Life Safety and Fire Analysis
Aircraft Hangar

FPE596 Culminating Project

Fire Protection Engineering

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Statement of Disclaimer

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KEYWORDS

Aircraft Hangar, Life Safety Analysis, High Expansion Foam, Pool Fire, Performance Based Design, Pathfinder, FDS

Executive Summary

A hangar originally built in 1958 then modified and expanded over the years was evaluated using both the prescriptive requirements and a performance analysis. For the prescriptive analysis the building was evaluated against the 2015 International Building Code and the current NFPA codes and in a few cases the Department of Defense (DoD) Unified Facilities Criteria (UFC). During the prescriptive analysis a few areas were identified that do not meet the current codes due to areas being broken up into separate rooms and hallways and rooms being separated by security doors that only allow unobstructed travel in one direction. These modifications over the years have created a few areas that have a common travel paths and dead ends that exceed the requirements as set forth by NFPA 101 Life safety code. Due to the size of the hangar the notification devices installed do not meet the audibility or illumination requirements. It is recommended that the rotating beacons be installed per the new UFC 4-211-01 requirements.

For the performance analysis a pool fire created from jet fuel was ignited both under the aircraft and in the vicinity of an aircraft. The hangar was then evaluated for both life safety by verifying that the available safe egress time (ASET) was greater than the required safe egress time (RSET). The RSET was calculated using both hand calculations and a pathfinder computer model. The ASET was determined using a NIST Fire Dynamic Simulator (FDS). The FDS modeling showed that the ASET was significantly greater than the RSET thus there was no issue with life safety. Asset protection from the fire scenarios chosen was not as promising. For both fire scenarios chosen in the hangar the aircraft suffered some damage. It was also determined from the modeling that the current activation sequence of the high expansion foam (HEF) system, using the sprinkler flow switches to activate the system, would be ineffective due to the delay in activating the sprinklers at the 70 ft ceiling level and the mechanical timer in the flow switch. A better way to activate the HEF system would be using multiple optical flame detectors as now required by UFC 4-211-01.

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1 Introduction

The building being analyzed is an aircraft maintenance hangar that was built in 1958 and modified over the years for various uses. The most recent change was from a manufacturing facility back to a hangar for flight test. The hangar is currently rated for fueled aircraft maintenance and storage. The building is approximately 120,000 square feet with 60,000 square feet of it as a hangar bay and the remaining area office and support areas. There are two additional buildings in close proximity to the hangar which will be considered part of the building to be analyzed. These buildings are under the overhang of the main building. One building is separated from the main building by 4 feet and is used as a machine shop. This building is 3,600 square feet. The other building houses an electrical substation and is 1,100 square feet. Figure 1-1 and Figure 1-2 show the exterior of the hangar in 1961 and how it looks today.

The hangar building has 3 levels of manufacturing or office/support space. Over the years this area has also changes significantly. In the early years it was used primarily for manufacturing and production support with open ceilings and metal partitions. Today all of the space is used for offices, conference rooms, control rooms, flight simulator, instrumentation, or test support and has a drop ceiling with fabric covered partitions (Figure 1-3). The hangar bay interior has not changed significantly over the years other than being expanded it remains an open area with exposed roof trusses (Figure 1-4).

Figure 1-1: Hangar in 1961

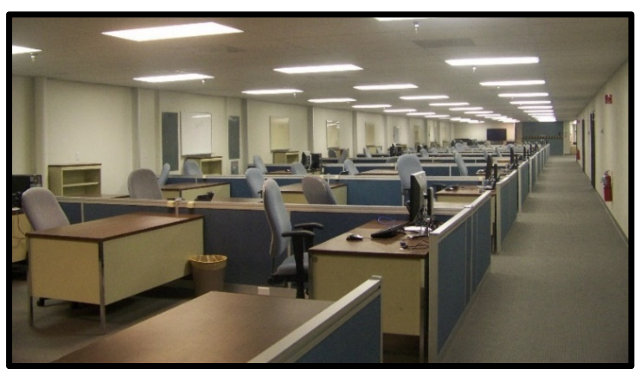
North Side

(b) NE Corner

(c) East Side

(d) SW Corner

Figure 1-2: Hangar Today



(a) 1958

(b) Today

Figure 1-3: Second Floor Office & Support area 1958 and today

Figure 1-4: Hangar bay today

The main building was built in 1958 and consisted of low portion of the hangar bay and the areas to the east which were used as manufacturing and support shops at the time. The original building has an overhang where aircraft were parked for servicing (Figure 1-1). In the 1970s the building was expanded to support space shuttle final assembly with the addition of the north high bay portion of the hangar. The office area to the east was also extended to the north and mechanical/electrical rooms were added to the east of the office area (Figure 1-2). At some time later (late 70's or 80's) the two story addition to the north and the machine shop and electrical substation were added. Figure 1-5 shows the growth history of the building.

When the space shuttle program ended the building was no longer needed for manufacturing and was transformed back to an aircraft hangar for flight testing in 2014. The electrical installations in the hangar were modified and upgraded to meet the NFPA 70 and 409 requirements for a fueled aircraft hangar. The fire suppression system was upgraded with the addition of a high expansion foam (HEF) system. As part of the HEF system, an addition to the west side was added to house the foam tank and the required fire pumps.

There is a sprinkler system throughout the building. The hangar bay has both a wet pipe sprinkler and a high expansion foam system installed to support the storage of fueled aircraft. A fire alarm and mass notification system (MNS) are installed in the building which reports to the local fire dispatch. The MNS system is not in the hangar high bay of the building due to its poor acoustics.

Access to the building is controlled at the fence line to the facility. All personnel in the building have been trained on the hazards in the facility and the hangar bay to include fire emergencies and the hazards associated with the high expansion foam system. Guests to the facility are escorted at all times by permanently assigned occupants.

A prescriptive life safety and fire analysis is being performed on this building using the current NFPA codes, Unified Facility Codes (UFC) and International building code (IBC). After the prescriptive analysis is completed a performance analysis will be conducted looking at both life safety and asset protection in the hangar. Computer simulations using Pathfinder to determine the egress time and a Fire Dynamics Simulator (FDS) to look at tenability conditions and asset protection in the hangar bay will be performed.

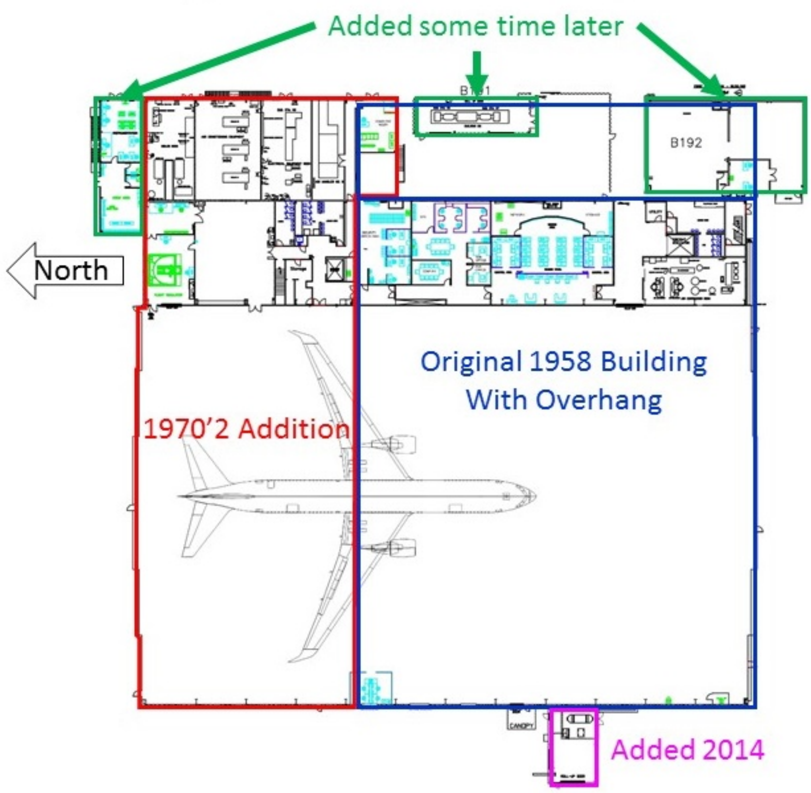


Figure 1-5: Construction History

2 Building Occupancy Classification per NFPA 101

The building is classified as "industrial" by the LSC and a Group I hangar by NFPA 409. In addition to the hangar bay, the building has offices, conference rooms, break/lunch areas, and storage. These would fall into "business", "assembly" and "storage". These areas are not all separated by a fire wall thus the occupancy in this area would be considered "Mixed Occupancy" per LSC section 6.1.14.3. The three floors and the mechanical area are not uniformly spaced apart. The second floor is 28 feet above the ground floor and the third floor is 14 feet above the second floor (42 feet from the ground level). The small room outside to the north is 17 feet above the ground level thus between the ground and second floors. It is shown and discussed as part of the second floor. The upper mechanical rooms are 20.5 feet above the ground floor thus also lower than the second floor. These rooms are only accessible from the exterior stairs on the east side of the building. These rooms will also be discussed as part of the second floor.

2.1 Ground Floor

Figure 2-1 shows how the ground floor is divided for occupancy use. The main area on the ground floor is the hangar bay (18) which has a 50 foot ceiling on the south 200 feet and a 75 foot ceiling on the north 100 feet. Areas 1-4 are flight test support areas. Areas 5-8 are mechanical rooms and electrical rooms. Area 9 is a telecom room/computer network area. Areas 10, 11 and 12 are offices consisting of cubicles with low walls or 8 foot walls that extend to the drop ceiling but not the true ceiling. Area 13 is a small conference room primarily used by the occupants of room 12. Area 14 is an information laboratory used for researching distributed networks and virtual flight testing. The occupancy of this area is assessed to be "business". The floor has two men's restrooms and one woman's rest room. The floor also has an air compressor room which has a roll-up door that is held open by a fusible link thus will close automatically when a fire is present.

The floor has two exit corridors. The exit corridor to the north leads from the center exit stairs to the exterior of the building on the east side.

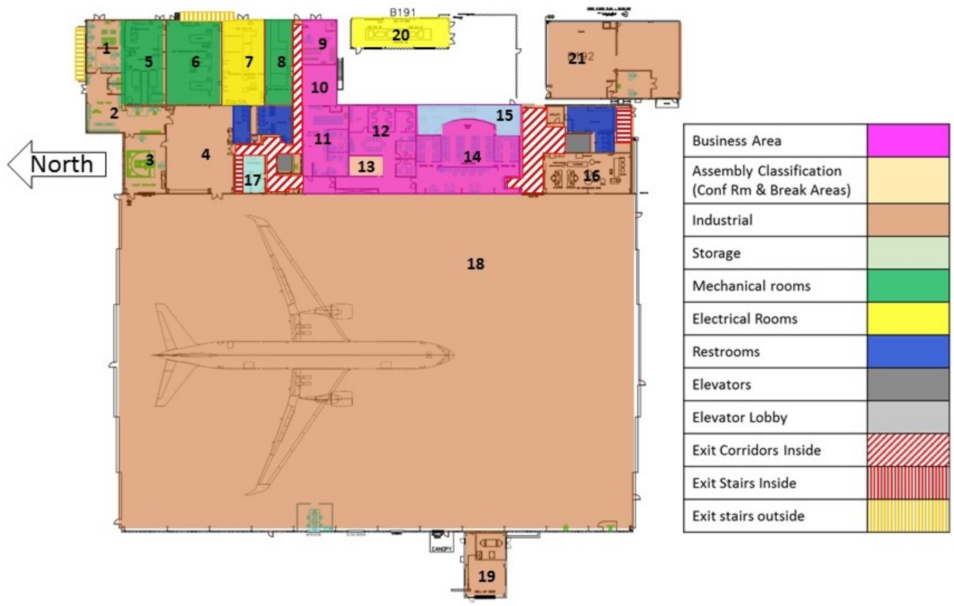


Figure 2-1: Ground Floor Occupancy Type

2.2 Second Floor

Figure 2-2 shows how the second floor is divided for occupancy use. Area 1 is external to the main building and is only accessible from the outside either from the second floor exit door via down the exterior stairs or up the exterior stairs from outside. Areas 2 and 3 are offices consisting of either low cubical walls or 8 foot walls that extent to the drop ceiling. These walls do not reach the true ceiling, which is 14 feet. Areas 4 & 6 are conference rooms and 5 & 7 are break areas both classified as "assembly". Area 8 is a small storage room. Electrical room 10 and the mechanical rooms 11 & 12 are only accessible from outside via the exterior stairs on the east side. The floor is serviced by both passenger and freight elevators. There are two men's and woman's restroom restrooms on this floor near the center stairs and at the south end. There are three exits stairs servicing this floor, the north exit stairs being external to the building.

Figure 2-2: Second Floor Occupancy Type

2.3 Third Floor

Figure 2-3 shows how the third floor is divided for occupancy use. The third floor is very similar to the second floor. Areas 1 is an office area and areas 2, 3 & 4 are computer and data processing rooms. These rooms are secure areas with limited access from the elevator lobby. Area 5 is an office area which are divided up, either with low partition walls, or 8 foot walls that extent past the drop ceiling but not to the true ceiling. Areas 6, 7 and 8 are conference rooms and area 9 is a break area. Areas 5 to 9 are also access controlled areas form the elevator lobby. There are three exits stairs servicing this floor, the north exit stairs being external to the building.

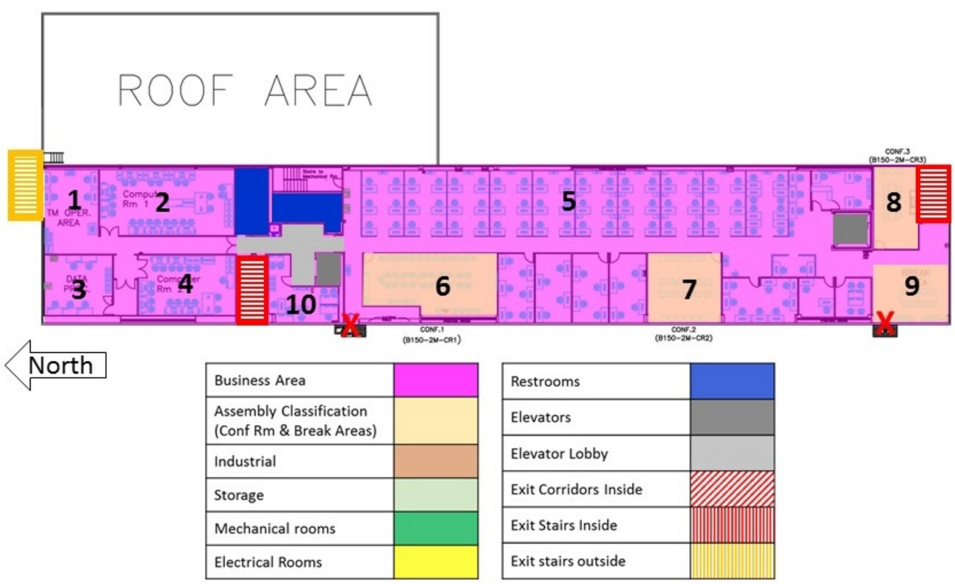


Figure 2-3: Third Floor Occupancy Type

2.4 Use and Occupancy Classification per the 2015 IBC

The Hangar portion of the building is classified as Storage (S-1) by the IBC Section 311.2 since it is used for aircraft storage and maintenance. The office portion classified as Business (B) per IBC section 304. Since the conference rooms are small and incidental to the main purpose of the building they are also classified as B per Section 303.1.2. The boiler, electrical, and chiller rooms are incidental to the main purpose of the building and also classified as B per Section 509. The machine shop adjacent to the main building is classified as Factory (F-1) per section 306.2 but could be classified as F-2 since it primarily machines metal but since there is oils and lubricants involved it would better to classify it as F-1. Figure 2-4 shows the layout of the building and the Classifications of the areas.

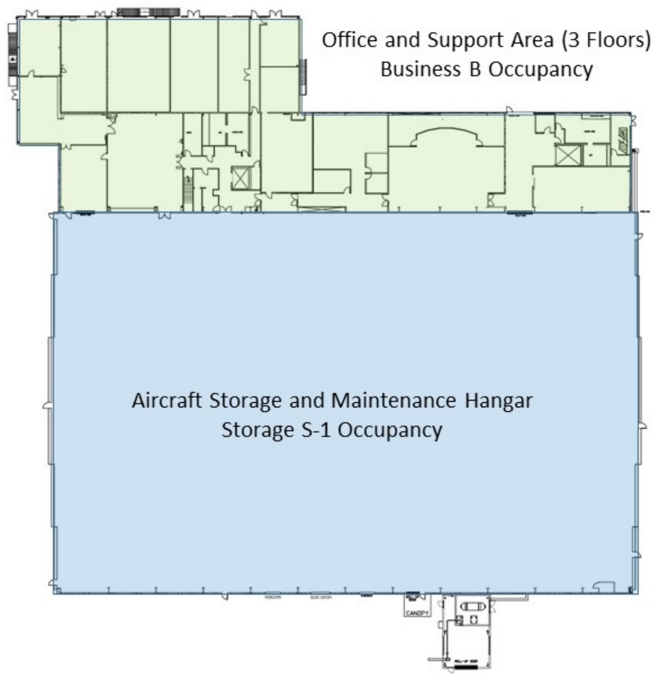


Figure 2-4: Use and Occupancy Type per the 2015 IBC

Now that the use and occupancy of the various parts of the building have been determined let's look at the construction requirements for these occupancies to see if the building meets the current code requirements.

3 Building Construction Requirements per IBC

3.1 Hangar and Office building construction type

The building has a steel frame work with most exterior walls being cement for the first 7 feet then corrugated 20 gage steel sheeting with insulation the remaining way to the roof line. There are a few exterior walls around the office area that are cement block the entire way to the roof line. The interior wall separating the hangar space from the office space is a cement block wall from floor to ceiling with the columns on the office side of the wall. The interior steel structure does not have any fire proofing except where there is a sheet rock wall built around the columns for aesthetic purposes. The office and support areas have a drop ceiling that is 8 feet from the floor. The mechanical rooms are open to the ceiling. The floors are 6 inch poured in place cement over a steel decking. The decking is supported by steel beams and joists. The roof is a membrane material over insulation on top of a steel decking. The roof is supported by a steel truss system. The roof trusses have no fire protection applied. Because the building does not have a fire protection of the support structure this build would be Type IIB construction per the IBC Table 601.

3.2 Construction Type Requirements

The hangar is 90 feet tall thus per Table 504.3 for occupancy B & S with sprinklers Type IB construction would be required since it allows for 180 foot heights. The building has 3 stories in the office/support area. Table 504.4 for occupancy S-1 allows Type IIB allows 3 stories and for occupancy B allows 4 stories thus construction Type IIB would be acceptable. The total area of the building is 119,700 ft^2. The building has over 30 feet of frontage to the public way on all sides thus an area increase of 75% can be applied to the values in Table 506.2. For Occupancy S-1 multi story with sprinklers, Type IIB the maximum allowable area is 52,500 + 75% or 91,875 ft^2 which is less than the total area of the building but greater than the hangar area alone which is 60,000 ft^2. Looking at occupancy B, multistory with sprinklers, Type IB the maximum allowable area is 69,000 + 75% or 120,750 which is greater than the entire building. In summary looking at the building as a whole the building would be required to be Type IB.

Section 503.1 indicates that the building can be divided into sections which can be evaluated independently if there is a fire wall separating the areas that meet the requirements of Section 706.3. The building has a fire wall separating the hangar area from the office support area. Table 706.4 requires a 3 hour wall to separate S-1 (Hangar) from B (office/support) occupancies. This building has an 8 inch cement fire wall between the hangar and the office area that meets the 3 hour requirements, thus the hangar area and the office area will be considered separately to see what kind of construction type is required.

3.2.1 Hangar Area

The north end of the hangar is 90 feet tall and the south end is 70 feet tall. The floor area of the hangar is 60,000 ft^2. Table 504.3 of the IBC shows that the maximum height of an Occupancy Classification S, Type IIB building can only be 75 feet. In order to meet the 90 feet height requirement a Type IB building is required since Type IB allows a height of 180 feet. Section 504.1 provided an exception for 1 story aircraft hangars if the building is entirely surrounded by "public way" or "yards" equal to 1.5 times the building height with a sprinkler system. Since this building has a two story office area adjacent to the hangar space within the same building it would not meet this exception. The maximum number of stories for Type IIB construction, S-1 occupancy with sprinklers (S-1, S) is 3 per Table 504.4. This building meets that requirement. The maximum area for Type IIB construction, S-1 occupancy one story with sprinklers (S-1, S1) is 70,000 ft^2 per Table 506.2. This building meets the requirement. In summary the building does not meet the 2015 IBC requirements based on its current use and occupancy due to the height of the hangar. When the hangar was expanded and the 90 foot section was added the building was being used as a factory and per Section 503.1 "Special industrial occupancies" the height restriction would not apply for special machinery and equipment.

3.2.2 Office Area

The maximum height requirement for occupancy classification B, with sprinklers and type IIB construction is 75 feet per table 504.3. The office portion of the building is 70 feet to the roof thus the building meets the height requirement. The maximum number of stories is 4 per Table 504.4. This building only has 2 thus meeting this requirement. Based on Table 506.2 the maximum area of occupancy classification B, multistory with sprinklers and type IIB construction is 69,000 ft^2. This portion of the building meets the area requirement since the office and incidental areas of this building is 59,700 ft^2 even without the additional area allowed for access to the public way.

3.3 Fire Resistance Rating Requirements of Building Components

3.3.1 Hangar Area

The hangar is required to be Type IB construction. Table 3-1 shows the requirements per the 2015 IBC.

Table 3-1: 2015 IBC Fire Resistance Rating Requirements (IBC Table 601)

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame^f (see Section 202)	3^a	2^a	1	0	1	0	HT	1	0
Bearing walls Exterior^{e,f} Interior	 3 3^a	 2 2^a	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior			See Table 602						
Nonbearing walls and partitions Interior^d	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1^1/_2{}^b$	$1^{b,c}$	$1^{b,c}$	0^c	$1^{b,c}$	0	HT	$1^{b,c}$	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.
b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.
d. Not less than the fire-resistance rating required by other sections of this code.
e. Not less than the fire-resistance rating based on fire separation distance (see Table 602).
f. Not less than the fire-resistance rating as referenced in Section 704.10.

The hangar's primary steel structure only supports the roof thus per "note a" the roof structure fire protection can be reduced to 1 hour of rating. Since the building's primary structure has no applied fire protection then the construction is Type IIB. The exterior walls are not load bearing thus Table 602 applies. The fire separation distance is greater than 30 feet thus per Table 602 the exterior walls do not require a fire rating. The interior wall separating the hangar from the office is also not load bearing thus per Table 601 does not require a fire resistance rating. The wall does require a 3 hour rating since it is separating the S-1 occupancy from the B occupancy per Table 706.4. The floor is required to have a 2 hour rating, the floor is 12 inch concrete on grade and exceeds the thickness requirements for a 2 hour rated concrete floor per IBC Table 7.21.1(3). The roof is required to have a 1 hour rating. Section 1505 defines the roofing classification for different types of construction. For Type IB in Table 1505.1 a roofing classification of "B" is required. The specification of the roofing material installed on the building is Class B per the UL testing report.

In addition to the requirements of Type IB construction, aircraft hangars have special construction requirements per Section 412.4.

Section 412.4.1 Exterior Walls: Does not apply since the building is more than 30 feet from the lot line or public way.

Section 412.4.2 Basements: May apply since there is an unoccupied utility service tunnel under the building. The floor between the basement and the hangar is required to be of Type IA construction. The hangar floor over the tunnel is 12” concrete with no additional fire protection applied. There is no openings to allow communications from the hangar to the tunnel and the entrance to the tunnel is from the outside of the building thus meeting these requirements.

412.4.3 Floor Surface: Floors shall be graded and drained to prevent water or fuel from remaining on the floor. Floor drains shall discharge through an oil separator to the sewer or to an outside vented sump. This hangar does not meet this requirement. This requirement may not have been required in 1958 and 1970 when the building was constructed.

412.4.4 Heating Equipment: Heating equipment shall be placed in another room separated by a 2 hour fire barrier. The hangar area meets this requirement.

412.4.4 Finishing: Does not apply since finishing or “doping” does not take place in this hangar.

412.4.6 Fire Suppression: Aircraft hangars shall be provided with fire suppression system designed in accordance with NFPA 409. The hangar is classified as Group I and has a high expansion foam fire suppression system per NFPA 409.

3.3.2 Office area

The office are of the building is required to be Type IIB construction. There is no fire protection requirements on the structure per IBC Table 601. There are several walls that do require a fire rating due to separation from other areas or due to vertical shaft or exit way requirements.

3.3.3 Hangar to Office area separation

The wall separating the office area and the hangar is required to be a 3 hour rated wall per Table 706.4 for the office and hangar to be considered separate buildings.

3.3.4 Mechanical rooms to Office area separation

Section 509 of the IBC requires that the wall separating the boiler and refrigeration rooms from the office area be a 1 hour rated wall unless the building has sprinklers. This building has sprinkler thus the wall does not need to be 1 hour rated.

3.3.5 Office area to conference room separation

The office area is occupancy B and the conference rooms are assembly areas (A). Table 508.4 does not require a fire wall separation between these occupancy areas.

3.3.6 Vertical Shaft Walls

The building has two elevators and two exit stair wells in the office area connecting the ground floor with the upper two floors. Section 713.4 requires a 1 hour rating for the walls since the vertical shafts connect less than 4 stories. Section 1023.2 also specified 1 hour rating for walls within exit stair when connecting less than 4 stories.

3.3.7 Exit Corridor

The building has a horizontal exit corridor connecting the center stairs to the building exit. The walls and ceiling of the corridor are required to be 1 hour rated per Section 1024.3.

3.3.8 Exterior Stairs

The wall adjacent to the exterior stairs is required to have a 1 hour rating within 10 feet of the stairs per Sections 1023.2 and 1027.

Figure 3-1 through Figure 3-4 illustrate the code requirements for the building construction type and the fire resistance ratings for the walls.

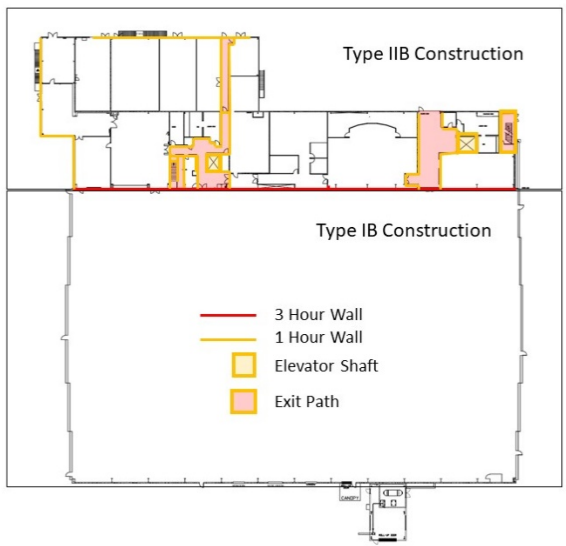


Figure 3-1: Hangar Area Fire Resistance Requirements

Figure 3-2: Ground Floor Office Area Fire Resistance Requirements

Figure 3-3: Ground Floor Office Area Fire Resistance Requirements

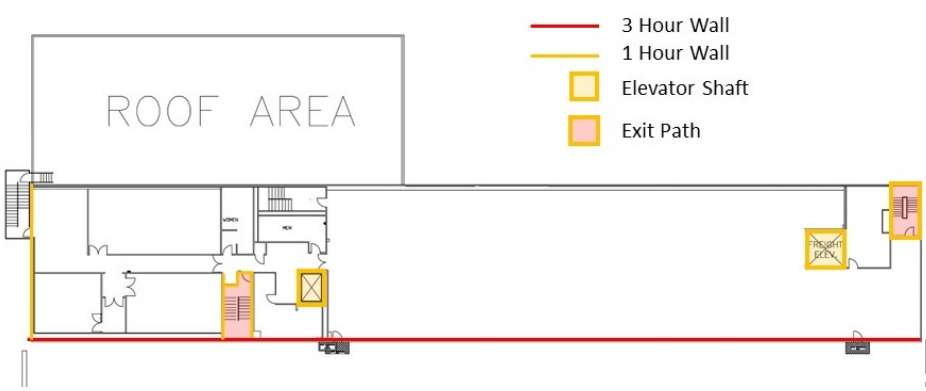


Figure 3-4: Second Floor Office Area Fire Resistance Requirements

3.4 Structural Design

The building is a steel structure with non-load bearing cement and metal walls. The roof structure of the original 1958 building are trusses over the hangar area and the office area extending past the outside wall to the east creating an overhang. The addition added in the 1970s has a truss system over the hangar portion but a girder and joist structure to support the roof of the office and mechanical areas. The floors in the office area are supported by steel girders and joists connected to the main support columns. The floors are cast in place concrete. Figure 3-5 to Figure 3-7 shows the structure layout of the main columns and the roof truss system. Figure 3-8 to Figure 3-10 show the structural layout for the office and mechanical area floors and roof. The structural floor layout in overlaid on the floor below the structure since this is the structure that will be seeing the fire on the floor below.

