and the racquetball courts—are constructed with metal bearing stud walls supporting the metal roof joists and roof deck. The stud walls that face the exterior of the building are covered with masonry veneer. The backing of the masonry is a plywood panel that also functions as a sheer wall. A steel moment frame is used at the interior facing wall with metal infill studs above steel tube beams and a full width glass curtain wall. The gymnasium building consists of steel moment frames with a post-tension concrete masonry exterior wall. The masonry exterior wall functions as a shear wall below the clerestory window. Steel bracing is used at the clerestory area for lateral shear transfer between the roof and the masonry wall.

3.1.4.5 Interior Walls and Partitions

Various configurations of interior walls are used throughout the facility. Interior non-load bearing walls are generally composed of steel studs of various gauges spaced 16" on center with 5/8" gypsum board on both sides and filled with insulation batting for acoustical purposes. As mentioned earlier, where a fire rating is required Type X gypsum board is generally used along with acousticL insulation batting.

3.1.5 Fire Resistance Ratings

3.1.5.1 Columns and Beams

Primary structural frame members are required to have a 1-hour fire resistance rating for Type IIA construction. For Type IIB there is no required fire-resistance rating. The gymnasium is the only Type II-A area in the facility. In this location the primary structural elements are exposed to the fire and therefore require a fire-resistance rating of one hour.

3.1.5.2 Floor and Roof Assemblies

For floor and roof assemblies that are Type IIB construction there are no required fire resistance ratings. Roof and floor assemblies that are Type IIA are required to have a one hour fire-resistance rating.

3.1.5.3 Exterior Walls

None of the exterior walls in the fitness center require a fire-resistance rating with the exception of the gymnasium walls. These are load bearing Type IIA walls which require a 1-hour fire rating. Since all exposures of the building have more than 30 feet fire separation distance from other buildings they do not require a fire resistance rating per Table 602 of the IBC.

3.1.5.4 Interior Walls and Partitions

Non-bearing interior walls and partitions are not required to have a specific fire resistance rating for Type IIA or B construction. As such, none of the interior walls or partitions in the fitness center have a specified fire resistance rating with the exception of those walls previously mentioned which lie between two different occupancies.

3.1.5.5 Door Openings, Joints, and Penetrations

Requirements for openings, joints, and penetrations are not specified in the IBC. The fire resistance requirements for these features should match the assemblies they are integrated with. There are only a few locations in building that require fire safing. These are primarily where fire walls meet the corrugated steel roofing.

3.1.5.6 Interior Finishes

Chapter 8 of the IBC addresses fire performance of interior finishes. Interior finishes are evaluated based on flame spread index and smoke develop index. Table 5 shows the letter values assigned to various flame spread and smoke-developed indices.

Table 5 – Classification of Flame Spread and Smoke Developed Indices

Class	Flame Spread Index Range	Smoke Development Index Range
A	0-25	0-450
B	25-75	
C	76-200	

Table 6 which is taken from Chapter 8 of the IBC shows the interior finish requirements for certain occupancies. The fitness center is equipped with an automatic sprinkler system. As such, only the right portion of Table 6 applies. Additionally, the building is only one story so the requirement for interior exit stairways and doors can be downgraded to a Class C requirement, per note "b" of the chart below.

Per the IBC flame spread is typically evaluated using ASTM E84, also known as the Steiner Tunnel Test. However, this test is insufficient for evaluating the foam padding installed on the east and west walls of the gym. In order for foam padding to meet the code it must be evaluated in accordance with the NFPA 286 test which allows the foam to be tested in the configuration in which it is used. I was unable to determine if the foam presently installed in the gym had ever met the NFPA 286 standard, however the remaining interior finishes installed in the building meet the standards outlined in the IBC.

Table 6 – Interior Wall and Ceiling Finish Requirements by Occupancy

GROUP	SPRINKLERED[l]			NONSPRINKLERED		
	Interior exit stairways and ramps and exit passageways[a, b]	Corridors and enclosure for exit access stairways and ramps	Rooms and enclosed spaces[c]	Interior exit stairways and ramps and exit passageways[a, b]	Corridors and enclosure for exit access stairways and ramps	Rooms and enclosed spaces[c]
A-1 & A-2	B	B	C	A	A[d]	B[e]
A-3[f], A-4, A-5	B	B	C	A	A[d]	C
B, E, M, R-1	B	C	C	A	B	C
R-4	B	C	C	A	B	B
F	C	C	C	B	C	C
H	B	B	C[g]	A	A	B
I-1	B	C	C	A	B	B
I-2	B	B	B[h, i]	A	A	B
I-3	A	A[j]	C	A	A	B
I-4	B	B	B[h, i]	A	A	B
R-2	C	C	C	B	B	C
R-3	C	C	C	C	C	C
S	C	C	C	B	B	C
U	No restrictions			No restrictions		

For SI: 1 inch = 25.4 mm, 1 square foot = $0.0929m^2$.

a. Class C interior finish materials shall be permitted for wainscotting or paneling of not more than 1,000 square feet of applied surface area in the grade lobby where applied directly to a noncombustible base or over furring strips applied to a noncombustible base and fireblocked as required by Section 803.13.1.

b. In other than Group I-3 occupancies in buildings less than three stories above grade plane, Class B interior finish for nonsprinklered buildings and Class C interior finish for sprinklered buildings shall be permitted in interior exit stairways and ramps.

c. Requirements for rooms and enclosed spaces shall be based upon spaces enclosed by partitions. Where a fire-resistance rating is required for structural elements, the enclosing partitions shall extend from the floor to the ceiling. Partitions that do not comply with this shall be considered enclosing spaces and the rooms or spaces on both sides shall be considered one. In determining the applicable requirements for rooms and enclosed spaces, the specific occupancy thereof shall be the governing factor regardless of the group classification of the building or structure.

d. Lobby areas in Group A-1, A-2 and A-3 occupancies shall not be less than Class B materials.

e. Class C interior finish materials shall be permitted in places of assembly with an occupant load of 300 persons or less.

f. For places of religious worship, wood used for ornamental purposes, trusses, paneling or chancel furnishing shall be permitted.

g. Class B material is required where the building exceeds two stories.

h. Class C interior finish materials shall be permitted in administrative spaces.

i. Class C interior finish materials shall be permitted in rooms with a capacity of four persons or less.

j. Class B materials shall be permitted as wainscotting extending not more than 48 inches above the finished floor in corridors and exit access stairways and ramps.

k. Finish materials as provided for in other sections of this code.

l. Applies when protected by an automatic sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2.

3.1.6 Summary of Structural Fire Protection

From a structural standpoint the building meets code. The structural elements of the building are sufficiently protected from the effects of fire to ensure the safety of the occupants during the course of a fire emergency. The building however, cannot endure fire indefinitely. Therefore provisions on the type of occupancy and egress paths available to occupants must take into consideration the structural limits of the facility. These provisions will be discussed next.

3.2 Occupancy and Egress Analysis

During a fire safety, of life is paramount. The goal of LSC is to protect the occupants of a building who are not intimate with the fire and to improve the survivability of those who are. From a prescriptive approach protection of the occupants is achieved by ensuring that the number of occupants in a given space does not exceed certain requirements, and, if an evacuation is required, there is a sufficient number of exits, those exits are appropriately located, and of sufficient capacity to allow occupants to egress safely. This section will evaluate these areas with respect to the LSC and current building codes.

3.2.1 Occupancy Classification

As mentioned in the section on Structural Fire Protection, the fitness center was built under the 1997 UBC. Occupancy classification under the UBC was slightly different than the current IBC. Figure 16Figure 16 - Occupancy Data as Depicted on the Drawings shows the occupancy classifications as shown on the as-built drawings. Of note is the total square footage value listed in Figure 16, as it is incorrect. For the purposes of this report the correct value of 34,513 SF will be used. Refer to Figure 15 for a depiction of these occupancies on the building floor plan.

DESIGN DATA

1997 UNIFORM BUILDING CODE

OCCUPANCY GROUP TABLE 3A

TYPE	A 2.1	(GYMNASIUM)	8,476 SF
TYPE	A 3	(REMAINDER OF BUILDING)	21,526 SF
TYPE	B	(OFFICE & LAUNDRY)	4,514 SF
		TOTAL	34,281 SF

1 HOUR OCCUPANCY SEPARATION IS REQUIRED BETWEEN A 2.1 AND B OCCUPANCY PER TABLE 5B

Figure 16 - Occupancy Data as Depicted on the Drawings

3.2.1.1 Room Classification

According to the IBC various rooms only meet specific classification categories when certain conditions are meet. One example is storage rooms. In the IBC storage rooms smaller than 100 sq. ft. are not considered storage occupancies. All of the storage rooms in the fitness center fall into this category and therefore can be classified as part of the overall assembly occupancy.

3.2.2 Occupant Load

The occupant load for this facility was calculated using values from the 1997 UBC. The results of this calculation are shown below in Figure 17.

OCCUPANT LOADS AND EXITS

A 2.1 GYMNASIUM OCCUPANT LOAD 565

A 3 RACQUETBALL, WEIGHT ROOM, AEROBIC EXERCISE, LOBBY, LOCKER ROOMS 432

B OFFICE, LAUNDRY 58

TOTAL LOAD 1,055

Figure 17 – Design Drawing Occupant Loads

For the sake of comparison occupant loads under the IBC and LSC were also calculated. These calculations are performed by dividing the building area by an occupancy load factor. Occupancy load factors are dependent on building use and can be found in Table 1004.12 of the IBC or Table 7.3.1.2 of the LSC. The results of the occupancy calculations are shown in Table 7. The load calculations under the newer codes are slightly more conservative than the UBC but still in close agreement.

Table 7 – Occupancy Load Calculations for Various Model Codes

		1997 UBC		2015 IBC		2015 LSC	
Occupancy Type	**Area**	**Load Factor**	**Occupant Load**	**Load Factor**	**Occupant Load**	**Load Factor**	**Occupant Load**
Assembly (A-2.1 or A-4)	8,476	15	566	15	566	15	566
Assembly (A3)	21,526	50	431	50	431	50	431
Business (B)	4,514	78	58	100	46	100	46
Total	34,516		**1055**		**1043**		**1043**

3.2.4 Exit Capacity

Under the UBC exit capacity was calculated based on inches of exit width. This method of calculation resulted in a specific number of inches of exit required. This value could then be divided by the size of an individual exit to determine the required number of exits. The results of these calculations for the fitness center are shown in Figure 18.

EXITS REQUIRED

GYMNASIUM 3 EXITS REQUIRED
115 INCHES OF EXIT WIDTH REQUIRED
3 EXITS PROVIDED
208 INCHES OF EXIT WIDTH PROVIDED

OFFICE AREA 2 EXITS REQUIRED
8 INCHES OF EXIT WIDTH REQUIRED
2 EXITS PROVIDED
68 INCHES OF EXIT WIDTH PROVIDED

REMAINDER OF 2 EXITS REQUIRED
BUILDING 88 INCHES OF EXIT WIDTH REQUIRED
6 EXITS PROVIDED
272 INCHES OF EXIT WIDTH PROVIDED

Figure 18 – Exits Required According to Design Drawings

Under the current codes exit capacity is calculated slightly differently. For example in the LSC capacity factors (shown in Table 8) are used with the exit width to determine the capacity of each exit. This exit capacity combined with the occupancy load will determine the number of exits. Calculations using this procedure are shown in the next section.

Table 8 – Life Safety Code© Capacity Factors

Table 7.3.3.1 Capacity Factors

Area	Stairways (width per person)		Level Components and Ramps (width per person)	
	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

3.2.5 Exit Adequacy

3.2.5.1 Number

Calculations for the number of required exits are shown in Table 9. In all cases the number of provided exits is more than adequate for the number of individuals using these exits. Overall building exit capacity is not the only thing that needs to be considered when determining if the number of exits is adequate. Individual rooms should also be considered in order to ensure that there is sufficient capacity for smooth evacuation.

Table 9 – Exit Capacity

Area	Occupant Load	Number of Exits	Number of Doors	Exit Width (in)	Exit Capacity (in/person)	Exit Capacity	Total Capacity
Gymnasium	565	3	6	36	0.2	180	1080
Office Area	58	2	2	36	0.2	180	360
Remainder of Building	432	4	6	36	0.2	180	1080

Section 7.4.1.2 indicates that at least one exit is sufficient if a room contains less than 50 people. By observation it's clear that most of the rooms in the fitness center with single exits are sufficiently small that the number of occupants will not exceed 50. The one exception to this is the aerobics room, shown in Figure 19. Even though there is a double door exiting this room it is considered one exit and therefore no more than 49 individuals can occupy this space. This room is approximately 2000 sq. ft. so there is capacity for more than 49 people to occupy the room. Based on the use of the room (aerobics classes) this is unlikely. It is the responsibility of the building owner to ensure that this limit is enforced via some method, such as signage, in order to maintain compliance with the code.

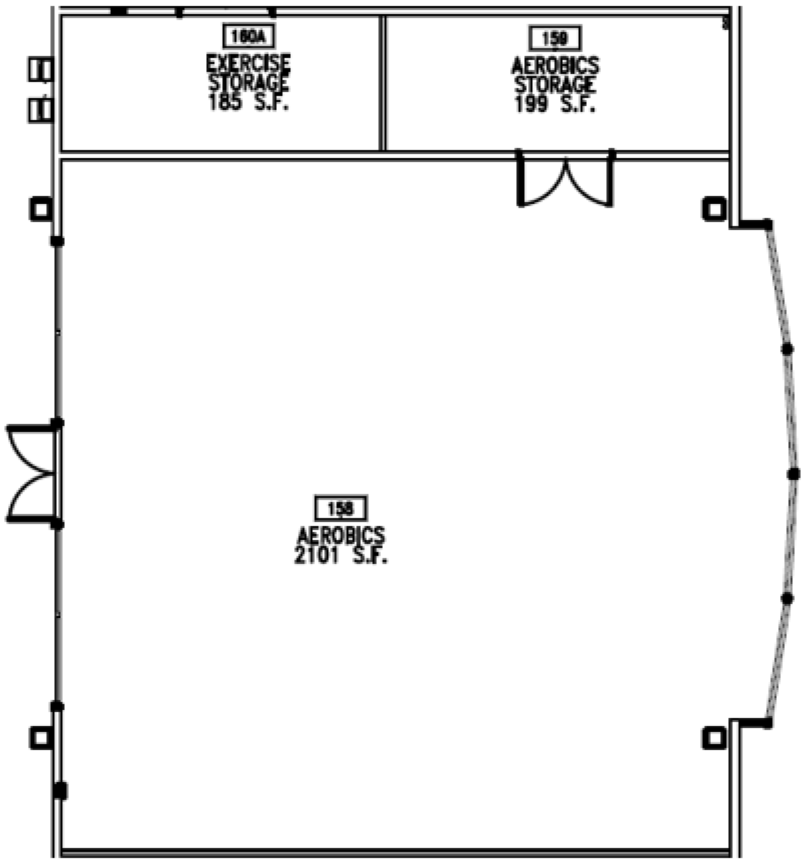

Figure 19 – Aerobics Room Exit Capacity

If a room has more than 499 occupants more than two exits will be required. The only room where this is the case is the gymnasium. This room has a total of three exits, two of which exit to the exterior of the building and one that exits into a lobby. The main exit from the building is on the opposite side of this lobby about 50 ft. away.

3.2.5.2 Arrangement

In addition to having a sufficient number of exits, the exits in each room must be remote enough that a single fire will not block more than one. Section 7.5.1.3.2 and 7.5.1.3.3 require that the minimum distance between exits for sprinklered buildings be greater than 1/3 the diagonal distance of the whole room. Figure 20 shows that the diagonal dimension of the gymnasium is 135 feet, therefore the exits must be more than 45 feet apart. The distance between the two closest exits is 62 feet so the room meets the code.

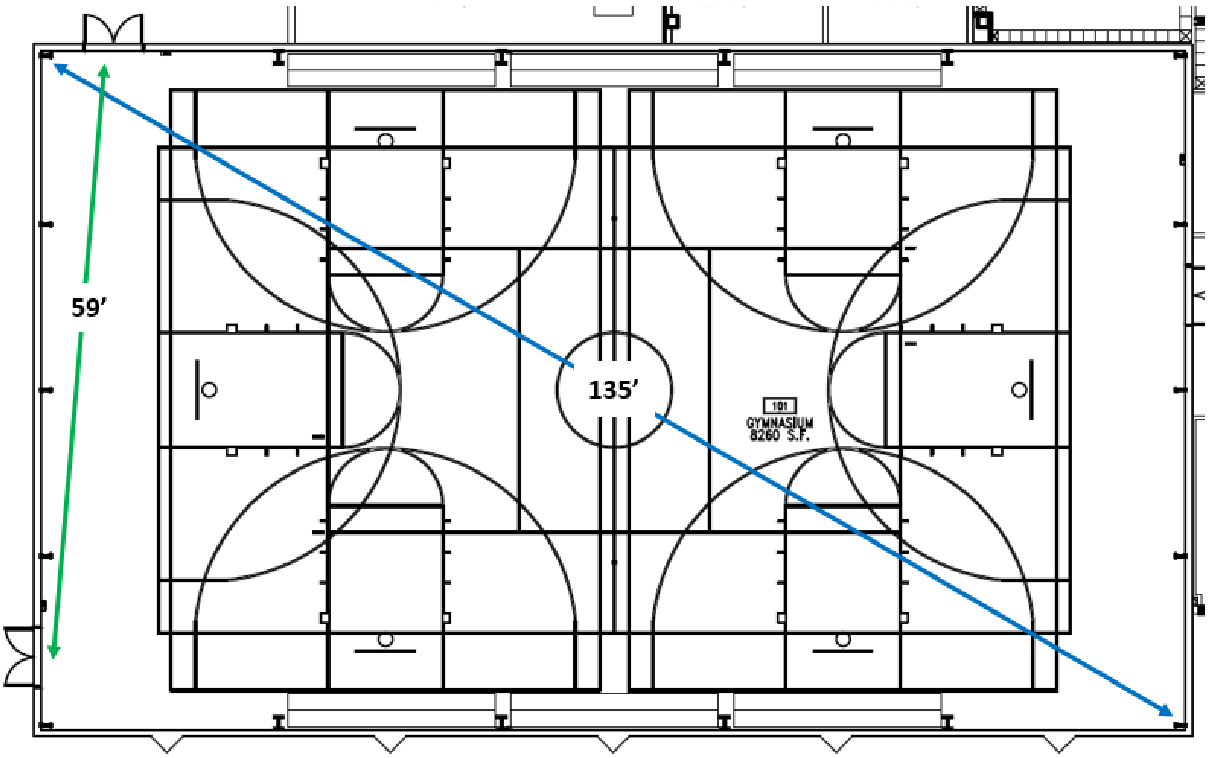

Figure 20 – Gymnasium Exit Remoteness Detail

3.2.6 Egress Paths

3.2.6.1 Fire Walls

The only required fire walls for this facility are between the gymnasium and the remainder of the building. The gym walls are constructed of CMU up to the clearstories. This type of wall construction has a 2-hour fire rating. Due to the nature of their construction, most walls throughout the facility have a 1-hour fire rating.

3.2.6.2 Egress Signage

Egress signage should be provided for all exits which may not immediately be recognized as exits. Such exits requiring signage would include all the exits in the fitness center with the exception of the main entrance and the entrance on the west side of the building. Both of these are glass doors which are easily recognizable as exits. Locations where signs would be placed indicating exits are shown as blue dots on Figure 21. The red dots on the figure indicate locations where direction signs should be placed in order to direct individuals to exits. This need for direction is particularly important for patrons that would be egressing towards the south via the main hallway. In this circumstance its important the patrons turn left to exit the building. A right turn at this point will take them into the gym.