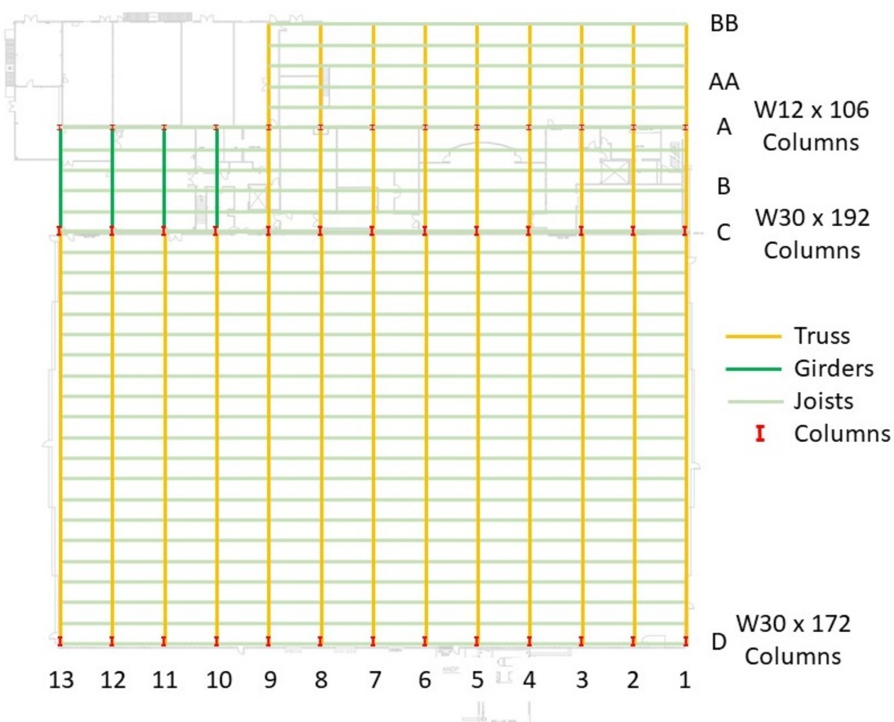


Figure 3-5: Building columns and Truss layout

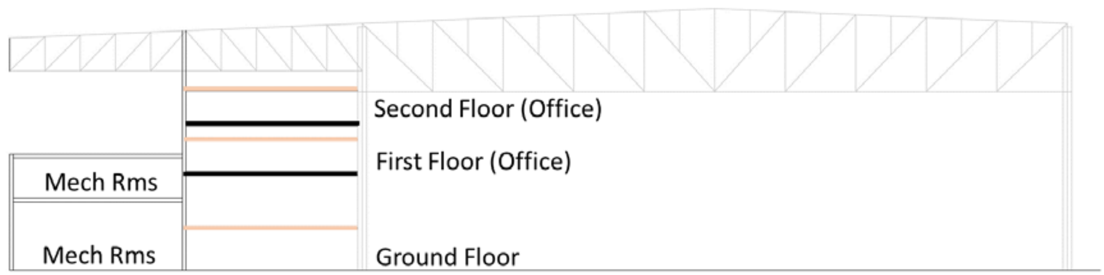


Figure 3-6: Cross Section of Low Section showing Floors and Truss Layout

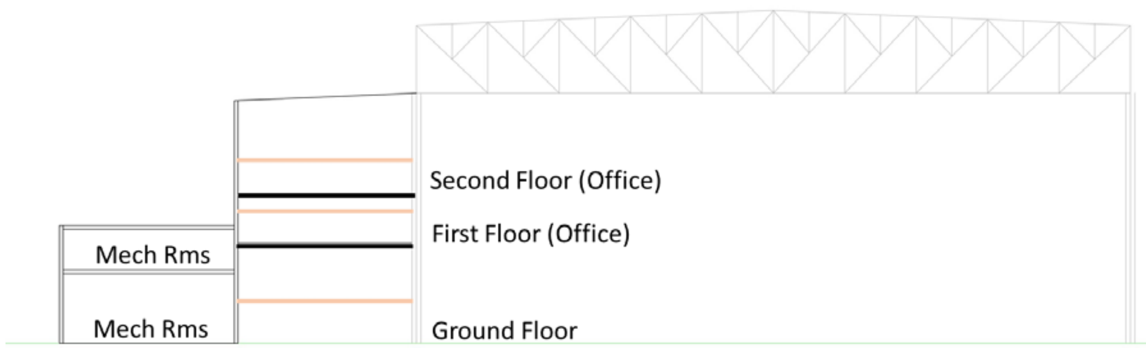


Figure 3-7: Cross Section of High Section showing Floors and Truss Layout

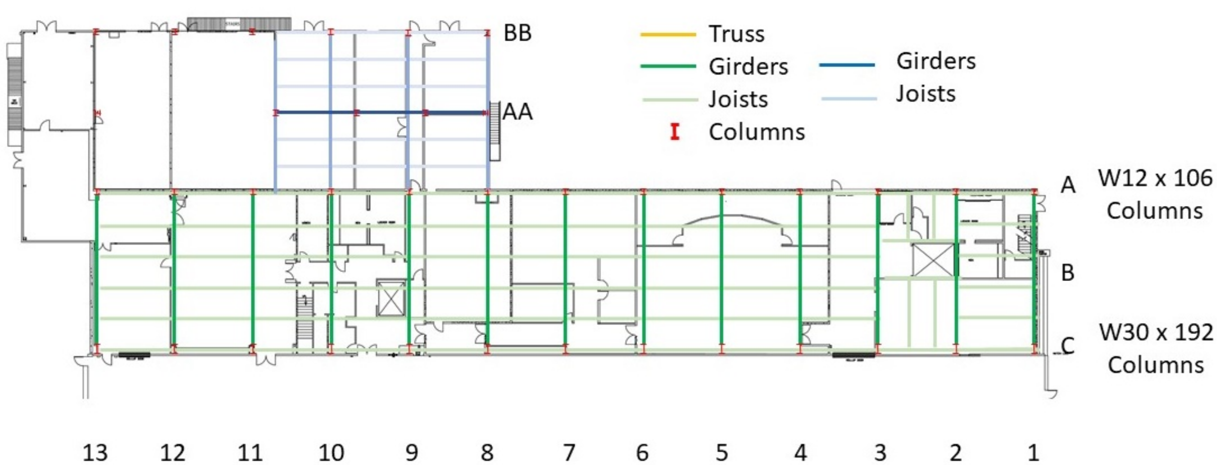


Figure 3-8: Second Floor Structure overlaid on Ground Floor Office Area

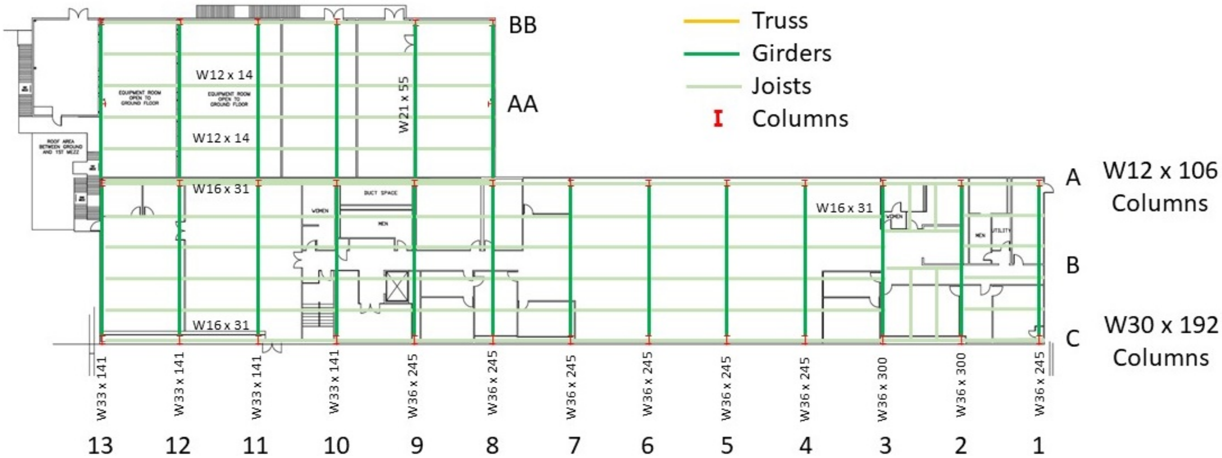


Figure 3-9: Third Floor Structure overlaid on Second Floor Area

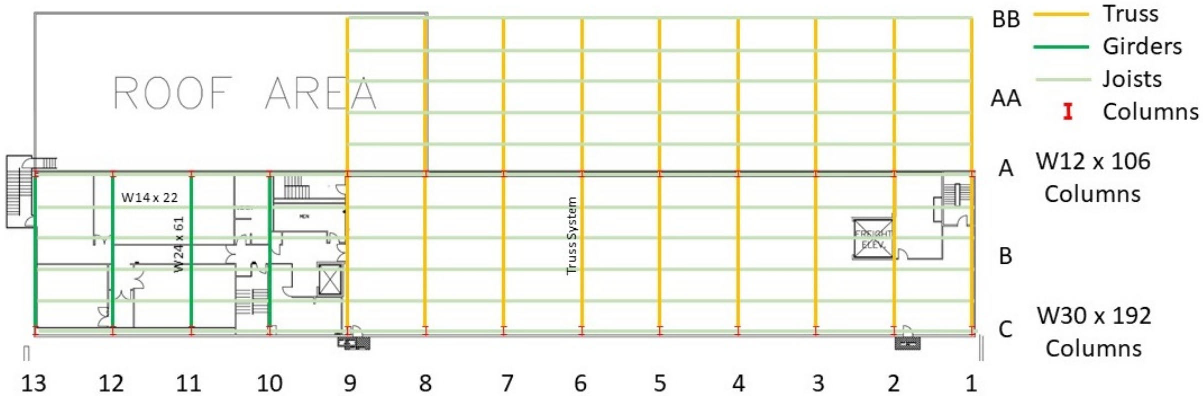


Figure 3-10: Roof Structure overlaid on Third Floor Area

3.4.1 Interior and Exterior Wall Construction

Figure 3-11 to Figure 3-14 show the wall type construction for the building. All walls that are not specifically identified in the figures are ½ sheet rock partitions that only go to the drop ceiling. The open office cubicles are fabric type walls that extend up 4 feet. The fire resistance of these partitions is unknown.

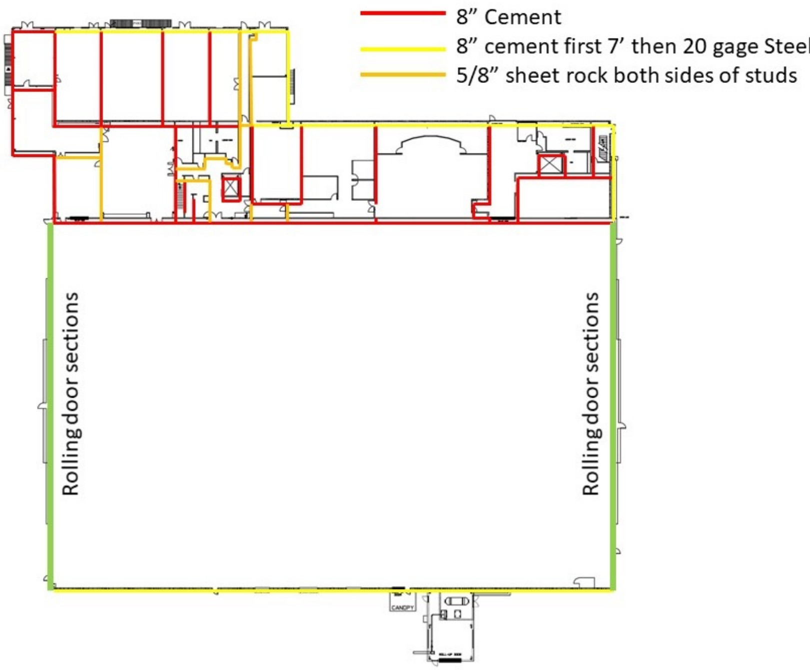


Figure 3-11: Hangar Area Wall Types

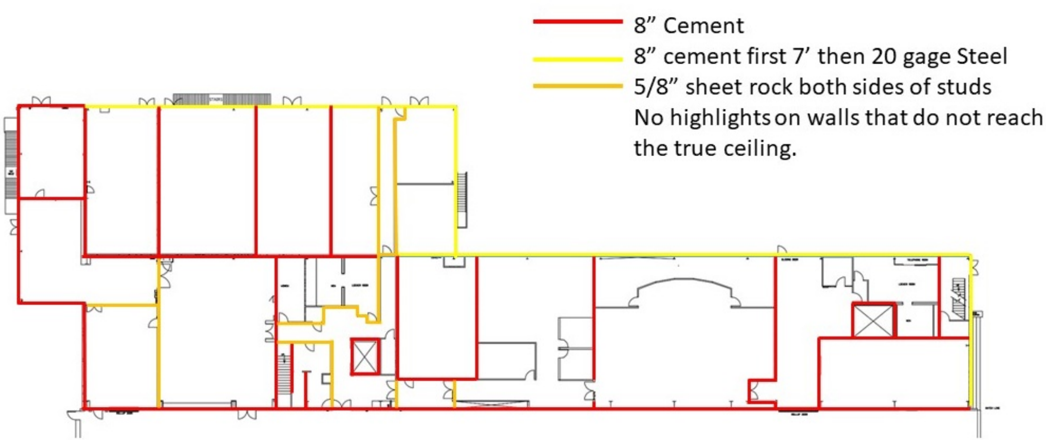


Figure 3-12: Ground Floor Office Area Wall Types

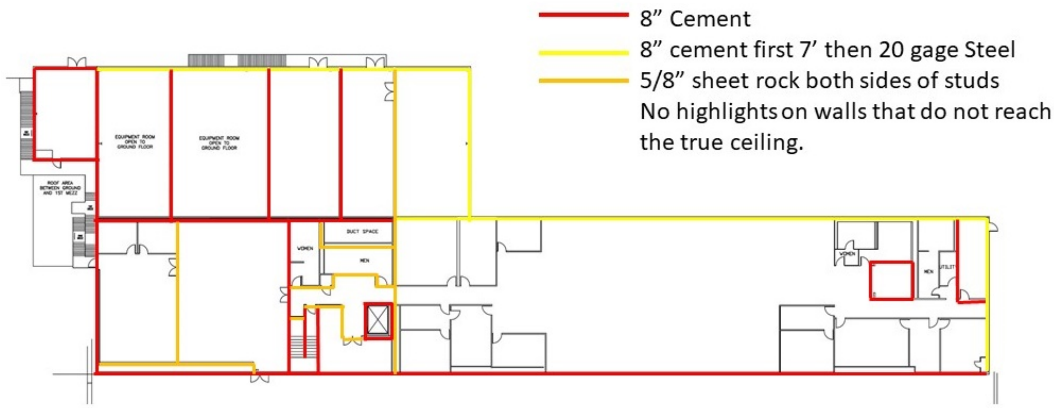


Figure 3-13: Second Floor Office Area Wall Types

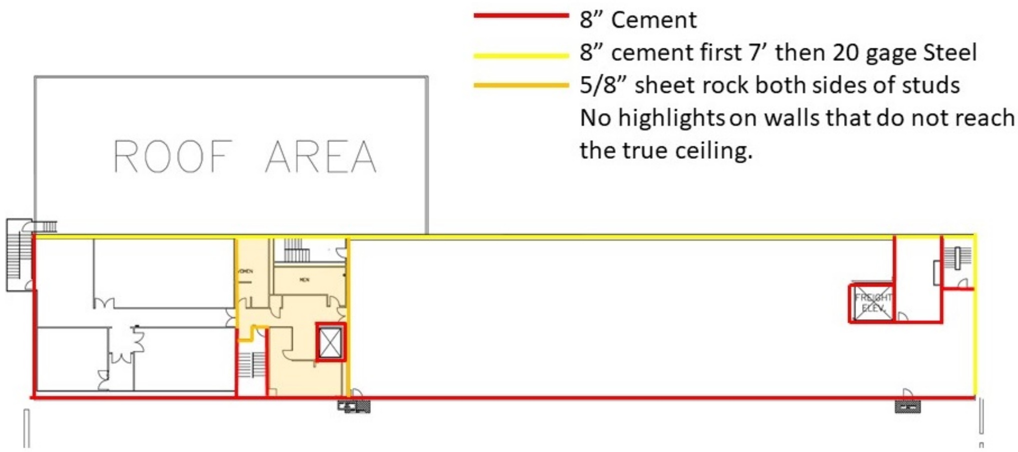


Figure 3-14: Third Floor Office Area Wall Types

3.4.2 Hangar Area

The hangar area has exposed W30 x 172 columns on the west side and a protected W30x192 columns on the east side. The east side columns are protected by an 8 inch concrete wall from floor to roof. The north and south sides are rolling doors that open the full 200 foot width of the hangar. The west wall is cement for the first 7 feet then steel the remaining way to the roof line. The trusses in the hangar area are shown in Figure 3-6 and Figure 3-7 for the south portion built in 1958 and the north high portion built in the 1970s respectively. The roof is a PVC membrane over insulation and the steel decking. The steel decking and the trusses have no fire protection applied. The roofing assembly is a Class B as certified by Underwriters Laboratories. The 8 inch cement wall is good for over 4 hours per Table 721.1(2) on the 2015 IBC thus the 8 inch wall provides the required 3 hour fire rating between the office and hangar area and the protection for the east side columns.

3.4.3 Ground Exit Corridors

The walls of the center exit corridor are either 8 inch concrete or 5/8 inch sheet rock on both sides of the supporting studs. The walls go from the floor to the true ceiling in that area. The center corridor area has a sheet rock ceiling 8 feet from the floor. The south exit corridor has an 8 inch cement wall on the north side and either cement of sheet rock wall on the south side. The area is open to the true ceiling (bottom of the second floor). These walls meet the 1 hour rating required by the code.

3.4.4 Exit Stair Shafts

The center stairs well consist of 8 inch cement walls on three sides and sheet rock on the side with the entry/exit doors. The sheetrock wall consists of 5/8 inch sheet rock on either side of the supporting studs. The walls go from floor to true ceiling to completely enclose the stair well. All of the doors are metal with metal frames connected to the sheet rock walls. These walls meet the 1 hour rating required by the code.

The south exit stairs is cement on the inside walls and cement and steel on the exterior walls. The cement goes from ground to 7 feet then steel the remaining way to the roof line. The south exit stairs provides roof access. These walls meet the 1 hour rating required by the code.

3.4.5 Elevator shaft

Both elevator shafts are 8 inch cement walls on all sides. These walls meet the 1 hour rating required by the code.

3.4.6 Exterior Exit Stair Walls

The north wall of the building is 8 inch concrete with no windows within 10 feet of the north exterior exit stairs. The wall on the east side adjacent to the exit stairs from the upper mechanical rooms is concrete for the first 7 feet then steel the remaining way to the roof line. These walls meet the 1 hour rating required by the code.

3.5 Building Construction Summary

The building is a steel structure with non-load bearing cement and metal exterior walls. The building construction is Type IIB due to no fire proofing on the structural steel frame work but is required to be Type IB due to the building height and occupancy. The interior and exterior walls meet the required fire resistance ratings required for occupancy separation, exit stairs, exit corridors and elevator shafts. Life safety and building egress analysis based on the NFPA 101, Life Safety Code, will now be discussed.

4 Prescriptive Life Safety Analysis

4.1 Exits

4.1.1 Ground Floor

The hangar bay has 6 exits that lead outside and one that exits into the exit corridor that then exits out the east side, Figure 4-1. The exits on the hangar north, east, and South outside walls/doors are spaced less than 150 feet apart meeting the requirements of section 40.6.2.2. The distance from the south door exit (H8), to the East side Exit (H9) is approximately 200 feet but section 40.6.2.2 pertaining to hangars does not specify the distance on the interior wall only the exterior walls. The truck way roll-up door can't be considered an emergency exit since it closes automatically when a fire is detected.

Figure 4-2 shows the office/support area exits. There are 8 exits to the outside (E1-E8). Exit E9 is from the south stair well that services the second and third floors and provided roof access. This area has several access controlled areas and one way doors.*

Figure 4-1: Hangar Bay Exits

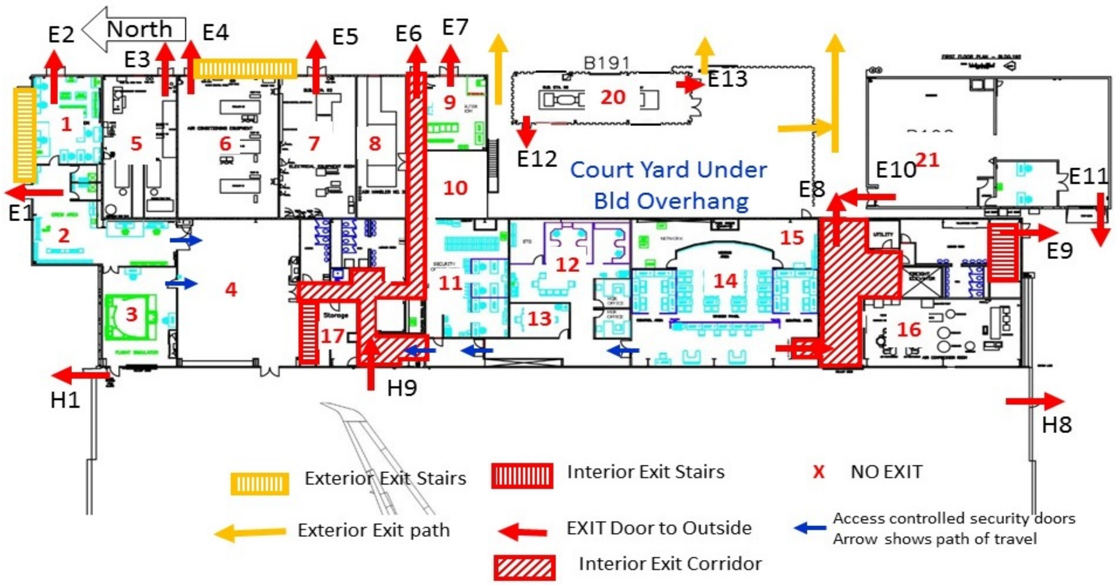


Figure 4-2: Ground Floor Exits in Office/Support Area

4.1.2 Second Floor

The main second floor has three exits, Figure 4-3. The first is the north exit (E21) from the building enters the exterior stairs (S1) that lead down to the ground floor. These stairs meet the LSC section 7.2.2.6 for outside stairs going from the exit floor to the ground level. The second is the center stairs (S2) that discharges into the Exit corridor on the ground floor. This is permitted by the LSC section 7.7.2 as long as less than 50% of the required exits and exit capacity is not through the interior passage way. In this case there are three exits on the floor and there is sufficient capacity for the occupancy load. The third exit is the South stairs (S3) which discharges directly outside.

The exterior rooms all have only one exit. This is sufficient since the occupancy load in each of these rooms is less than 50 people.

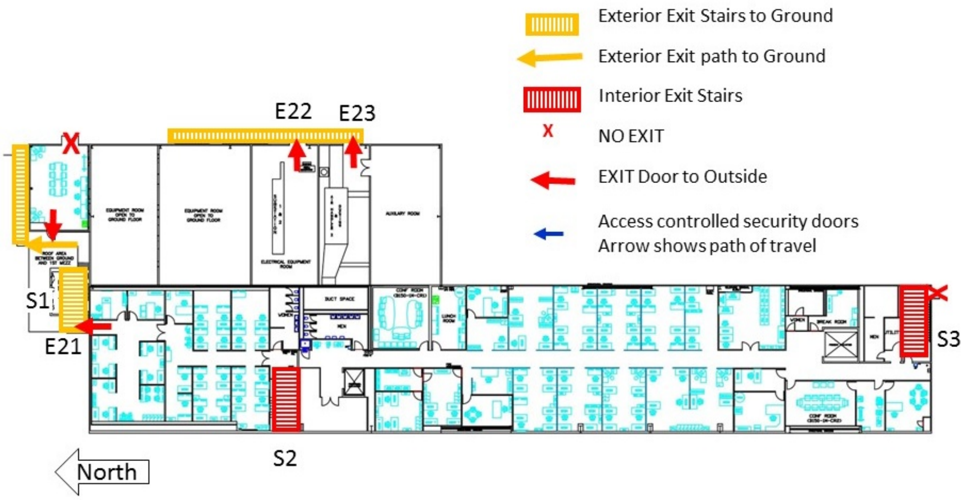


Figure 4-3: Second Floor Exits

4.1.3 Third Floor

The third floor also has three exits, Figure 4-4. The north exit out the building then down the exterior stairs. These stairs meet the LSC section 7.2.2.6 for outside stairs going from the exit floor to the ground level. The center stairs that discharges into the Exit corridor on the ground floor. This is permitted by the LSC section 7.7.2 as long as less than 50% of the required exits and exit capacity is not through the interior passage way. In this case there are three exits on the floor and there is sufficient capacity for the occupancy load. The third exit is the South stairs which discharges directly outside.

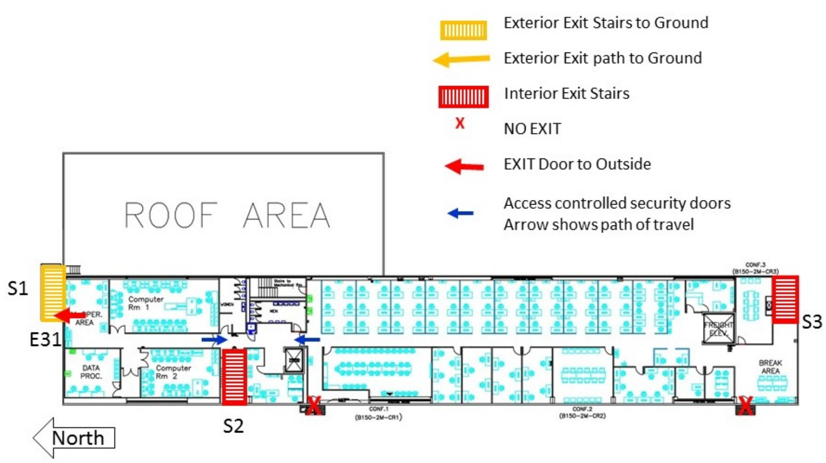


Figure 4-4: Third Floor Exits

4.2 Exit Discharge to Public way

Once outside the building the "Exit" continues to the "Public Way". For this building the public way is about ¾ mile away on Avenue M. The path to the public way is shown in Figure 4-5. At this facility there are assembly points where the occupants are to gather for accountability thus no one should be going to the public way until released after being accounted for.

Figure 4-5: Exterior exit route to "Public Way"

4.3 Occupancy Load and Exit Capacity

Table 4-1 & Table 4-2 shows the occupancy load and egress capacity for the ground floor, the machine shop and electrical substation. The load factors are based on the LSC Table 7.3.11.2 except for the hangar which is based on the 2015 IBC Table 1004.1.2 for aircraft hangars. The occupant loads calculated are much greater than the actual occupancy in the building. The current max occupancy is expected to be less than 130 on the ground floor. The mechanical, electrical and air compressor rooms only see the occasional maintenance personnel. The conference room (13) is primarily used by the personnel in office area 12 since it is in a secure area. The information laboratory is configured for about 40 people thus the concentrated business load factor was used. Areas 1 to 4 are support areas with few permanent occupants, most people in these areas have desks or offices elsewhere in the building. The hangar is used for aircraft maintenance and storage, generally never see more than 50 personnel at any one time.

Table 4-2 shown the egress capacity of the exits in addition to the occupancy load that they service. Since the hangar bay is a higher risk area than the office/support areas, the occupants on the east side should not be using the exits in the hangar bay to evacuate the building. Table 4-2 shows there is sufficient exit capacity on the ground floor even imposing this additional requirement.

Table 4-1: Occupancy Load for Ground floor

Ground Floor						
Room/Area	Rm #	Size (FT^2)	Occupancy Type	Occ Load Factor	Occupants	Referance
Total Ground Floor		84000				
Instrumentation Laboratory	1	690	Industrial	100	7	
Flight Support	2	1180	Industrial	100	12	2015 IBC- Table 1004.1.2 For aircraft Hangars
Simulator	3	870	Industrial	100	9	
Maintenance Support	4	2080	Industrial	100	21	
Boiler room	5	1200	Industrial	100	12	
Chiller Room	6	1700	Industrial	100	17	
Electrical	7	1200	Industrial	100	12	
Air Handler Room	8	800	Industrial	100	8	
Telecom	9	511	Buisness	100	6	
Office	10	260	Buisness	100	3	
Office	11	1120	Buisness	100	12	
Office	12	1416	Buisness	100	15	
Conf Room	13	240	Assembly	15	16	
Information Laboratory	14	2430	Buisness	50	49	Concentrated Buisness Use
Storage	15	770	Storage	500	2	
Compressor room	16	1224	Industrial	100	13	
Storage Rm	17	286	Storage	500	1	
Hangar	18	60000	Industrial	500	120	
Pump Bld	19	975	Industrial	100	10	
Remaining Area		5048	Industrial	100	51	
	Total Area	84000	Total Occupants		396	
Electrical Substation Bld	22	1100	Industrial	NA	5	Special Use- Electrical equipment enclosure
Machine Shop Bld	21	3600	Industrial	100	36	

Table 4-2: Egress Capacity for Ground floor

Ground Floor Exit Capacity						
Exit	Exit Dimensions		Exit Capacity			Occupancy
	# of Doors	Door Width (inches)	Door capacity using 0.2 #/in (#/door)	Total Capacity (people)	Total For area (people)	Total for area (people)
Hangar	8	36	180	1440	1800	120
Hangar	1	72	360	360		
Boiler room	1	96	480	480	480	12
Refrigeration room	1	72	360	360	360	17
Electrical room	1	72	360	360	360	12
Computer/telecom room	1	72	360	360	360	6
Life support room	1	72	360	360	1080	219
Truck Way to Outside	1	36	180	180		
Instrumentation Lab	1	72	360	360		
East Hallway	1	36	180	180		
Pump Bld	2	36	180	360	360	10
					Total Occupant Load	396
Machine Shop (B192)	2	36	180	360	360	36
Electrical Substation (B191)	2	36	180	360	360	5

The occupancy load for the second floor is shown in Table 4-3. The total occupancy is 232 people. The exterior rooms that are on various levels require their own exits. For the conference rooms the furniture was not subtracted since it made little difference to occupancy load. The actual occupancy on the second floor is much less than that calculated. In the current configuration there is room for about 80 occupants. Since this is not a public area the conference rooms and break areas are primarily used by the occupants in the office areas thus personnel are double counted by the occupancy load calculation. For the exit capacity and egress analysis in this report the calculated occupant loads will be used.

Table 4-3: Occupancy Load for Second floor

Second Floor						
Room/Area	**Rm #**	**Size (FT^2)**	**Occupancy Type**	**Occ Load Factor (ft^2/person)**	**Occupants**	**Notes**
Total Floor		15900				
Office	2	3400	Business	100	34	
Office	3	8080	Business	100	81	Requires 2 doors
Conference room	4	440	Assembly	15 net	30	Low density Non fixed seating
Break room	5	264	Assembly	15 net	18	Low density Non fixed seating
Conference room	6	400	Assembly	15 net	27	Low density Non fixed seating
Break room	7	181	Assembly	15 net	13	Low density Non fixed seating
Storage	8	380	Storage	500	1	
Remaining area		2755	Business	100	28	
				Total Occupants	**232**	
Second Floor Exterior Rooms						
Exterior Office	1	600	Buisness	100	6	
Electrical Room	10	1150	Industrial	100	12	
Mechanical Room	11	900	Industrial	100	9	
Old Mechanical Room	12	1250	Industrial	100	13	

Table 4-4 shown the egress capacity of the exit doors and stairs servicing the second floor. All exits are available to all occupants for this floor. The exit capacity is sufficient for the calculated occupancy load. Table 4-4 also shows the exit capacity and occupancy levels for the exterior rooms. The mechanical and electrical rooms share the stairs thus the total exit capacity form these areas should be 150 for both rooms and not for each room since the stairs is the limiting the capacity. All exits are sufficient to support the occupancy loads they service.

Table 4-4: Egress Capacity for Second floor

Second Floor Exit Capacity									
	Exit Dimensions			**Exit Capacity**					**Occupancy**
Exit	**Door Width (inches)**	**Stair Width (inches)**	**Stair Exit Width (inches)**	**Entry Door capacity using 0.2 #/in (#/door)**	**Stairs (#/door)**	**Exit Door (#/door)**	**Capacity (people)**	**Total For area (people)**	**Total for area (people)**
North Outside Stairs	36	45	NA	180	150	NA	150	483	232
Center Stairs	36	56	36	180	186	180	180		
South Stairs	36	46	60	180	153	300	153		
Second Floor Exterior Rooms									
Exterior Office	**36**	**45**	**NA**	180	150	NA	150	150	6
Electrical	**72**	**45**	**NA**	360	150	NA	150	150	34
Mechanical rooms	**72**	**45**	**NA**	360	150	NA	150		

The occupancy load for the third floor is shown in Table 4-5. The total occupancy is 307 people. The computer and data processing rooms are tightly packed thus the "Concentrated Business Use" was used per LSC Table 7.3.1.2. The conference rooms used the "Less concentrated use without fixed seating Assembly”. The area occupied by conference room tables were subtracted from the conference room area since this is a “net” load factor value per LSC Table 7.3.1.2 since the tables are large and make a significant impact of the occupant load in the room. The actual occupancy on the second floor is much less than that calculated. In the current configuration there is room for about 120 occupants at assigned desks. The computer and data processing rooms are used by personnel that sit in other locations on the floor thus are double counted. Since this is not a public area the conference rooms and break areas are primarily used by the occupants in the office areas thus many people are double counted in the occupancy load calculations. For the exit capacity and egress analysis in this report the calculated occupant loads will be used.

Table 4-5: Occupancy Load for Third floor

Third Floor						
Room/Area	**Rm #**	**Size (FT^2)**	**Occupancy Type**	**Occ Load Factor**	**Occupants**	**Notes**
Total for floor		15900				
Office Area	1	517	buisness	100	6	
Computer room	2	990	buisness	50	20	High Density
Data processing	3	483	buisness	50	10	High Density
Computer room	4	640	buisness	50	13	High Density
Office Area	5	8444	buisness	100	85	
Conference room	6	735	Assembly	15	49	Low density Non fixed seating. Subtract 30'x3'Table
Conference room	7	521	Assembly	15	35	Low density Non fixed seating. Subtract 18'x3'Table
Conference room	8	354	Assembly	15	24	Low density Non fixed seating. Subtract 12'x3'Table
Break Area	9	546	Assembly	15	37	Low density Non fixed seating. Subtract 3 - 6'x3'Tables
Office	10	350	buisness	100	4	
Remaining		2320	buisness	100	24	
				Total Occupants	307	

Table 4-6 shown the egress capacity of the exit doors and stairs servicing the third floor. The overall exit capacity is more than enough for the occupant load for this floor, but not all exits are available to all occupants for this floor due to the controlled access doors shown in Figure 4-4. The south stairs is not available to areas 1-4 which has an occupant load of approximately 50 people. The exits that are available have a capacity of 230 more than enough. The north outside stairs outside stairs is not available to areas 6-9 which has an occupant load of approximately 162 people. The exits that are available have a capacity of 333 people more than enough. Area 10 is only serviced by the center stairs which has a capacity of 180 people more than enough for those in area 10 and the adjacent lobby.

Table 4-6: Egress Capacity for Third floor

Third Floor Exit Capacity									
	Exit Dimensions			Exit Capacity					Occupancy
Exit	Door Width (inches)	Stair Width (inches)	Stair Exit Width (inches)	Entry Door capacity using 0.2 #/in (#/door)	Stairs (#/door)	Exit Door (#/door)	Capacity (people)	Total For area (people)	Total for area (people)
North Outside Stairs	36	45	45	180	150	225	150	483	307
Center Stairs	36	56	36	180	186	180	180		
South Stairs	36	46	60	180	153	300	153		

4.4 Exit Arrangement

The Figure 4-6 to Figure 4-8 show representative egress paths for the ground, second and third floors respectively. These figures do not show paths from all rooms but represent a set or rooms that are similar. The exits from the various rooms, areas and floor will be discussed as to how they meet or do not meet there requirements of Sections 7.5 and 7.6 of the LSC and the distances specified in the specific chapters dealing with Business (Chapter 39) and Industrial (Chapter 40) occupancies as shown in Table 4-7.

Table 4-7: Maximum Travel Distance Requirements

Distance Requirements				
	Business		Industrial	
	Distance	LSC Ref	Distance	LSC Ref
Common Path	100'	29.2.5.3.1	100'	Table 40.2.5.1
Dead End Corridors	50 '	39.2.5.2	50'	Table 40.2.5.1
Total Travel Distance	300'	39.2.6.3	250'	Table 40.2.5.1

The hangar area has no issues with common path, dead end corridors, total travel distance and remoteness. At any location in the hangar bay there are multiple exits to choose from. The closest exit is no more than 150 feet if standing in the center of the hangar.

Most rooms in the office/support area meet the requirement for common path, dead end corridors, total travel distance and remoteness. Rooms 10-13 on the ground floor do not meet the common path travel distance of 100 feet due to the limited access security doors. The center exit corridor is not a horizontal exit thus the common path is to the exit door on the east side of the building. The total common path travel is about 215 feet for rooms 10 - 12. If these occupants are allowed to exit through the hangar bay then the common path becomes less than 100 feet since there are two exit options when they enter the center exit corridor; one path through the hangar and out the north door and one out the east exit. Both of these paths are less than the total distance requirement of 250 feet. The final decision would be with the AHJ. There are two dead ends both less than 50 feet; 1) into room 12 from the corridor; 2) from the exit of room 11 to the south toward the access controlled door. Rooms 4 to 13 all have only one exit but the occupant load in all of these rooms is less than 50 people. The common path distance and total travel distance for all of the mechanical rooms is less than 100 feet.

There is a utility tunnel that runs under the hangar that is accessed form outside the building on the east side (Figure 4-6) that is a normally unoccupied area. The egress requirements of section 7.1 to 7.12 of the LSC do not apply to this area per section 7.13 "*Normally Unoccupied Building Service Equipment Support Areas*."

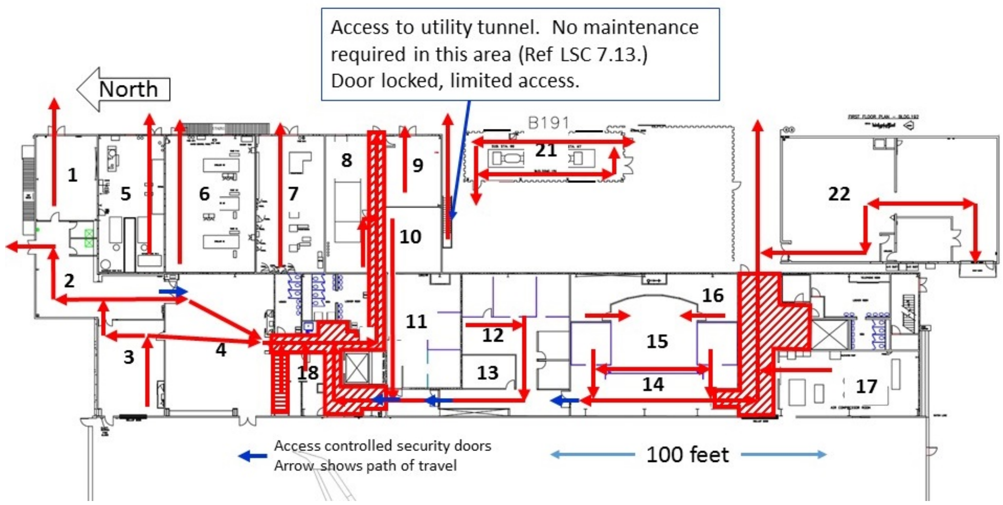


Figure 4-6: Representative Egress Paths for Ground Floor Office/Support Area

All rooms on the second floor meet requirement for common path, dead end corridors, total travel distance and remoteness. When a person exits their office and proceeds into the center hall way there are two exit options, north to stairs or south to stairs. The common path distance from the back of an office to the hallway is about 25 feet. The only dead end is in front of the elevator and this is about 10 feet.

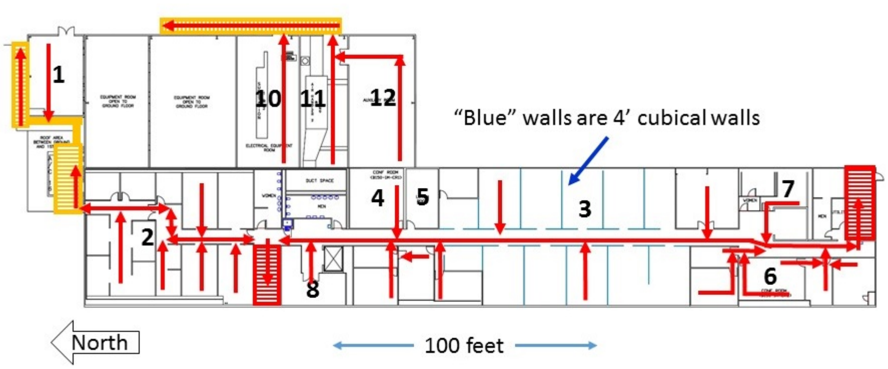


Figure 4-7: Representative Egress Paths for Second Floor

The third floor is divided into three areas for considering exits. The north area rooms 1-4 have 2 exits one using the exterior stairs to the north and the center stairs. The two exits are at each end of the area thus meeting the separation distance requirement. There are no common paths longer than 100 feet and the only dead end is less than 20 feet.

The area to the south, Rooms 5-9 also have two exits. These exits are the center exit stairs and the south exit stairs. Room 6 only has one exit and is a conference room with non-fixed seating and a large 3'x30' conference table. The calculated occupancy load is 49 which is on the border of requiring two exits. There is no common paths longer than 100 feet. There are two dead end corridors; one leads to electrical panels that is about 35 feet which still meets the 50 foot max requirement; the other is a 23 foot corridor to the access door to the HVAC and elevator mechanical room above the second floor. The mechanical room above the second floor meets the requirements of section 7.121 (2) and 7.12.2 for mechanical rooms in existing buildings and on stories used exclusively for mechanical equipment.

The center area by the elevator has only one exit but since the occupancy load of room 10 is only 4 people this would be acceptable.

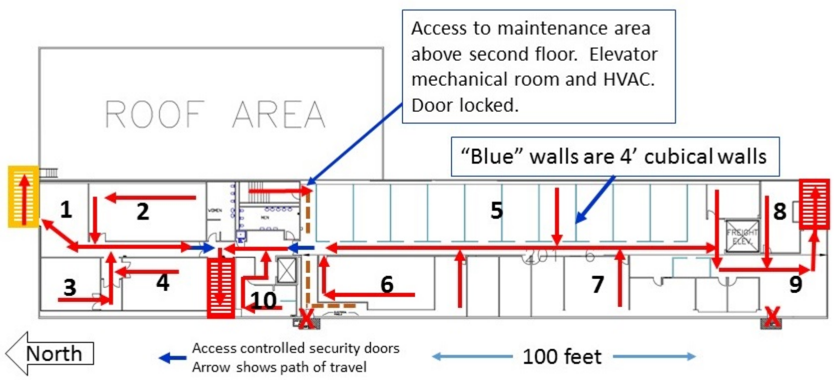


Figure 4-8: Representative Egress Paths for Third Floor

4.5 Regulatory Requirements

4.5.1 Exit Sign

Figure 4-9 show the recommended locations for exit signs in the hangar bay. There is an exit sign over each exit to the outside and one over the exit leading to the exit corridor on the east side of the hangar.

Figure 4-9: Exit Sign locations in Hangar Bay

Figure 4-10 show the recommended locations for exit signs and the fire walls for the ground floor Office and support area. The exit signs are positioned per section 7.10. They are located such that the exit path is clearly marked and none of the signs are more than 100 feet apart per 7.10.5.2. Directional arrow signs are located to ensure that the occupant follow the exit path. The door to the north of the center exit stairs is marked with a “NO Exit” per 7.10.8.3 because turning north does not lead to an exit. Room 14/15 have low wall thus the exit signs are visible from anywhere in the room. Other rooms have only one entrance/exit which is obvious to the occupants. The door in room 4 on the north east corner is also marked “NO EXIT” because this is an access controlled door that opens into room 4 and is not an exit from room 4.

Figure 4-10: Exit Sign and Fire Wall Locations in Ground Floor Office/Support Area

Figure 4-11 show the recommended locations for exit signs and the fire walls for the second floor. The exit sign by the center and south stairs is perpendicular to the flow in the hallway in order to be clearly visible to the occupant looking for the exit.

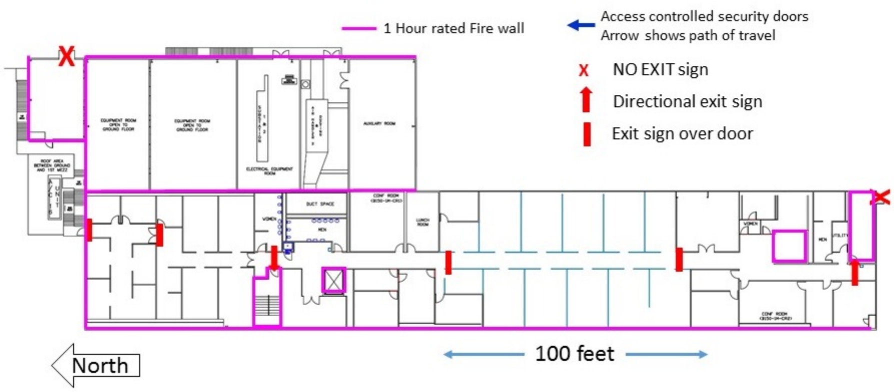


Figure 4-11: Exit Sign and Fire Wall Locations on Second Floor

Figure 4-12 show the recommended locations for exit signs and the fire walls for the third floor. The exit sign by the center and break area (9) near the south stairs is perpendicular to the flow in the hallway in order to be clearly visible to the occupant looking for the exit. The south stairs also has a sign directly over the door. Area 5 required a sign in the center of the hallway in order to meet the 100 foot distance between signs. The two doors that are locked and lead to work platforms in the hangar should be marked “NO EXIT” per 7.10.8.3. All of the exit and directional sign in the building are internally illuminated and on battery back-up power. The signs meet the ANSI/UL 924, *Standard for Emergency Lighting and Power Equipment.*

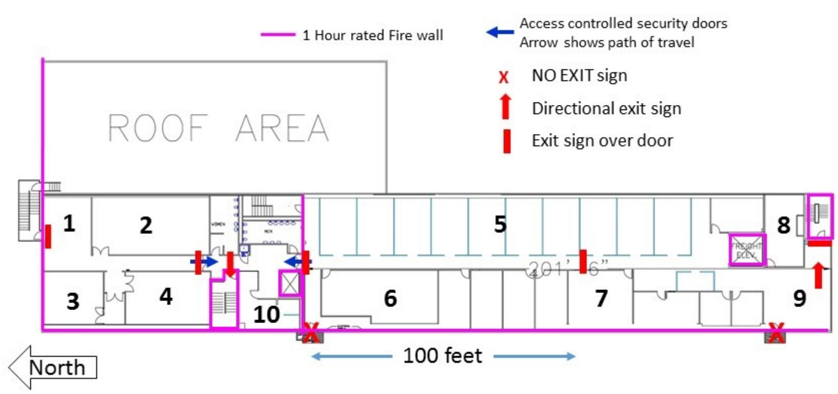


Figure 4-12: Exit Sign and Fire Wall Locations on Third Floor

4.5.2 Access Control Doors

The access control doors on the ground floor and third floor have fire panic hardware and self-closures that meet the requirements of 7.2.1.7 & 7.2.1.8 respectively. They do not meet the requirements of 7.2.1.6.2., thus function only in the one direction for egress purposes.

4.5.3 Interior Finish

The interior finish for the exit enclosures and exit corridors shall be Class A or Class B (7.1.4.1) and the floor finish shall be no less than Class II (7.1.4.2). Areas other than the exit enclosures and corridors will be Class A, B or C. The building exits and exit corridors walls are painted 5/8 inch sheet rock, CMU or steel. The floor finish on the stairs is also paint. The exit corridor on the ground floor is vinyl tile over cement.

4.5.4 Emergency Lighting

The building has emergency lighting both the battery operated type and some powered by the emergency generator. The exit signs are illuminated. Exits ways are illuminated per section 7.8.1. The exit signs are internally illuminated per section 7.9.

4.6 Prescriptive Life Safety Summary

The building has sufficient exits and exit capacity to accommodate the 1016 personnel that could be in the building based on the occupancy loads. The hangar has 9 exits to accommodate with a total exit capacity of 1440 people. This is more than sufficient to accommodate the occupancy load for industrial classification and also to accommodate the entire building occupancy if or when it is used as an assembly area for large luncheons or presentations. The office area has three levels and three exit stairs. The north stairs is outside while the other two are inside. The second and third floor layouts and exits meet the travel distance for total distance, common path and dead ends. The ground floor has been broken up into office areas with the addition of secure doors that limit travel on this floor. The common path and dead end travel distance is not meet for several rooms on the ground floor. In addition there is a conference room on the third floor which is marginal for the use of one door. This room would not meet code if the large conference table currently in the room was removed from the room. This room should have two doors to meet code.

5 Alarm System

The building is divided into separate secure areas that limit the type of cable and piping/conduit that pass through the walls. Each of the secure areas has its own Fire Alarm Control Panel (FACP) and Digital amplifier which are connected via dedicated fiber optic system to the master FACP and Digital Voice Control Panel (DVCP). Building 191 and 192 are under the overhang of the Hangar building thus are considered part of the buildings fire alarm (FA) system. Figure 5-1 to Figure 5-3 show the layout of the secure areas, the common area and the hangar along with the location of the FACPs.

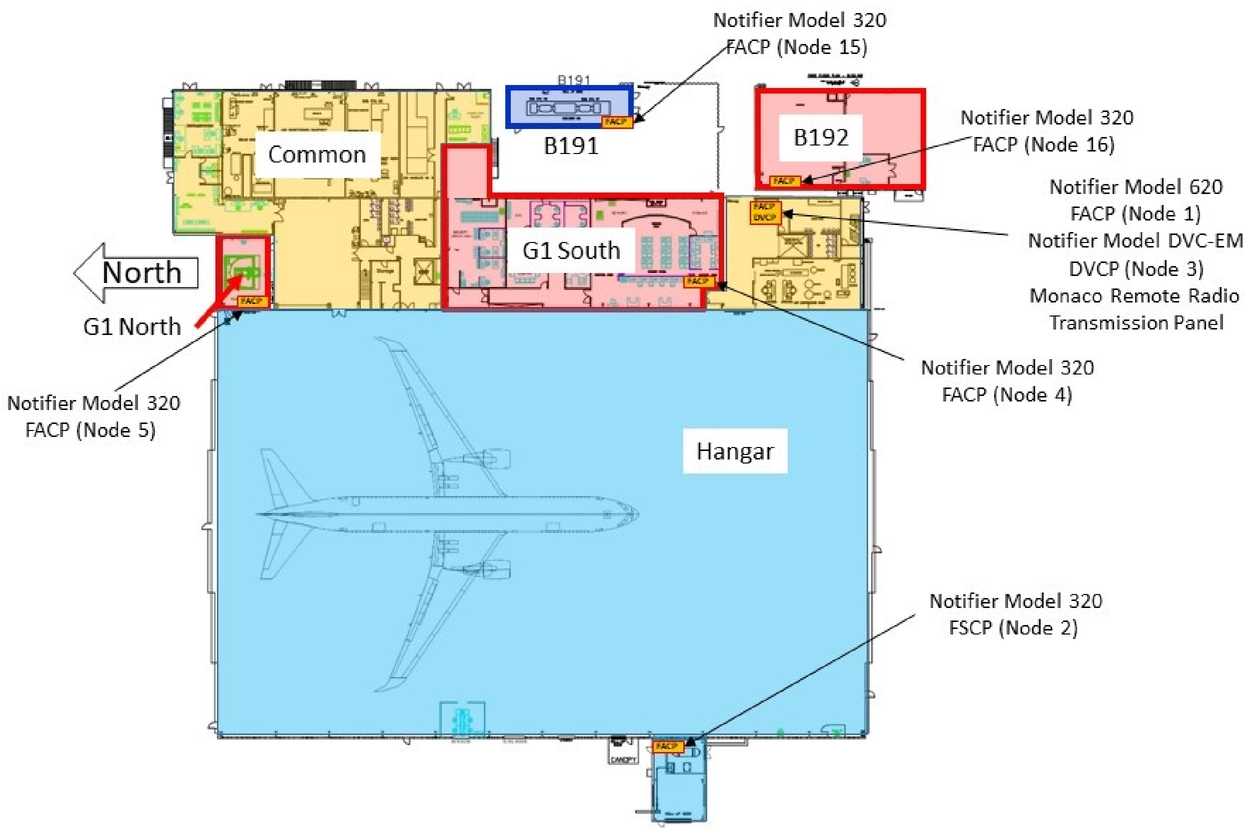


Figure 5-1: Ground Floor layout and FACP, FSCP, and DVCP locations

Figure 5-2: Second floor layout and FACP locations

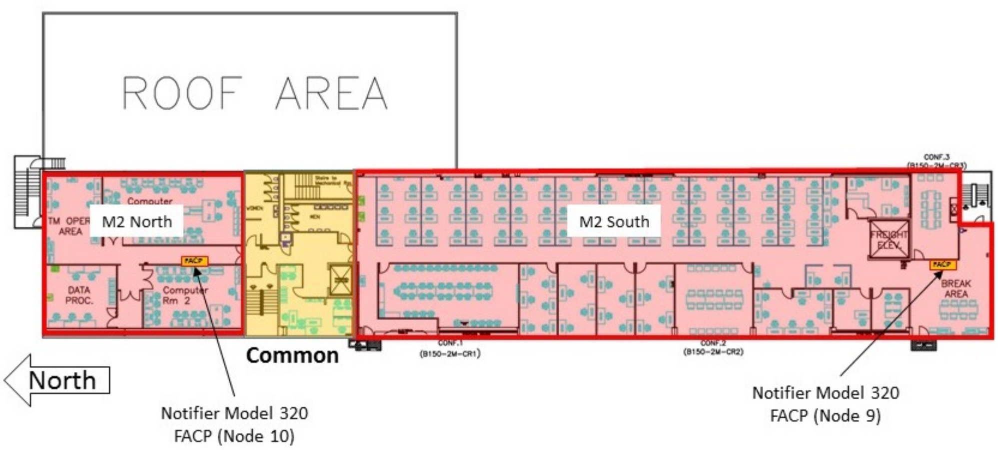


Figure 5-3: Third floor layout and FACP locations

The system consists of 10 FACPs, a Fire Suppression Control Panel (FSCP), for the High Expansion Foam Fire suppression system, and a Digital Voice Command Panel (DVCP) for the MNS. The make and model of each of the panels is listed in Table 5-1 along with the node number that identifies the panel on the fiber optic communications network. The Fiber network is dedicated to the FA & MNS system.

Table 5-1: FACP Node, description and Model

Node 1	Common and Hangar FACP	Notifier Model 640
Node 2	Hangar Hi Expansion Foam Suppression Control Panel	Notifier Model 320
Node 3	Digital Voice Command Panel	Notifier Model DVC-EM
Node 4	G1 South FACP	Notifier Model 320
Node 5	G1 North FACP	Notifier Model 320
Node 6	M1 South FACP	Notifier Model 320
Node 7	M1 North FACP	Notifier Model 320
Node 8	M1.5 North FACP	Notifier Model 320
Node 9	M2 South FACP	Notifier Model 320
Node 10	M2 North FACP	Notifier Model 320
Node 15	B191 Electrical Substation FACP	Notifier Model 320
Node 16	B192 Machine Shop FACP	Notifier Model 320
NA	Fire Management System Transceiver	Monaco Enterprise Model BT-XF
NA	Remote Addressable Fire Control Power Supply (FCSP)	Notifier Model ACPS-610(E)

The Common area has the largest FACP which is connected to the Monaco radio communication panel that communicates with fire dispatch. Figure 5-4 shows the common area FACP, the Monaco communication panel and the DVCP located in a dedicated thermally controlled room. If any of the nodes detects a fire then they all communicate to the others such that all of the notification devices activate and the system performs the required function. The MNS system then broadcasts the appropriate message depending on the alarm received. Table 5-2**Error! Reference source not found.** and Table 5-3 shows the alarm sequence table for the main alarm system and the High Expansion suppression system.