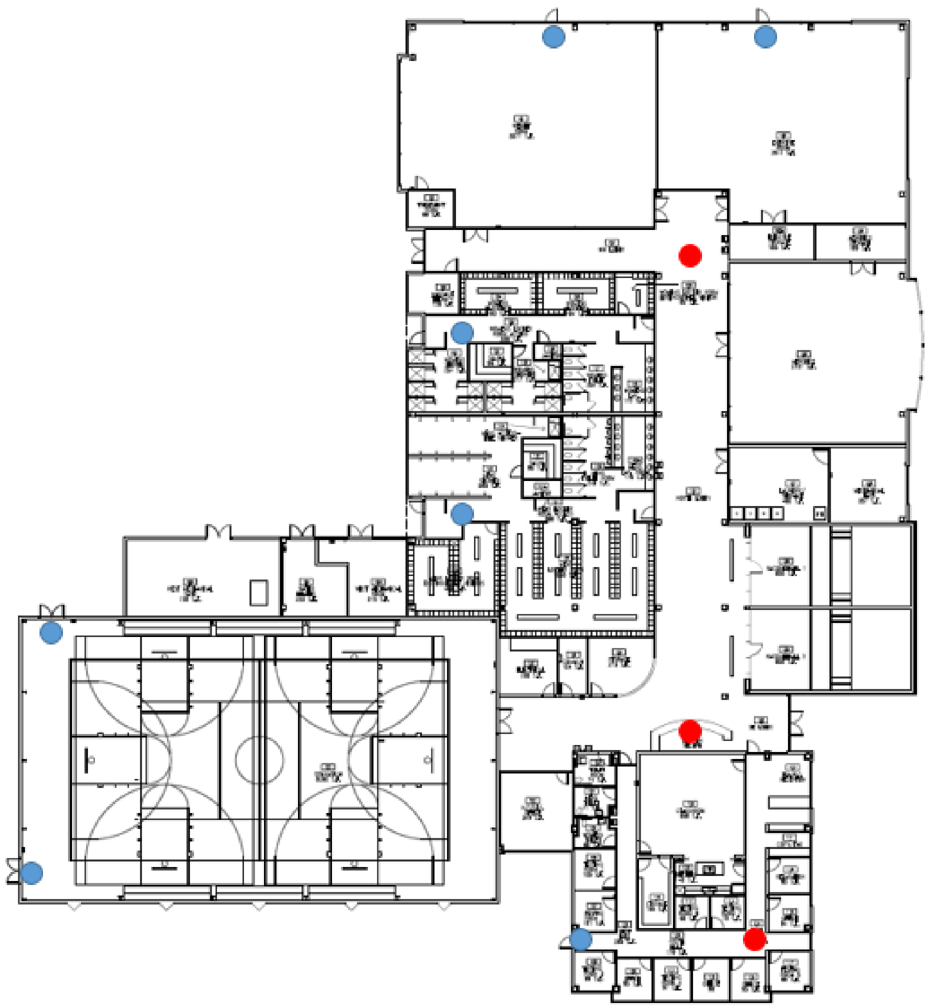

Figure 21 – Exit Signage Type and Location

3.2.6.3 Dead End Corridors

Figure 22 shows a detail of a dead end corridor in the administrative portion of the facility. Dead end corridors are paths that do not lead to an exit. For this type of occupancy the LSC limits dead end corridors to no more than 20'. The corridor highlighted in the figure measures about 10' and is therefore within the limits of the code.

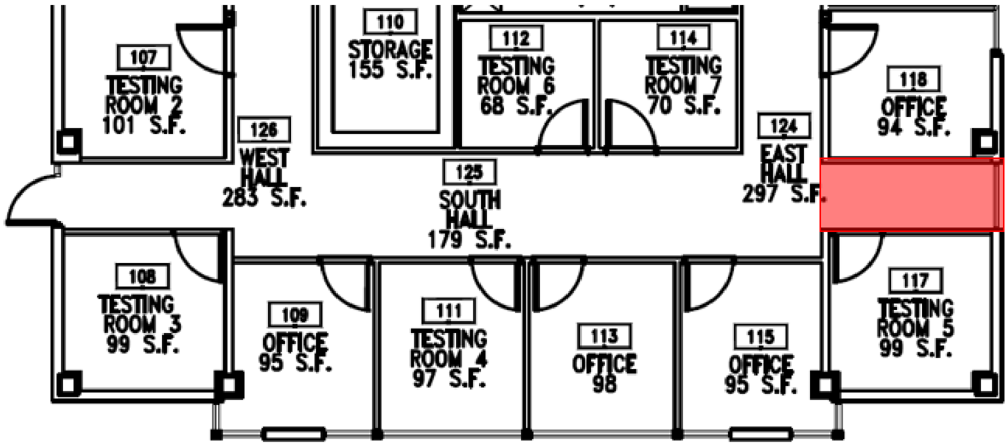

Figure 22 – Dead-End Corridor Detail

3.2.6.4 Common Travel Paths

The IBC defines common path of egress travel as that portion of the exit access travel distance measured from the most remote point of each room to that point where the occupants have separate and distinct access to two exits or exit access doorways. Table 10 from Chapter 10 of the IBC indicates that for A and B occupancies in sprinklered buildings the maximum allowable common path of egress travel distance is 75 and 100 feet respectively.

Table 10 – Maximum Common Path of Egress Travel Distance Based on Occupancy

OCCUPANCY	MAXIMUM OCCUPANT LOAD OF SPACE	MAXIMUM COMMON PATH OF EGRESS TRAVEL DISTANCE (feet)		
		Without Sprinkler System (feet)		With Sprinkler System (feet)
		Occupant Load		
		OL ≤ 30	OL > 30	
A[c], E, M	49	75	75	75[a]
B	49	100	75	100[a]
F	49	75	75	100[a]
H-1, H-2, H-3	3	NP	NP	25[b]
H-4, H-5	10	NP	NP	75[b]
I-1, I-2[d], I-4	10	NP	NP	75[a]
I-3	10	NP	NP	100[a]
R-1	10	NP	NP	75[a]
R-2	10	NP	NP	125[a]
R-3[e]	10	NP	NP	125[a]
R-4[e]	10	75	75	125[a]
S[f]	29	100	75	100[a]
U	49	100	75	75[a]

For SI: 1 foot = 304.8 mm.

NP = Not Permitted.

a. Buildings equipped throughout with an *automatic sprinkler system* in accordance with Section 903.3.1.1 or 903.3.1.2. See Section 903 for occupancies where *automatic sprinkler systems* are permitted in accordance with Section 903.3.1.2.
b. Group H occupancies equipped throughout with an *automatic sprinkler system* in accordance with Section 903.2.5.
c. For a room or space used for assembly purposes having *fixed seating*, see Section 1029.8.
d. For the travel distance limitations in Group I-2, see Section 407.4.
e. The length of *common path of egress travel* distance in a Group R-3 occupancy located in a mixed occupancy building or within a Group R-3 or R-4 *congregate living facility*.
f. The length of *common path of egress travel* distance in a Group S-2 *open parking garage* shall be not more than 100 feet.

Inspection of the floor plan of the fitness center reveals the most of the small offices with a single door have a common path of travel less than 15 feet. Many of the larger rooms in the facility such as, the gymnasium, the cardio room, and the weight room are served my two or more exits and therefor do not have a common path of travel. The largest room served by a single exit is the aerobics room. The common path of travel in this room is approximately 53 feet, as shown in Figure 23. This is well below the 75 foot maximum. The racquet ball courts are also large rooms served by a single exit but it is clear by inspection that the common path in these areas would be less than that of the aerobics room which has already been shown to meet code.

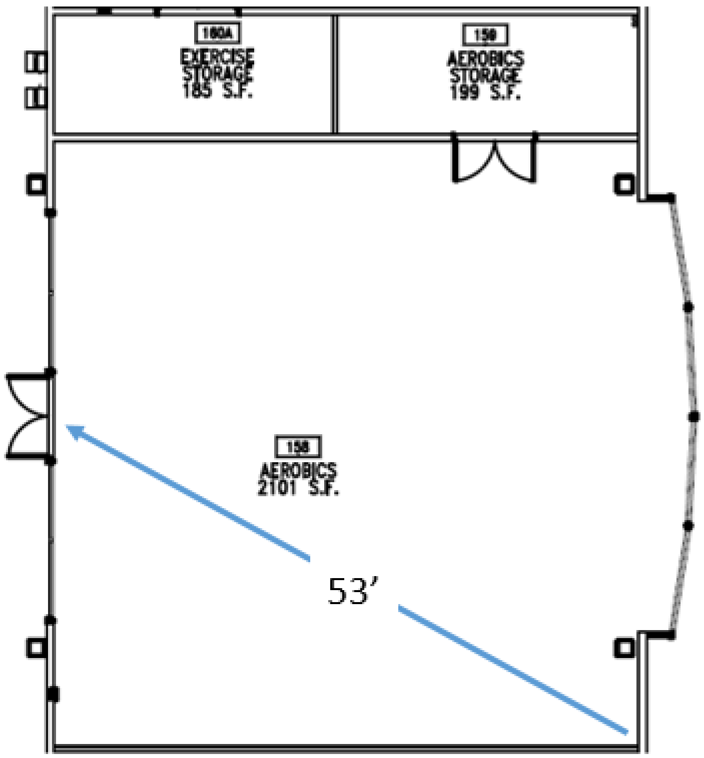

Figure 23 – Common Path of Travel in Aerobics Room

3.2.7 Summary of Occupancy and Egress Analysis

This section has compared the occupancy and egress capacity of the fitness center against the requirements of the IBC. The occupancy loads were calculated in accordance with chapter 10 of the IBC and compared to the exit capacity as calculated based on the method outlined in the same chapter. It was determined that in all cases exit capacity exceeded occupant load as required by the code. The prescriptive requirements addressed in this section also dealt with exit quantity and arrangement, exit signage, and egress path requirements such as the limitations on dead-end corridors and common paths of travel, all of which were determined to be sufficient. The next section will address the systems which serve to initiate an egress of the facility in fire emergency, the fire detection and notification systems.

3.3 Fire Detection and Notification System

Fire detection and alarm systems are intended to improve life safety through early detection of a fire and alerting of occupants in an effort to increase available safe egress time. Additionally, fire detection and notification systems can provide trouble signals in order to alert building owners and managers to potential problems with the fire suppression systems. This section evaluates the fitness centers fire alarm and notification systems with respect to the prescriptive measures of NFPA 72 the National Fire Alarm and Signaling Code.

3.3.1 Fire Detection System Overview

The primary fire detection system in this facility is the wet pipe automatic sprinkler system installed throughout the building. A single Potter VSR-F vane type waterflow switch is used as a means to detect a discharge of the sprinkler system. When the water flow rate exceeds a preset value, this switch will put the system into an alarm condition. Two tamper switches on the post indicator valve and the OS&Y control valve indicate disruption of the water supply through supervisory OS&Y switches, also manufactured by Potter. Smoke detection is provided in the electrical room and in the mechanical ducts.

3.3.1.1 System Description

Traditional fire detection systems rely heavily on smoke or heat detectors for fire detection. This building does not have any heat detectors and only a small number of smoke detectors, but a sprinkler can be considered a fixed temperature heat detector; therefore, it is appropriate that we classify the fitness center's automatic sprinkler system as a detection system. The fitness center is protected by a wet pipe fully automatic fire sprinkler system. The demonstration kitchen is equipped with a standalone wet-chemical system to protect the kitchen area.

3.3.1.2 Location and Spacing of Detectors

Sprinklers for this facility were installed in accordance with NFPA 13 – Standard for the Installation of Sprinkler Systems and UFC 3-600-01 – Fire Protection Engineering for Facilities. Concealed sprinklers were used in the racquetball courts while normal sprinklers were used everywhere else in the facility. One Firelite model SD305 photoelectric smoke detector was installed in the electrical room. The electrical room is a 15' by 15' room with a smooth ceiling approximately 9' above the finished floor.

The spacing requirements imposed on sprinkler systems by NFPA 13 are generally more stringent than those placed on other types of heat detectors. The inclusion of a flow switch makes this a sufficient fire detection system under the constraints of NFPA 72. For smoke detection NFPA 72 recommends a nominal 30 ft. spacing with modifications to be made based on the impact of contributing factors listed in NFPA 72 17.7.3.1.2, in the absence of specific performance-based criteria. These contributing factors don't impact the specific installation in the fitness center, so nominal 30 ft. spacing would be expected. NFPA 72 17.7.4.3 stipulates that in-duct smoke detectors cannot be used as a replacement for area smoke detection. As such, the in-duct smoke detectors in the building are installed in accordance with NFPA 72 17.7.5, with the intent of controlling smoke movement in the event of a fire. When the in-duct smoke detectors activate, a shut-down signal is sent to the HVAC control system. De-activation of the HVAC system during a fire event reduces the spread of smoke, which is a significant contributor to fire casualties. Both smoke detection systems are installed in accordance with the requirements of NFPA 72.

3.3.2 Fire Alarm System Overview

The fitness center includes a comprehensive notification system to alert occupants in the event of a fire. The system includes ceiling and wall mounted strobes on three notification appliance circuits (NAC). The system can be activated through discharge of the fire suppression system, detection of smoke through smoke detectors placed in mechanical ducts and electrical rooms, and through pull stations which are mounted at each exit to the facility.

3.3.2.1 System Description

The heart of the fire alarm system is a Firelite MS-9200 Fire Alarm Control Panel (FACP). This panel is located in the electrical room just off the main corridor (see Figure 24). The fitness center is a protected premises so signals from the fire alarm system are transmitted to the Base Defense Operations Center (BDOC) through a Monaco transmitter. The alarm system itself consists of Wheelock strobes and Wheelock combination horn/strobes. These devices are placed throughout the facility to provide audible and visual notification of a fire emergency.

3.3.2.2 Disposition of Signals

The sequence of operations matrix for the fitness center is shown in

RESULT \ ACTION	MANUAL PULL STATION	SMOKE DETECTOR	DUCT SMOKE DETECTOR	TAMPER SWITCH	POST INDICATOR VALVE	WATER FLOW SWITCH	LOSS OF POWER
ANNUNCIATE AT FIRE ALARM CONTROL PANEL	YES	YES	YES (SUPERVISORY)	YES (SUPERVISORY)	YES (SUPERVISORY)	YES	YES (TROUBLE)
ANNUNCIATE AT REMOTE ANNUNCIATOR	YES	YES	YES (SUPERVISORY)	YES (SUPERVISORY)	YES (SUPERVISORY)	YES	YES (TROUBLE)
ANNUNCIATE AT 24-HOUR ATTENDED REMOTE LOCATION	YES	YES	YES (SUPERVISORY)	YES (SUPERVISORY)	YES (SUPERVISORY)	YES	YES (TROUBLE)
ACTIVATE AUDIBLE/VISUAL ALARM SIGNAL THROUGHOUT BUILDING	YES	YES	YES	NO	NO	YES	NO
SHUTDOWN RESPECTIVE AC UNITS	NO	NO	YES	NO	NO	NO	NO

Figure 25. The table indicates that supervisory signals are sent whenever a duct smoke detector, tamper switch, or post indicator valve activates. The table also shows the four events that will activate the audible/visual notifiers, namely: activation of a manual pull station, detection of smoke by a smoke detector in the electrical room, detection of smoke by the duct detectors, and tripping of the water flow switch.

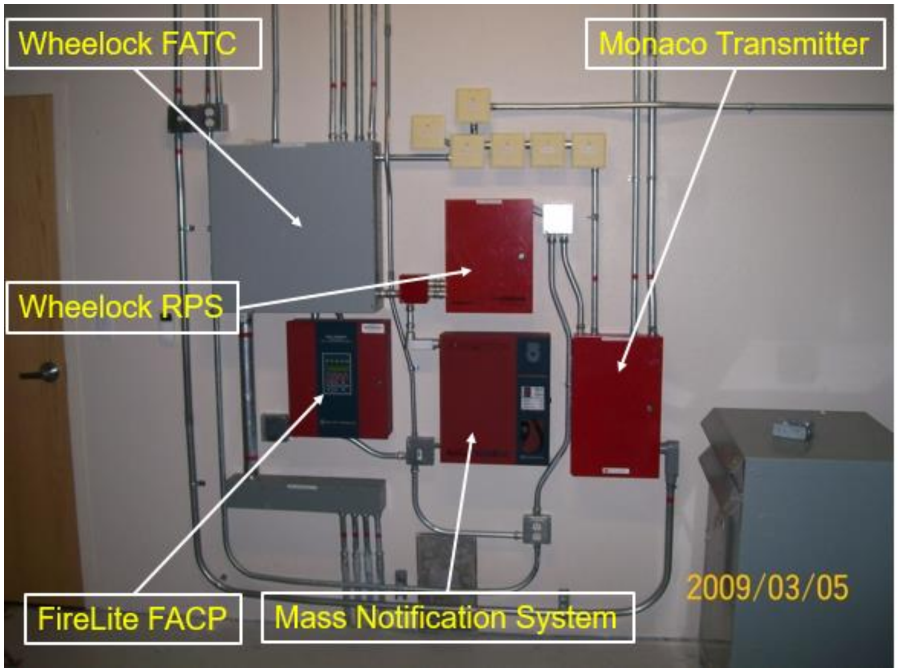

Figure 24 – Fire Alarm Control Panel in Electrical Room

RESULT \ ACTION	MANUAL PULL STATION	SMOKE DETECTOR	DUCT SMOKE DETECTOR	TAMPER SWITCH	POST INDICATOR VALVE	WATER FLOW SWITCH	LOSS OF POWER
ANNUNCIATE AT FIRE ALARM CONTROL PANEL	YES	YES	YES (SUPERVISORY)	YES (SUPERVISORY)	YES (SUPERVISORY)	YES	YES (TROUBLE)
ANNUNCIATE AT REMOTE ANNUNCIATOR	YES	YES	YES (SUPERVISORY)	YES (SUPERVISORY)	YES (SUPERVISORY)	YES	YES (TROUBLE)
ANNUNCIATE AT 24-HOUR ATTENDED REMOTE LOCATION	YES	YES	YES (SUPERVISORY)	YES (SUPERVISORY)	YES (SUPERVISORY)	YES	YES (TROUBLE)
ACTIVATE AUDIBLE/VISUAL ALARM SIGNAL THROUGHOUT BUILDING	YES	YES	YES	NO	NO	YES	NO
SHUTDOWN RESPECTIVE AC UNITS	NO	NO	YES	NO	NO	NO	NO

Figure 25 – Alarm System Sequence of Operations

3.3.2.3 Location and Spacing

The location and spacing of notification devices for the fire alarm system is based on the requirements of NFPA 72 Ch. 18. Section 18.5.5 provides a prescriptive approach for determining the location of visual notifiers in public mode. Section 18.5.5.1 stipulates that strobes must be mounted between 80 and 96 inches above the finished floor. The entire lens of the strobe must lie within this window. Location of wall and ceiling mounted strobe must be in accordance with the spacing listed in Table 18.5.5.4.1(a) and (b) respectively. Taking the gymnasium as an example we can evaluate the use of these tables to determine notifier spacing. The layout of the gym is shown in Figure 26.

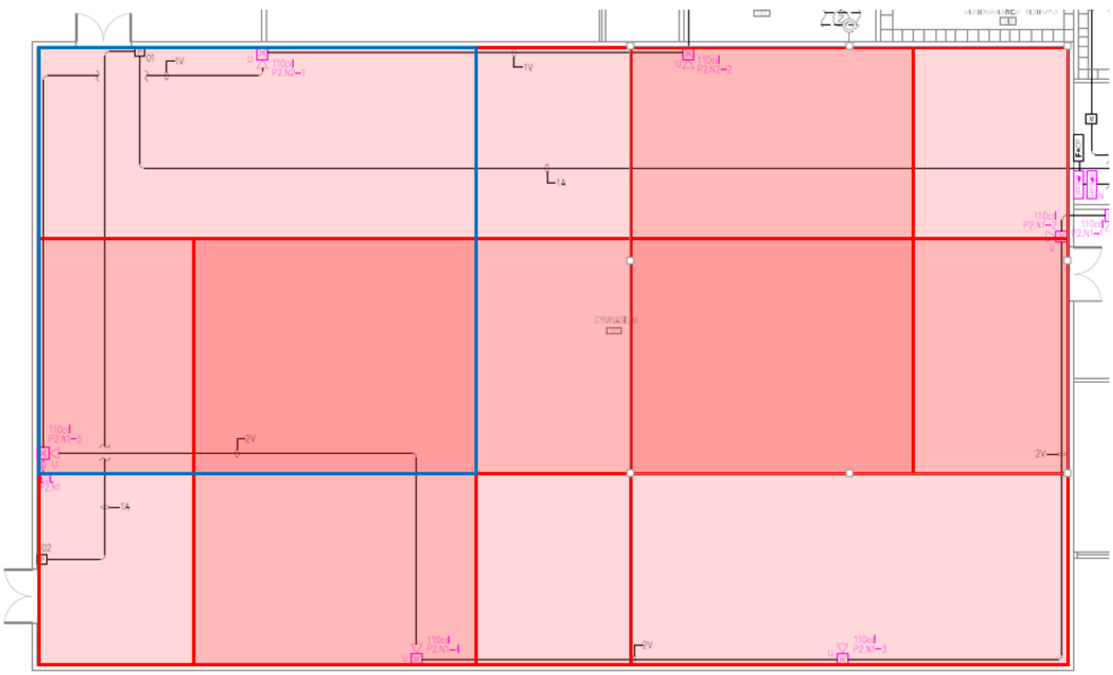

Figure 26 – Notifier Coverage in Gym

There are 6 combination horn/strobe notification appliances (NA's) in the gym (shown in pink in Figure 26). These devices are 110 cd horn/strobes. The gym is approximately 117 ft. by 70 ft. Based on Table 18.5.5.4.1(a) 110 cd strobes can be used in a maximum room size of 54 ft. by 54 ft. To determine spacing for rooms larger than these dimensions the room simply needs to be broken into smaller segments. The square outlined in blue represents the 54'x54' coverage area of a single strobe. Each of the remaining strobes have the same coverage area. With these coverage areas superimposed over the layout of the gymnasium it's clear that complete coverage is achieved. A slightly different method is used to determine if audio coverage is sufficient. NFPA 72 18.4.3.1 indicates that audible alarms must be 15 dB above the average ambient noise level and 5 dB above the maximum sound level having a duration of at least 60 seconds. For the purposes of this code, sound level is measured at ear level the furthest distance from the speaker. In the gymnasium example used above the greatest distance from a speaker is 62 ft. Based on NFPA 72 Table A.18.4.3 places of assembly have an average ambient sound level of 55 dBA. If we add 15 dB to that number we find that we need at least 70 dBA. Per NFPA A.18.4.3 sound level drop by 6 dB every time the distance from the source doubles. At a distance of 62’ from the speaker we’ll need to add 18 dB to our target value. This makes our new required speaker output 88 dBA. This 88 dBA output is within the capabilities of the speakers used in this application.

3.3.3 Mass Notification System Overview

In accordance with the requirements of UFC 4-010-01 – DOD Minimum Anti-Terrorism Standards for Buildings, a Mass Notification System (MNS) is installed in the fitness center. This system meets all the requirements of UFC 4-021-01 – Design and O&M: Mass Notification Systems. This facility uses speakers that are part of an existing PA system for mass notification. The MNS provides a means to reliably notify all personnel throughout the facility by visual and audible means of an emergency condition.

3.3.4 Power Requirements

Primary power for the fire alarm and suppression system is provided by a dedicated branch circuit as required by NFPA 72 Ch. 10. The primary system has sufficient mechanical and overcurrent protection as required by the NFPA. For secondary power backup batteries are used. The size of these backup batteries was determined by performing battery and voltage drop calculations. Battery calculations are shown in Table 11 while voltage drop calculations are shown in Table 12. Total current demand during supervisory and alarm conditions was calculated. NFPA 72 Ch. 10 stipulates that a secondary power supply must be capable of supplying the fire alarm system in standby for 24 hours and then in alarm for 5 min at the conclusion of the 24 hour period. For this circuit 3.3 amp-hours are need to meet this requirement. A derating factor of 1.2 is applied to this value in order to add a margin of safety. Required amp-hour value is approximately 4 amp-hours. To meet this demand two 7 amp-hour batteries were selected to power the system in the event of a loss of primary power.

Table 11 – Power Calculations

Qty.	Model	Description	Supervisory Current (Amps)	Alarm Current (Amps)	Total Supervisory Current (Amps)	Total Alarm Current (Amps)
1	PS-8	NAC Power Supply	0.13	0.13	0.13	0.13
7	ZNS-MCW	Multi-Candela (110 cd) 2-Wire Horn/Strobe Wall	0.00	0.24	0.00	1.71
6	ZNS-MCC	Multi-Candela (15 cd) Strobe Ceiling	0.00	0.06	0.00	0.40
				Total Supervisory and Alarm Current (Amps)	0.13	2.24
				Standby and Alarm Sounding (Hours)	24	0.08
				Total Supervisory and Alarm Currents (Amp-Hours)	3.12	0.19
				Total Supervisory Plus Alarm Currents (Amp-Hours)	3.31	
				Derating Factor)	3.97	
				2 Batteries Provided at	7	

Table 12 – Worst Case Voltage Drop Calculation

Qty	Model	Description	Alarm Current (Amps)	Total Alarm Current (Amps)
2	ZNS-MCW-FW	Multi-Candela (110 cd) 2-Wire Horn/Strobe Wall	0.24	0.48
6	ZRS-MCC-FW	Multi-Candela (15 cd) Strobe Ceiling	0.07	0.39
			Total Alarm Current	0.87
			Total Distance (Ft.)	450
			Wire Gage (14) (Cir. Mims)	4110
			%VD	**8.57%**

3.3.5 Inspection, Testing, and Maintenance

3.3.5.1 Inspection

Procedures for inspection, testing, and maintenance of fire alarm systems are covered in NFPA 72 Ch. 14. Table 14.3.1 (Appendix B) provides an outline and schedule of visual inspections to be performed on fire alarm systems. On a regular basis systems that are connected to a monitoring station should be inspected for a normal condition. Fuses, lamps, and interface equipment should be inspected on regular interval. Batteries should be checked for leaks and tightness of connections should be verified. Initiating devices should be inspected for secure attachment and proper orientation. Many manufactures publish data on inspection procedures for their products. These instructions should be followed if they are available.

3.3.5.2 Testing

Testing schedules are outlined in NFPA 72 14.4.3.2 and provided by manufactures in their recommendations. The testing outlined in NFPA 72 is in addition to facility acceptance testing, which should take place at the commissioning of a new or newly renovated facility. On LA AFB the fire alarm system is tested during regularly scheduled fire drills, usually corresponding with quarterly base wide exercises. The mass notification system is tested weekly and during exercises to verify correct operation and intelligibility. A critical part of both testing and inspection is records. NFPA 72 provides sample record forms to be used in compliance with the regulations of NFPA 72. Some AHJ's may require more robust forms to be kept as records. Lack of required documentation is often viewed by courts as presumptive evidence that testing or inspection was not performed on the system.

3.3.5.3 Maintenance

Fire alarm systems are relatively maintenance free however, there are specific areas that require special attention. Any batteries in the system need to be checked regularly and if found to be in poor condition replaced. Specific maintenance procedures are handed down to the customer through training and O&M manuals supplied at the conclusion of construction. It's critical that instructions in these documents are followed closely, not just to insure a well maintained system, but to check on items that many still be under warranty.

3.3.5 Summary of Fire Detection and Notification Systems

This section has addressed the code requirements of fire detection and notification systems. The codes considered were NFPA 70 and 72. Location and spacing of both fire detectors and notification appliances was found to be in compliance with the code requirements. Audibility of notifiers was addressed along with power requirements both of which were likewise found to be in compliance. This section ended with a discussion of inspection, testing, and maintenance requirements which play a critical role in ensuring detection and ultimate activation of the building's fire suppression systems, which will be discussed in the next section.

3.4 Fire Suppression System

Fire suppression systems significantly improve the safety of facilities they are installed in. Automatic fire suppression can reduce the amount of damage in a facility due to a fire and can significantly improve the chances of occupants safely egressing a burning building. This section will analyze the fire suppression system elements of the fitness center with respect to the prescriptive elements of NFPA 13 – Standard for the Installation of Sprinkler Systems in order to determine compliance with the provisions of that code.

3.4.1 Wet-Pipe Automatic Sprinkler System

3.4.1.1 Sprinkler Type

Table 13 is taken from the drawings. It shows the three types of sprinklers used in the fitness center. These are standard quick response sprinklers. The coverage area required by the design is less that the maximum coverage area provided by these sprinklers. Additionally, the pressure and flow rate provided by the water supply falls in the range that these sprinklers are allowed to operate in. The concealed sprinklers listed on the table are used in the racquetball courts. This is appropriate for this application since the likelihood of damage decreased through the use of concealed sprinklers.

Table 13 – Fire Sprinkler Types

FIRE SPRINKLER LEGEND												
SYMBOL	MANUFACTURER	MODEL	TYPE	COVERAGE	RESPONSE	NPT	ORF.	K	TEMP	FINISH	ESCUTCH.	QTY.
●	CENTRAL	GB–QR	PENDENT	225sg.ft.	QUICK	1/2"	1/2"	5.6	212	WHITE	REC	6
⊗	CENTRAL	GB–QR	UPRIGHT	225sg.ft.	QUICK	1/2"	1/2"	5.6	212	WHITE	REC	86
∅	CENTRAL	GB–4	CONCEALED	225sg.ft.	QUICK	1/2"	1/2"	5.6	155	BRASS	REC	0
TOTAL SPRINKLERS THIS PROJECT								323	TOTAL SPRINKLERS THIS DRAWING			92

3.4.1.2 Water Demand

The density and area of operation for the sprinkler system can be found by using Figure 11.2.3.1.1 from NFPA 13, shown below as Figure 27. UFC 3-600-01 requires that fitness centers regardless of size or occupancy type be classified as Ordinary Hazard for the purposes of sprinkler protection. A density of 0.15 gpm/ft^2 and an area of 1500 ft^2 were selected for this application. Hose stream allowance and water supply duration are determined using NFPA 13 Table 11.2.3.1.2, shown below as Table 14. For this facility a hose stream allowance of 250 gpm and a duration of 60-90 min is appropriate.

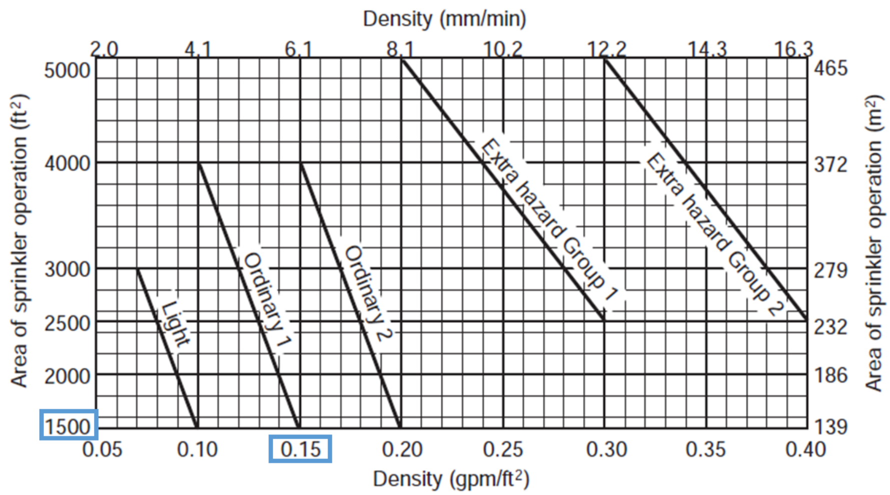

Figure 27 – Density/Area Curve

Table 14 – Hose Stream Allowance and Water Supply Duration Requirements

TABLE 11.2.3.1.2 Hose Stream Allowance and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	gpm	L/min	gpm	L/min	
Light hazard	0, 50, or 100	0, 189, or 379	100	379	30
Ordinary hazard	0, 50, or 100	0, 189, or 379	250	946	60–90
Extra hazard	0, 50, or 100	0, 189, or 379	500	1893	90–120

The largest distance between sprinklers is 10 feet and the largest distance between branch lines is 11 feet, resulting in a sprinkler area of coverage of 110 ft^2. Both of these dimensions are larger than twice the distance from the wall. The total amount of water flow from each sprinkler is 16.5 gpm. The remote area is then selected ensuring that the length of the longest side is at least 1.2 times the square root of the area. This length needs to be at least 46.5 feet. The layout of the remote area is shown in red in Figure 28. The actual size of the remote area is 1570 ft^2.

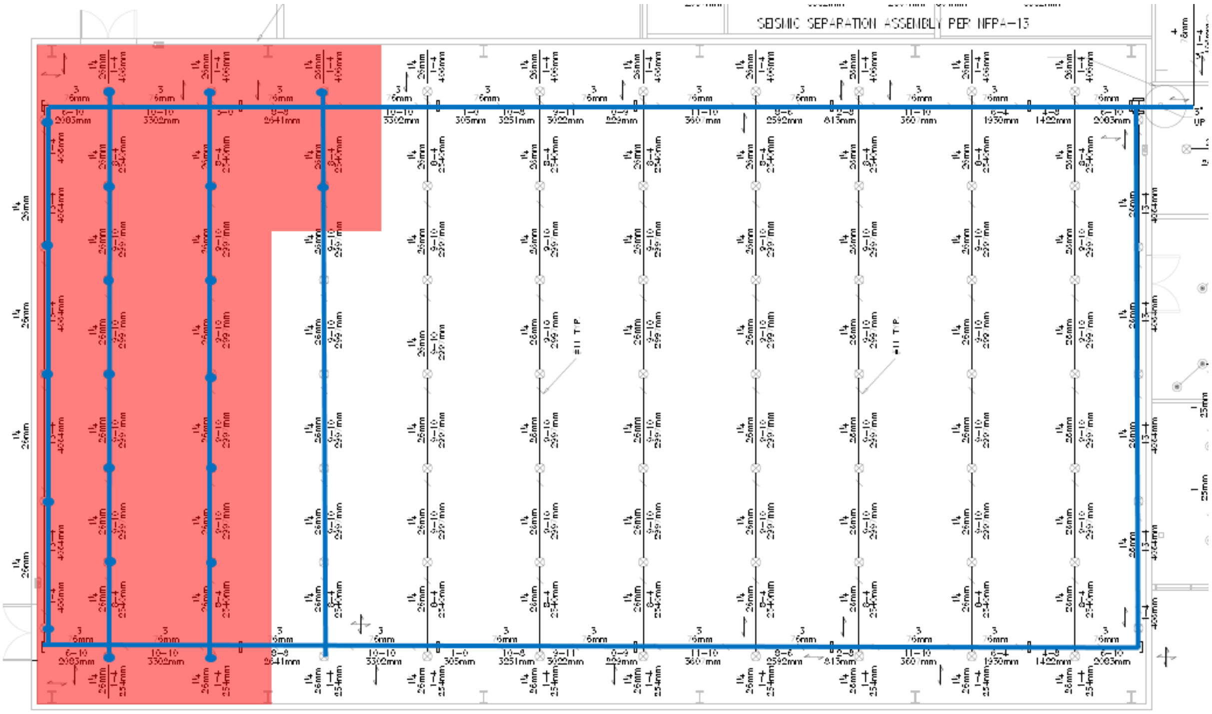

Figure 28 – Remote Area

Since the sprinkler system in the gymnasium is a gridded system hydraulic calculations are more complicated. Calculations were performed using a computer program. To determine the most remote area multiple configurations were tested with the most demanding configuration selected. The results of the calculations are summarized in Table 15. This calculation was carried to the point of connection so that it could more accurately be compared to the city supplied test data. Detailed calculation results can be found in Appendix A. At the time of construction the results of hydraulic calculations performed on the system were provided on the design drawings however, no details of the calculations were made available. The difference between the calculations performed as part of this report and the results presented on the design drawings is less than 10%.

Table 15 – Point of Connection Demand

POC Demand	
Flow (gpm)	404.3
Pressure (PSI)	80.6

3.4.1.3 Water Supply

Water for this facility is provided by the city of El Segundo. Water supply data collected during a flow test performed by Industrial Fire Sprinkler Company is presented in Table 16. This flow test was performed at the hydrant closest to the building on the south east edge of the property as shown in Figure 29. Also shown in Figure 29 is the connection point to the building. The building is fed by a 10" PVC fire main which parallels the east side of the building and the connection point is made just outside the east mechanical room. This is also where the fire department connection is. Since this is the only side of the facility which faces a road and the mechanical room is centrally located and within easy access to the main building entrance this is a good location for the FDC. The sprinkler riser is located near this area just inside the building in the mechanical room. This room provides the clear space and protection from damage that is required by the code.

Table 16 – Water Supply Data

Water Supply	
Static Pressure	93 PSI
Residual Pressure	88 PSI
Flow	1100 GPM

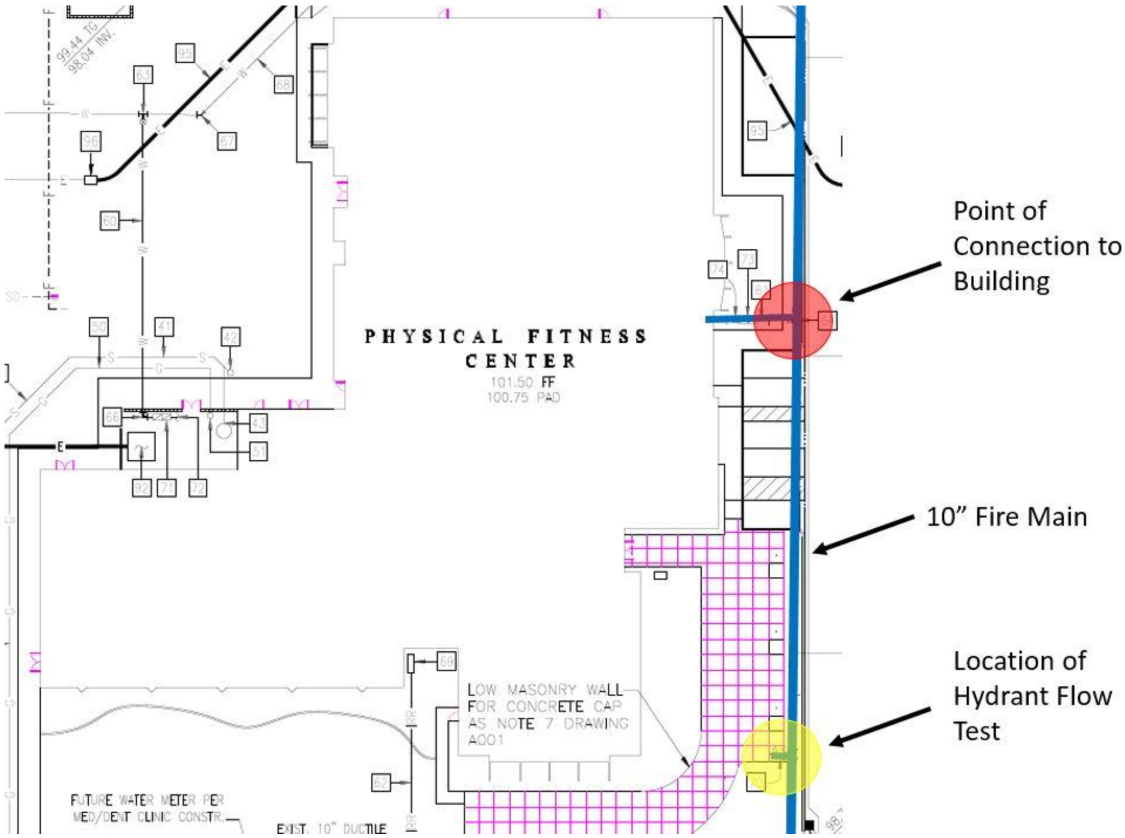

Figure 29 – Flow Test and Building Connection Location

3.4.1.4 Supply vs Demand

The supply from the city and the sprinkler demand are shown in Figure 30. City supply exceeds sprinkler demand by more than 10 psi.