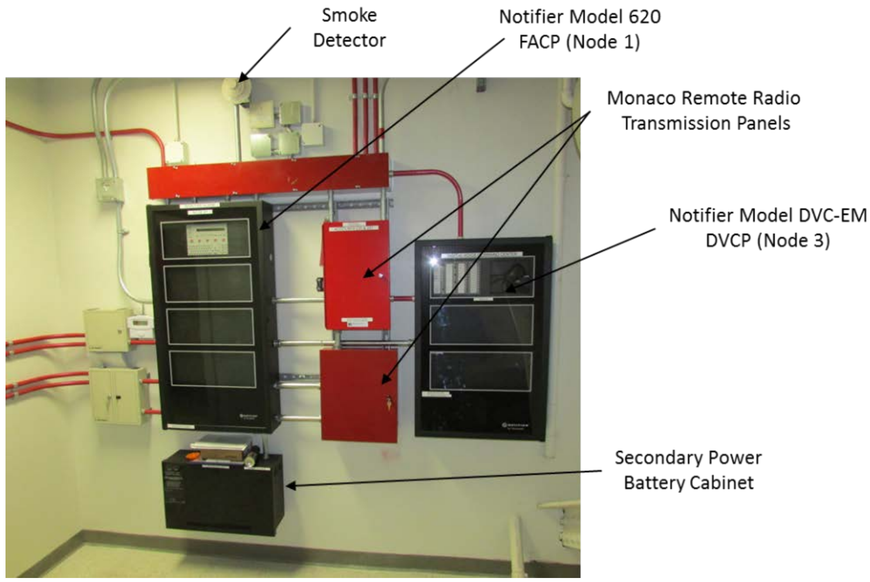


Figure 5-4: Common area/Main FACP, Monaco, and DVCP

Table 5-2: Sequence Table for Main FA/MNS System

SEQUENCE OF OPERATION

SYSTEM OUTPUTS

FIRE ALARM SYSTEM OUTPUTS (CONTROL UNIT & ANNUNCIATION; NOTIFICATION; REQUIRED FIRE SAFETY CONTROL)

SYSTEM INPUTS	No.	Input	A ACTUATE COMMON ALARM SIGNAL INDICATOR	B ACTUATE AUDIBLE ALARM SIGNAL	C ACTUATE COMMON TROUBLE SIGNAL INDICATOR	D ACTUATE AUDIBLE COMMON TROUBLE SIGNAL	E ACTUATE COMMON SUPERVISORY SIGNAL INDICATOR	F INDICATE INDIVIDUAL DEVICE IN ALARM	G ACTUATE CLEAR LENS FIRE STROBES	H TRANSMIT FIRE ALARM OR MNS SIGNAL TO SUPERVISING STATION	I TRANSMIT TROUBLE SIGNAL TO SUPERVISING STATION	J TRANSMIT SUPERVISORY SIGNAL TO SUPERVISING STATION	K NOT USED	L SHUT DOWN ALL AIR HANDLING UNITS	M RECALL ELEVATOR TO GROUND FLOOR	N RECALL ELEVATOR TO 1ST MEZZANINE	O SHUNT TRIP ELEVATOR IF PROVIDED
FA SYSTEM INPUTS	1	MANUAL PULL STATIONS	●	●				●	●	●							
FA SYSTEM INPUTS	2	AREA SMOKE DETECTOR	●	●				●	●	●							
FA SYSTEM INPUTS	3	NOT USED															
FA SYSTEM INPUTS	4	NOT USED															
FA SYSTEM INPUTS	5	DUCT SMOKE DETECTOR	●	●				●	●	●				●			
FA SYSTEM INPUTS	6	WATER FLOW SWITCH	●	●				●	●	●							
FA SYSTEM INPUTS	7	VALVE TAMPER					●					●					
FA SYSTEM INPUTS	8	FIRE ALARM AC POWER FAILURE			●	●					●						
FA SYSTEM INPUTS	9	FIRE ALARM SYSTEM LOW BATTERY			●	●					●						
FA SYSTEM INPUTS	10	OPEN CIRCUIT			●	●					●						
FA SYSTEM INPUTS	11	GROUND CIRCUIT			●	●					●						
FA SYSTEM INPUTS	12	NOTIFICATION APPLIANCE CIRCUIT SHORT			●	●					●						
FA SYSTEM INPUTS	13	SMOKE DETECTOR ELEVATOR LOBBY GRN FLR	●	●				●	●	●						●	
FA SYSTEM INPUTS	14	SMOKE DETECTOR ANY OTHER FLOOR	●	●				●	●	●					●		
FA SYSTEM INPUTS	15	SMOKE DETECTOR IN ELEVATOR EQUIP ROOM	●	●				●	●	●						●	
FA SYSTEM INPUTS	16	SMOKE DETECTOR ELEVATOR SHAFT	●	●				●	●	●					●		
FA SYSTEM INPUTS	17	HEAT DETECTOR IN ELEVATOR EQUIP ROOM	●	●				●	●	●						●	●
FA SYSTEM INPUTS	18	WATERFLOW ELEVATOR SHAFT	●	●				●	●	●						●	●
MASS NOTIFICATION SYSTEM INPUTS	19	MNS PRIMARY MICROPHONE										●					
MASS NOTIFICATION SYSTEM INPUTS	20	MNS BUTTON #1 MESSAGE 1							●								
MASS NOTIFICATION SYSTEM INPUTS	21	MNS BUTTON #2 MESSAGE 2															
MASS NOTIFICATION SYSTEM INPUTS	22	MNS BUTTON #3 MESSAGE 3															
MASS NOTIFICATION SYSTEM INPUTS	23	MNS BUTTON #4 MESSAGE 4															
MASS NOTIFICATION SYSTEM INPUTS	24	MNS BUTTON #5 MESSAGE 5															
MASS NOTIFICATION SYSTEM INPUTS	25	MNS BUTTON #6 MESSAGE 6															
MASS NOTIFICATION SYSTEM INPUTS	26	MNS BUTTON #7 MESSAGE 7															
MASS NOTIFICATION SYSTEM INPUTS	27	MNS BUTTON #8 MESSAGE 8															
MASS NOTIFICATION SYSTEM INPUTS	28	MASS NOTIFICATION AC POWER FAILURE			●	●					●						
MASS NOTIFICATION SYSTEM INPUTS	29	MASS NOTIFICATION SYSTEM LOW BATTERY			●	●					●						
MASS NOTIFICATION SYSTEM INPUTS	30	MASS NOTIFICATION OPEN CIRCUIT			●	●					●						
MASS NOTIFICATION SYSTEM INPUTS	31	MASS NOTIFICATION GROUND CIRCUIT			●	●					●						
MASS NOTIFICATION SYSTEM INPUTS	32	MASS NOTIFICATION APPLIANCE CIRCUIT SHORT			●	●					●						
MASS NOTIFICATION SYSTEM INPUTS	33	MASS NOTIFICATION OVERRIDE THE FA SYSTEM										●					
MASS NOTIFICATION SYSTEM INPUTS	34	NOT USED															

MASS NOTIFICATION SYSTEM OUTPUTS (CONTROL UNIT ANNUNCIATION; NOTIFICATION)

No.	Input	P ACTUATE COMMON MNS ACTIVE INDICATOR	Q ACTUATE AUDIBLE ALARM SIGNAL	R ACTUATE COMMON TROUBLE SIGNAL INDICATOR	S ACTUATE AUDIBLE COMMON TROUBLE SIGNAL	T PRIORITY 1 MESSAGE – BOMB THREAT	U PRIORITY 2 MESSAGE – HOSTILE INTRUDER	V PRIORITY 3 MESSAGE – TAKE COVER	W PRIORITY 4 MESSAGE – EVACUATE	X PRIORITY 5 MESSAGE – FIRE EVACUATE	Y PRIORITY 6 MESSAGE – SEVERE WEATHER	Z PRIORITY 7 MESSAGE – ALL CLEAR	A1 PRIORITY 8 MESSAGE – TEST	B1 ACTUATE SPEAKERS	C1 ACTUATE AMBER LENS ALERT STROBES	D1 OVER RIDE ALL MESSAGES	E1
1	MANUAL PULL STATIONS	●	●							●							
2	AREA SMOKE DETECTOR	●	●							●							
3	NOT USED																
4	NOT USED																
5	DUCT SMOKE DETECTOR	●	●							●							
6	WATER FLOW SWITCH	●	●							●							
7	VALVE TAMPER																
8	FIRE ALARM AC POWER FAILURE																
9	FIRE ALARM SYSTEM LOW BATTERY																
10	OPEN CIRCUIT																
11	GROUND CIRCUIT																
12	NOTIFICATION APPLIANCE CIRCUIT SHORT																
13	SMOKE DETECTOR ELEVATOR LOBBY GRN FLR	●	●							●							
14	SMOKE DETECTOR ANY OTHER FLOOR	●	●							●							
15	SMOKE DETECTOR IN ELEVATOR EQUIP ROOM	●	●							●							
16	SMOKE DETECTOR ELEVATOR SHAFT	●	●							●							
17	HEAT DETECTOR IN ELEVATOR EQUIP ROOM	●	●							●							
18	WATERFLOW ELEVATOR SHAFT	●	●							●							
19	MNS PRIMARY MICROPHONE	●												●	●	●	
20	MNS BUTTON #1 MESSAGE 1	●				●								●	●		
21	MNS BUTTON #2 MESSAGE 2	●					●							●	●		
22	MNS BUTTON #3 MESSAGE 3	●						●						●	●		
23	MNS BUTTON #4 MESSAGE 4	●							●					●	●		
24	MNS BUTTON #5 MESSAGE 5	●								●				●	●		
25	MNS BUTTON #6 MESSAGE 6	●									●			●	●		
26	MNS BUTTON #7 MESSAGE 7	●										●		●	●		
27	MNS BUTTON #8 MESSAGE 8	●											●	●	●		
28	MASS NOTIFICATION AC POWER FAILURE			●	●												
29	MASS NOTIFICATION SYSTEM LOW BATTERY			●	●												
30	MASS NOTIFICATION OPEN CIRCUIT			●	●												
31	MASS NOTIFICATION GROUND CIRCUIT			●	●												
32	MASS NOTIFICATION APPLIANCE CIRCUIT SHORT			●	●												
33	MASS NOTIFICATION OVERRIDE THE FA SYSTEM																
34	NOT USED																

Table 5-3: Sequence Table for High Expansion Fire Suppression System

FIRE ALARM / FOAM RELEASE SEQUENCE OF OPERATIONS																			
ACTION \ EVENT	BUILDING MANUAL PULL STATION	HI-EX FOAM MANUAL PULL STATION	DEPRESS AND HOLD DOWN ON STOP/STRT ABORT STATION	RELEASE STOP/STRT ABORT STATION	LOW TEMP HI-BAY HI/LO TEMP FACP RM PUMP RM	WATERFLOW SWITCH (HANGAR BAY)	FOAM RISER PRESSURE SWITCH	FOAM PUMP RUN OR TRBL	VALVE TAMPER SWITCH (ALL)	FOAM RELEASING PANEL (ALARM)	FOAM RELEASING PANEL (SUPERVISORY)	FOAM RELEASING PANEL (TROUBLE)	IR3 FLAME DETECTOR ALARM	RELEASE SOLENOID POWER DISABLE KEY SWITCH	IR3 FLAME DETECTOR TROUBLE	LOW BATTERY POWER	CIRCUIT FAULT	AC POWER FAILURE	SUPERVISE COMPONENT FAILURE
ACTIVATE BUILDING ALARM STROBES AND HORNS	●	●				●	●			●			●						
TRANSMIT ALARM SIGNAL TO FIRE DEPARTMENT	●	●				●	●			●			●						
DISPLAY SUPERVISORY CONDITION ON FACP					●			●	●		●		●						
TRANSMIT SUPERVISORY SIGNAL TO FIRE DEPARTMENT			●		●			●	●		●								
CLOSE ROLL-UP DOORS IF OPEN		●				●	●			●									
START FIRE PUMPS		●				●				●									
ACTIVATE FOAM RELEASE SOLENOID		●				●													
ACTIVATE BLUE BEACONS FOR FOAM RELEASE		●				●													
DISPLAY ALARM CONDITION ON RELEASING PANEL		●				●													
DISPLAY TROUBLE CONDITION ON FACP												●		●	●	●	●	●	●
TRANSMIT TROUBLE CONDITION TO FIRE DEPARTMENT												●		●	●	●	●	●	●
STOP THE FLOW OF FOAM SOLUTION THROUGH THE FOAM FLOW CONTROL VALVE			●											●					
RESUME THE FLOW OF FOAM SOLUTION IF THE FOAM CONTROL VALVE WAS PREVIOUSLY OPENED BY A SPRINKLER FLOW SWITCH OR A FOAM DISCHARGE STATION				●															
ABORT SWITCH SUPERVISORY ALARM AT THE FOAM RELEASING PANEL AND THE BUILDING FIRE ALARM CONTROL PANEL			●																
DISPLAY TROUBLE CONDITION ON FSCP														●	●	●	●	●	●

All alarms are sent to the airports 24/7 fire dispatch center who then dispatches the airports fire brigade. Trouble and supervisory signals are reported to the fire dispatch who then notifies the sites security Operations Center (SOC) who dispatches an officer to investigate and notifies the facility manager and/or facility engineer of the problem.

5.1 Initiating and Detection Devices

The building has multiple initiating and detection devices. Table 5-4 lists the types of devices and their actions.

Table 5-4: Initiating and Detector Devices

Description	Signal Type
Pull Station	Alarm
Water flow switch	Alarm
Optical Flame Detectors	Alarm
Smoke detector	Alarm
Duct Smoke detector	Alarm
Heat Detector	Alarm
Valve Tamper switch	Trouble
Fire Pump Trouble signals	Trouble
FACP, FSCP,FCPS, DVCP trouble signal	Trouble

5.1.1 Pull Stations

The building has Notifier NBG-12LX addressable pull stations to meet NFPA 101 requirements. The pull stations are located at all of the building exits, exits from each floor and the exits from the Hangar into the office area (Figure 5-5 to Figure 5-7). The Hangar has not only the building FA pull stations but also has High Expansion Foam activation and abort stations. These are located at the exits of the hangar. The activation station latches on and starts the foam system. Foam takes about 30 seconds to start discharging from the generators. The ABORT station is a dead man switch and must be held in order for the foam to stop or not start discharging. Figure 5-8 shows a typical building pull station and Foam activation/abort station.

Figure 5-5: Pull Station and Detector Locations (Ground Floor)

Figure 5-6: Pull Station and Smoke Detector Locations (2nd Floor)

Figure 5-7: Pull Station and Smoke Detector Locations (3rd Floor)

Figure 5-8: Typical Pull Station and Foam Activation/Abort Station

5.1.2 Water flow switch

Each sprinkler riser has a flow switch that indicates when a sprinkler head has activated. The flow switches in the wet pipe system are paddle type switches. For the Dry pipe and Deluge systems there is a pressure switch that indicates when water has entered the piping. Both of these types of devices indicate when the system has activated and notifies the fire dispatch. Figure 5-9 shows a typical paddle flow switch.

Figure 5-9: Typical Paddle Type Flow Switch

5.1.3 Optical Flame Detectors

The hangar has 8 Sprectrex SharpEye model 40/40i, Triple IR (IR3) Optical flame detectors, Figure 5-10 has the general specifications for the detector. These detectors look at three IR bands to determine if a fire has initiated. Comparing multiple IR bands reduces the probability of false alarms. The detectors have three sensitivity levels for varying range. Figure 5-11 shows the coverage in the hangar and a typical installation of the detector. The coverage chart shows that most of the hangar is serviced by a minimum of two detectors except in the corners where only one covers the area (light pink in Figure 5-11). When the system was designed, the optical detectors were only allowed for detection and not for activation of the fire suppression systems per AF policy and the AHJ. In April 2017, the policy changed and they are now allowed for activation when two independent sensors detect the fire. To meet the new requirements, four additional flame detectors will need to be added to the hangar for complete coverage by two detectors.

GENERAL SPECIFICATIONS	
Spectral Response	Three IR Bands
Detection Range (at highest Sensitivity Setting for 1ft^2 (0.1m^2) pan fire)	Fuel ft / m: n-Heptane 215 / 65; Gasoline 215 / 65; Diesel Fuel 150 / 45; JP5 150 / 45 Fuel ft / m: Kerosene 150 / 45; Ethanol 95% 135 / 40; Methanol 115 / 35; IPA (Isopropyl Alcohol) 135 / 40 Fuel ft / m: Methane* 100 / 30; LPG * 100 / 30; Polypropylene Pellets 16 / 5; Office Paper 33 / 10 * 20" (0.5m) high, 8" (0.2m) width plume fire
Response Time	Typically 5 seconds
Adjustable Time Delay	Up to 30 seconds
Sensitivity Ranges	4 Sensitive ranges for 1 ft^2 (0.1m^2) n-heptane pan fire from 50 ft (15m) to 215 ft (65m)
Field of View	Horizontal 100°; Vertical 95°
Built-in-Test (BIT)	Automatic (and Manual)
Temperature Range	Operating: -67°F to +167°F (-55°C to +75°C) Option: -67°F to +185°F (-55°C to +85°C) Storage: -67°F to +185°F (-55°C to +85°C)
Humidity	Up to 95% non-condensing (withstands up to 100% RH for short periods)
Heated Optics	To eliminate condensation and icing on the window

Figure 5-10: General Specifications for IR3 Flame Detectors

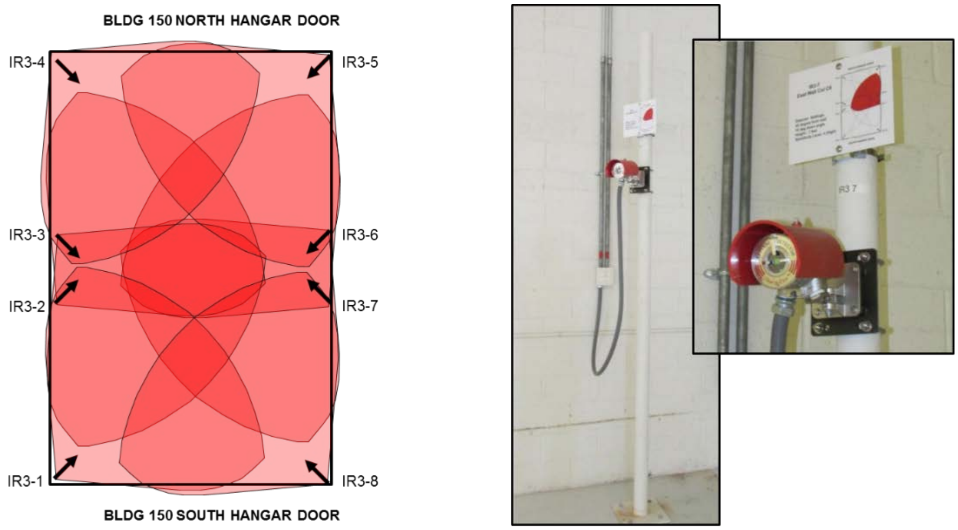


Figure 5-11: Optical Flame Detector Coverage and Installation

5.1.4 Smoke Detectors

Ceiling smoke detectors are located at the lobby/landing servicing each of the elevators, in the elevator mechanical room, and over each of the FACP per NFPA requirements. The electrical sub-station, B191, only has smoke detectors for fire alarm activation. The elevator lobby detectors not only activate the building alarms and notify dispatch but also recall the elevators to either the ground floor (primary) or to the second floor (Alternate), if the ground floor smoke detector alarms.

Duct smoke detectors are located in all 6 of the HVAC systems in the building since they are all over 2000 CFM. The duct smoke detectors activate the alarm and also shut down ALL of the HVAC units in the building. Since three of the building's HVAC units are dual duct system there are three detectors in their units: 1) Cold deck supply, 2) Hot deck supply, 3) return/fresh air supply. The other three HVAC units only have supply and return detectors. Each of the detectors have a remote test key switch. The detectors are not near the motor control center for the HVAC units thus the detectors send a signal to the FACP which then activates a relay on the SLC that shuts off the HVAC units. In some instances the FACP that has the smoke detectors are in secure areas and thus they communicate over the fiber optic network to the common area FACP which has the relay to shut down the HVAC fan motors. Figure 5-12 shows the ceiling mounted and duct smoke detectors.

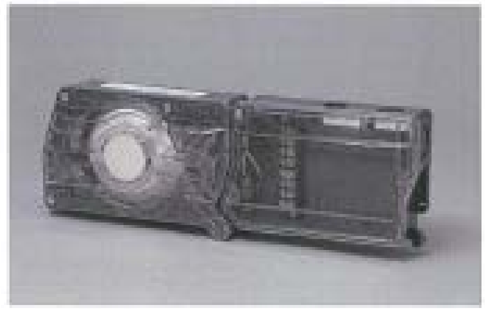


Figure 5-12: Notifier FSP-851(A) Ceiling and DNR(A) Duct Smoke Detectors

5.1.5 Smoke Control

The building does not have a smoke control system other than having the activation of the smoke detectors shut down all of the HVAC systems as discussed above in Section 5.1.4. By shutting down all of the HVAC system on any duct smoke detectors the possibility of spreading smoke is reduced as compared to just shutting down individual units when their detectors activate.

5.1.6 Heat Detectors

The only heat detector that activates the FA alarm system in located in the elevator equipment room above the elevator shaft. This detector shuts down the elevator prior to the sprinkler system actuating in the elevator shaft and equipment room. Figure 5-13 shows a typical heat detector.

Figure 5-13: Notifier FST-851(A) Heat Detector

5.1.7 Valve Tamper Switches

All of the critical valves in the sprinkler water flow path have tamper switches. The OS&Y and ball valves have exterior bolt on switches. The tamper switches for the butterfly valves are integral to the valve. All of the tamper switches are monitored and any change in position of the valve is transmitted as a trouble to the fire dispatch.

5.1.8 Other Trouble Signals

The Fire pump has multiple signals that are reported to the FACP and relayed to fire dispatch as troubles. The FACP, FSCP, DVCP and Remote power supplies all have health signals that are transmitted to the main FACP and reported to fire dispatch as troubles. The Site security operations center is notified of these troubles and they then relay the problem to the facility manager and engineer.

5.2 Notification Devices

The building's notification devices consist of Horns, Strobes, and Speakers. The Hangar area and Electrical substation have horns and strobes, while the office area and machine shop have strobes and audio announcements from the Mass Notification System (MNS). The Fire Alarm system uses CLEAR strobes, the MNS uses AMBER strobes and the High Expansion Foam system uses BLUE strobes. Figure 5-14 to Figure 5-16 show the location of the notification devices.

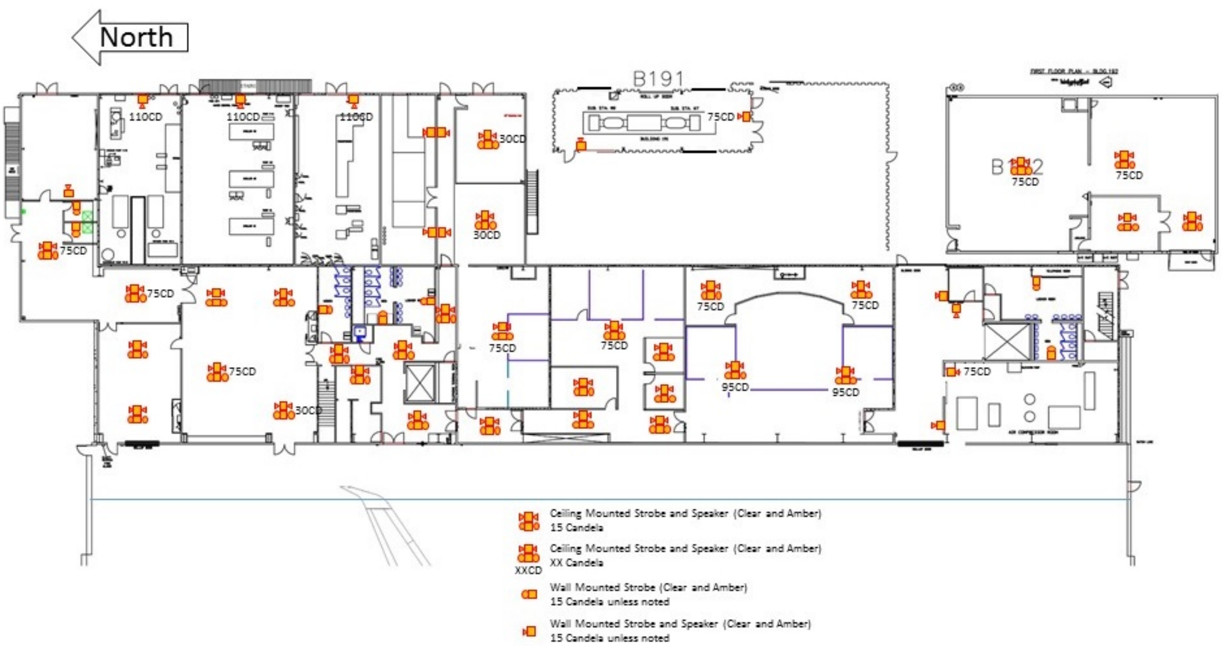


Figure 5-14: Notification Device Locations (Ground Level East Side)

Figure 5-15: Notification Device Locations (2nd Floor)

Figure 5-16 Notification Device Locations (3rd Floor)

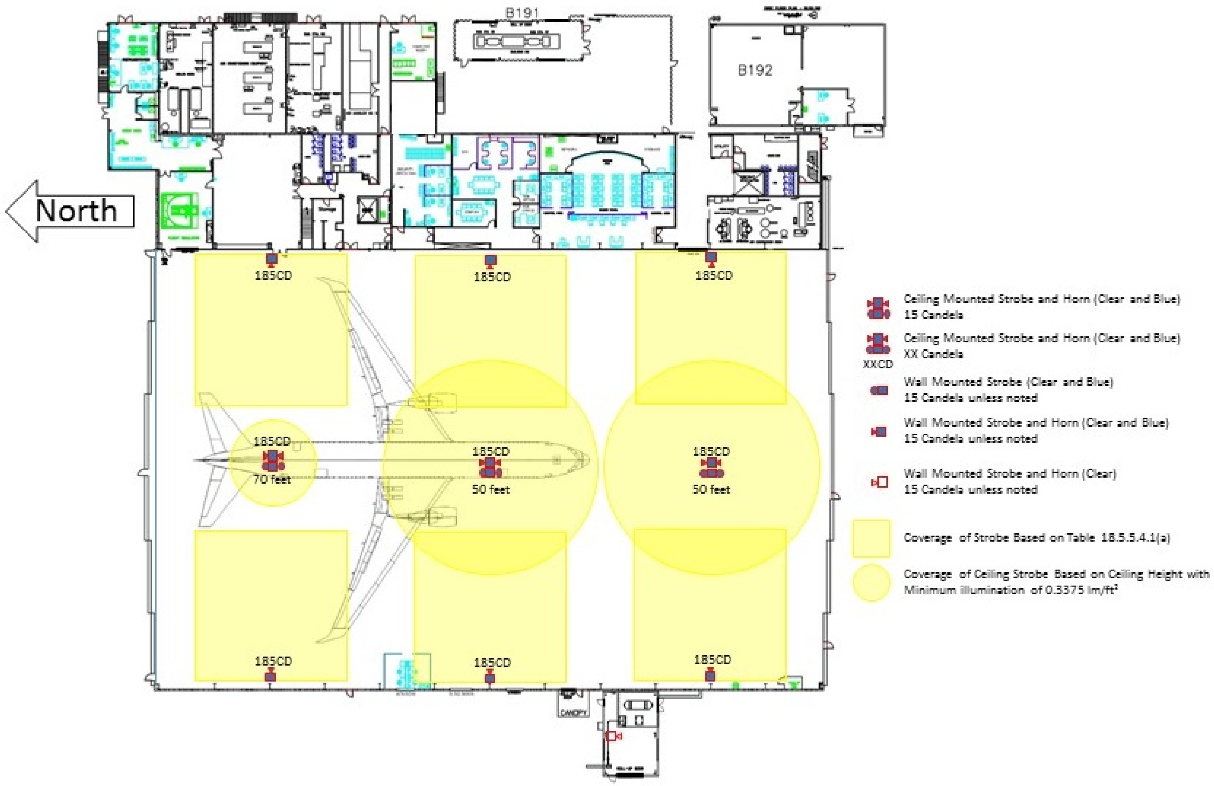


Figure 5-17: Notification Device Locations and Coverage (Hangar)

The office area uses strobes and the MNS messages to alert personnel of the problem. All of the private offices have a speaker/strobe in them that covers the area. The open bays with 6ft partitions are covered with ceiling mounted speaker/strobes that completely cover the area. The open bay on the 2nd floor south end is covered by 3 ceiling mounted 75CD speaker/strobes which have a coverage of 45'x45' but the room is 50 feet wide. The spacing along the length of the room meets the code but the areas next to the east and west walls fall short.