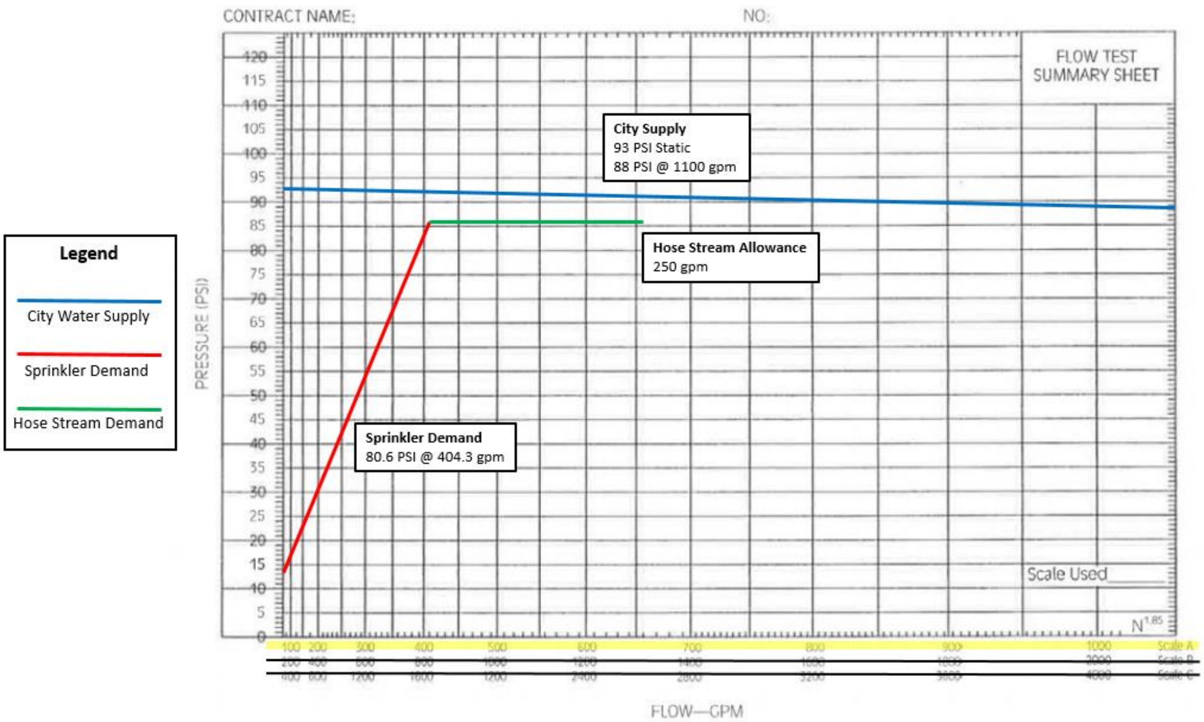

Figure 30 – City Water Supply vs Sprinkler System Demand

3.4.2 Wet-Chemical Fire Suppression System

The cooking area of the demonstration kitchen is protected by a Kitchen Knight II wet-chemical fire suppression system which operates independently of the automatic fire suppression system. This system uses a potassium carbonate-based wet agent to suppress flames and remove air in the vicinity of a fire. This is a pre-engineered system that is meets NFPA and IBC standards when installed in accordance with the manufactures recommendations. The system is activated manually through the use a of pull handle or automatically through the use of fusible links.

3.4.3 Inspection, Testing, and Maintenance

NFPA 25 provides the baseline for inspection, testing, and maintenance of water-based fire suppression systems. Some of the important points made in NFPA 25 are reiterated below.

3.4.3.1 Inspection

Sprinkler systems need to be inspected for absent sprinklers, particularly in rooms that are concealed, or small enclosures, like closets. The position of sprinkler deflectors should be verified and storage rooms should be check to confirm that items aren't being stacked to closely to the sprinklers. Sprinklers should be inspected to verify that they are in the positons they intended, have acceptable manufacturing dates, are the proper temperature rating, installed correctly, and not loaded. Additionally, the entire system should be regularly inspected for leaks and signs of corrosion.

3.4.3.2 Testing

System water flow testing should be performed to verify that supplies and connections are in good working order. Both main drain and inspectors test water flow tests should be performed. Water flow devices should be tested semi-annually and pressure switches should be tested quarterly. Valves should also be tested in ensure they seat properly.

3.4.3.3 Maintenance

NFPA 25 provides maintenance intervals for various components that are part of the automatic fire suppression system. Annual maintenance should be performed on valves, drain lines, and hose connections and fire hydrants. Every five years the system should be inspected for obstructions and devices like sprinklers can be replaced on an as need basis.

3.4.4 Summary of Fire Suppression System

This section has focused on the fitness centers fire suppression systems. The system was shown to meet the requirements of NFPA 13 by first determining what the available city water supply is and what the demand from the sprinklers are. The demand from the sprinklers is determined by performing hydraulic calculations. The results of these calculations were plotted along with the city supply to demonstrate that supply exceeds demand by a margin of 10 psi. The wet-chemical system was not analysis as this is a pre-engineered system and it is assumed to have been installed in accordance with manufacture recommendations.

3.5 Building Smoke Control

There is no dedicated smoke management system for this building. Smoke is managed passively through the use of in-duct smoke detectors which, when triggered, will shut down the HVAC system in order to reduce the spread of smoke. Additionally, there are multiple clearstories (see Figure 31) which may serve as smoke reservoirs in the event of a fire. These clearstories will increase the time it takes the smoke level to drop to a point where it impacts building evacuation.

Figure 31 – Clearstory above the Weightlifting Room

3.6 Summary of Prescriptive Analysis

A review of the prescriptive measures of the structural fire protection systems, occupancy and egress analysis, fire detection and notification, and fire suppression systems had demonstrated that the fitness center has been designed in accordance with applicable codes and standards. The next section will evaluate the building against the performance-based objectives of NFPA 101.

4 PERFORMANCE-BASED ANALYSIS

Chapter 5 of NFPA 101 provides a performance-based alternative to the prescriptive approaches mentioned in the previous section. Performance-based analysis has several advantages over prescriptive approaches, foremost among these being flexibility. Performance-based design allows fire protection engineers to deviate from prescriptive approaches if it can be determined that these deviations meet performance goals to protect the life and safety of occupants involved in a fire. This section will analyze the fitness center using the performance-based approach outlined in the LSC along with supplemental information from the SFPE Handbook of Fire Protection Engineering (5th Edition) and the NFPA Fire Protection Handbook. Additional information was pulled from various research papers which are cited in Section 7 of this report.

4.1 Fire Scenarios

The fire scenario is the heart of any performance-based design. The fire scenario determines what the design fire will look like, primarily in terms of heat release rate and fire growth rate. These important parameters will dictate the challenge the building is expected to withstand. The LSC requires that the following eight fire scenarios be considered.

1. An occupancy specific fire representative of a typical fire for the occupancy
2. An Ultra-Fast developing fire in the primary means of egress
3. A fire that starts in a normally unoccupied room
4. A fire that originates in a concealed wall or ceiling
5. A slowly developing fire, near a large occupancy, shielded from suppression
6. Most severe fire from highest possible fuel load
7. An outside exposure fire
8. An ordinary fire in a room with no detection or suppression

Design fires from the above scenarios should consider characteristics of the building, occupants, and expected fire. For building characteristics the reader is directed to Section 3 of this report on prescriptive design. Occupant and fire characteristics will be discussed below.

4.1.1 Analyzed Scenarios

The following two scenarios were analyzed for this report.

4.1.1.1 Sauna Fire

The first scenario involves a fire in one of the two saunas in the fitness center. This scenario meets criteria 1 from the list above as sauna fires are somewhat typical for fitness centers equipped with them. Since there is some visible damage, rust, signs of leaks, and significant loading on the sprinklers, particularly in the locker room where the sauna is located this scenario will also look at the effects of non-operation of the building sprinkler system which covers number 8 from the above list.

The fire starts when an occupant carelessly drops a towel on the heating element in the sauna as he is leaving the room. This towel ignites, subsequently setting the western red cedar paneling in the sauna on fire. This results in a t-squared fire with a peak heat release rate (HHR) of 250 kW/m^2 and a medium fire growth rate. A representative fire curve for western red cedar, taken from the Handbook of Environmental Degradation of Materials, is shown in Figure 32. Due to the condition of the sprinkler system, it does not activate and the fire burns undetected until noticed by other patrons in the locker room who activate the fire alarm via a manual pull station as they egress the building.

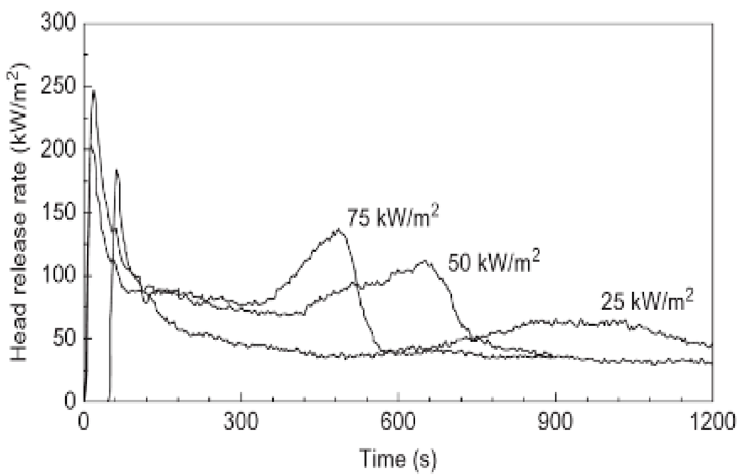

Figure 9.11 Cone Calorimeter heat release rate data for western red cedar.

Figure 32 – Sauna Fire Curve

4.1.1.2 Foam Tumble Mat Fire

The second scenario involves a fire in the gymnasium which occurs when a cell phone left charging against the tumble mats stored in the gymnasium has a malfunction and ignites the stack of vinyl covered polyurethane foam tumbling mats which are stored behind a partition along with other gym equipment. The partition is in place to hide the mats and equipment due to a ceremony taking place in the gym. The ceremony has resulted in an unusually large crowd of over 500 people. This fire, burning behind the partition, goes unnoticed until the fire alarm system is activated by discharge of the sprinklers. This scenario addresses items 2 and 6 from the above list.

4.1.2 Other Scenarios

Other scenarios were considered to address the items listed in the LSC. Since this facility has very few concealed ceilings or walls, and the risk from an outside fire is very remote due the spacing between this facility and other facilities, scenarios involving these items from the list were not considered. Other fire scenarios which address the remainder of the items listed in the LSC are explained in the sections that follow.

4.1.2.1 Laundry Room Fire

In this scenario a fire starts in the laundry room of the fitness center due to the buildup of lint near the heating element of the fire. The laundry room is situated between the aerobics room and the racquet ball courts, two areas with the potential to have relatively large numbers of people. The laundry room in the fitness center has been converted into a multi-use room for the staff. Equipment and supplies are stored in a cluttered fashion in the room. Additionally, wooden lockers have been added to the room which doubles as a locker room for staff. The lockers are configured in a u shape facing away from the door in an effort to maintain privacy. This locker configuration seriously hampers egress from the room. The scenario address item number 5 since the fire developing inside the dryer would be shielded from the suppression system. It also addresses items 1 and 8 from the above list. This fire was not selected due to the complex nature of modeling the fuel load in a fire involving multiple materials and the belief that the other scenarios chosen would represent more demanding fires that pose higher risks to a greater number of occupants.

4.1.2.2 Communications Rack Fire

This scenario involves an electrical fire that starts in the computer server rack that is stored in the telecommunications room adjacent to the electrical room. This type of fire is a slow developing fire in a normally unoccupied space. The fire, occurring within the rack, would also be shielded from the fire suppression system. This scenario addressed items 3 and 5, as the telecommunications room is located near the gym, which could have a high number of occupants. This scenario was not considered since it is relatively unlikely and wouldn’t result in as large of an impact to the building as other scenarios.

4.1.2.3 Gym Bag Fire

This final scenario involves a gym bag left unattended on upholstered foam furniture in the common area outside the gymnasium which catches fire when a cell phone left in the bag malfunctions. This scenario was not considered because the fuel load was not as high as the scenario involving the foam tumble mats and the location of the fire would facilitate early detection. This scenario would address item number 2 as it would involve foam furnishings just outside the main exit from the gymnasium.

4.2 Performance Criteria

The established performance criterion of the LSC is to prevent occupants not intimate with the fire from becoming incapacitated due to exposure to instantaneous or cumulative untenable conditions. This performance criterion can be met by ensuring the required safe egress time (RSET) is less than the available safe egress time (ASET) by an acceptable factor of safety. An important step in the evaluation of ASET is the establishment of tenability criteria against which to measure the effectiveness of life safety measures. Of primary concern to the determination of the RSET is the characteristics and capabilities of the occupants expected to be in the facility at the time of the fire. Initial tenability criteria and occupant characteristics are discussed below.

4.2.1 Tenability Criteria

4.2.1.1 Visibility

Visibility Tenability Criteria (Sauna Fire): 7 m
Visibility Tenability Criteria (Foam Mat Fire): 10 m

Visibility conditions have a significant impact on the ability of occupants to safely escape from a fire. As visibility decreases movement slows and decision making is impaired. Additionally, visibility is likely to be the first condition that becomes untenable. Studies have shown that occupants are more likely to egress through smoke when they can recognize the location of and the distance to an exit (NFPA 4-35). A wide variety of research has been conducted in the area of visibility in smoke. Table 17 shows a summary of visibility tenability limits proposed by various fire researchers. Table 61.3, shown below as Table 18, of the SFPE Handbook of Fire Protection Engineering shows that occupants unfamiliar with a space will need visibility in excess of 13 m to safely egress while those who are familiar with a space need 4 m or greater.

Table 17 – Visibility Limits for Tenability from Various Researchers

Table 61.4 Visibility and/or allowable smoke density for fire safe escape proposed by fire researchers

Proposer	Visibility	Smoke density (extinction coefficient)
Kawagoe [21]	20 m	0.1 1/m
Togawa [22]	–	0.4 1/m
Kingman [23]	4 ft (1.2 m)	–
Rasbash [24]	15 ft (4.5 m)	–
Los Angeles Fire Department [25]	45 ft (13.5 m)	–
Shern [26]	–	0.2 1/m
Rasbash [27]	10 m	0.2 1/m

Table 18 – Allowable Smoke Densities and Visibility That Permits Safe Escape

Table 61.3 Allowable smoke densities and visibility that permits safe escape

Degree of familiarity with inside of building	Smoke density (extinction coefficient)	Visibility
Unfamiliar	0.15 1/m	13 m
Familiar	0.5 1/m	4 m

The first fire scenario that will be evaluated involves a sauna fire in the locker room of the fitness center. Most patrons of the fitness center use the facility several times a day and are very familiar with the layout. Additionally, the locker room is a small space and the egress path is short. For situations such as this Purser and McAllister recommend a less restrictive tenability limit of 5 m, see Table 19. For the purposes of the sauna fire scenario a tenability limit of 7 m was selected because this value fell between the widely accepted value of 10 m and the 5 m value listed in Table 19. For the second scenario which involves a fire which occurs in the much larger gymnasium during a base ceremony, it is expected that a large percentage of the occupants will be unfamiliar with the building. For this reason the standard 10 m visibility criteria was selected.

Table 19 – Suggested Tenability Limits Based on Enclosure Size and Travel Distance

Table 63.5 Reported effects of smoke on visibility and behavior

Smoke density and irritancy OD/m (extinction coefficient)		Approximate visibility (diffuse illumination)	Reported effects
None		Unaffected	Walking speed 1.2 m/s
0.5 (1.15)	Nonirritant	2 m	Walking speed 0.3 m/s
0.2 (0.5)	Irritant	Reduced	Walking speed 0.3 m/s
0.33 (0.76)	Mixed	3 m approx.	30 % people turn back rather than enter
Suggested tenability limits for buildings with:			
Small enclosures and travel distances:		OD/m 0.2 (visibility 5 m)	
Large enclosures and travel distances:		OD/m 0.08 (visibility 10 m)	

4.2.1.2 Toxicity

Carbon Monoxide Tenability Criteria: 1,500 ppm
Oxygen Concentration Tenability Criteria: 15%

When carbon monoxide is respirated into the body carboxyhemoglobin forms in the red blood cells. Carboxyhemoglobin is a stable complex that forms more readily than oxyhemoglobin. This hinders the oxygen carrying capability of hemoglobin resulting in hypoxia. Exposure to high concentrations of carbon monoxide can result in incapacitation and death. Table 20 lists exposure levels that can result in incapacitation and death for different species at rest and during light activity. The occupants egressing the fitness center can be considered as being engaged in light activity as the building is a single-story structure with no stairs. For these conditions Table 21 lists list incapacitation as occurring in the range of 30,000 to 35,000 ppm. CO exposure experiments in primates have shown that for short exposures to high concentrations CO uptake is approximately linear. Therefore, we can assume that, using the lower 30,000 ppm level, an exposure of 1,500 ppm over 20 min will lead to incapacitation. Due to the short egress times expected for this facility, it is not anticipated that CO exposure will be an issue, however, untenable conditions will be assumed if at any time the CO concentration exceeds 1,500 ppm.

Table 20 – CO Exposure Doses for Incapacitation and Death

Table 63.9 $C \cdot t$ product exposure doses for incapacitation and death by CO for different species at rest and during light activity

	Incapacitation		Fatal	
	CO at rest ppm · min	CO light activity ppm · min	CO at rest ppm · min	CO light activity ppm · min
Human 70 kg	80,000–100,000	30,000–35,000	~110,000–240,000	~60,000–190,000
Baboon ~20 kg		34,000		
Macaque 3–4 kg	38,000–40,000	27,000		
Rat ~ 300 g	30,000–40,000	22,000–36,000	162,000	

4.2.1.3 Temperature and Heat Flux

Temperature Tenability Criteria: 60°C
Heat Flux Tenability Criteria: 2.5 kW/m^2

Exposure to heat can result in incapacitation due to heat stroke, skin burns, or respiratory tract burns. Temperature and heat flux tenability criteria address these issues by placing an upper limit on room temperature at a specified height, usually 2 m, and heat flux. The temperature and heat flux tenability limits were selected from Table 63.20 of the SFPE Handbook of Fire Protection Engineering, shown below as Table 21.

Table 21 – Tenability Conditions Due to Heat

Table 63.20 Limiting conditions for tenability caused by heat [18]

Mode of heat transfer	Intensity	Tolerance time
Radiation	$<2.5\ kW \cdot m^{-2}$	>5 min
	$2.5\ kW \cdot m^{-2}$	30 s
	$10\ kW \cdot m^{-2}$	4 s
Convection	$<60\ °C$ 100 % saturated	>30 min
	$100\ °C <10\ \%\ H_2O^a$	12 min
	$120\ °C <10\ \%\ H_2O$	7 min
	$140\ °C <10\ \%\ H_2O$	4 min
	$160\ °C <10\ \%\ H_2O$	2 min
	$180\ °C <10\ \%\ H_2O$	1 min

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A value of 60°C is recommended for occupancies with water-based fire protection systems, and breathing difficulty is reported for exposures to temperatures greater than 60°C in saturated air. Severe skin pain is reported for victims exposed to a heat flux greater than 2.5 kW/m^2 for more than 5 min. Because automatic sprinkler systems are present in each of these scenarios, if heat flux exceeds 60°C at any time in a space that space will be considered untenable.

4.2.2 Occupant Characteristics

4.2.2.1 Population Number

The occupant load for both scenarios is 1,055 people. This occupant load is the maximum number of people allowed in the building per the occupancy provisions of the 1997 UBC, the under which the building was designed. This figure is slightly higher than the value of 1,043 calculated under the current IBC and LSC, however since the UBC value is the higher values and is also the value reflected on the signage throughout the facility this value will be used. Under normal circumstances the occupancy of the fitness center doesn't approach this number; it represents a worst case scenario.

4.2.2.2 Distribution and Activities

For both fire scenarios it is assumed that there is an event occurring in the gymnasium. Consequently, occupants in this room are organized in a uniform manner. Occupants in the bleachers are facing the center of the gym while occupants in the middle of the room are facing to the east. These occupants are engaged in the event and therefore not focusing on other tasks. The remainder of the occupants are randomly distributed throughout the building. These occupants may be engaged in a wide variety of activities including weightlifting, aerobic exercise, showering and changing, or participating in sports. There will be a tendency for occupants to take time to wrap up these functions before starting their egress, especially when there is a general feeling of safety as is common during the early stages of notification.