The Mechanical rooms on the ground floor east side are 50 feet deep and covered by a wall mounted 110Cd strobe which have a coverage of 54 feet thus meet the requirements. All of the hallways have speaker/strobes within 15 feet of their ends. All of the restrooms have strobes.

The electrical substation (B191) has two horn/strobe combination to notify personnel that may be working in there. Horn/Strobes were acceptable since this is not generally occupied. There was no need for a MNS system in this building.

The machine shop (B192) is covered by the main building MNS and with speaker/strobe combination. The coverage of the 75CD strobes is sufficient to cover the area of the building.

The hangar appears to have insufficient coverage by the horn/strobe units. Figure 5-17 shows the location and coverage of the 185cd strobes. The wall strobes are good for 70ft x 70ft per NFPA 72 Table 18.5.5.4.1(a). The ceiling strobes are located at a height of 50 ft and 70 ft depending on their location. Using the inverse square law to calculate the intensity at eye level (assume 5 ft above floor) we get a radius of coverage of 50 ft at the 50 ft end and 20 ft and the 70 ft end. This assumes full rating on the ceiling strobes. These areas are shown in Figure 5-17.

The audibility requirements for the hangar per NFPA 72 are 15db above ambient. The ambient in the hangar varies greatly but if we assume "Industrial Occupancies" average sound level of 80db per NFPA 72 Table A.18.4.3 then the required level would be 95bd throughout the hangar. The horns in the hangar are only rated for 88db. If we assume a business levels of 55db then the required level would be 70db. The horns would then have a radius of effectiveness of 80 feet which still would not cover the entire hangar area.

5.3 Secondary Power

The fire alarm systems primary power is from the buildings emergency power circuits which are backed up by an emergency generator. Each of the panels and remote power supplies have battery back-up for secondary power. The battery back-up secondary power was designed to meet the 2013 revision of UFC 3-600-01 "FIRE PROTECTION ENGINEERING FOR FACILITIES" which required rechargeable batteries per NFPA 72 to operate the fire alarm system under supervisory conditions for 48 hours and all alarm devices for an additional 10 minutes. The new 2016 revision of UFC 3-600-01 now required 48 hours under supervisory conditions and additional 15 minutes in alarm conditions per Section 9-18.11.3 "Secondary Power". Table 5-5 summarized the secondary battery size. Detail calculations are in Appendix A.

Table 5-5: Battery Size for Control Panels

FACP, FCPS, DVCP	Required Battery Size (amp-hr)	Installed Battery Size (amp-hr)	Two of the listed Models
Main and Common Area FACP (Node 1)	54	55	PS-12550
Ground and 1st Mezzanine Common Area FCPS (Node 1)	8	12	PS-12120
Common Area 2nd Mezzanine FCPS (Node 1)	8	12	PS-12120
Digital Voice Command Panel (Node 2)	34	55	PS-12550
Secure Area G1 South (Node 4)	22	35	PS-12350
Secure Area G1 North (Node 5)	26	35	PS-12350
Secure Area M1 South (Node 6)	26	35	PS-12350
Secure Area M1 North (Node 7)	21	35	PS-12350
Secure Area M1.5 North (Node 8)	21	35	PS-12350
Secure Area M2 South (Node 9)	26	35	PS-12350
Secure Area M2 North (Node 10)	21	35	PS-12350
Electrical Substation B191 (Node 15)	19	35	PS-12350
Machine Shop B192 (Node 16)	21	35	PS-12350

5.4 Alarm System Summary

The alarm system consist of 12 nodes which are interconnected with a fiber optic network. This network is part of the larger site fire alarm network which communicates to the other buildings and the security operations center. The communications from the Main FACP to the fire dispatch is via a MONACO radio transmitter. The system detectors consist of pull stations, heat & smoke detectors, flow switches, and optical flame detectors. The location of the detectors meet the NFPA code requirements and the AF ETL requirements in the hangar at the time of installation. The notification devices in the office area are strobes and a Mass Notification System which broadcasts pre-recorded announcements to evacuate the building or shelter in place depending on the situation.

The hangar bay only has horns and strobes due to the poor acoustics. The notification devices in the hangar appear not meet the NFPA 72 code requirements for coverage due to the height of the ceiling and the distance from wall to wall. The 185 cd strobes mounted on the ceiling and walls do not provide complete coverage. The horns in the hangar bay are rated for 88 db and if the hangar is considered “industrial occupancy” then 95 db would be required.

The fire suppression systems that either activate the alarm or are activated by the alarm system will be discussed next.

6 Water Based Fire Suppression Systems

6.1 Building Hazard Classifications

The hazard classifications for the building are shown in Figure 6-1 to Figure 6-3 for the three building levels. Figure 6-4 shows the location of the twelve (12) system risers in the building, the type of system and the area they serve.

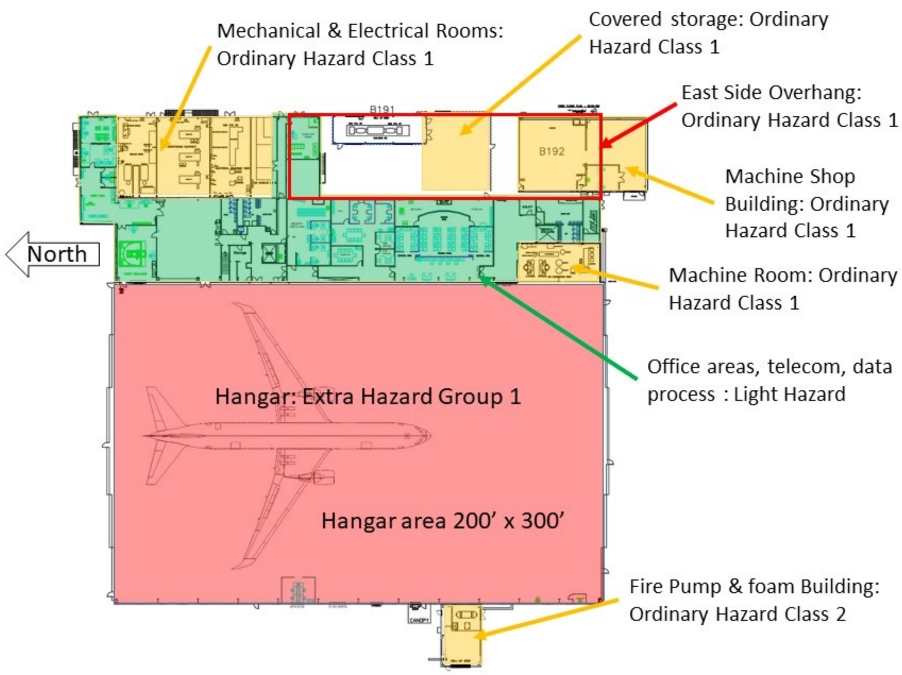


Figure 6-1: Ground Floor Hazard classification

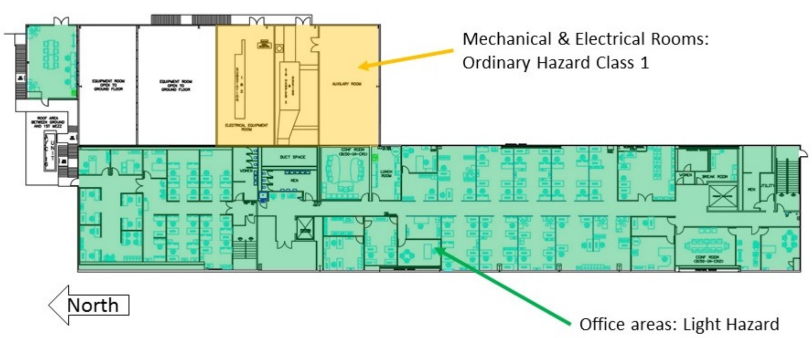


Figure 6-2: Second Floor Hazard classification

Figure 6-3: Third Floor Hazard classification

6.2 Fire System Risers

The building has 12 fire risers supporting the water based fire suppression systems. These are shown in Figure 3-4 with a general discussion of the requirements in the following sub-sections. Section 6.8 will provide detailed description of each riser, along with the hydraulic flow analysis.

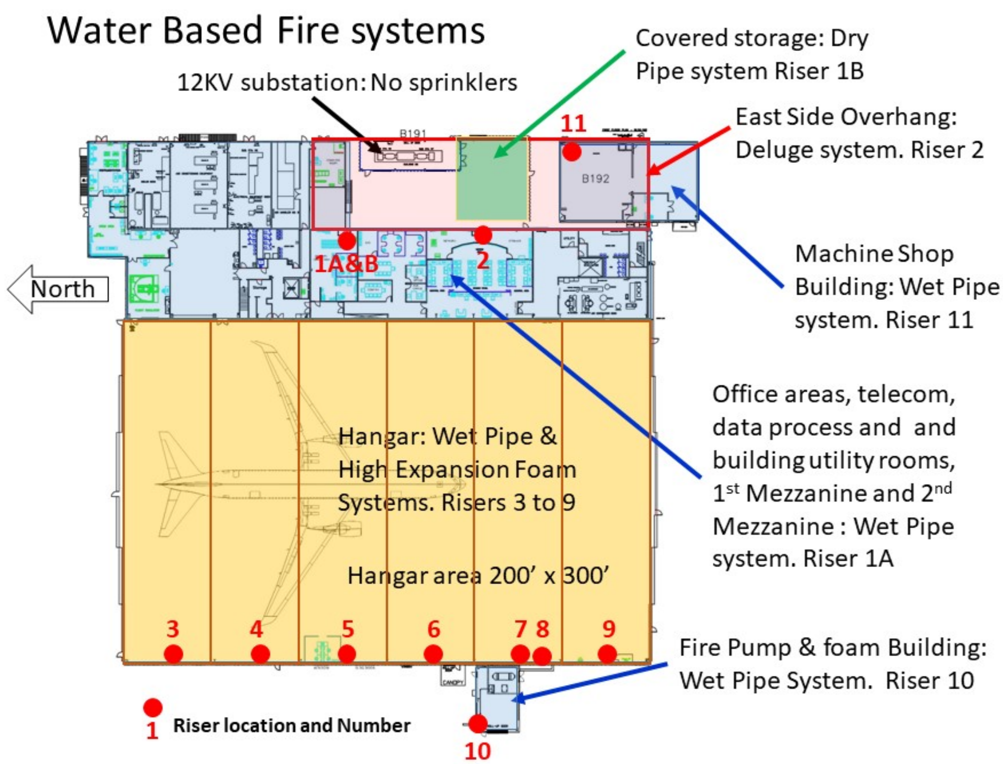


Figure 6-4: Riser locations, type of system and the areas they serve

6.2.1 Office area and Mechanical rooms (Riser #1A):

The office areas, the telecom room, the computer rooms, and the rest rooms, on all three floors, are all considered light hazard. The mechanical rooms and the compressor room are considered Ordinary Hazard 1 areas. All of these areas are supplied by Riser #1A. The flow requirement for this riser are based on the highest demand which would normally be the Ordinary Class 1 area which per NFPA 13 section 11.2.3 the flow requirements are 0.15 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes. The minimum water flow would be 225+250=475 gpm.

6.2.2 Exterior covered storage (Riser 1B)

The covered storage area on the east side (Figure 6-1) is considered to be Ordinary Hazard 1 since it is used primarily for vehicle parking and storage of low combustible items such as metal furniture. Based on NFPA 13 section 11.2.3 the flow requirements are 0.15 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes if it was a wet pipe system but since it is a dry pipe system the area needs to be increased by 30% (NFPA 13 Section 11.2.3.2.5). The design area is now 1950 ft^2 thus the minimum water supply would be 293 + 250 = 543 gpm.

6.3 East overhang (riser #2):

The east side overhang was once used for parking aircraft and thus the system was designed as a deluge system per the original construction specifications. In the current usage this is no longer required to be deluge system but the system has never been changed. In the current utilization the system should be Ordinary Hazard 1 since there are some combustible items stored below the overhang and most likely be designed based on performance criteria. The overhang is 65 feet above the ground and made of steel with a membrane roof material. The system will be analyzed as installed. The original 1957 specification called for 0.2 gpm/ ft^2 for the overhang and to be hydraulically designed. The area is 10,000 ft^2 and at 0.2 gpm/ ft^2 the minimum flow would be 2,000 gpm + 250 hose allowance for a total of 2,250 gpm. This would be a very high demand on the water supply.

6.4 Hangar (Risers 3 to 9)

The Hangar is considered to be Extra Hazard Group 1. The AF Engineering Technical Letter (ETL) 02-15 requires both a wet pipe system and a High Expansion Foam (HEF) suppression system. The Wet pipe system will have a minimum of 0.2 gpm/ ft^2 and a design area of 5000 ft^2 (AF ETL 02-15 Paragraph A1.3.1.1.2.). There are 6 wet pipe systems in the hangar each with its own riser. These were installed originally in 1958 as a deluge system but were changed to a wet pipe system in 2014. The original piping was not changed. Each system covers 10,000 ft^2 and is separated by a draft curtain. The minimum flow would be 1000 + 250 = 1250 gpm.

The High Expansion Foam system is designed in accordance with NFPA 11A and AF ETL 02-15. The water demand for this system will be dependent on the generators selected and the ETL design criteria. The design and water requirements will be discussed in Section 6.8.5.

6.4.1 High Expansion Foam System Requirements (AF ETL 02-15):

Below are a few pertinent requirements for the HEF system directly from the AF ETL 02-15 (Refer to the ETL for the complete listing of requirements).

A1.3.3.1. Installation. Locate low-level high-expansion foam generators so that foam discharge falls close to, but not directly on, the aircraft fuselage or wings. Mount generators in the overhead roof support structure and/or high on the walls just below the roof support structure. Initial discharge of foam must protect the under aircraft and underwing area and then spread to the remaining hangar floor area.

A1.3.3.2.1 Low-level high-expansion foam systems must cover 90 percent of the aircraft silhouette area projected on the floor in one minute or less. (Note: Wall mounted generators alone in larger rectangular/square shaped hangars cannot normally achieve this performance requirement.) The area under engines extending beyond the wing edge and under rear elevators does not have to be considered in the aircraft's silhouette area.

A1.3.3.2.2 Low-level high-expansion foam systems must cover the aircraft servicing area and adjacent accessible areas to a depth of one meter (3.2 feet) in four minutes or less.

A1.3.3.3. Rate of Discharge. The minimum rate of discharge or total generator capacity will be calculated in accordance with NFPA 11A; however, it will never be less than 0.8 $m^3/min/m^2$ (2.6 $ft^3/min/ft^2$). Application rates in the range of 0.8 to 1.2 $m^3/min/m^2$ (2.6 to 4 $ft^3/min/ft^2$) are required to meet the performance requirements A1.3.3.3.1. The minimum rate of discharge or total generator capacity will be calculated from the following formula:

R = ([V/T] + RS) x CN x CL

where:

R = Rate of discharge in m^3/min (ft^3/min)

V = Submergence volume in m^3 (ft^3) determined by the following formula:

V = A x D

where:

A = Area of the aircraft servicing floor and adjacent floor areas not cut off from the aircraft servicing floor m2 (ft2) D = Depth = 1 meter (3.28 feet) (see paragraph A1.3.3.2) which is greater than the 0.6-meter (2-foot) minimum foam depth over the hazard required in NFPA 11A

T = Submergence time in minutes = 4 (see paragraph A1.3.3.2)

RS = Rate of foam breakdown by sprinklers in ^{ft3}/min (m^3/min) determined by the following formula:

RS = S xQ

where:

S = Foam breakdown from sprinkler discharge = 0.0748 m^3 per minute • L/min (10 ft^3 per minute • gpm)

Q = Estimated total discharge from maximum number of sprinklers expected to operate in L/min (gpm).

CN = Compensation for normal foam shrinkage = 1.15. This is an empirical factor based on average reduction in foam quantity from solution drainage, fire, wetting of surfaces, and absorbency of stock.

CL = Compensation for loss of foam due to leakage around doors and windows and through unclosable openings determined by the design engineer after proper evaluation of the structure. This factor for Air Force hangars cannot be less than 2.0 for hangars less than 1394 square meters (15,000 ft2), 2.5 for hangars less than 2787 m2 (30,000 ft2), and 3.0 for all other hangars.

A1.3.3.4. Concentrate and Water Supply. Concentrate and water supply will permit continuous operation of the system to generate four times the submergence volume, but for not less than 15 minutes. No additional foam is required for maintenance of the submergence volume beyond 15 minutes. Do not provide a connected reserve concentrate supply.

6.5 Fire Pump Building (Riser #10):

The Fire pump building is Ordinary Hazard Class 2 (NFPA 13 Section A.5.3.2). The Pump building has its own riser. Based on NFPA 13 Section 11.2.3 the flow requirements are 0.2 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes. Minimum flow would be 300 + 250 = 550 gpm.

6.6 Machine Shop (Riser #11):

The machine shop is Ordinary Hazard Class 2 (NFPA 13 Section A.5.3.2 (13)). The machine shop has its own riser. Based on NFPA 13 Section 11.2.3 the flow requirements are 0.2 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes. Minimum flow 300 +250=550 gpm.

6.7 Building Fire water supply

6.7.1 Fire Water Supply

The Fire water for the building is provided from a private water supply system. The water supply is dedicated to fire protection for the production facility. The system consists of two fire pump facilities, one on the south side (pump House #1) of the main runway and one on the North side (pump House #2). The pump houses can be connected by opening a valve in the loop system but the primary water supply is from pump house #2. Pump house #2 has three electric fire pumps and 3 diesel back-up pumps in parallel. Each electric pump is rated for 2200 gpm at 100 psig. The water supply is from a 1M gallon aboveground storage tank which is filled from a dedicated ground water well. The pressure is maintained by a jockey pump and a pressure tank. The feed line from the pump house to the hangar is shown in Figure 6-5 &Figure 6-6.

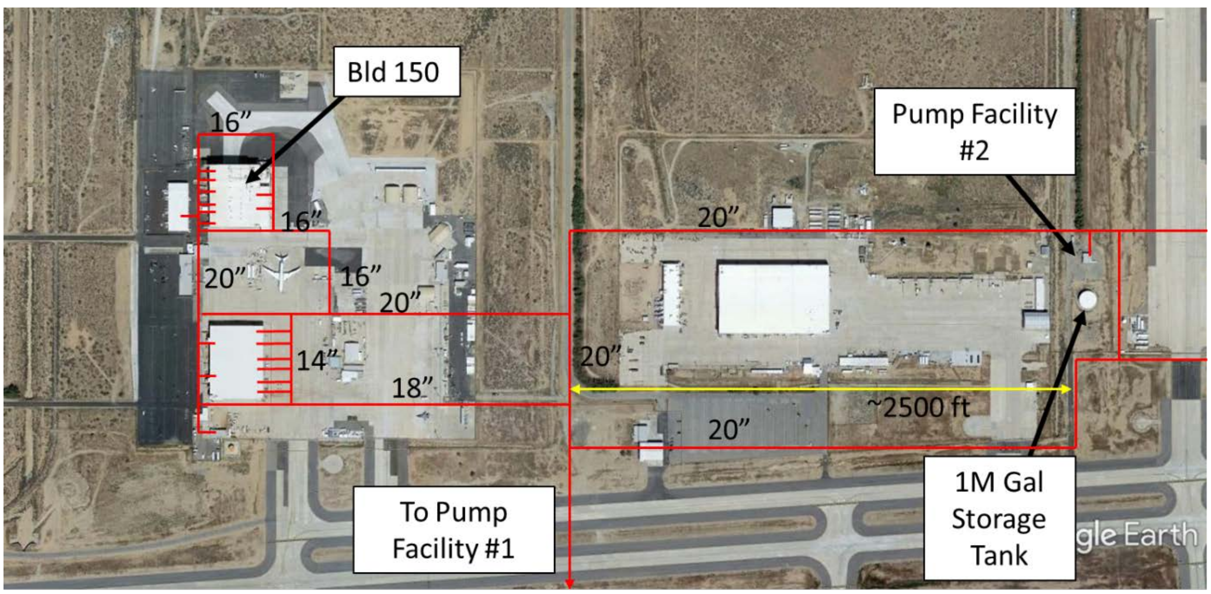


Figure 6-5: Fire Water Mains from Pump Facility (Minor piping and Hydrants not shows)

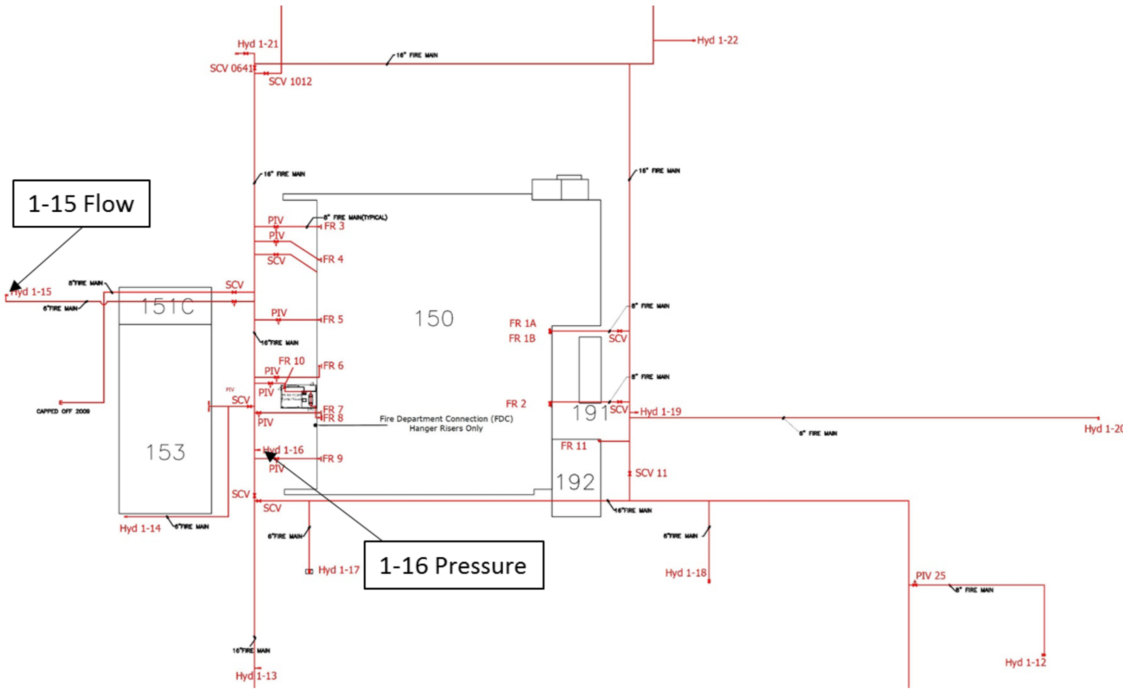


Figure 6-6: Fire Water supply around B150 showing risers supply and Hydrants

6.7.2 Water Flow Test

A water flow test was performed in June 2012 to support the high expansion foam design. The flow was from hydrant 1-15 and the static pressure was from hydrant 1-16 as shown on Figure 6-6. The static pressure was 112 psig and the residual pressure was 95 psig at 2700 gpm as shown in Figure 6-7.

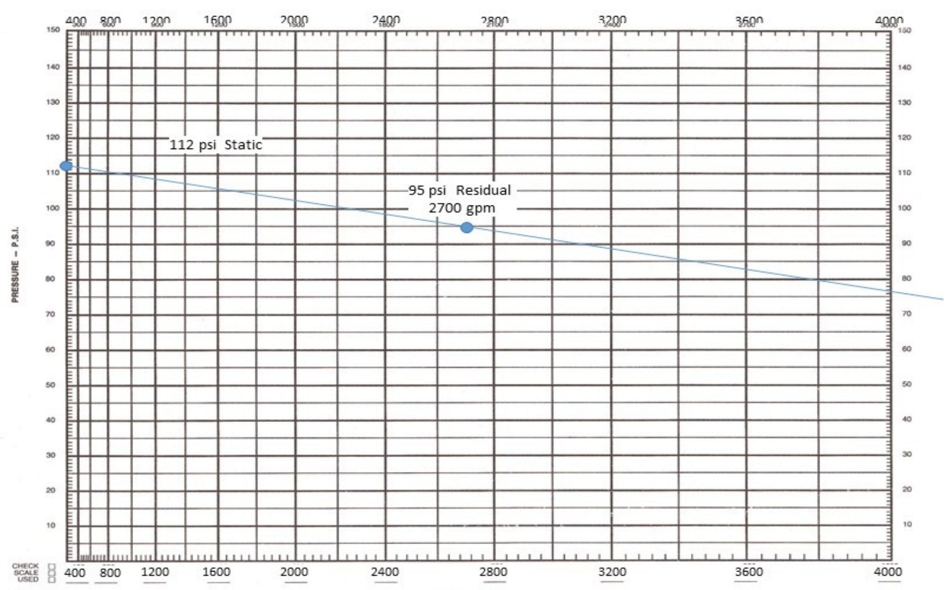


Figure 6-7: Water supply flow versus pressure.

The pump facility #2, that is the primary supply for building 1, has 3 fire pumps each rated for 2200 gpm at 100 psig. The churn pressure is 120 psig and the 150% flow is 3300 gpm at 75 psig. The performance of the pumps is plotted in Figure 6-8 for a single pump. Since the pumps operate in parallel then the flow would be doubled or tripled depending if two or three pumps were operating. It is unknown as to how many pumps were operating when the flow test was performed. The pumps start depending on the demand and the supply line pressure. The exact control of the pump facility was not available.

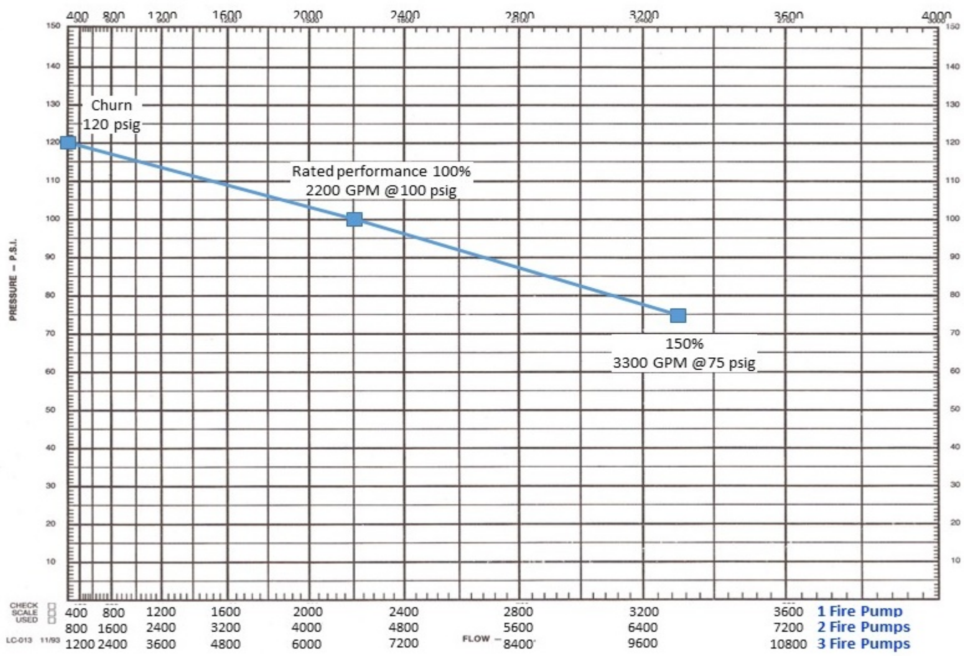


Figure 6-8: Pump Performance for Fire Pump Facility #2

6.8 System Description and Hydraulic Analysis

While researching the drawings for the facility I found that many of the drawings were not updated when modifications were made. Others were just not available. The drawings for the original building were found along with the drawings for the original sprinkler systems. The hydraulic calculations were also found for the original deluge systems. The sprinkler system drawings for the modifications made in the 1970s and later were not found. The drawings used for the hydraulic analysis and presented in this report were developed from field measurements and building observations. In some cases the piping was not visible and best engineering estimates were used to determine pipe sizes and lengths. For the most part the drawings are a good representation of what exists today. Drawings for the high expansion foam system and the wet pipe system in the hangar were available. The details of the hydraulic calculation are presented in Appendix B:.

6.8.1 Office area and Mechanical rooms (Riser #1A):

The office areas, the telecom room, the computer rooms, and the rest rooms, on all three floors, are all considered light hazard. The mechanical rooms and the compressor room are considered Ordinary Hazard 1 areas. All of these areas are supplied by Riser #1A. Figure 6-9 to Figure 6-11 show the piping configuration for each of the floors and Figure 6-12 shows the riser in a cross sectional view. The building has drop ceiling on each floor but the branch lines are along the true ceiling. Each sprinkler is dropped from the BL to below the drop ceiling. The sprinklers are Tyco model TY3211 Standard response 165°F sprinklers with a K=5.6.

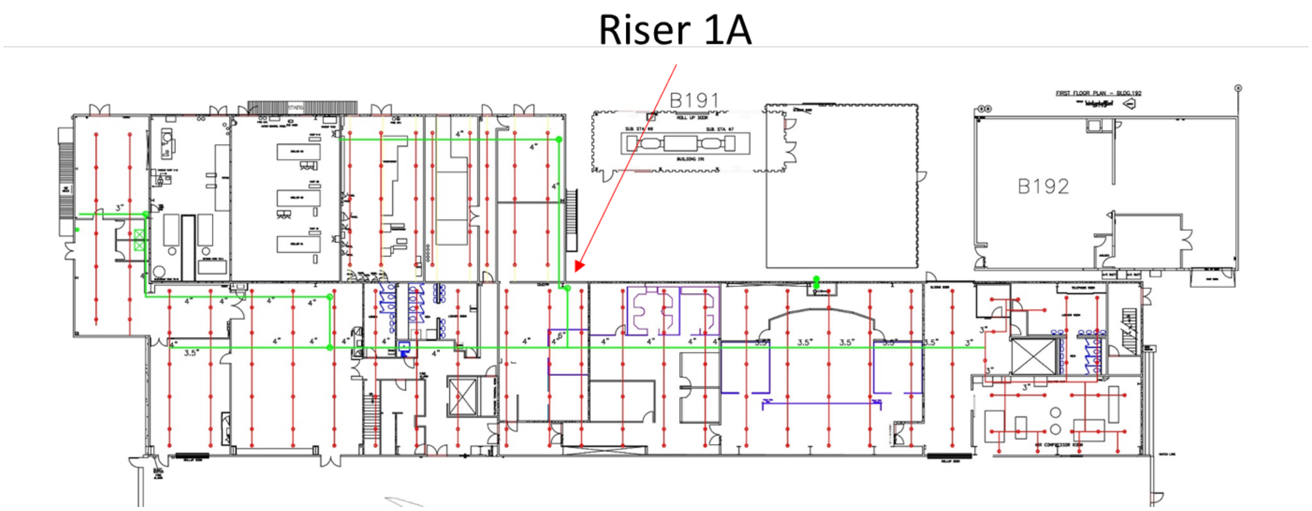


Figure 6-9: Ground floor Sprinkler system layout

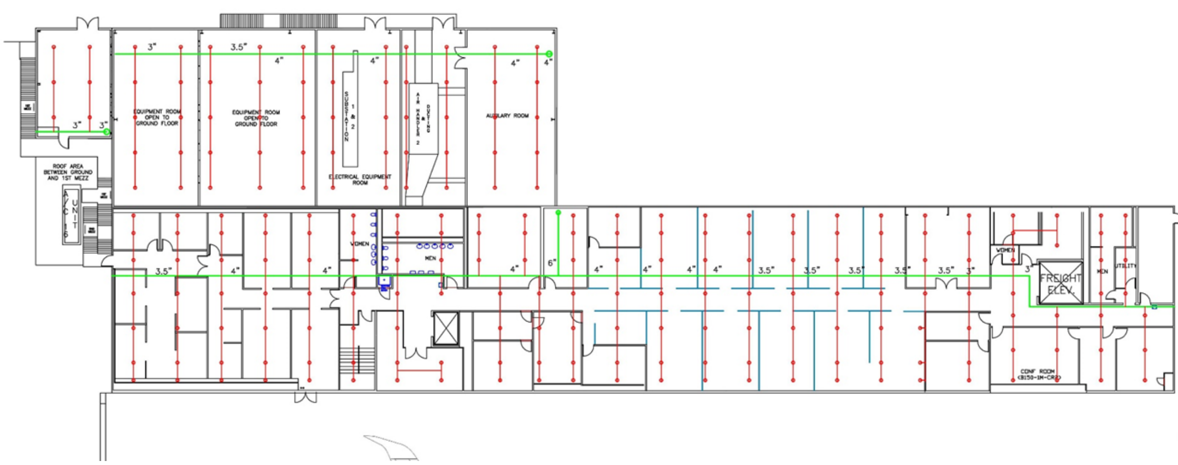


Figure 6-10: Second Floor Sprinkler system layout

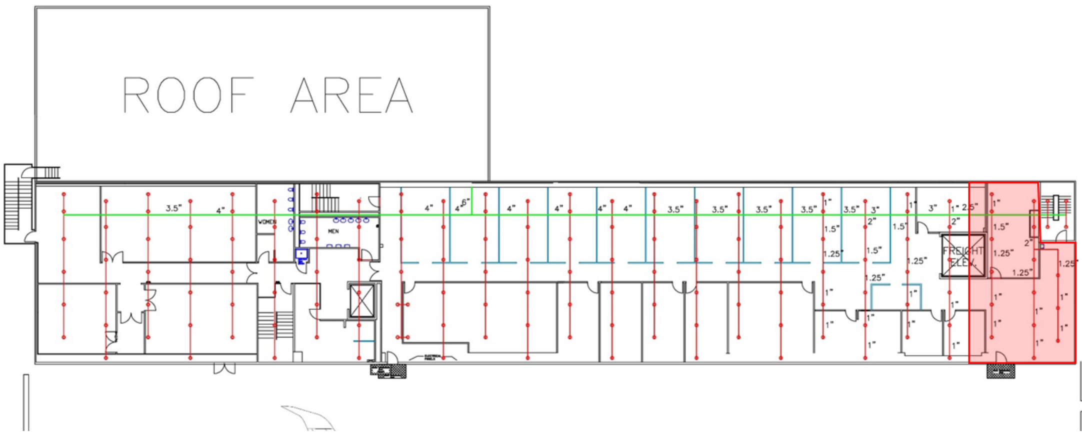


Figure 6-11: Third Floor Sprinkler system layout showing hydraulically remote area

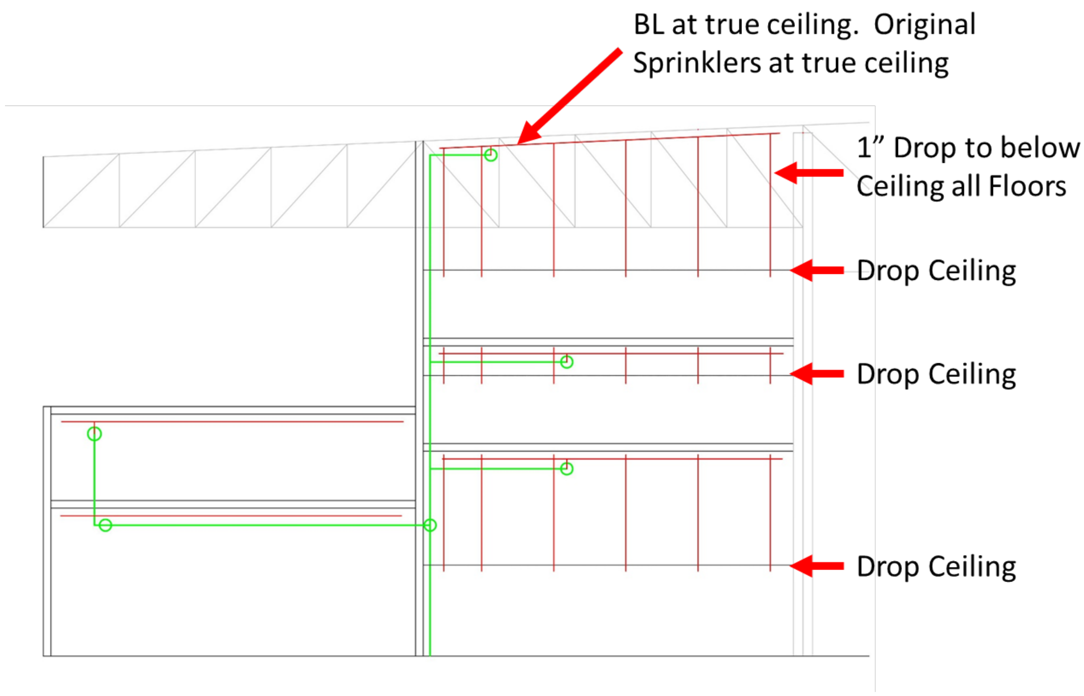


Figure 6-12: Riser 1A Cross section layout showing highs to cross mains and feed mains

The Riser is shown in Figure 6-13. The riser is 6 inch pipe with an alarm check valve and associated trim. The riser is fed from am 8 inch underground feed from the 16 inch main at the POC. The water supply at the POC will be assumed to be that measured on the other side of the building.

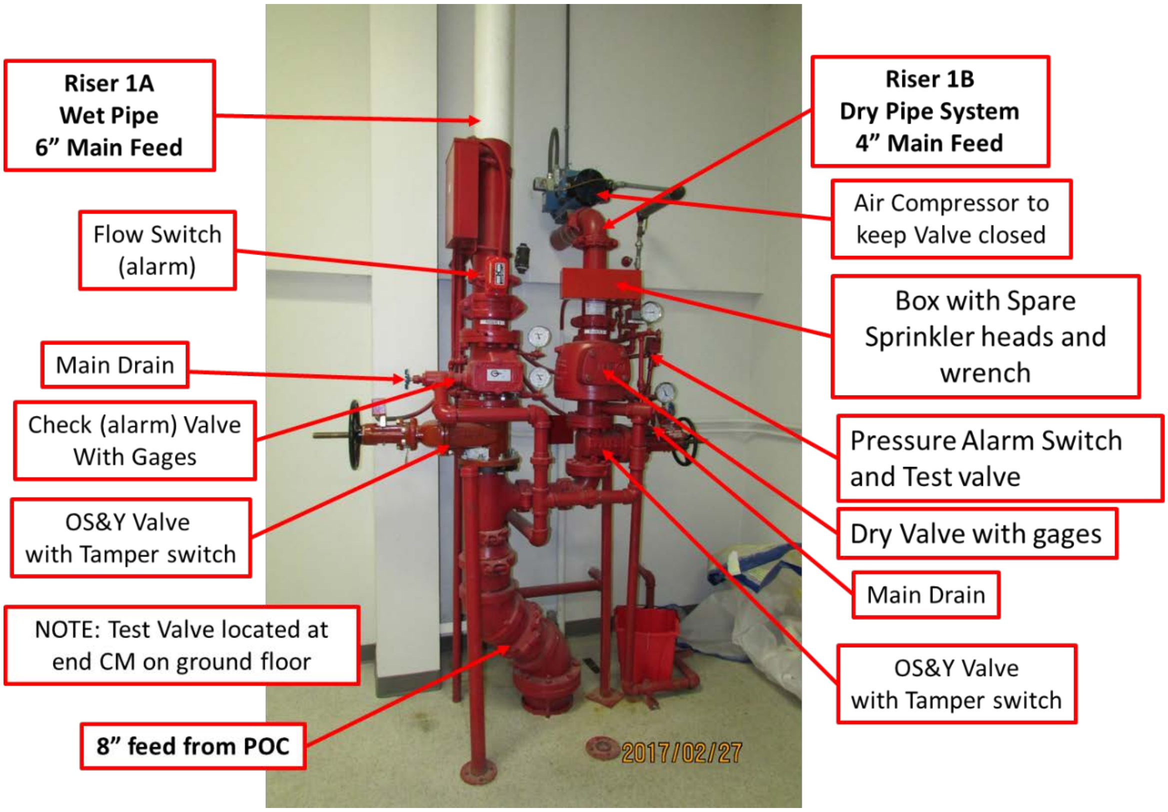


Figure 6-13: Photograph of Riser 1A and 1B

The hydraulically most demanding area is the area on the third floor south end. Since this building was originally an industrial facility which would have been Ordinary Hazard Group 1 or 2 depending on the use, when 1500 ft^2 is mapped out there are additional sprinkler heads, thus the actual flow for 1500 ft^2 is greater than 0.1 gpm/ ft^2 required for a light hazard area. For the most demanding area in the hydraulic calculations I chose an area containing the last three branch lines on the third floor and used the actual sprinklers on the lines. See Figure 6-11 for the area chosen. Figure 6-14 shows the demand compared to the available water supply. The point of connect is at the 16 inch main. This riser has no water supply issues. The hydraulic calculations are presented in Appendix B.1.

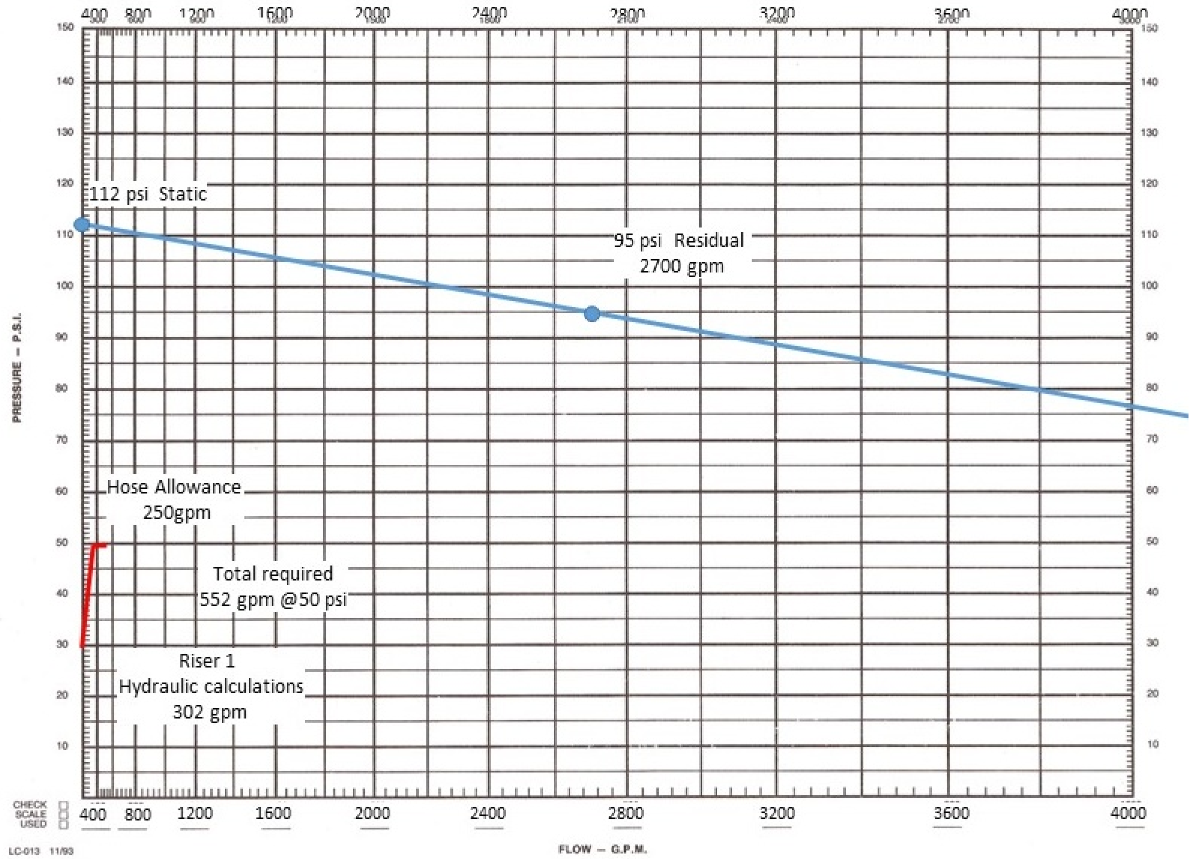


Figure 6-14: Flow requirement for Riser 1A versus available water supply

6.8.2 Exterior covered storage (Riser 1B)

The covered storage area on the east side (Figure 6-1) is considered to be Ordinary Hazard 1 since it is used primarily for vehicle parking and storage of low combustible items such as metal furniture. Based on NFPA 13 Section 11.2.3 the flow requirements are 0.15 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes if it was a wet pipe system; but since it is a dry pipe system the area needs to be increased by 30% (NFPA 13 Section 11.2.3.2.5). The design area is now 1950 ft^2.

The piping layout is shown in Figure 6-15 along with the hydraulically most remote area. The Riser is a 4 inch riser fed from the same 8 inch feed as riser 1A. The riser is shown in Figure 6-13. The riser has a 4 inch dry valve, associated trim, gages, drain and an air compressor to maintain the required pressure in the piping. The sprinklers are Tyco model TY3211 Standard response 165F sprinklers with a K=5.6. Figure 6-16 shows the demand compared to the available water supply. The Point of connect is at the 16 inch main same as for riser 1A. The hydraulic calculations are presented in Appendix B.2.

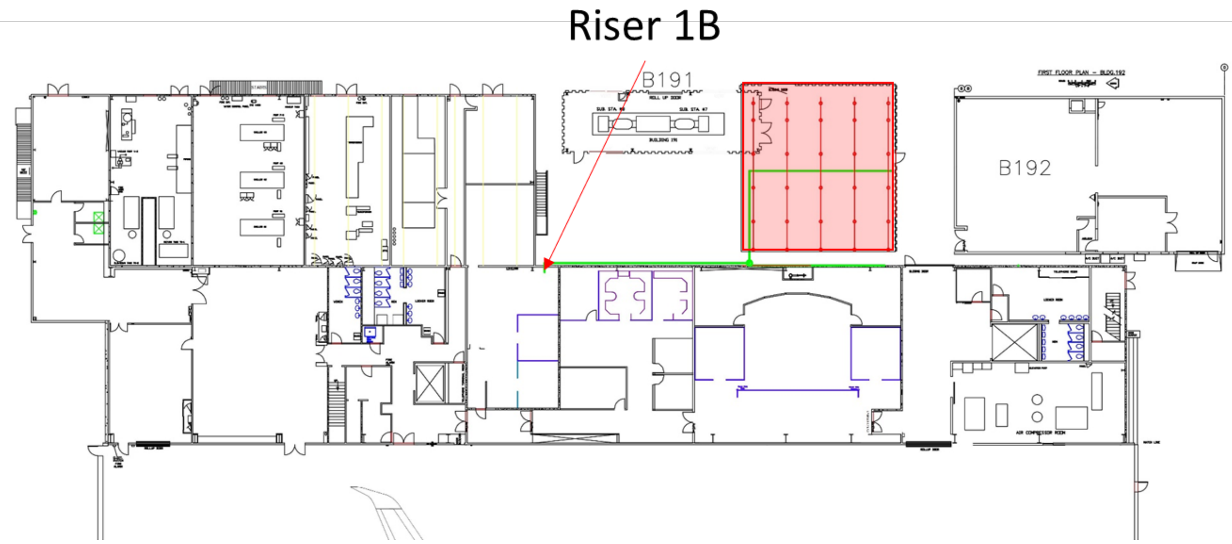


Figure 6-15: Exterior Covered Storage Sprinkler system layout

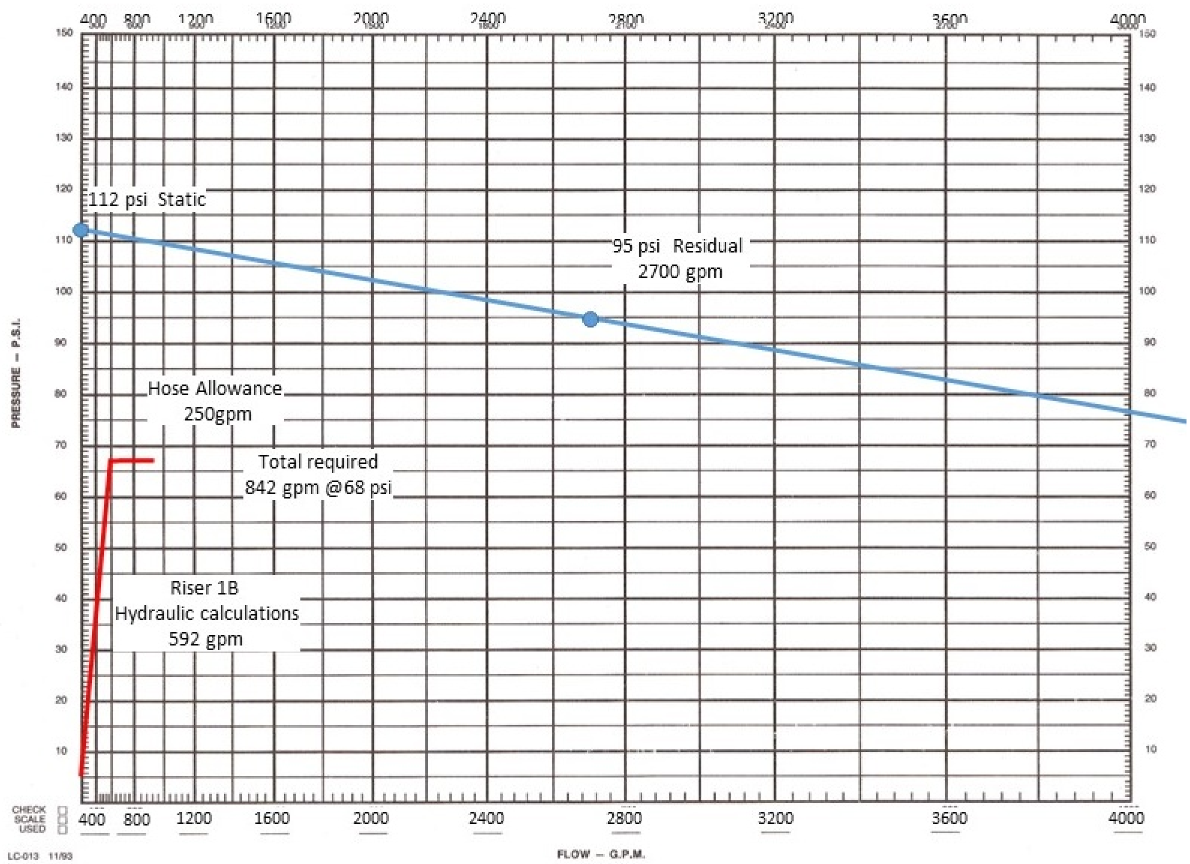


Figure 6-16: Flow requirement for Riser 1B versus available water supply

6.8.3 East Overhang Deluge System (Riser #2):

The east side overhang was once used to parking aircraft and thus the system was designed as a deluge system per the original construction specifications. In the current usage this is no longer required to be deluge system but the system has never been changed. In the current utilization the system should be Ordinary Hazard 1 since there are some combustible items stored below the overhang (NFPA 13 Section 5.3.) and most likely be design based on performance criteria. The overhang is 65 feet above the ground and made of steel with a membrane roof material. The system will be analyzed as installed. The original 1957 specification called for 0.25 gpm/ ft^2 for the overhang.

The piping layout is shown in Figure 6-17 & Figure 6-18, since this is a deluge system all of the sprinklers flow at the same time thus there is no hydraulically remote area. The sprinkler area is the entire 10,000 ft^2. The Riser is a 6 inch riser fed from an 8 inch feed line from the 16 inch main where the POC is located. The riser is shown in Figure 6-19. The riser is about 8 feet prior passing through the wall and extending the remaining distance outside the building to the lower side of the overhang. The original 1957 deluge valve is still in use and is activated by heat detectors on the lower side of the overhang. The deluge heads are Automatic Sprinkler Corporation of America's "Automatic Spray Sprinkler" with the heat sensor and plug removed. They have a 7/16 orifice with an estimated K=5.34 from curve fitting the data in the spec sheet. Figure 6-20 shows the demand compared to the available water supply. The Point of connect is at the 16 inch main on the east side of the building. The water supply is assumed to be the same as on the west side of the building. The hydraulic calculations are presented in Appendix B.3.

Figure 6-17: East Overhang deluge Sprinkler system layout

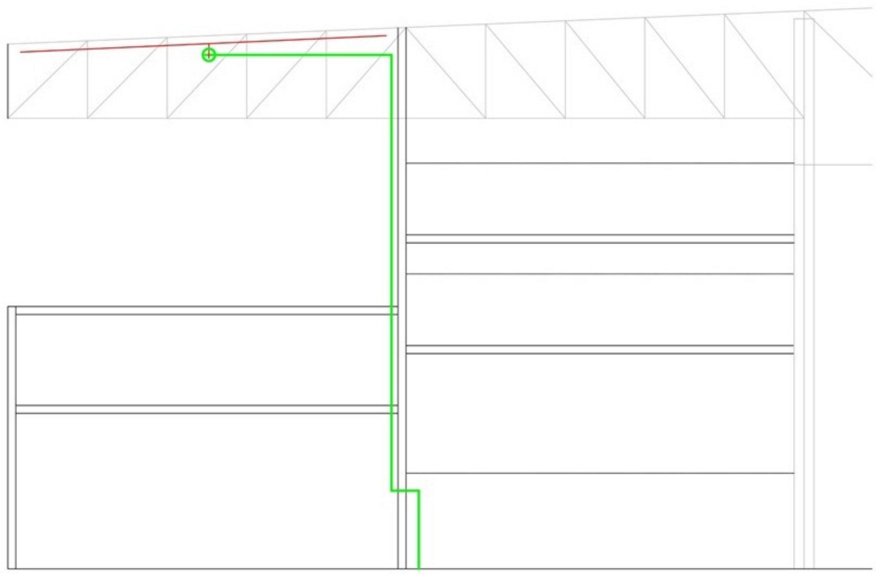


Figure 6-18: East Overhang deluge Sprinkler system end view

Figure 6-19: Photograph of Riser 2 and the test heat detector

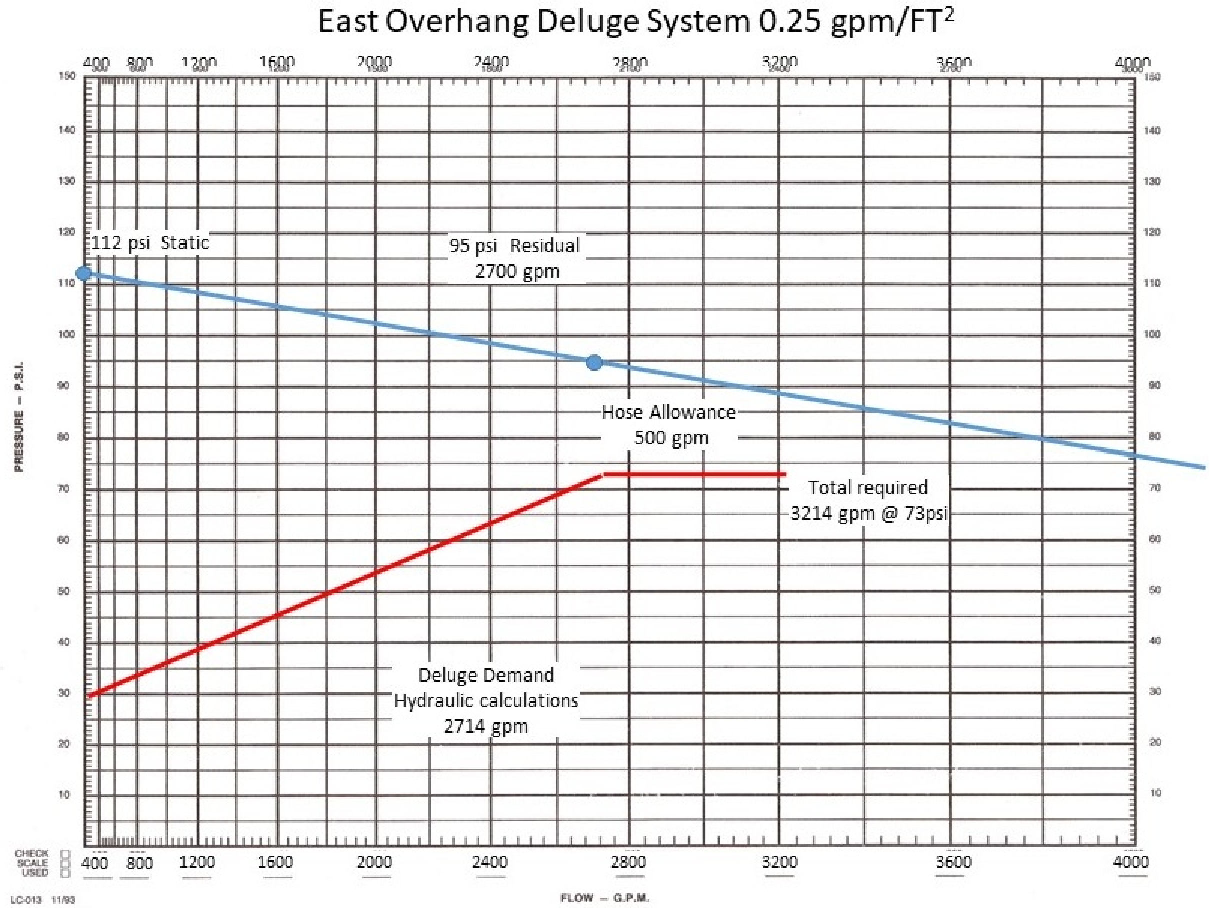


Figure 6-20: Flow requirement for Riser 2 versus available water supply

6.8.4 Hangar Wet Pipe system (Risers 3 to 7 & 9)

The Hangar is considered to be Extra Hazard Group 1. The AF Engineering Technical Letter (ETL) 02-15 requires both a wet pipe system and a High Expansion Foam suppression system. The Wet pipe system will have a minimum of 0.2 gpm/ft^2 and a design area of 5000 ft^2 and use quick response sprinkler heads (AF ETL 02-15 Paragraph A1.3.1.1.2 & A1.3.2.5). There are 6 wet pipe systems in the hangar each with its own riser. These were installed originally in 1958 as a deluge system but were changed to a wet pipe system in 2014. The original piping was hydraulically designed and was not changed during the upgrade. New Tyco Series Ty-FRB K=5.6 Quick Response standard coverage, 200^{o}F sprinklers were installed. Each system covers 10,000 ft^2 and is separated by a draft curtain. The Northern two systems are in the highest portion of the building and would represent the hydraulically worst case. The other risers are at a lower elevation thus would require less pressure. Figure 6-22 shows the layout of a nominal system. Figure 6-23 & Figure 6-24 show the risers in the hangar and Figure 6-25 shows the water demand versus supply. The hydraulic calculations are presented in Appendix B.4.