4.2.2.3 Familiarity

Most occupants using the fitness center will be very familiar with the layout of the building. Patrons typically use the fitness center three to five times a week and are sometimes in the building multiple times a day. On occasion when the gymnasium is used as a multipurpose room the portion of the population that is unfamiliar with the building may become more significant. For the purposes of egress modeling for this report it is assumed that occupants in the gymnasium are somewhat familiar with the building while occupants in the remainder of the facility are very familiar with the building.

4.2.2.4 Social Affiliation

Due to unit cohesion and the psychology of military service there is a high degree of social affiliation for the occupants of the gymnasium. Even among retiree groups that make up a significant portion of the fitness center patrons there will be a sense of comradery. These affiliations may cause people to feel responsible for others and take measures to assist before evacuating themselves.

4.2.2.5 Alertness and Limitations

Occupants using fitness centers are generally able-bodied and alert. Level of intoxication is expected to be very low and occupants will generally be prepared for and anticipating movement. Most patrons of the fitness facility will be young to middle-age and in good physical condition. However, the building is also available to retirees and wounded warriors. The alertness and limitations of these populations can vary significantly from person to person and these limitations must be considered.

4.3 Required Safe Egress Time (RSET)

The fundamental goal of performance-based design when it comes to egress analysis is to ensure the time required to safely exit a building, known as Required Safe Egress Time (RSET) is less than the time is takes for conditions in the space to become untenable. The time it takes for conditions to become untenable is known as Available Safe Egress Time (ASET). As long as ASET exceeds RSET by a reasonable factor of safety the building is considered to have passed this portion of the performance-based design. The RSET of a given fire scenario is based on the multiple different times listed in Figure 33, which comes from chapter 36 of the SFPE Handbook of Fire Protection Engineering. Individual component times of the RSET are listed below

- Detection Time (t_{dec}) – Time required for the fire to be detected

- Warning Time (t_{warn}) – Time from detector activation to alarm sounding
- Pre Movement Time (t_{pre}) – Composed of recognition and response time
    - Recognition Time (t_{rec}) – Time to recognize the alarm
    - Response Time (t_{res}) – Time to respond to the alarm and start movement
- Movement Time (t_{trav}) – Time required to travel to exit

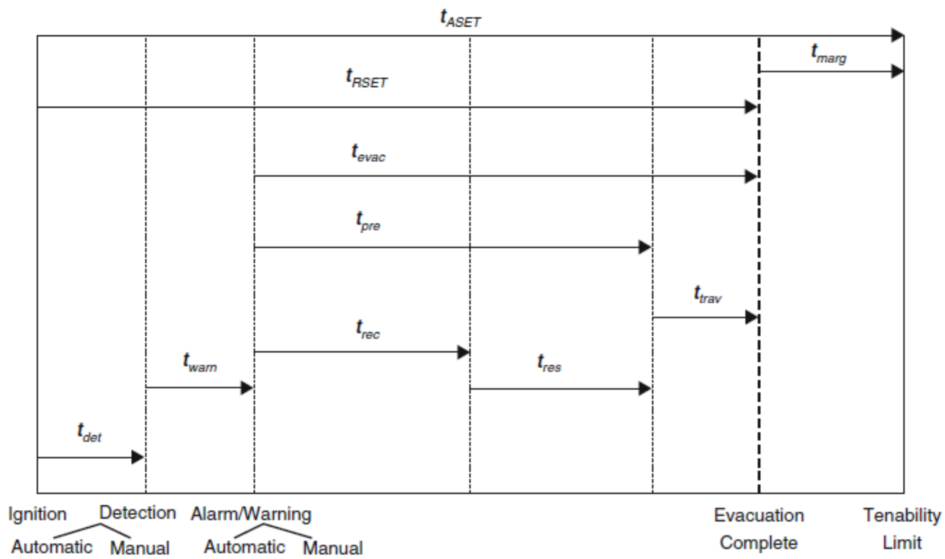

Figure 33 – Required Safe Egress Timeline

4.3.1 Detection and Notification Time

4.3.1.1 Sauna Fire Detection and Notification Time

In the sauna fire scenario a single sprinkler in the sauna was activated at 50 seconds. The activation of this sprinkler triggered the water flow switch in the sprinkler riser which sent a signal to the FACP to activate the fire alarm. Ten seconds is a conservative estimate of the time it takes for signal to reach the FACP and the alarm to activate. Therefore, 60 seconds after ignition the fire alarm sounds and occupants are alerted that there is a fire in the facility.

4.3.1.2 Foam Mat Fire Detection and Notification Time

In the case of the foam mat scenario sprinklers also activate. This sprinkler activation occurs 186 seconds after the fire starts. In this scenario it's very unlikely that occupants in the gymnasium will wait for the fire alarm to initiate evacuation. 30 seconds after ignition almost half of the gymnasium ceiling would be covered with smoke. This smoke layer would be very noticeable. Furthermore, in this same time interval the temperature in the room would have risen by several degrees. Therefore, it is reasonable to assume that occupants in the gym will detect the fire within 30 seconds. At this point the pre-movement time would start. Occupants not in the gym will be unaware of the fire and will wait to evacuate until 60 seconds into the fire.

4.3.2 Pre-Movement Time

Pre-movement time is the time it takes occupants to initiate evacuation movement. This time can vary widely and multiple factors contribute to this time such as detection, denial, and pre-movement actions. Pre-movement actions are actions that are taken during pre-movement time. These are typically actions taken to prepare for movement. These can include packing up belongings, getting dressed, or looking for friends or family members. Pre-movement times for business occupancies were collected from various research sources and tabulated in Table 64.3 of the SFPE Handbook. Pre-movement times generally averaged around 30 seconds. For example, Sharma et al. identified a pre-movement time range of 10-55 seconds, while Christoffersen and Soderlind observed a range of 12-105 seconds. Ranges for assembly occupancies tend to be on the lower half of the business occupancy ranges. For example, Purser and Bensilum established a range of 10-36 seconds. Since the fitness center is a combination of business and assembly occupancies, a pre-movement time of 30 seconds was chosen. This value falls in the conservative range of both occupancies.

4.3.2.1 Sauna Pre-Movement Time

As discussed above a pre-movement time of 30 seconds was chosen for this scenario so occupants will start moving 60 seconds after ignition.

4.3.2.2 Foam Fire Pre-Movement Time.

As discussed above, the initial detection for those occupants in the gym is via human senses. Human detection is assumed to take about 30 seconds. Pre-movement time for fire, as above, is also 30 seconds. Occupants in the gym will start moving around 60 seconds. It will take the first few occupants 5 seconds to reach a pull station. When the pull station is activated the alarm will sound and the remainder of this building will be alerted to the fire. At this point the pre-movement time for all the occupants in parts of the facility other that the gym will start. Occupants not in the gym will be expected to start egressing after 90 seconds.

4.3.3 Movement time

4.3.3.1 Model Design

Pathfinder was used to model movement time. Pathfinder is a computer-based emergency egress simulator which uses triangulation to predict movement times during building evacuations. Users can input various parameters in order to influence how occupants move in the model. These inputs are divided in to two categories: profiles and behaviors.

4.3.3.1.1 Profiles

Profiles are those parameters which dictate things like how large a person is, how fast they move, etc. For both studies a constant value of 3.9 ft/s was used for walking speed and 17 inches was used as the average occupant width.

4.3.3.1.2 Behaviors

Behaviors are the actions a person might take in an evacuation, such as choosing one exit over another. The fitness center is a controlled access facility that uses only one exit, the main entrance, on a daily bases. In a fire emergency occupants, particularly those who are not familiar with the location have a tendency to use the exit they used to enter the building. Single entry access is especially prevalent in fitness centers. This scenario takes this into account by assuming that 70 percent of the occupants will favor the main entrance while the rest will chose any exit available.

4.3.3.2 Sauna Fire Movement Time

The movement time for the sauna fire scenario was 340 seconds. This movement time combined with the 30 second detection time and the 30 second pre-movement time results in a total evacuation time of just under 400 seconds. The application of a safety factor of 1.5 to this figure results in an RSET of 600 seconds.

4.3.3.3 Foam Mat Fire Movement Time

For the foam mat fire the pre-movement time for all the occupants in the fitness center was 30 seconds, however, notification time for occupants in the gym was 30 seconds based on human detection while for those outside the gym notification was via the fire alarm system which took longer. Those outside the gym did not start evacuating until 90 seconds into the fire. The movement time for this scenario was 260 seconds so the total evacuation time was 350 seconds. The application of a safety factor of 1.5 to this figure results in an RSET of 525 seconds.

4.4 Available Safe Egress Time

4.4.1 Model Design

ASET was determined by using Fire Dynamics Simulator (FDS) to model the fire behavior of each of the scenarios. FDS is a program developed by NIST for solving complex computation fluid dynamics equations specific to fire dynamics and heat flow. FDS was used to determine the point at which conditions became untenable for the two scenarios evaluated.

4.4.2 Sauna Fire

4.4.2.1 Design Fire

The design fire parameters are listed below. Data on Western Red Cedar came from the Handbook of Environmental Degradation of Materials.

Fuel: Western Red Cedar

Surface Area: 0.5 m^2

HRRPUA: 250kW/m^2

Fire Growth Rate: Medium ($\alpha = 0.012$ kW/s^2)

Time to Peak HRR: 145 seconds

4.4.2.2 Performance

In this scenario a fire starts in the sauna when a towel is inadvertently left on the sauna's heating element. This issues is exacerbated when the door to the sauna is stuck in the open position due to interference with a floor mat, see Figure 34. This results in an open door which allows smoke to flow into the room and causes conditions in the shower area to become untenable in about 70 seconds, see Figure 35. Fortunately, the occupants egress this area in about 60 seconds. Figure 36 shows the status of the evacuation at 70 seconds. However, conditions rapidly deteriorate and by 80 seconds visibility has dropped below tenability limits in the vicinity of the west exit from the room (Figure 37). At this point occupants are still in the room. By 100 seconds the locker room is empty. This is about 20 seconds before the visibility drops below 7 m throughout the entire room. Once it exits the locker room smoke flows north and south along the corridors and rapidly collects at the ends of the corridors where the primary exits are. 300 seconds after ignition conditions have dropped below tenability limits at both corridors exits (Figure 38). At this point there are still over 200 occupants in the fitness center, see Figure 39. At 396 seconds the evacuation is complete. At this point visibility throughout most of the gym has dropped below 4 m as shown in Figure 40.

Figure 34 – Sauna Door Stuck on Non-Slip Floor Mat

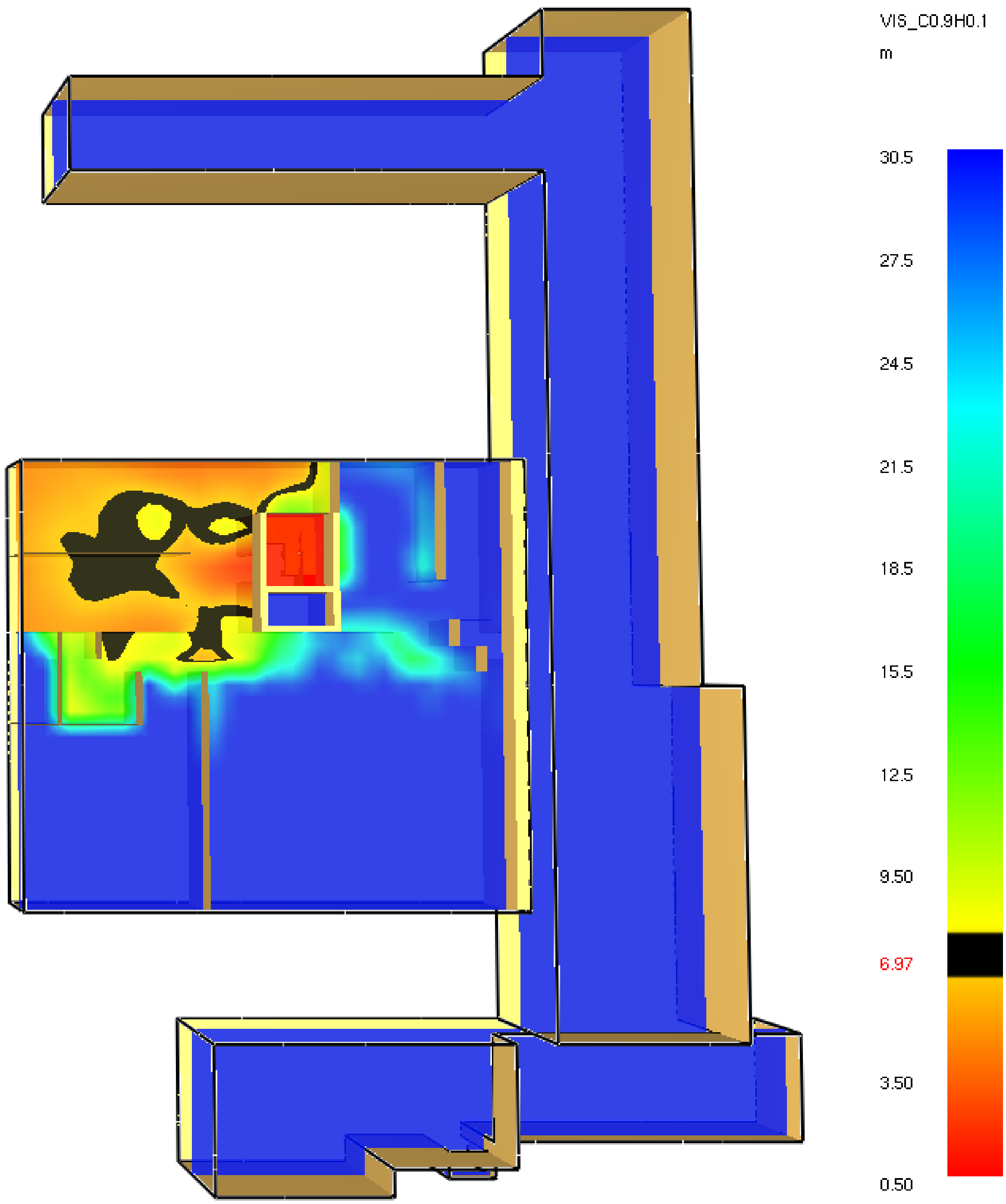

Figure 35 - Tenability Conditions 70 Seconds after Ignition

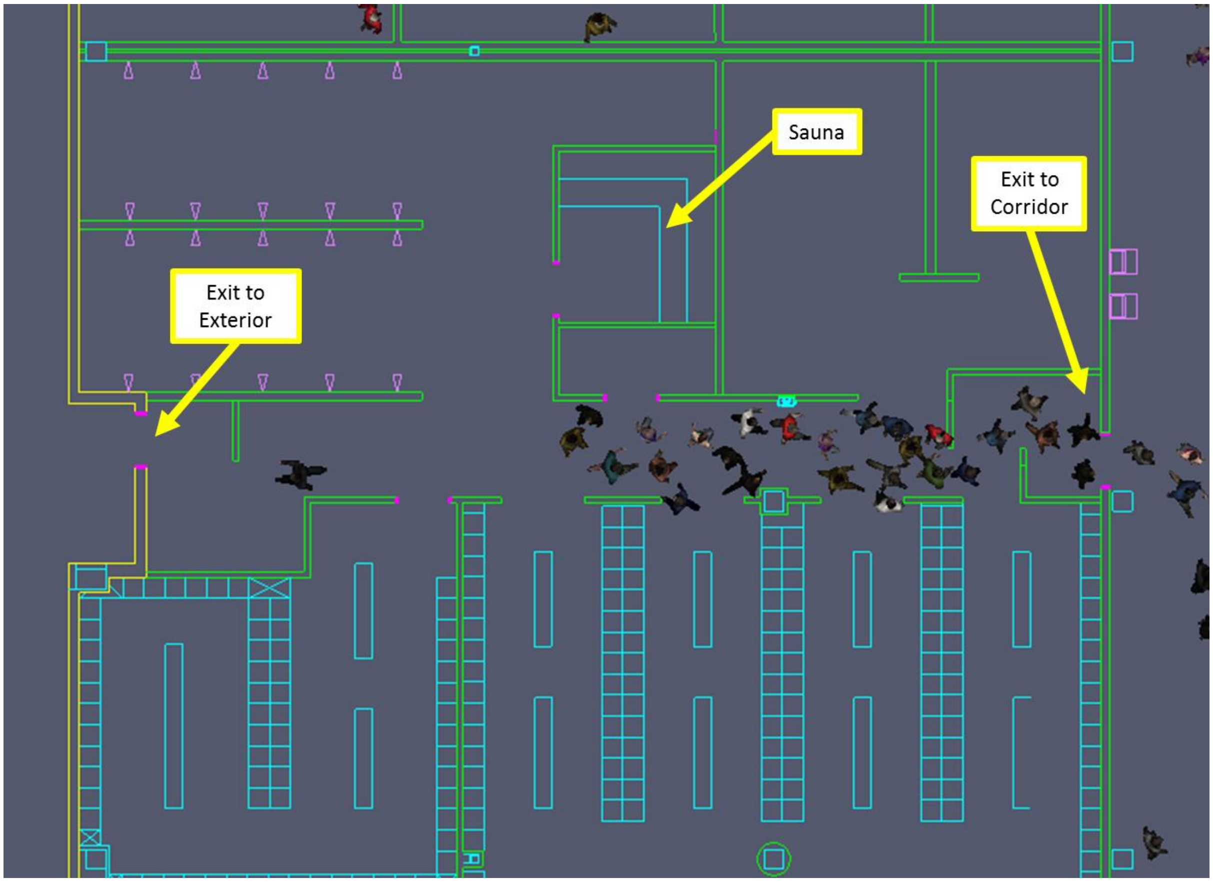

Figure 36 – Status of Evacuation 70 Seconds after Ignition

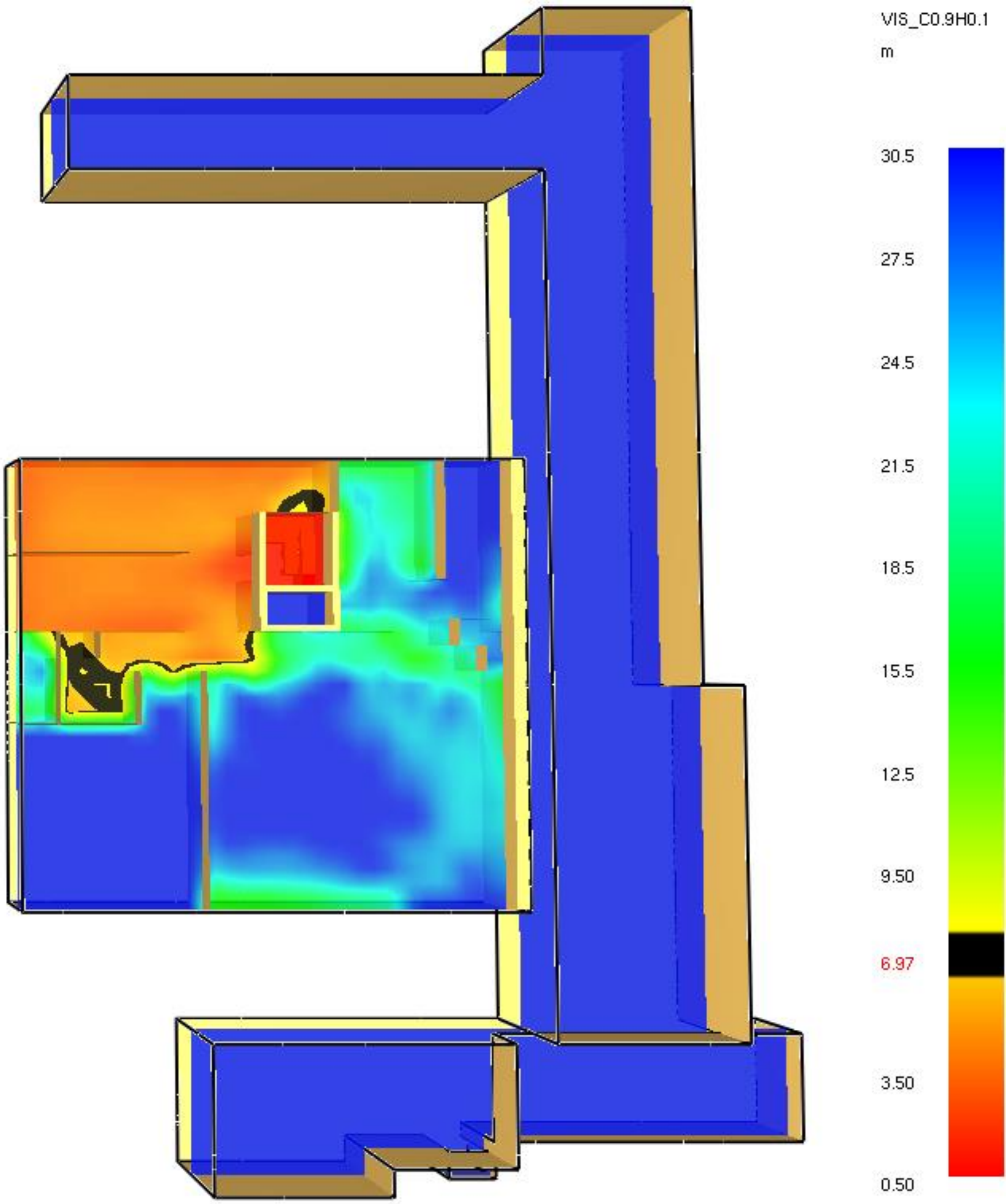

Figure 37 – Visibility 80 Seconds after Ignition

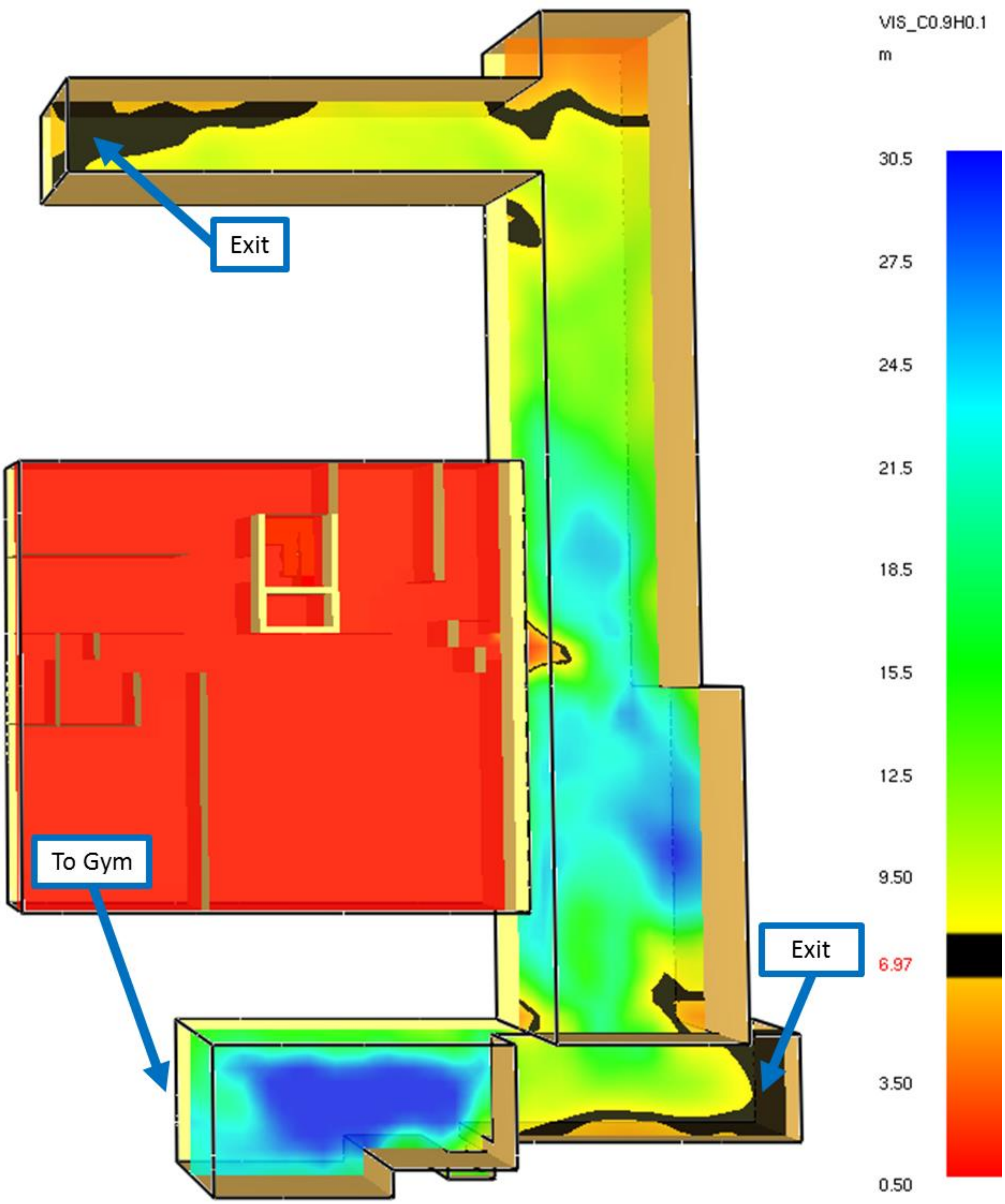

Figure 38 – Major Exits are Inaccessible at 300 Seconds

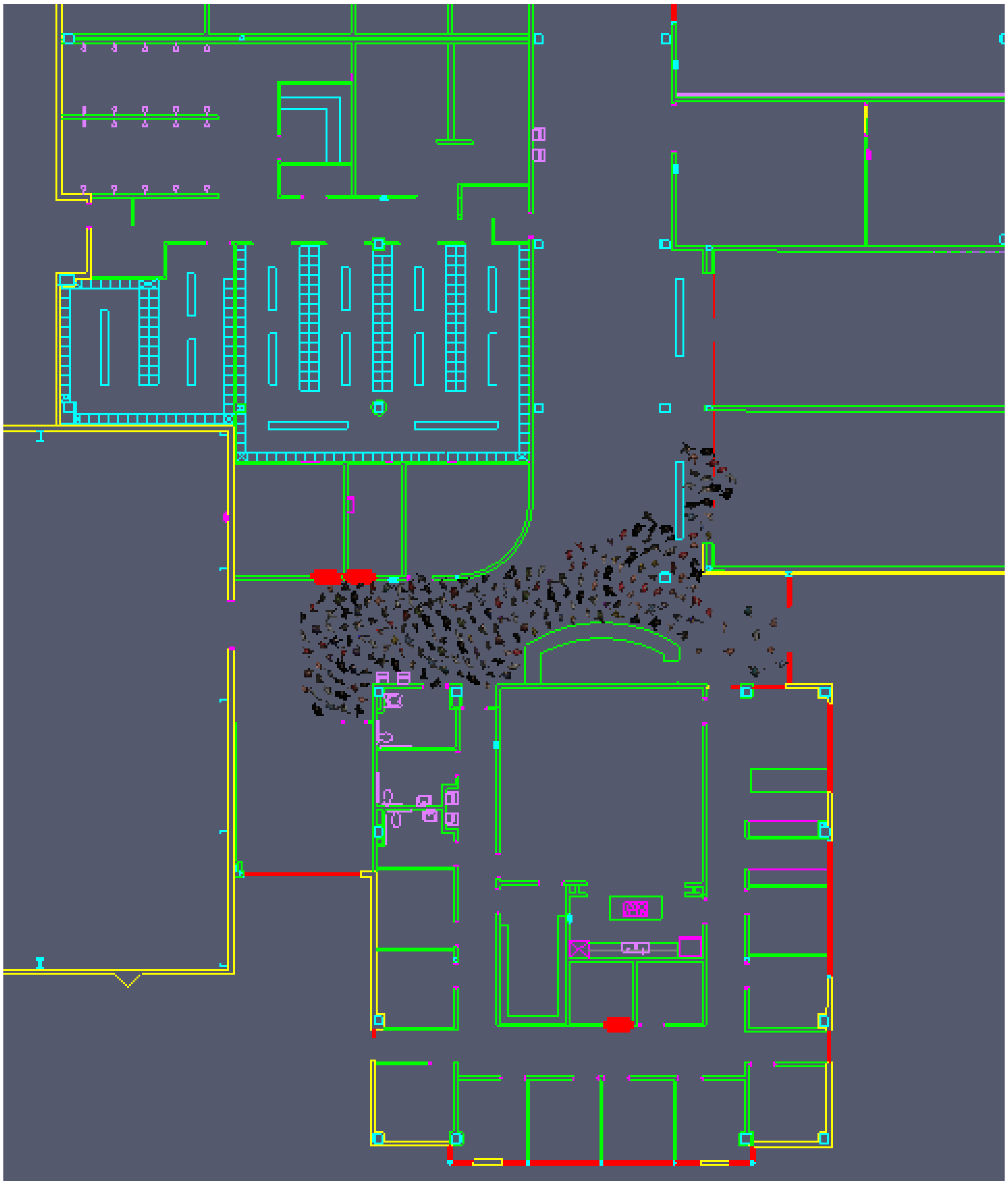

Figure 39 – Evacuation Status at 300 Seconds

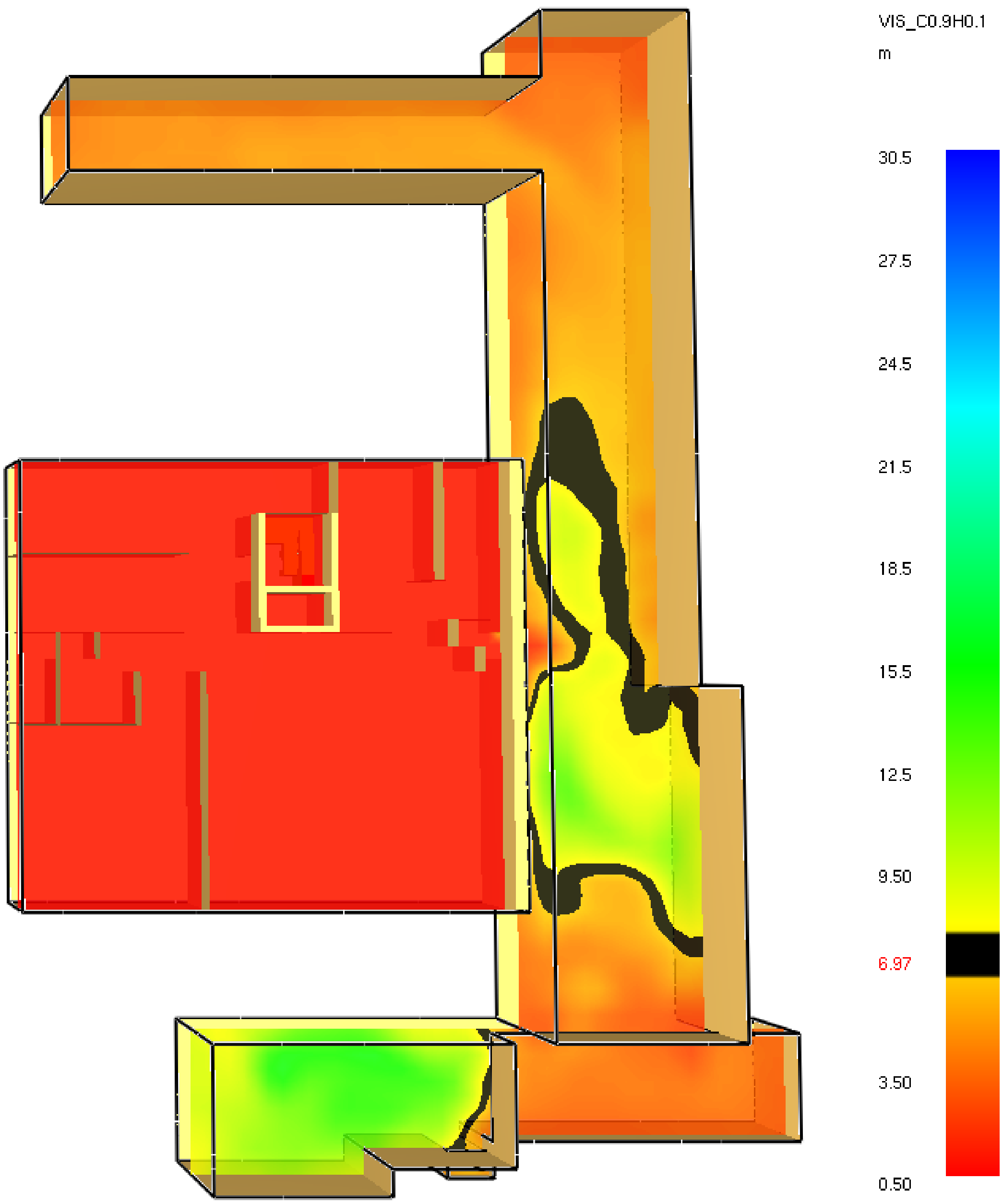

Figure 40 – Visibility at Completion of Evacuation

From a temperature standpoint conditions in the locker room become untenable in 120 seconds, about 20 seconds after the last occupant has left the locker room. Figure 41 shows conditions in the locker room at 120 seconds. Once outside the locker room temperature never rises above 45°C.

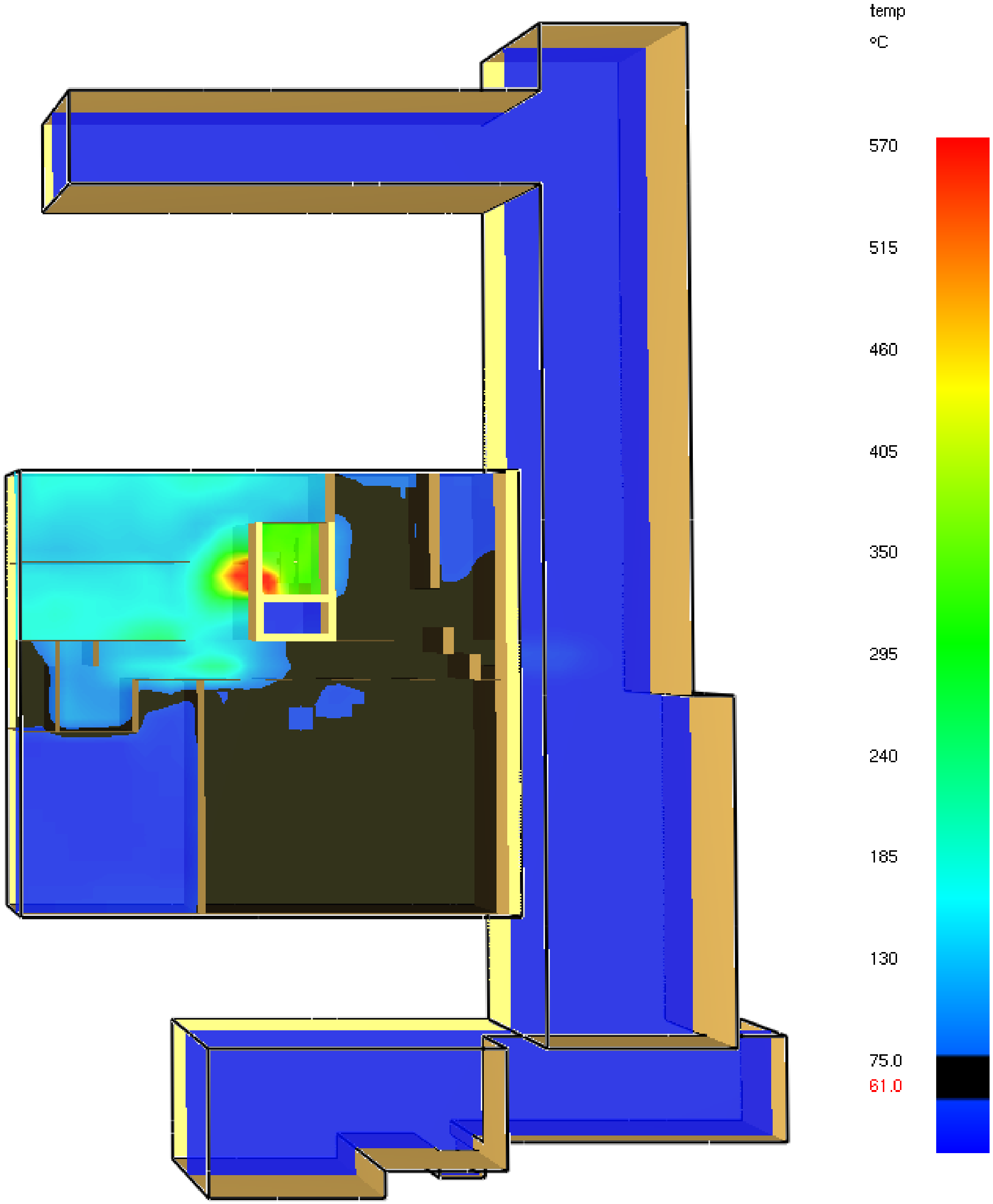

Figure 41 – Temperature in the Locker Room 120 Seconds after Ignition

4.4.3 Foam Tumbling Mat Fire

4.4.3.1 Design Fire

Design fire parameters for the foam tumbling mat fire are listed below. Data on PU foam came from the SFPE Handbook.

Fuel: Polyurethane Foam Mats
Surface Area: $9m^2$
HRRPUA: 400 kW/m^2
Fire Growth Rate: Ultra-Fast ($\alpha = 0.188\ kW/s^2$)
Time to Peak HRR: 47 seconds

4.4.3.2 Performance

Figure 42 is a Pathfinder depiction of the occupancy configuration at the start of the foam mat fire. Since the fire occurs by one of the gymnasium exits, this exit will not be available during the evacuation. This scenario will evaluate the impact of this on the ability of the occupants to safety egress from the building. FDS analysis determined that visibility was the constraining tenability criteria for this scenario. Temperature conditions during the fire never exceeded 45°C. Conditions in the vicinity of the main exit in the gymnasium became untenable due to lowered visibility at 230 seconds. At this point conditions were still tenable at the other exit but due to occupants favoring the main exit a large crowd still remains in the gym. Figure 43 shows the corresponding visibility slice file for this point in the simulation. Figure 44 shows the crowd of occupants at the primary gymnasium exit at the point conditions become untenable. Complete evacuation of the gym doesn't occur until 260 seconds after ignition. Occupants in this portion of the gym were exposed to untenable conditions in the gym for approximately 30 seconds. At 360 seconds conditions became untenable throughout the gym as shown in Figure 45.