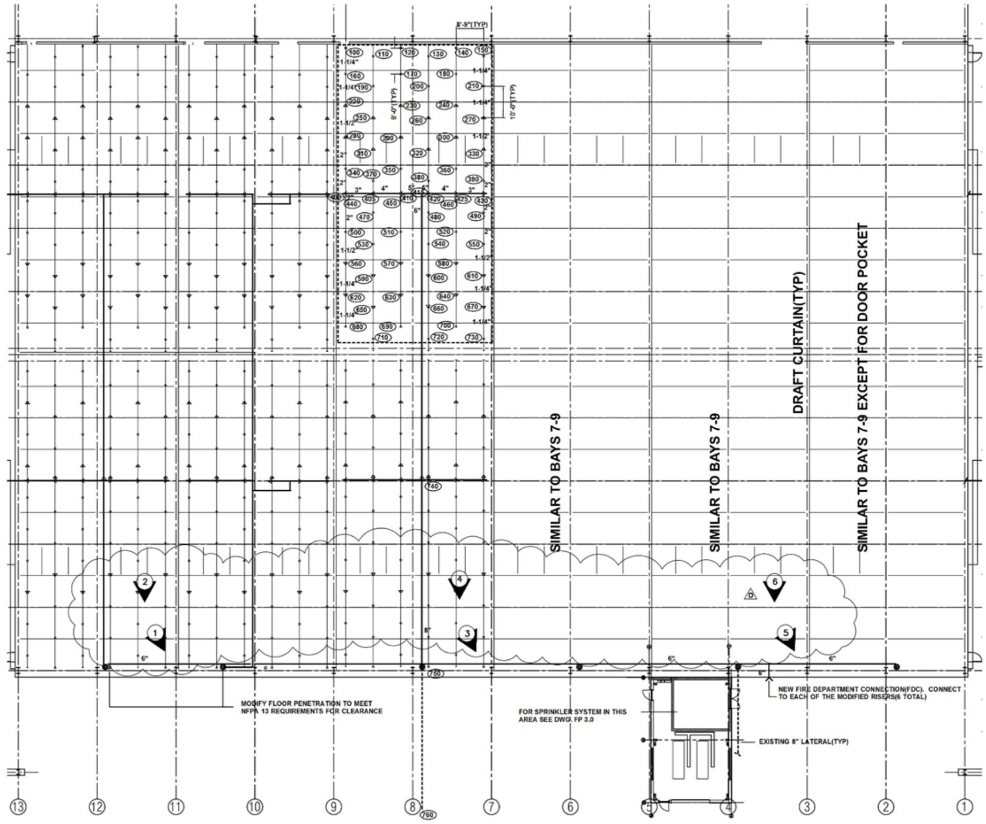


Figure 6-21: Hangar Bay sprinkler Design

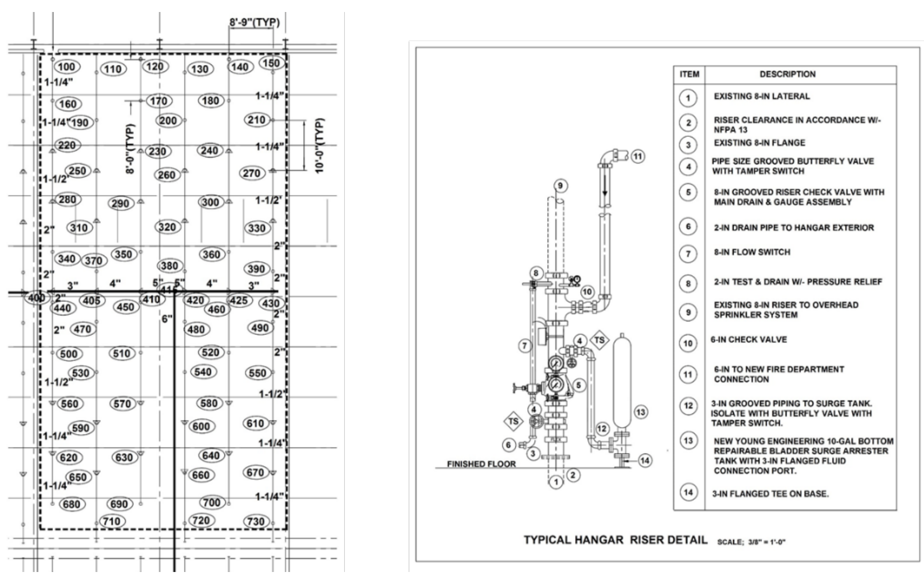


Figure 6-22: Details of Sprinkler layout for design area and Riser drawing

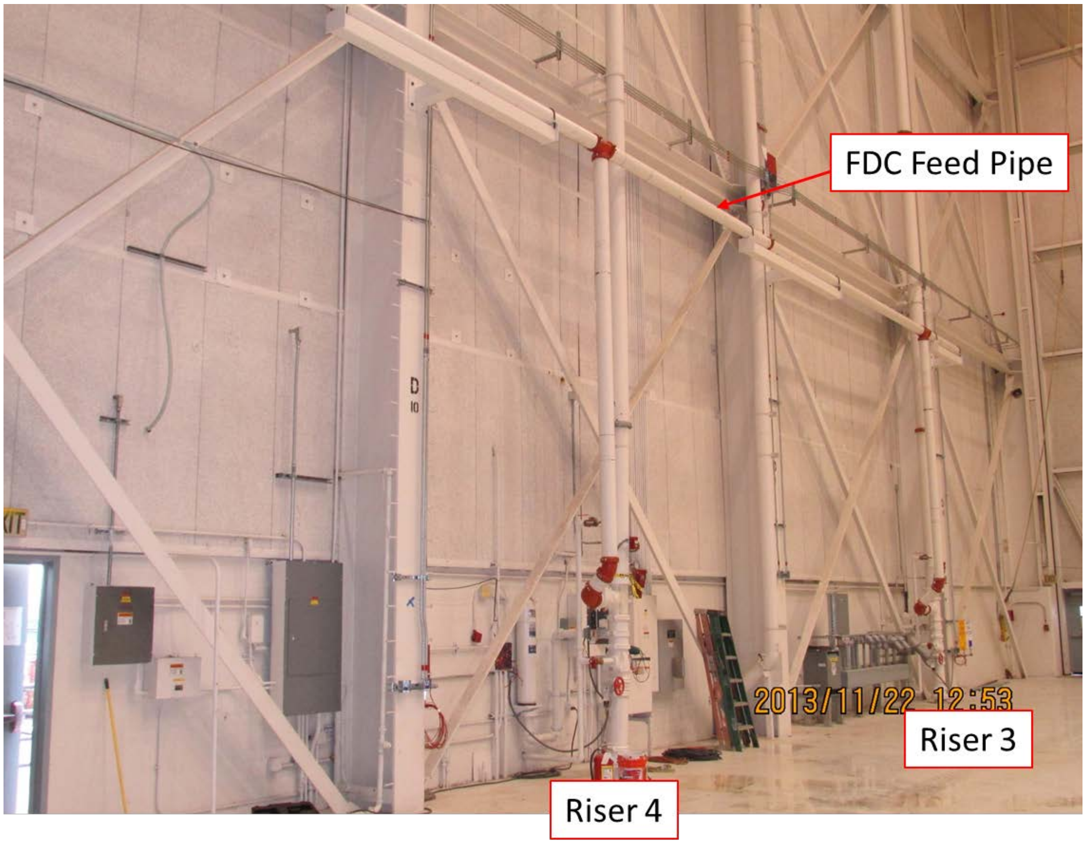


Figure 6-23: Photo showing rises 3 and 4 as a representative of risers 3 to7 & 9

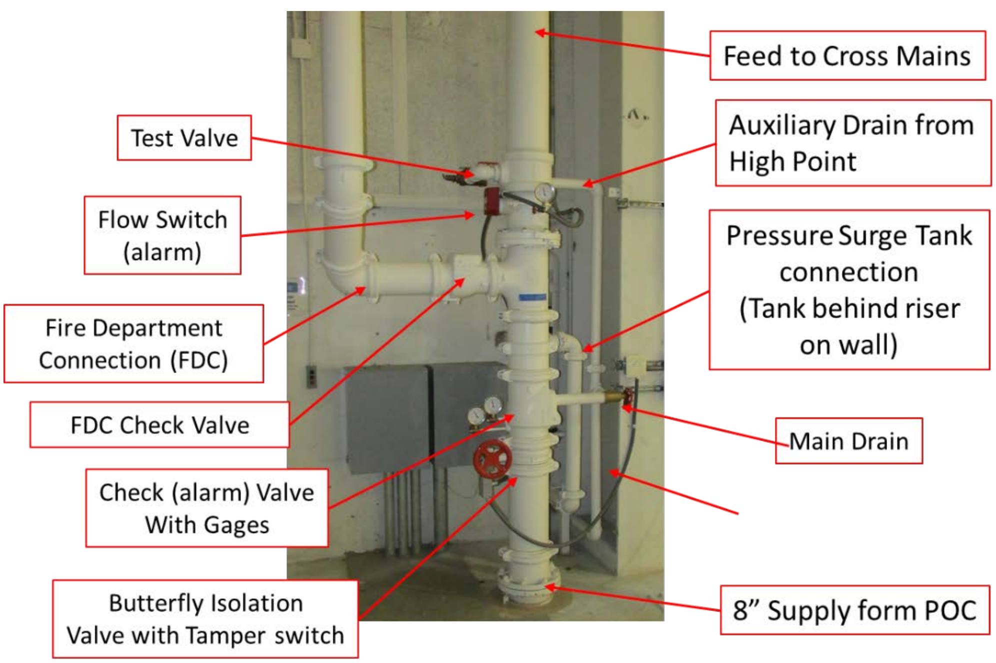


Figure 6-24: Nominal hangar riser showing components

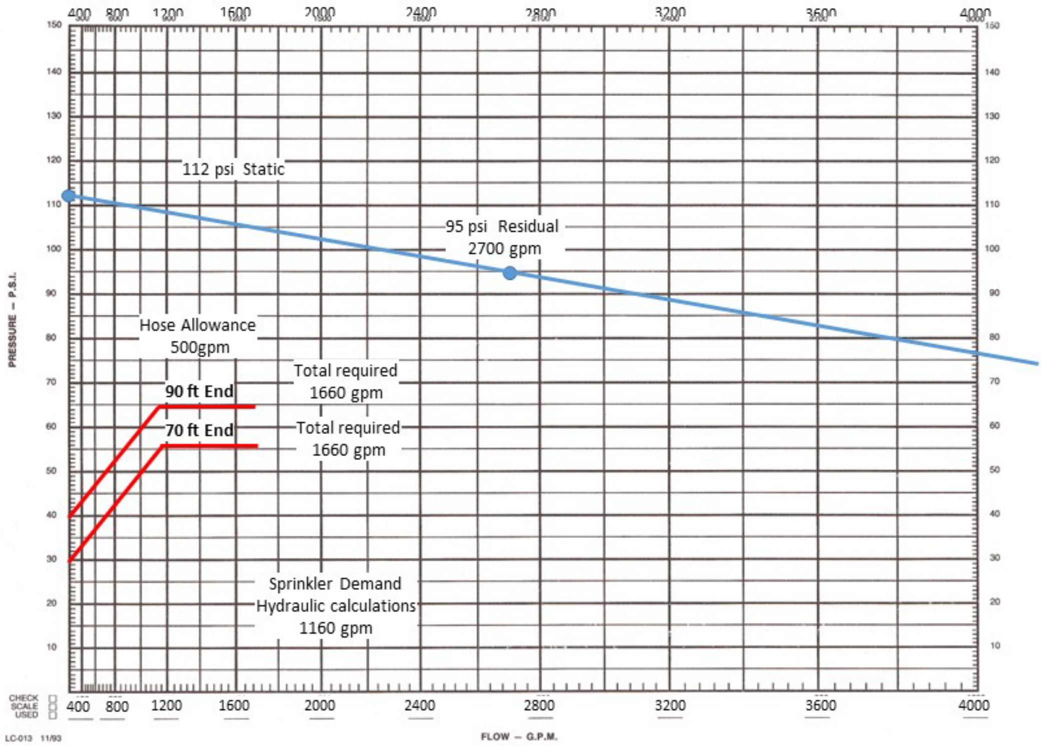


Figure 6-25: Flow requirement for Riser 3-7 & 9 versus available water supply

6.8.5 Hangar High Expansion Foam (HEF) System (Risers 8)

The High expansion Foam system is designed in accordance with NFPA 11A and AF ETL 02-15. The calculations for the foam delivery are shown in Figure 6-26. In order to meet the AF requirements the system needs to deliver 207,000 ft^3 of foam per minute. Based on the layout of the hangar and the 767 type aircraft that will be in the hangar 12 generators were chosen each with 17,250 ft^3/min of foam generating capability, Figure 6-27 & Figure 6-28. The Chemguard model 25000WP was chosen for the system. This generator will provide 19,000 ft^3 per minute at 40 psi with a flow of 178 gpm of 2% solution. The hydraulic calculations for the system show that the water supply is insufficient for the operation of the Generators at 40psi (Figure 6-29). The supply pressure needs to be 126 psi at 2556 gpm. The hydraulic calculations are presented in Appendix B.5.

A diesel fire pump was installed to boost the water pressure to meet the demand requirements. The pump is rated at 100 psi at 1500 gpm but was found be actually be 105 psi at 2500 gpm during the acceptance testing. The Pump curve and the supply curves are shown in Figure 6-30. With the pump operating the pressure in the piping downstream is 235 psi at churn and is 200 psi while flowing through the HEF generators at 2500 gpm. Since this pressure is over the rated pressure of the HEF storage tank a pressure reducing CLA valve was installed in the supply line feeding the HEF riser to regulate the pressure at 175 psi. In addition to the pressure reducing valve a pressure relief valve was installed in the event that the CLA valve failed the pressure in the foam tank would not exceed the working pressure of the tank. All of the piping in the system is ASTM 53 Grade B Schedule 40 carbon steel pipe. The largest pipe is 12 inch which has a maximum working pressure of 1500 psi based on the ASME B31.3 “Process Piping Code” but is limited to 350 psi per ASME 31.9 “Building Services Piping Code”. The piping flanges are Class 150 which have a pressure rating of 290 psi at ambient temperature conditions. Thus the piping system is rated for 290 psi between the fire pumps and the CLA pressure regulator.

R = ([V/T] + RS) x CN x CL

Area=	60000	ft^2
Depth=	3.2	ft
V=	192000	ft^3
T=	4	min
RS=SxQ		
S=	10	ft^3/(min-gpm)
Q=	1200	gpm
RS=	12000	ft^3/min
CN=	1.15	Per AF ETL 02-15
CL=	3	Per AF ETL 02-15
Rate=	207000	ft^3/min
# Genrators	12	
Rate per generator	17250	ft^3/min/Generator
Chemguard model 25000 WP	19063	CFM at 40 psi
Flow Rate	178	gpm fluid

CHEMGUARD 25000WP
HIGH EXPANSION FOAM GENERATOR
ELEV. PERFORMANCE MATRIX

Pressure	CFM	Flow Rate
40	19063	178
45	20470	187
50	21562	194
55	22500	203
60	23440	210
65	24375	216
70	25150	224
75	25900	230
80	26200	235
85	26250	240
90	26200	244
95	25900	248
100	25300	252

Figure 6-26: Foam calculations

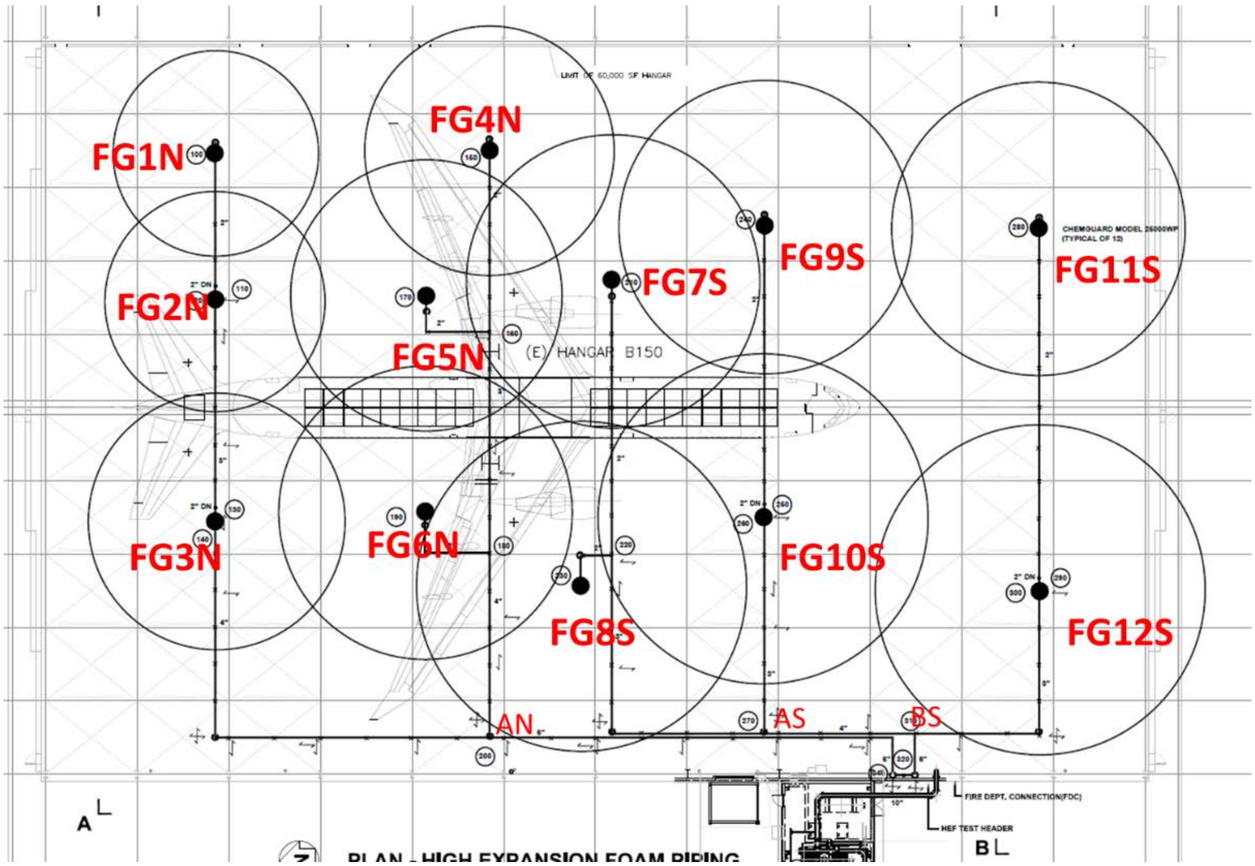


Figure 6-27: Generator Layout

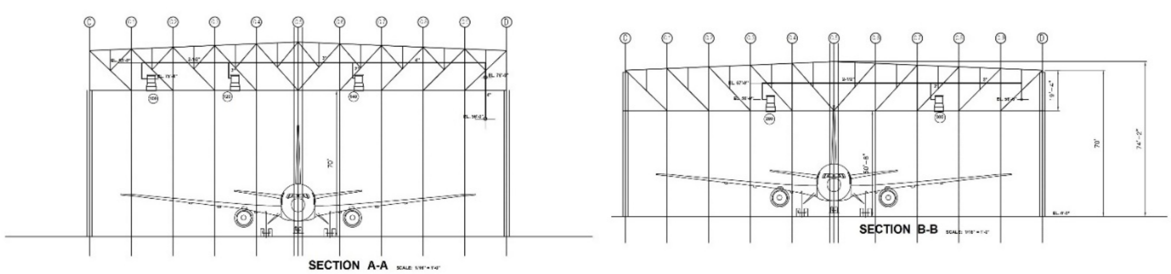


Figure 6-28: Generator Layout Looking South (High & Low Sections)

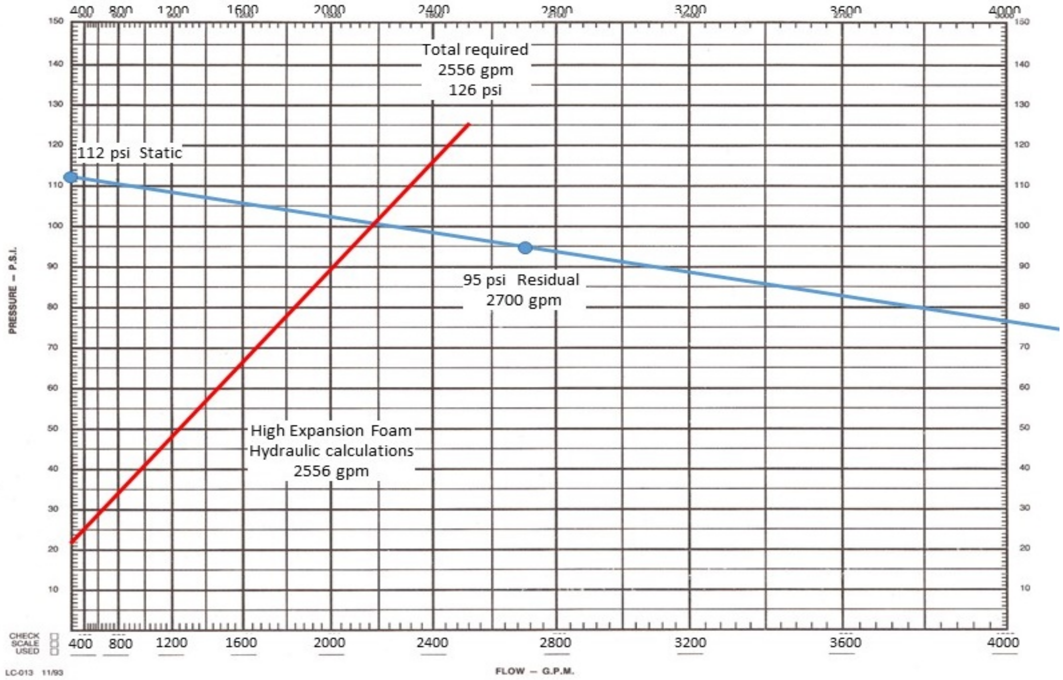


Figure 6-29: Flow requirement versus supply without Pump

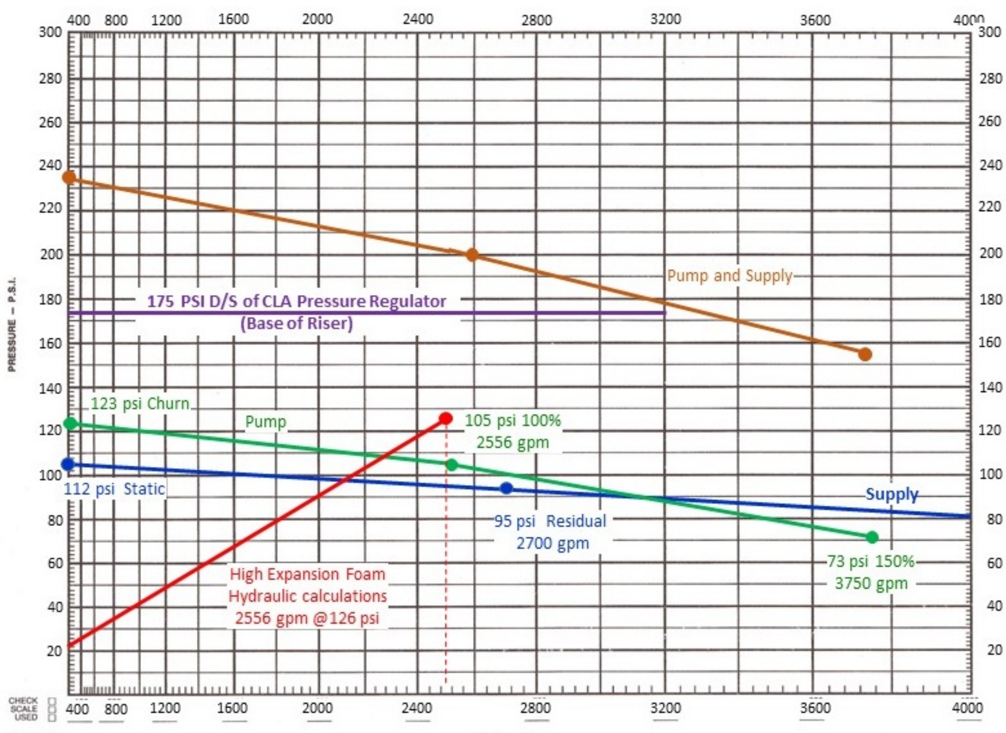


Figure 6-30: Flow requirement versus supply with Fire Pump

While looking at this system it occurred that both the wet pipe sprinkler system and the HEF system may be operating at the same time during a fire. IF you add the 1660 GPM demand for the Hangar wet pipe system to the 2556 gpm for the HEF system the requirement at the POC would be 4216 at 68 psi which is the required pressure at the POC for the wet pipe system (Risers 3-7 & 9). If you extrapolate the supply line out the POC pressure is 73 psi at 4216 gpm. This would be sufficient for both systems to operate with the hose allowance.

The HEF riser is shown in Figure 6-31. The Riser has an 8 inch Viking Flow control valve to allow the system to discharge and still be capable of closing to abort the system. The flow after the 8 inch valve splits into two 6 inch lines with foam proportioners. The AF ETL 02-15 only allows proportioners up to 6 inch the requirement for two lines, one feeding the north generators and one the south generators.

The foam generators are ceiling mounted as shown in Figure 6-32. Figure 6-33 shows the system in operation during the acceptance testing.