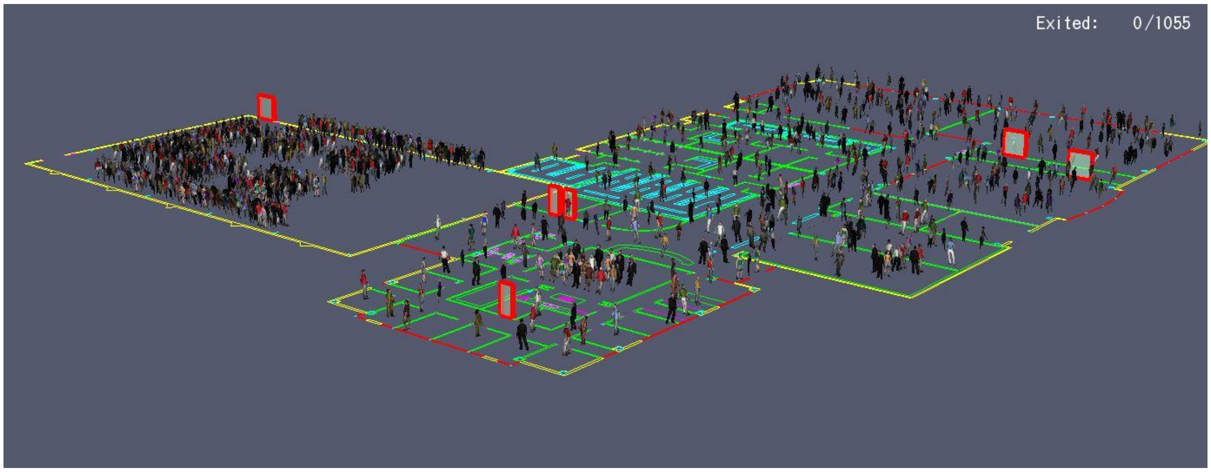

Figure 42 – Occupancy Conditions at the Start of the Foam Mat Fire

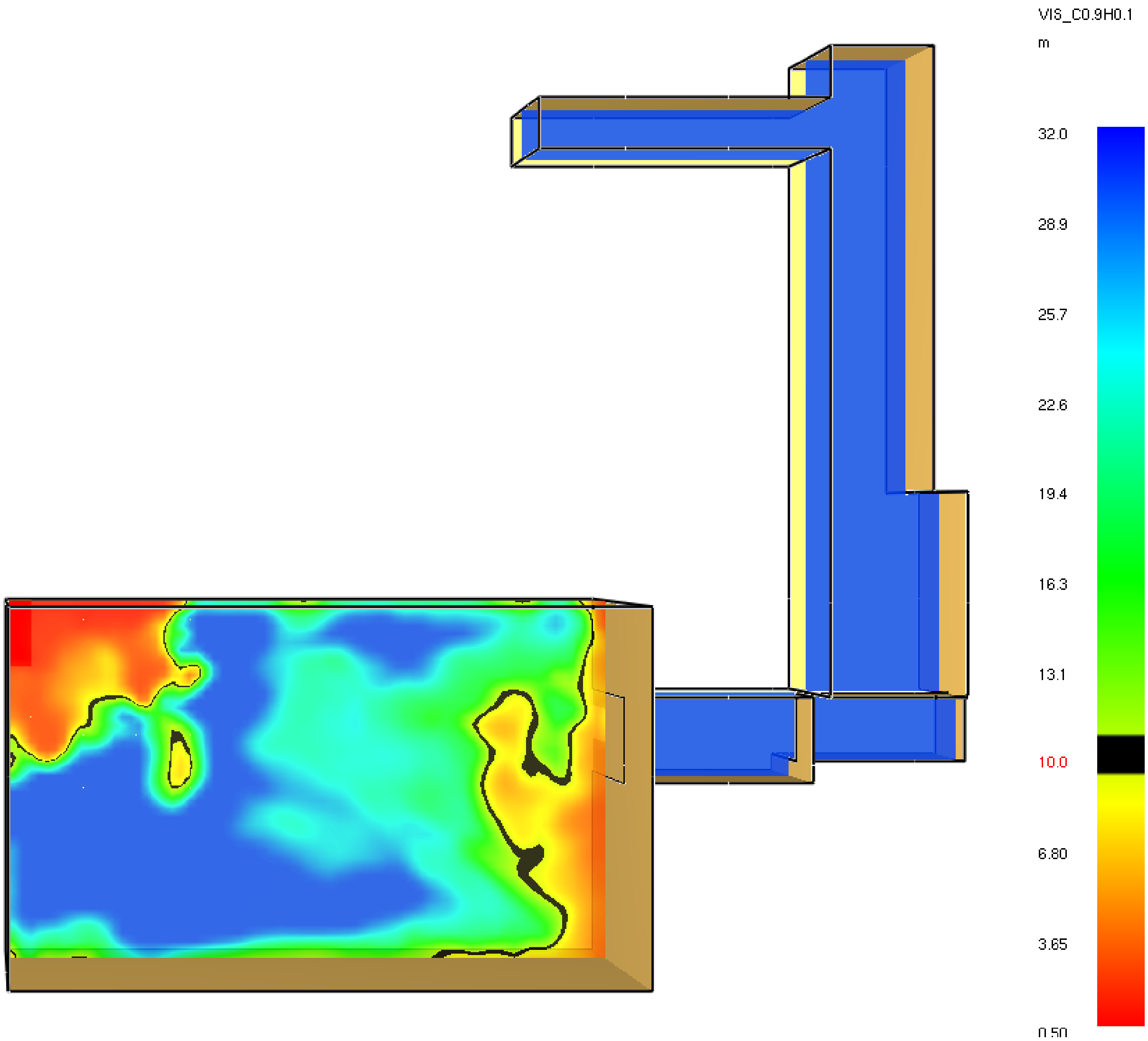

Figure 43 – Visibility Level at 230 Seconds

Figure 44 – Gymnasium Occupants 230 Seconds after Ignition

Figure 46 is the corridor just outside the gym 380 seconds into the fire. You can see from the figure that conditions have dropped below tenability limits due to the discontinuity in the ceiling. This discontinuity is also responsible for the sharp demarcation between the two areas of the corridors. This sharp demarcation is allowing more people to escape as shown in the Pathfinder image taken at the same time, see Figure 47. At the 380 second mark conditions in the corridor just outside the gym drop below the tenability criteria. However at this time in the simulation remaining occupants are already past this point. Complete evacuation of the building occurs 388 seconds after ignition. Conditions in the vicinity of the main exit don't drop below tenability levels until over 100 seconds later, 490 seconds after ignition.

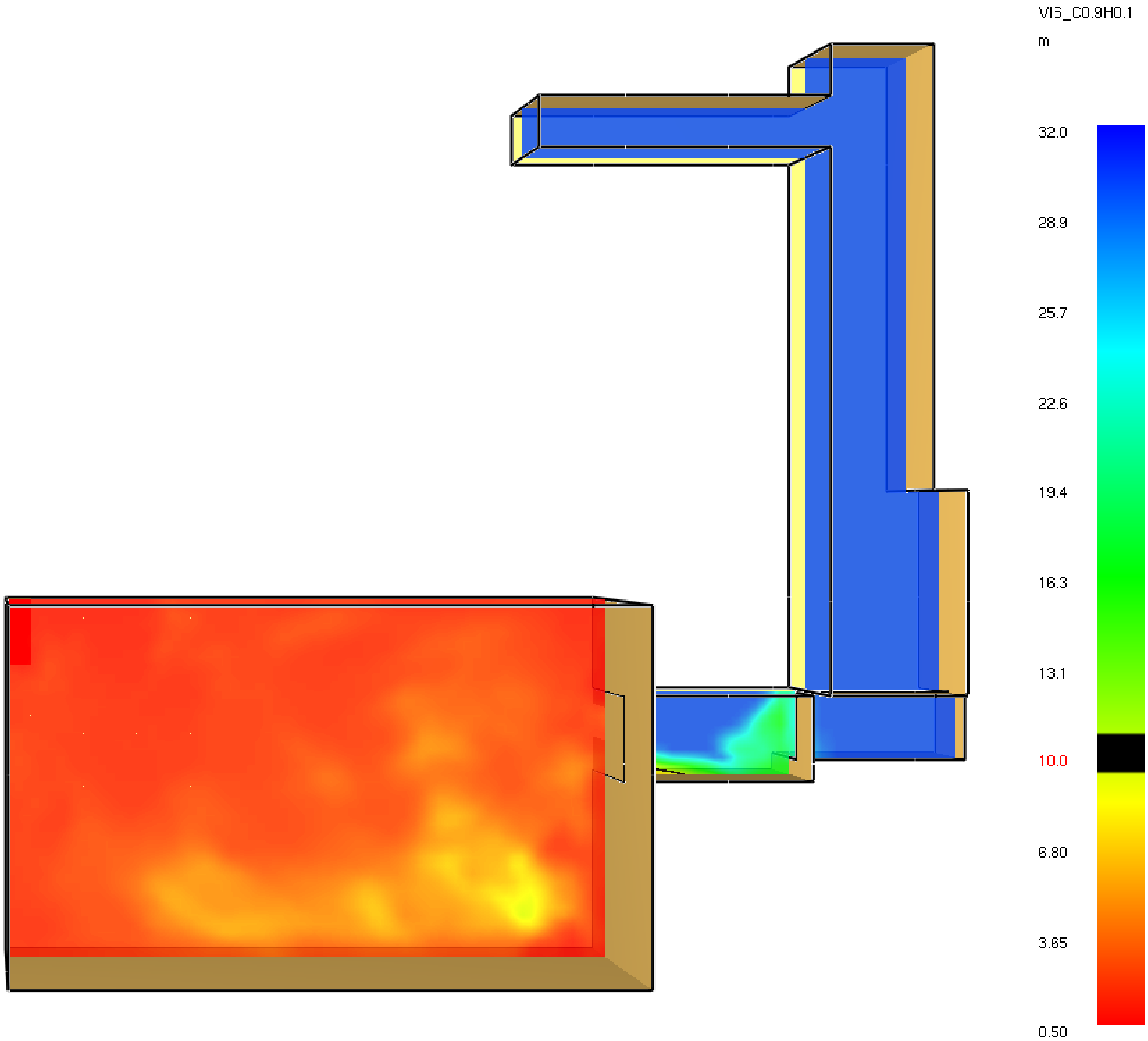

Figure 45 – Untenable Conditions due to Visibility in the Gymnasium

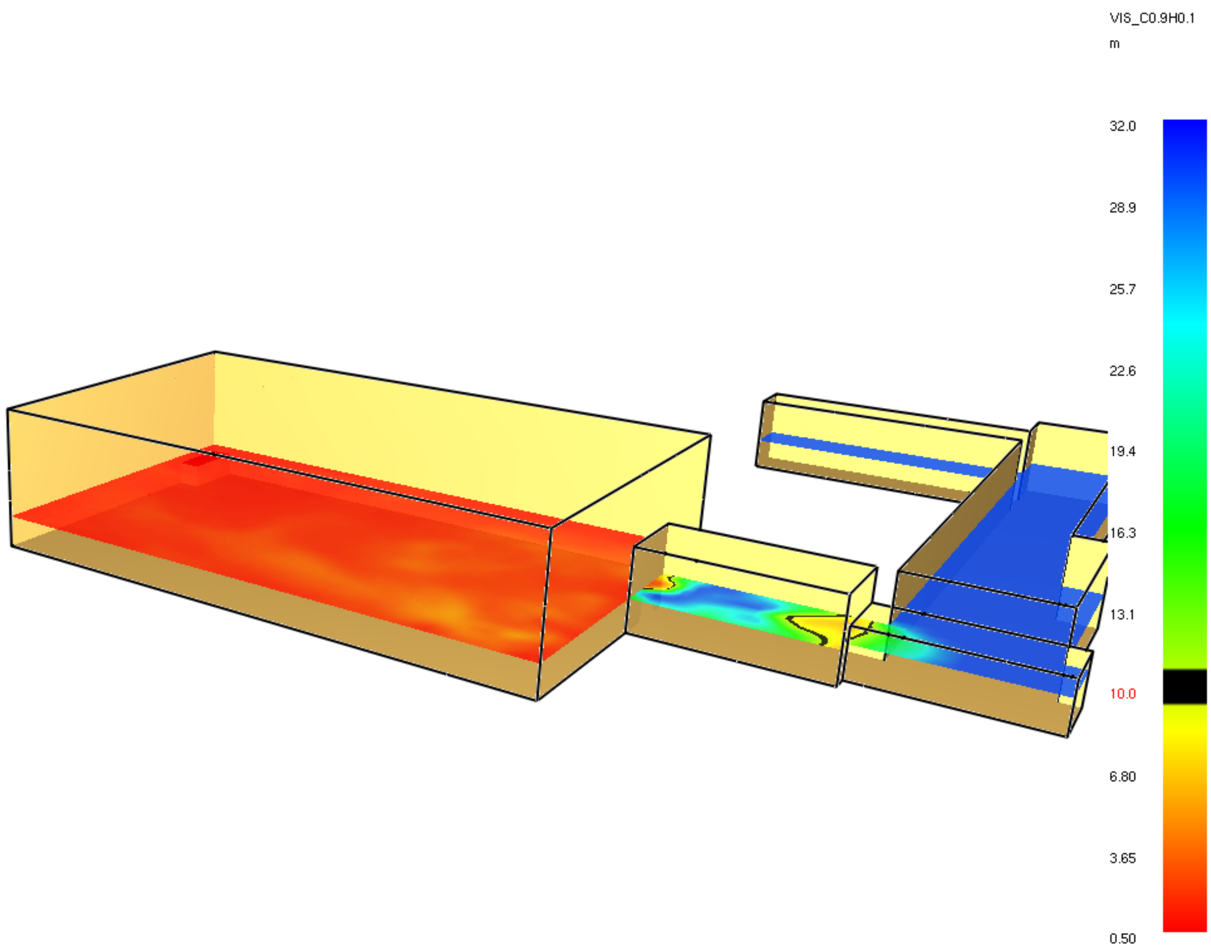

Figure 46 –Gymnasium Corridor at 380 Seconds Showing Smoke Reservoir Effect

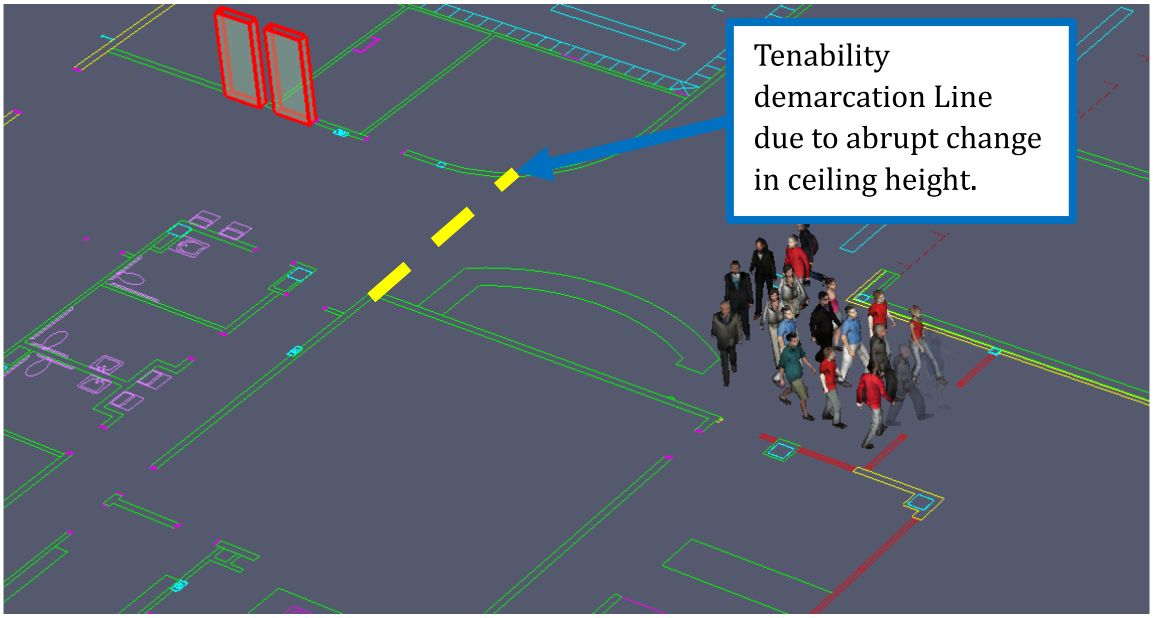

Figure 47 – Effect of Discontinuity in Ceiling Height

For both the sauna fire and the foam mat fire the tenability limits for CO concentration were never reached. Due to the short duration of the event occupants were not exposed to CO in sufficient quantity to be untenable.

4.5 Summary of Performance-Based Analysis

This section evaluated the life safety features of the fitness center from a performance-based standpoint. In this section two fire scenarios were evaluated. The ASET as computed using FDS was compared to the RSET to determine if a sufficient safety margin existed in order to protect the occupants of the building. Three tenability criteria were used to evaluate the performance of the buildings fire protection systems. In the first scenario the RSET was determined to be 600 seconds. The FDS model shows that visibility dropped below tenable conditions in about half the time required to safely egress the building. In the second scenario the RSET was determined to be 525 seconds, and the FDS model shows that the conditions at 2 of the 3 exits become untenable at 230 seconds, exposing occupants to untenable conditions for 30 seconds. This shows that the building fails the performance based analysis.

5 OVERALL CONCLUSIONS

5.1 Prescriptive Analysis

The prescriptive analysis of the fitness center evaluated whether the building met UBC, IBC, and NFPA codes in structural fire protection, occupancy and egress, fire detection and notification, fire suppression, and building smoke control. During this analysis it was determined that the fitness center meets all the prescriptive requirements of the UBC it was designed under and most of the requirements of the current IBC. The structural elements of the building are sufficiently protected from the effects of fire to ensure the safety of the occupants during the course of a fire emergency. Under the current IBC the building occupancy would be slightly lower that that allowed under the UBC but this difference is insignificant, however, the exit capacity as calculated exceeded occupant load as required by the code. The location and spacing of both fire detectors and notification appliances was found in compliance with the code, and the fire suppression system is sufficient in sprinkler type, water demand, and water supply. Smoke control is managed through the use of in-duct smoke detectors which will shut down the HVAC system when triggered.

5.2 Performance-Based Analysis

Two fire scenarios were analyzed in the performance based analysis, a fire originating in the sauna, and a fire started on foam tumbling mats stored behind a partition in the gymnasium. The fitness center fails the performance-based criteria for both simulations. In the sauna fire simulation there was insufficient time for occupants to exit the building before conditions became untenable. Occupants were able to exit the locker room in sufficient time, however, once in the corridor exits from the building were rapidly blocked by deteriorating conditions. At 300 seconds all the major exits from the building were blocked due to low visibility. This is nearly 100 seconds before the building is completely evacuated. Temperature and toxicity were not factors in this fire scenario. By contrast, in the foam fire scenario occupants not in the same room as the fire egressed safely, but the fire developed too quickly within the gymnasium for occupants in the gym to safely egress. At 380 seconds conditions are completely untenable in the gym due to visibility, yet some of the occupants remain in the gym because of queuing. Temperature and toxicity were not factors in this fire scenario. In both cases the rapid development of smoke and the limited visibility that results prevented significant numbers of occupants from safely evacuating the facility. Due to occupants being unable to safely egress before conditions became untenable, the following recommendations have been made to ensure the safety of occupants.

6 RECOMMENDATIONS

Failure of the performance based design scenarios was due primarily to a lack of positive administrative controls. In both cases casualties could have been severely limited or eliminated altogether if tighter controls were in place. The fire in the gymnasium would not have been as severe if foam gym mats were not allowed to be stored in that location and in those quantities. In the sauna scenario smoke escaping into the room could have been curtailed if the door did not jam in the open position. Following is a list of recommendations that will aid in preventing these and other scenarios.

- Remove or distribute foam mats throughout the facility to reduce the fuel load.
- Clear corridors of exercise equipment.
- Multiple storage areas have been converted to offices. These should remain storage areas so that clutter doesn't accumulate in the halls and fitness areas.
- Remove non-slip mats from in front of sauna door.
- Clean out laundry room, remove stored items, and lockers.

7 REFERENCES

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SFPE Handbook for Fire Protection Engineering, 5th edition. (2016). Society of Fire Protection Engineers: Springer

APPENDIX A: Hydraulic Calculations

SOURCE DUTY AT PIPE 1 = 1530.5 L/min at 5.555 bar

Operating sprinkler heads / nozzles / hosereels / hydrants

Head no	"K" factor	Flows in L/min Minimum	Flows in L/min Actual	Area m2	Density mm/min Minimum	Density mm/min Actual	Height m	Pipe to head No	Pipe to head mm	Pipe to head Vel	MRH	Pressures bars Minimum	Pressures bars Normal	Pressures bars Vel	Pressures bars Total
1	80.0	60.0	94.3	12.000	5.00	7.86	4.420	42	25	5.3		0.563	1.390		1.390
2	80.0	60.0	91.3	12.000	5.00	7.61	4.420	50	25	2.5		0.563	1.302		1.302
3	80.0	60.0	77.0	12.000	5.00	6.41	4.420	62	25	6.7		0.563	0.926		0.926
4	80.0	60.0	76.5	12.000	5.00	6.37	4.420	63	25	6.6		0.563	0.914		0.914
5	80.0	60.0	81.4	12.000	5.00	6.79	4.420	64	25	5.2		0.563	1.036		1.036
6	80.0	60.0	65.7	12.000	5.00	5.47	4.420	68	25	4.4		0.563	0.674		0.674
7	80.0	60.0	60.8	12.000	5.00	5.06	4.420	69	25	2.4		0.563	0.577		0.577
8	80.0	60.0	60.4	12.000	5.00	5.04	4.420	70	25	0.6		0.563	0.570		0.570
9	80.0	60.0	62.0	12.000	5.00	5.16	4.420	71	25	1.3		0.563	0.600		0.600
10	80.0	60.0	69.7	12.000	5.00	5.81	4.420	72	25	3.1		0.563	0.759		0.759
11	80.0	60.0	84.2	12.000	5.00	7.02	4.420	73	25	5.2		0.563	1.109		1.109
12	80.0	60.0	65.3	12.000	5.00	5.44	4.420	74	25	4.3		0.563	0.665		0.665
13	80.0	60.0	60.4	12.000	5.00	5.03	4.420	75	25	2.4		0.563	0.569		0.569
14	80.0	60.0	60.0	12.000	5.00	5.00	4.420	76	25	0.6	Yes	0.563	0.563		0.563
15	80.0	60.0	61.5	12.000	5.00	5.13	4.420	77	25	1.2		0.563	0.592		0.592
16	80.0	60.0	69.2	12.000	5.00	5.77	4.420	78	25	3.1		0.563	0.749		0.749
17	80.0	60.0	83.6	12.000	5.00	6.97	4.420	79	25	5.2		0.563	1.093		1.093
18	80.0	60.0	72.4	12.000	5.00	6.03	4.420	80	25	2.8		0.563	0.819		0.819
19	80.0	60.0	72.0	12.000	5.00	6.00	4.420	81	25	0.6		0.563	0.809		0.809
20	80.0	60.0	74.6	12.000	5.00	6.22	4.420	82	25	1.6		0.563	0.870		0.870
21	80.0	60.0	88.2	12.000	5.00	7.35	4.420	83	25	3.8		0.563	1.215		1.215

Pipe no	Size mm	Type	H-W "C"	Bore mm	Flow L/min	Length m	EL	45	LT	TE	GV	GL	AV	BV	CV	AN	ST	Total Eq Length m	Vel m/s	Static m	Height m	Pressures bars Start	Frict	Vel	End
1	80	S40	120	77.90	1530.5	4.420	1				1							6.860	5.4	4.420	4.420	5.555	-0.283		4.839
2	80	S40	120	77.90	1530.5	0.506	1											2.636	5.4	0.000	4.420	4.839	-0.109		4.730
3	80	S40	120	77.90	1530.5	26.175	1											28.305	5.4	0.000	4.420	4.730	-1.168		3.563
4	80	S40	120	77.90	1530.5	8.563	1											10.693	5.4	0.000	4.420	3.563	-0.441		3.122
5	80	S40	120	77.90	1530.5	0.406	1											2.536	5.4	0.000	4.420	3.122	-0.105		3.017
6	80	S40	120	77.90	1530.5	2.740	1											4.870	5.4	0.000	4.420	3.017	-0.201		2.816
7	80	S40	120	77.90	1530.5	2.083				1								6.653	5.4	0.000	4.420	2.816	-0.274		2.542
8	25	S40	120	26.60	105.4	1.000	1											1.610	3.2	0.000	4.420	2.542	-0.088		2.454
9	25	S40	120	26.60	105.4	16.662												16.662	3.2	0.000	4.420	2.454	-0.912		1.542
10	25	S40	120	26.60	105.4	1.000	1											1.610	3.2	0.000	4.420	1.542	-0.088		1.454
11	80	S40	120	77.90	105.4	0.154				1								4.724	0.4	0.000	4.420	1.454	-0.001		1.452
12	80	S40	120	77.90	201.5	0.154				1								4.724	0.7	0.000	4.420	1.452	-0.005		1.448
13	80	S40	120	77.90	289.1	0.154				1								4.724	1.0	0.000	4.420	1.448	-0.009		1.439
14	80	S40	120	77.90	368.9	0.154				1								4.724	1.3	0.000	4.420	1.439	-0.014		1.425
15	80	S40	120	77.90	441.5	0.154				1								4.724	1.5	0.000	4.420	1.425	-0.020		1.405
16	80	S40	120	77.90	507.8	0.154				1								4.724	1.8	0.000	4.420	1.405	-0.025		1.380
17	80	S40	120	77.90	568.8	0.154				1								4.724	2.0	0.000	4.420	1.380	-0.031		1.349
18	80	S40	120	77.90	625.3	0.154				1								4.724	2.2	0.000	4.420	1.349	-0.037		1.312
19	80	S40	120	77.90	1425.1	0.154				1								4.724	5.0	0.000	4.420	2.542	-0.171		2.371
20	80	S40	120	77.90	1329.0	0.154				1								4.724	4.6	0.000	4.420	2.371	-0.150		2.221
21	80	S40	120	77.90	1241.4	0.154				1								4.724	4.3	0.000	4.420	2.221	-0.132		2.089
22	80	S40	120	77.90	1161.6	0.154				1								4.724	4.1	0.000	4.420	2.089	-0.117		1.972
23	80	S40	120	77.90	1089.0	0.154				1								4.724	3.8	0.000	4.420	1.972	-0.104		1.868
24	80	S40	120	77.90	1022.7	0.154				1								4.724	3.6	0.000	4.420	1.868	-0.092		1.775
25	80	S40	120	77.90	961.7	0.154				1								4.724	3.4	0.000	4.420	1.775	-0.082		1.693
26	80	S40	120	77.90	905.2	0.154				1								4.724	3.2	0.000	4.420	1.693	-0.074		1.619
27	25	S40	120	26.60	-96.2	1.000	1											1.610	2.9	0.000	4.420	1.452	0.074		1.527
28	25	S40	120	26.60	-87.6	1.000	1											1.610	2.6	0.000	4.420	1.448	0.063		1.510
29	25	S40	120	26.60	-79.7	1.000	1											1.610	2.4	0.000	4.420	1.439	0.053		1.492
30	25	S40	120	26.60	-72.6	1.000	1											1.610	2.2	0.000	4.420	1.425	0.044		1.469
31	25	S40	120	26.60	-66.3	1.000	1											1.610	2.0	0.000	4.420	1.405	0.037		1.443
32	25	S40	120	26.60	-61.0	1.000	1											1.610	1.8	0.000	4.420	1.380	0.032		1.412
33	25	S40	120	26.60	-56.5	1.000	1											1.610	1.7	0.000	4.420	1.349	0.028		1.377
34	25	S40	120	26.60	9.0	1.000	1											1.610	0.3	0.000	4.420	1.312	-0.001		1.311
35	25	S40	120	26.60	96.2	1.000	1											1.610	2.9	0.000	4.420	2.371	-0.074		2.297
36	25	S40	120	26.60	87.6	1.000	1											1.610	2.6	0.000	4.420	2.221	-0.063		2.158
37	25	S40	120	26.60	79.7	1.000	1											1.610	2.4	0.000	4.420	2.089	-0.053		2.036
38	25	S40	120	26.60	72.6	1.000	1											1.610	2.2	0.000	4.420	1.972	-0.044		1.927
39	25	S40	120	26.60	66.3	1.000	1											1.610	2.0	0.000	4.420	1.868	-0.037		1.830
40	25	S40	120	26.60	61.0	1.000	1											1.610	1.8	0.000	4.420	1.775	-0.032		1.743
41	25	S40	120	26.60	56.5	1.000	1											1.610	1.7	0.000	4.420	1.693	-0.028		1.665
42	25	S40	120	26.60	176.6	1.000	1											1.610	5.3	0.000	4.420	1.619	-0.229		1.390
43	25	S40	120	26.60	96.2	16.662												16.662	2.9	0.000	4.420	2.297	-0.770		1.527
44	25	S40	120	26.60	87.6	16.662												16.662	2.6	0.000	4.420	2.158	-0.648		1.510
45	25	S40	120	26.60	79.7	16.662												16.662	2.4	0.000	4.420	2.036	-0.544		1.492
46	25	S40	120	26.60	72.6	16.662												16.662	2.2	0.000	4.420	1.927	-0.458		1.469
47	25	S40	120	26.60	66.3	16.662												16.662	2.0	0.000	4.420	1.830	-0.387		1.443
48	25	S40	120	26.60	61.0	16.662												16.662	1.8	0.000	4.420	1.743	-0.331		1.412
49	25	S40	120	26.60	56.5	16.662												16.662	1.7	0.000	4.420	1.665	-0.288		1.377
50	25	S40	120	26.60	82.2	2.540												2.540	2.5	0.000	4.420	1.390	-0.088		1.302
51	25	S40	120	26.60	-9.0	2.997												2.997	0.3	0.000	4.420	1.302	0.002		1.304
52	25	S40	120	26.60	-9.0	2.997												2.997	0.3	0.000	4.420	1.304	0.002		1.306
53	25	S40	120	26.60	-9.0	2.997												2.997	0.3	0.000	4.420	1.306	0.002		1.307
54	25	S40	120	26.60	-9.0	2.997												2.997	0.3	0.000	4.420	1.307	0.002		1.309
55	25	S40	120	26.60	-9.0	2.540												2.540	0.3	0.000	4.420	1.309	0.001		1.311
56	80	S40	120	77.90	616.3	0.154				1								4.724	2.2	0.000	4.420	1.312	-0.036		1.275
57	80	S40	120	77.90	394.2	0.154				1								4.724	1.4	0.000	4.420	1.275	-0.016		1.260
58	80	S40	120	77.90	173.5	0.154	1											2.284	0.6	0.000	4.420	1.260	-0.002		1.258
59	80	S40	120	77.90	728.6	0.154				1								4.724	2.5	0.000	4.420	1.619	-0.049		1.570
60	80	S40	120	77.90	470.9	0.154				1								4.724	1.6	0.000	4.420	1.570	-0.022		1.548
61	80	S40	120	77.90	215.1	0.154	1											2.284	0.8	0.000	4.420	1.548	-0.002		1.545
62	25	S40	120	26.60	222.1	1.000	1											1.610	6.7	0.000	4.420	1.275	-0.350		0.926
63	25	S40	120	26.60	220.7	1.000	1											1.610	6.6	0.000	4.420	1.260	-0.346		0.914
64	25	S40	120	26.60	173.5	1.000	1											1.610	5.2	0.000	4.420	1.258	-0.222		1.036
65	25	S40	120	26.60	215.1	1.000	1											1.610	6.5	0.000	4.420	1.545	-0.330		1.215
66	25	S40	120	26.60	255.8	1.000	1											1.610	7.7	0.000	4.420	1.548	-0.454		1.093
67	25	S40	120	26.60	257.7	1.000	1											1.610	7.7	0.000	4.420	1.570	-0.461		1.109
68	25	S40	120	26.60	145.1	2.540												2.540	4.4	0.000	4.420	0.926	-0.251		0.674
69	25	S40	120	26.60	79.4	2.997												2.997	2.4	0.000	4.420	0.674	-0.097		0.577
70	25	S40	120	26.60	18.6	2.997												2.997	0.6	0.000	4.420	0.577	-0.007		0.570
71	25	S40	120	26.60	-41.8	2.997												2.997	1.3	0.000	4.420	0.570	0.030		0.600
72	25	S40	120	26.60	-103.7	2.997												2.997	3.1	0.000	4.420	0.600	0.159		0.759
73	25	S40	120	26.60	-173.5	2.540												2.540	5.2	0.000	4.420	0.759	0.350		1.109
74	25	S40	120	26.60	144.2	2.540												2.540	4.3	0.000	4.420	0.914	-0.248		0.665

Pipe no	Size mm	Type	H-W "C"	Bore mm	Flow L/min	Length m	E4LTGGABCAS L5TEVLVVVNT	Total Eq Length m	Vel m/s	Static m	Height m	Pressures bars Start	Frict	Vel	End
76	25	s40	120	26.60	18.6	2.997		2.997	0.6	0.000	4.420	0.569	-0.007		0.562
77	25	s40	120	26.60	-41.4	2.997		2.997	1.2	0.000	4.420	0.562	0.029		0.592
78	25	s40	120	26.60	-102.9	2.997		2.997	3.1	0.000	4.420	0.592	0.157		0.749
79	25	s40	120	26.60	-172.1	2.540		2.540	5.2	0.000	4.420	0.749	0.345		1.093
80	25	s40	120	26.60	92.1	4.470	1	5.080	2.8	0.000	4.420	1.036	-0.217		0.819
81	25	s40	120	26.60	19.7	4.064		4.064	0.6	0.000	4.420	0.819	-0.010		0.809
82	25	s40	120	26.60	-52.3	4.064		4.064	1.6	0.000	4.420	0.809	0.061		0.870
83	25	s40	120	26.60	-126.9	4.470		4.470	3.8	0.000	4.420	0.870	0.345		1.215

APPENDIX B: Inspection, Testing, and Maintenance Requirements for Fire Alarm Systems

Table 14.3.1 Visual Inspection

Component	Initial Acceptance	Periodic Frequency	Method	Reference
1. All equipment	X	Annual	Ensure there are no changes that affect equipment performance. Inspect for building modifications, occupancy changes, changes in environmental conditions, device location, physical obstructions, device orientation, physical damage, and degree of cleanliness.	14.3.4
2. Control equipment:				
(a) Fire alarm systems monitored for alarm, supervisory, and trouble signals			Verify a system normal condition.	
(1) Fuses	X	Annual		
(2) Interfaced equipment	X	Annual		
(3) Lamps and LEDs	X	Annual		
(4) Primary (main) power supply	X	Annual		
(5) Trouble signals	X	Semiannual		
(b) Fire alarm systems unmonitored for alarm, supervisory, and trouble signals			Verify a system normal condition.	
(1) Fuses	X	Weekly		
(2) Interfaced equipment	X	Weekly		
(3) Lamps and LEDs	X	Weekly		
(4) Primary (main) power supply	X	Weekly		
(5) Trouble signals	X	Weekly		
3. Reserved				
4. Supervising station alarm systems — transmitters			Verify location, physical condition, and a system normal condition.	
(a) Digital alarm communicator transmitter (DACT)	X	Annual		
(b) Digital alarm radio transmitter (DART)	X	Annual		
(c) McCulloh	X	Annual		
(d) Radio alarm transmitter (RAT)	X	Annual		
(e) All other types of communicators	X	Annual		
5. In-building fire emergency voice/alarm communications equipment	X	Semiannual	Verify location and condition.	
6. Reserved				
7. Reserved				
8. Reserved				
9. Batteries			Inspect for corrosion or leakage. Verify tightness of connections. Verify marking of the month/year of manufacture (all types).	10.6.10
(a) Lead-acid	X	Monthly	Visually inspect electrolyte level.	
(b) Nickel-cadmium	X	Semiannual		
(c) Primary (dry cell)	X	Monthly		
(d) Sealed lead-acid	X	Semiannual		
10. Reserved				

(continues)

Table 14.3.1 *Continued*

	Component	Initial Acceptance	Periodic Frequency	Method	Reference
11.	Remote annunciators	X	Semiannual	Verify location and condition.	
12.	Notification appliance circuit power extenders	X	Annual	Verify proper fuse ratings, if any. Verify that lamps and LEDs indicate normal operating status of the equipment.	10.6
13.	Remote power supplies	X	Annual	Verify proper fuse ratings, if any. Verify that lamps and LEDs indicate normal operating status of the equipment.	10.6
14.	Transient suppressors	X	Semiannual	Verify location and condition.	
15.	Reserved				
16.	Fiber-optic cable connections	X	Annual	Verify location and condition.	
17.	Initiating devices			Verify location and condition (all devices).	
	(a) Air sampling				
	(1) General	X	Semiannual	Verify that in-line filters, if any, are clean.	17.7.3.6
	(2) Sampling system piping and sampling ports	X		Verify that sampling system piping and fittings are installed properly, appear airtight, and are permanently fixed. Confirm that sampling pipe is conspicuously identified. Verify that sample ports or points are not obstructed.	17.7.3.6
	(b) Duct detectors				
	(1) General	X	Semiannual	Verify that detector is rigidly mounted. Confirm that no penetrations in a return air duct exist in the vicinity of the detector. Confirm the detector is installed so as to sample the airstream at the proper location in the duct.	17.7.5.5
	(2) Sampling tube	X		Verify proper orientation. Confirm the sampling tube protrudes into the duct in accordance with system design.	17.7.5.5
	(c) Electromechanical releasing devices	X	Semiannual		
	(d) Fire extinguishing system(s) or suppression system(s) switches	X	Semiannual		
	(e) Manual fire alarm boxes	X	Semiannual		
	(f) Heat detectors	X	Semiannual		
	(g) Radiant energy fire detectors	X	Quarterly	Verify no point requiring detection is obstructed or outside the detector's field of view.	17.8
	(h) Video image smoke and fire detectors	X	Quarterly	Verify no point requiring detection is obstructed or outside the detector's field of view.	17.7.7; 17.11.5
	(i) Smoke detectors (excluding one- and two-family dwellings)	X	Semiannual		
	(j) Projected beam smoke detectors	X	Semiannual	Verify beam path is unobstructed.	
	(k) Supervisory signal devices	X	Quarterly		
	(l) Waterflow devices	X	Quarterly		
18.	Reserved				

Table 14.3.1 *Continued*

Component	Initial Acceptance	Periodic Frequency	Method	Reference
19. Combination systems			Verify location and condition (all types).	
(a) Fire extinguisher electronic monitoring device/systems	X	Semiannual		
(b) Carbon monoxide detectors/systems	X	Semiannual		
20. Fire alarm control interface and emergency control function interface	X	Semiannual	Verify location and condition.	
21. Guard's tour equipment	X	Semiannual	Verify location and condition.	
22. Notification appliances			Verify location and condition (all appliances).	
(a) Audible appliances	X	Semiannual		
(b) Audible textual notification appliances	X	Semiannual		
(c) Visible appliances				
(1) General	X	Semiannual		18.5.5
(2) Candela rating	X		Verify that the candela rating marking agrees with the approved drawings.	18.5.5
23. Exit marking audible notification appliances	X	Semiannual	Verify location and condition.	
24. Reserved				
25. Area of refuge two-way communication system	X	Annual	Verify location and condition.	
26. Reserved				
27. Supervising station alarm systems — receivers				
(a) Signal receipt	X	Daily	Verify receipt of signal.	
(b) Receivers	X	Annual	Verify location and normal condition.	
28. Public emergency alarm reporting system transmission equipment			Verify location and condition.	
(a) Publicly accessible alarm box	X	Semiannual		
(b) Auxiliary box	X	Annual		
(c) Master box				
(1) Manual operation	X	Semiannual		
(2) Auxiliary operation	X	Annual		
29. Reserved				
30. Mass notification system				
(a) Monitored for integrity			Verify a system normal condition.	
(1) Control equipment				
(i) Fuses	X	Annual		
(ii) Interfaces	X	Annual		
(iii) Lamps/LED	X	Annual		
(iv) Primary (main) power supply	X	Annual		
(2) Secondary power batteries	X	Annual		
(3) Initiating devices	X	Annual		
(4) Notification appliances	X	Annual		

(continues)

Table 14.3.1 *Continued*

Component	Initial Acceptance	Periodic Frequency	Method	Reference
30. Mass notification system *(continued)*				
(b) Not monitored for integrity; installed prior to adoption of the 2010 edition			Verify a system normal condition.	
(1) Control equipment				
(i) Fuses	X	Semiannual		
(ii) Interfaces	X	Semiannual		
(iii) Lamps/LED	X	Semiannual		
(iv) Primary (main) power supply	X	Semiannual		
(2) Secondary power batteries	X	Semiannual		
(3) Initiating devices	X	Semiannual		
(4) Notification appliances	X	Semiannual		
(c) Antenna	X	Annual	Verify location and condition.	
(d) Transceivers	X	Annual	Verify location and condition.	