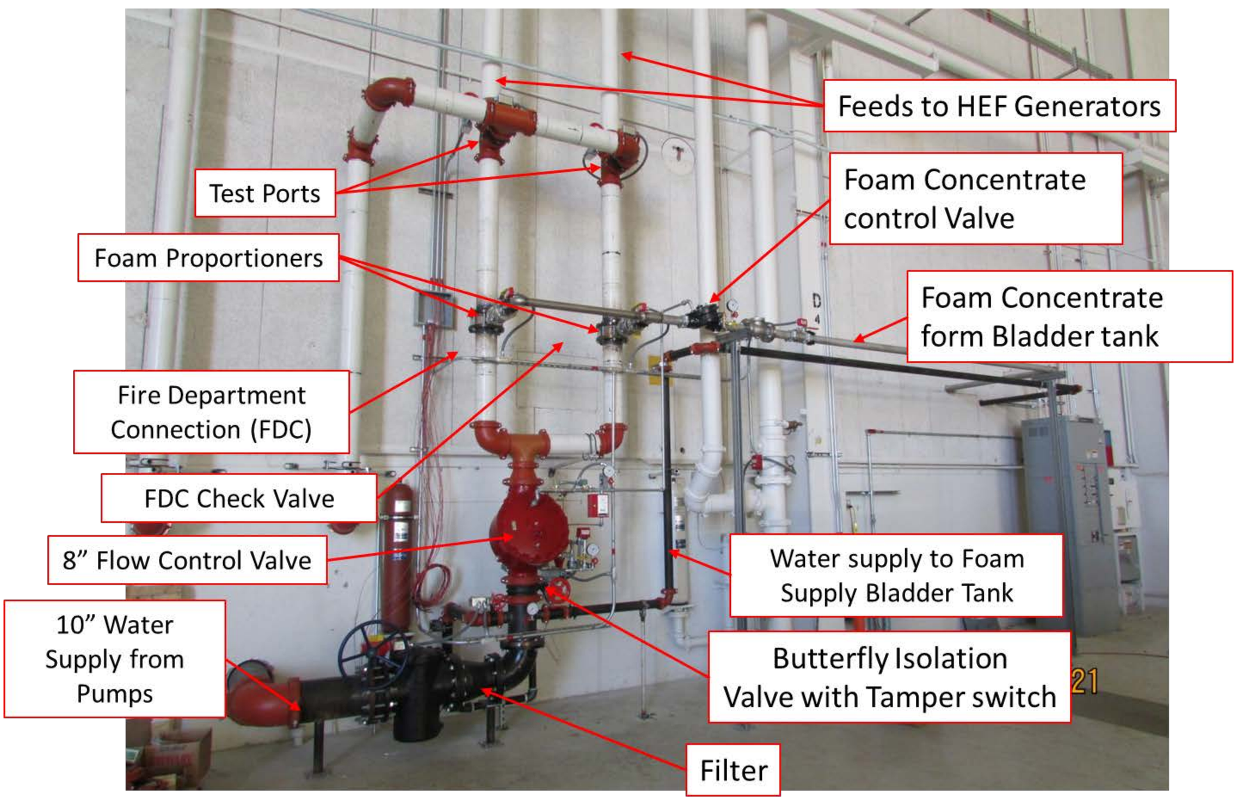


Figure 6-31: HEF Riser in Hangar

Figure 6-32: HEF Foam generators. (Note the smoke curtains separating the wet pipe systems)

Figure 6-33: HEF Acceptance Test

6.8.6 Fire Pump Building (Riser #10):

The Fire pump building is Ordinary Hazard 1 (NFPA 13 Section A.5.3.1 (11). Based on NFPA 13 section 11.2.3 the flow requirements are 0.2 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes. Since the building is only 1000 ft^2 the area will be reduced to the entire building with all of the sprinklers operating. The minimum flow would be 200 gpm or 25 gpm per head since there are only 8 sprinklers. The Tyco Series Ty-FRB K=5.6 Quick Response standard coverage, 175^{o}F sprinklers are installed. Figure 6-34 shows the layout. The hydraulic calculations show that 230 gpm at 54 psi plus the hose stream of 250 gpm for a total of 480 gpm is required which is well within the capability of the supply. Figure 6-35 shows the riser drawing and Figure 6-36 is a photo of the riser. The hydraulic calculations are presented in Appendix B.6.

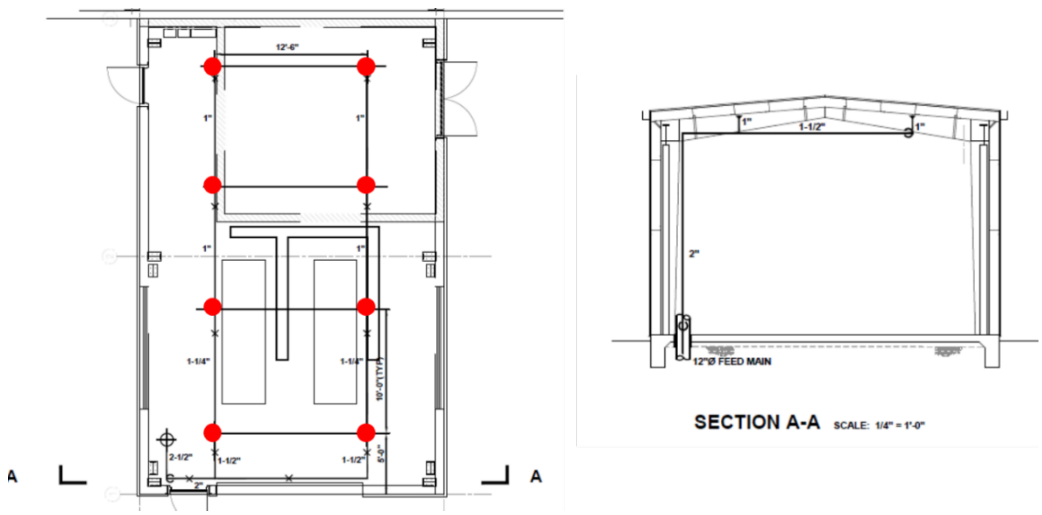
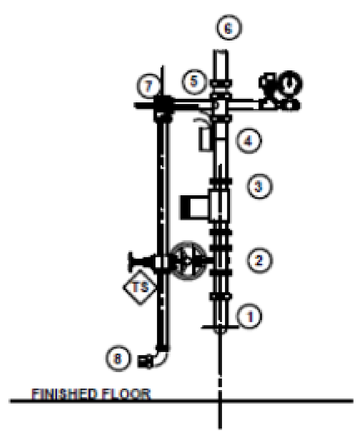


Figure 6-34: Pump building layout and riser dimensions



ITEM	DESCRIPTION
1	2-1/2-IN RISER FEED
2	PIPE SIZE GROOVED BUTTERFLY VALVE WITH TAMPER SWITCH
3	PIPE SIZE GROOVED CHECK VALVE WITH PRESSURE GAUGE FITTINGS.
4	2-1/2-IN FLOW SWITCH
5	2-1/2- IN X 2-IN GROOVED REDUCER
6	2-IN PIPE TO SYSTEM
7	1-IN TEST & DRAIN W/- PRESSURE RELIEF
8	1-IN DRAIN PIPE TO HANGAR EXTERIOR

Figure 6-35: Pump building riser drawing

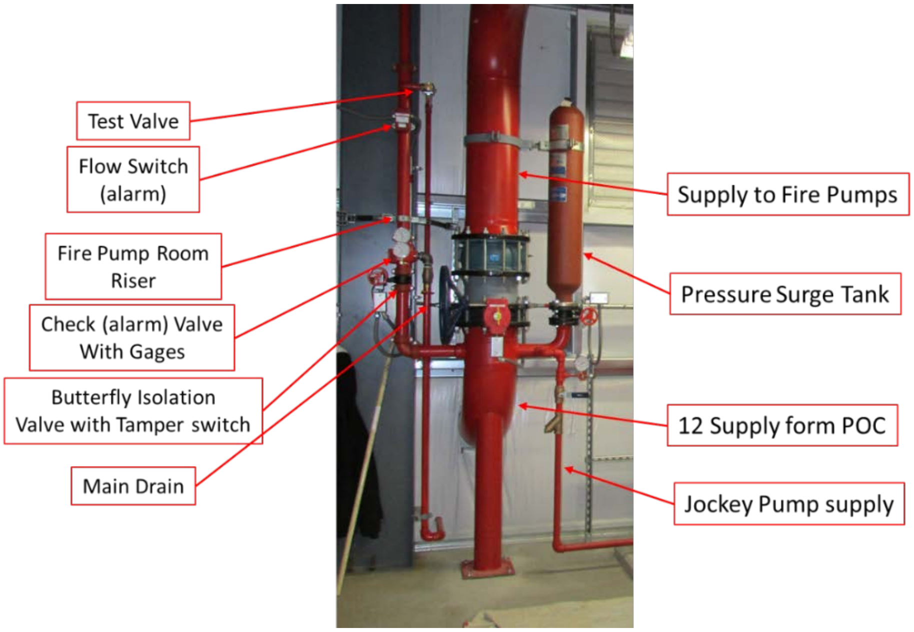


Figure 6-36: Pump building riser showing components

6.8.7 Machine Shop (Riser #11):

The machine shop is Ordinary Hazard Class 2 (NFPA 13 Section A.5.3.2 (13)). Based on NFPA 13 section 11.2.3 the flow requirements are 0.2 gpm over 1500 ft^2 plus hose stream of 250 gpm for 60-90 minutes. The sprinkler system in the machine shop is another wet pipe system. It has a 4 inch riser feeding a single cross main. The sprinklers are layout as shown in Figure 6-37. The hydraulically most remote section contains 13 sprinklers on 3 branch lines. The room has a drop ceiling thus each sprinkler is on a 1" drop. For calculation purposes I did not include the drop. The sprinklers are standard response 165°F pendent type sprinklers. There are two types in the building, RASCO model G and STAR SSP-1. The feed line from the POC is an 8 inch line that reduces to 6 inch line then to a 4 inch Alarm check Valve. The riser is shown in Figure 6-38. The flow demand versus available supply is shown in Figure 6-39. The hydraulic calculations are presented in Appendix B.7.

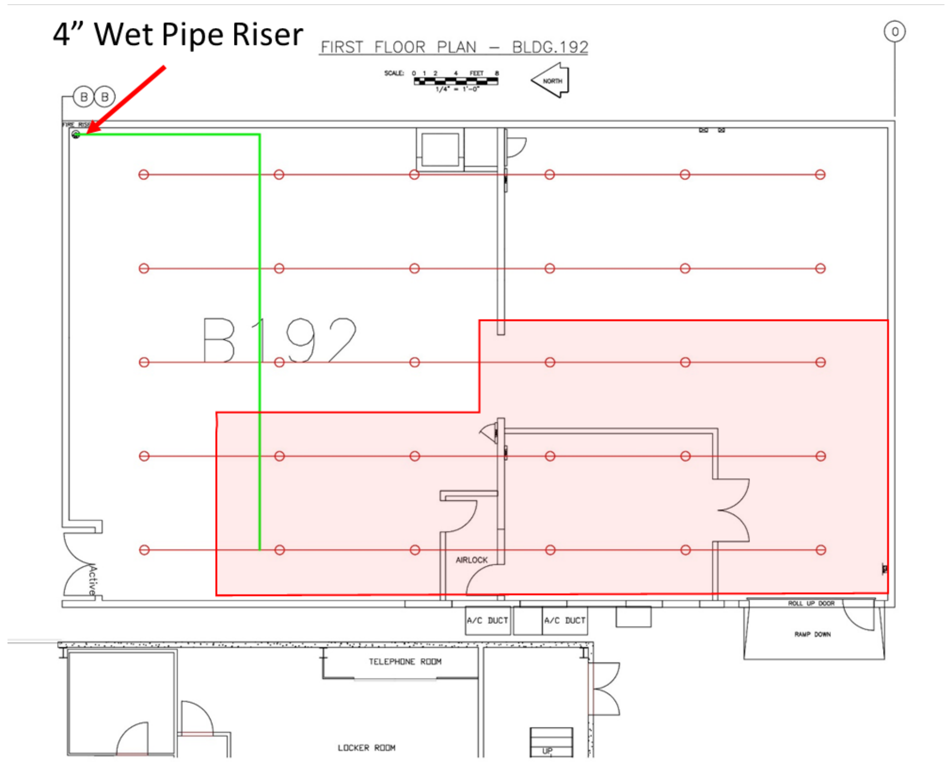


Figure 6-37: Machine Shop Sprinkler system layout

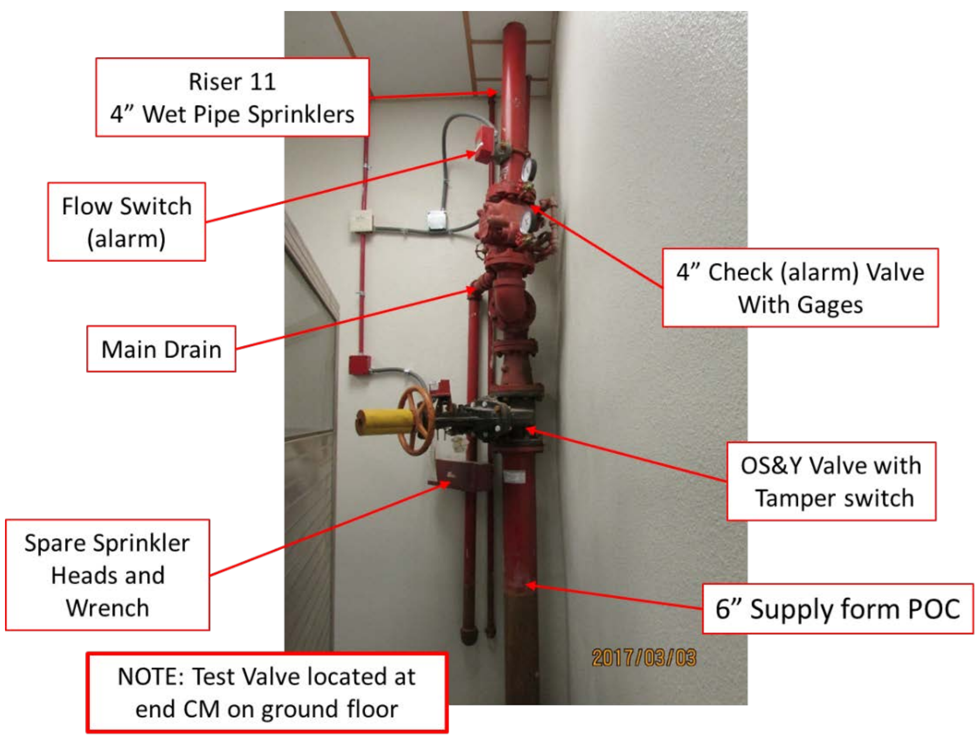


Figure 6-38: Riser 11 in machine shop showing components

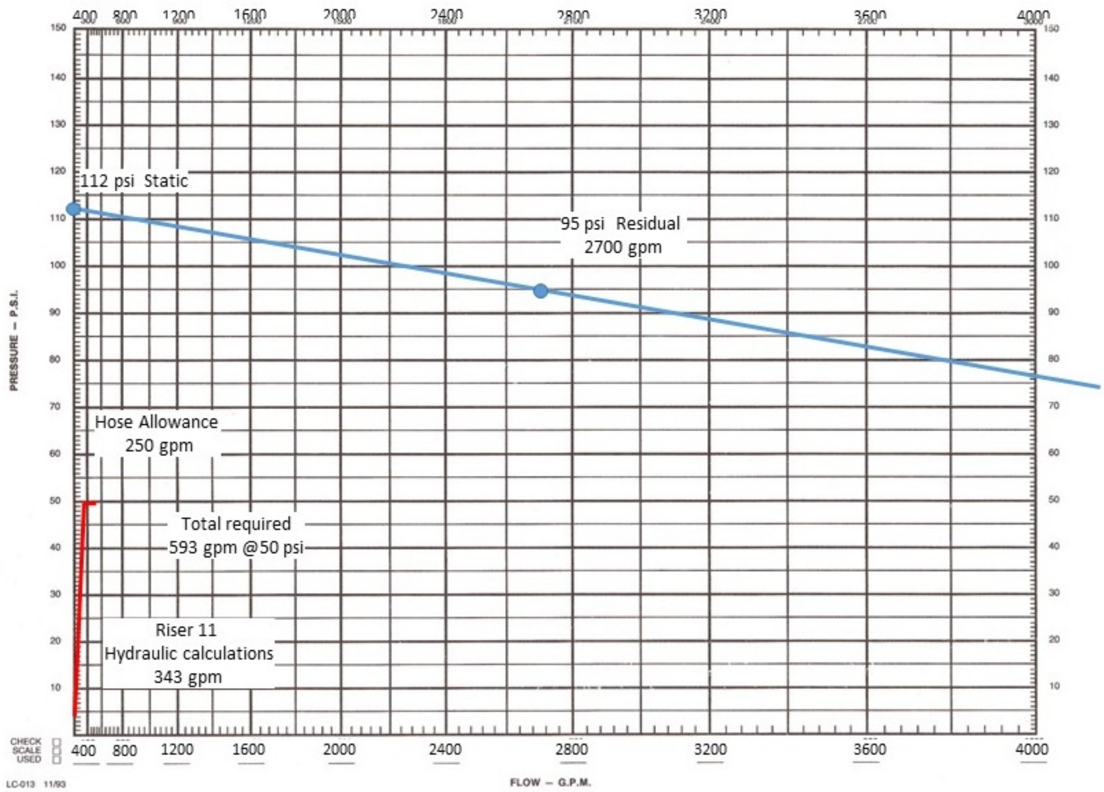


Figure 6-39: Flow requirement for Riser 11 versus available water supply

6.9 Suppression Summary

The buildings fire sprinkler systems meet the flow and pressure requirements for the occupancy types. The available water supply is adequate for all of the systems. The water pressure after the fire pump for the high expansion foam system is greater than the 175 psi required by NFPA 13 but the piping has been designed for the higher pressure. To limit the base of the riser to 175 psi a pressure reducing valve is installed in the system with a relief valve for protection against valve failure. Now that the prescriptive requirements have been analyzed for the building a performance analysis well be performed for the building with emphasis on the hangar portion.

7 Performance Based Analysis

The aircraft hangar was also analyses using the Performance Based Analysis (PBA) process to evaluate life safety and asset protection. The analysis will use both hand calculation and computer simulations to look at egress time and the National Institute of Standards and Technology (NIST) Fire Dynamics Simulator (FDS) to evaluate the tenability conditions and the effect of fire on the asset in the hangar.

7.1 Goals and Objectives

The objective of the performance based analysis as related to life safety is to ensure that the Available Safe Egress Time (ASET) is greater than the Required Safe Egress Time (RSET) plus a safety margin. The performance criteria will is defined by the LSC Section 5.2.2 as "*Any occupant who is not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions*." In addition to the life safety criteria the PBA approach can be used to evaluate other performance criteria that may be established by the stakeholders such as damage to aircraft or structural damage to the building. In this project we will assess the damage to aircraft in the hangar, in addition to life safety. Building survivability will not be evaluated.

7.2 Tenability Criteria

The Hangar is a large open area and would be hard to find your way out in poor visibility. The best way to ensure that all personnel exit the hangar safely is to ensure that the smoke layer does not reach the 6 foot level prior to all occupants leaving the Hangar. This may be possible since there is a high ceiling (>50 feet) in the Hangar. This criteria could also work for the office/support area since the "hard" ceiling is 28 feet for the ground floor, 14 feet for the second floor and 28 feet for the third floor. The recommended tenability criteria would be to have the building evacuated prior to the smoke layer reaching the 6ft level (LSC Section A.5.2.2 Method 2). If this is not achievable then having the following criteria would be advisable:

Visibility: The hangar bay is a large open space with ordinary lighted exit signs. The SFPE handbook Chapter 61 sub-section "visibility of signs through smoke" lists a threshold of 10m for these types of signs. The visibility criteria will be taken as 30 feet for this analysis.

Carbon Monoxide: The SFPE Handbook Table 63.9 lists a Ct value of 30,000 to 35,000 ppm-min for incapacitation for humans performing light activity. Using the lower value and assuming 20 minutes to evacuate the building the allowable CO concentration would be 1,500 ppm of CO. Applying a safety factor of 2 the maximum CO should be around 750 ppm or 0.75 x10^{-4} kg/kg.

Temperature: The SFPE Handbook Table 63.17 lists reported tolerance times for exposure to hot air. The research listed showed that the body could withstand dry air at 110^{o}C humans for 25 minutes. The hangar is located in a dry climate thus this would be applicable. The 110^{o}C temperature will be used as the tenability criteria for this study.

7.3 Aircraft Damage Criteria

The damage criteria for aircraft is very dependent on the construction of the aircraft and the part of the aircraft exposed to the fire. Modern aircraft are made of multitude of materials. The exterior surface of modern aircraft are generally made of three types of material; Aluminum, Carbon composite or fiberglass/resin composite. For this study the aircraft will be assumed to be 6061-T6 aircraft aluminum alloy. A paper by Summers, et al stated that property degradation which occurs at temperatures as low as 150°C with a 50% yield strength reduction at ~275°C (Langhelle and Amdahl 2001). Summers looked at the strength during the fire and after the member returned to room temperature and found that the strength of the material is reduced by 37% when the temperature of the member is raised to 200-500 ^{o}C. The melting point of 6061 alloy aluminum is 582^{o}C. (ASM Handbook 2001). For this study the damage criteria will be 150^{o}C since this is when the material properties starts to degrade. For flight worthiness it is safer to replace damaged components than risk failure in flight.

7.4 Fire Scenarios

The NFPA 101 LSC code section 5.5.3 requires a minimum of 8 design fires to be investigated. For this study several fire scenario were considered and one was modeled and investigated further.

7.4.1 Fire Scenario 1: Large fuel pool fire in hangar (Greatest Risk)

This scenario is the greatest risk but also unlikely. The scenario would be a large JP-5 fuel spill (200+ gallons) and ignition. Any aircraft within the hangar would most likely suffer major damage due to heating from radiation. There most likely also would be secondary fires from the high radiation form the fire.

7.4.2 Fire Scenario 2: Small fuel pool fire in hangar (Most Likely)

This scenario is the one that will be further analyzed. This scenario is a small JP-5 fuel spill and ignition. Depending on where the fire is located the aircraft could survive with minimal damage. Sprinkler activation is also questionable due to height of hangar ceiling.

7.4.3 Fire Scenario 3: Fire in office store room

This scenario would be a fire in an office storage room where combustible paper and other material burn unobserved. The fire grows and activates sprinklers in the room then becomes sprinkler controlled.

7.4.4 Fire Scenario 4: Fire in hangar during assembly

This scenario would be a fire during an assembly or luncheon in the hangar bay. The hangar bay is occasionally used for assemblies for awards and luncheons. Tables are set-up with paper or plastic table cloths. The caterer has a warming tray with open flame burners to keep the food warm. The burner ignites a table covering and then the plastic table then spreads. The fuel for this fire would consists of tables, chairs, wood stage, paper products, etc. This would be an even smaller fire but of longer duration than the pool fires considered in scenario #2.

8 Required Safe Egress Time (RSET)

The required Safe Egress Time (RSET) is the time from when the fire ignites to when the last person is out of the building. RSET is made up of the alarm time plus the evacuation time. The Alarm time consists of the detection time and the time to activate the alarm once the fire is detected. In the case of a sprinkler riser flow switch the detection time is when the sprinkler activates but the alarm time is the detection time plus the mechanical timer attached to the flow switch and the time for the computer to process and activate the notification devices. Alarm time could be up to 60 seconds longer than the detection time in some cases. The evacuation time is the time to leave the building from when the alarm activates to when the last person has left the building. The evacuation time consists of the pre-movement time and the travel time. The pre-movement time is based on the characteristics of the occupants and their behavior. This is somewhat subjective and generally based on statistical data from similar situations, the data is fairly limited. In this report the pre-movement time is estimated from the tasks that occupants might perform prior to leaving the building. The travel time is calculated using the hand formulas or using a computer simulation, such as “Pathfinder”. The detection and alarm time will be determined form the FDS modeling and is fire scenario dependent. The time difference between the RSET and the ASET is termed the Safety Margin. The safety margin must be evaluated in order to account for errors in the modeling and assumptions that went into the modeling especially the pre-movement time assumptions. The magnitude of the safety margin is generally determined to be acceptable by evaluating actual engineering data for similar scenarios and comparing to that provided by the modeling. Figure 8-1 shows the how the various times discussed fit together. This analysis will calculate the travel time using the hand calculation method and the “Pathfinder” computer simulation then add the pre-movement times to determine the “Evacuation Time”. The RSET will be determined from the evacuation and Alarm time when discussing the fire scenarios and ASET in Section 9.

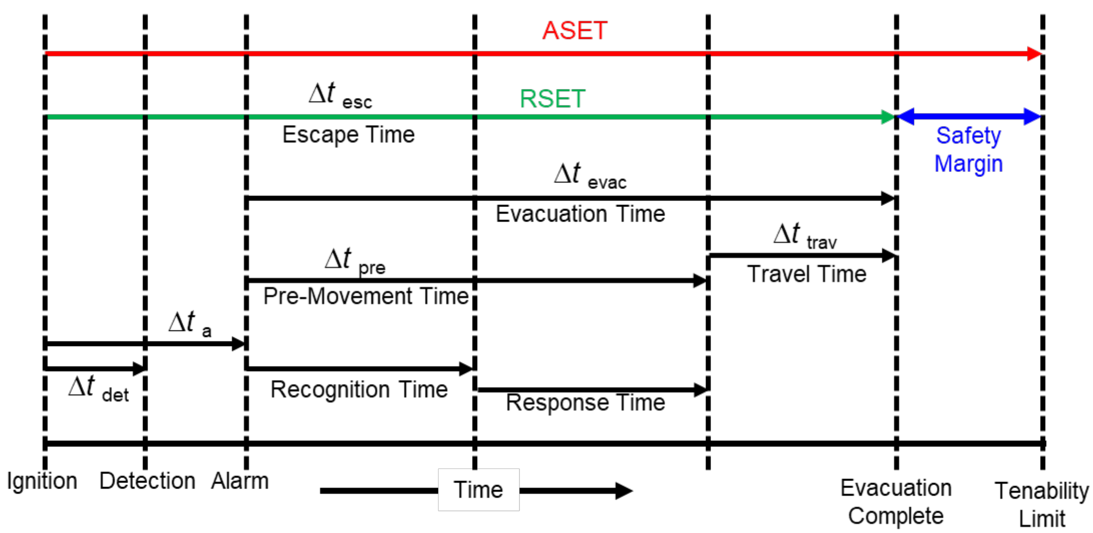


Figure 8-1: Egress time line showing parts of RSET and relation to ASET

8.1 Occupant Characteristics

This building has limited access and is used primarily for supporting flight testing. The personnel in the building are of three types: mechanics and maintenance support personnel, engineering and administrative and flight test personnel consisting of pilots, flight crews and control room support personnel. All of these people are generally healthy and in good physical condition. Their age ranges between the mid 20's to the mid 60's. All permanent personnel are trained in the hazards in the building and the evacuation plans. Any guests that are in the building are escorted at all times by a permanent occupant. Each of the floors have evacuation wardens identified to assist in getting the floor evacuated and ensuring all personnel have left the area. Most occupants will start egressing relatively quickly but there are some occupants that will be delayed due to where they are located while performing maintenance on the aircraft or if they are part of a flight test. Others would be delayed to secure computer systems, data or equipment. If there is an imminent threat to personnel safety occupants are trained to exit quickly and disregard any normal security activities required prior to leaving. Personnel safety is the first priority. Below is a list of some pre-movement activities and estimated times.

Pre-movement activities:

Office/engineering areas:	
Assess current threat to self	0.5 min
Verify if the alarm is real	1.0 min
Secure computer & documents	1.0 min
Gather personnel items	1.0 min
	Total: 3.5 min
Hangar areas:	
Assess current threat to self	0.5 min
Exit aircraft if working inside	1-2 min
Verify if the alarm is real	1.0 min
Secure support equipment and aircraft systems	2.0 min
Gather personnel items	1.0 min
	Total: 5.5 to 6.5 min Max
Actives during Flight test:	
Abort Test & re-call aircraft	1.0 min
Secure flight test data	3.0 min
Secure computer systems	2.0 min
	Total: 6.0 min

Some of the pre-movement activities could occur simultaneously since different people would be doing different activities thus adding the time times together would provide a worst case scenario. The egress times presented in the hand calculations and the pathfinder modeling DO NOT include pre-movement delay times. The pre-movement time will be added after the movement time has been calculated.

8.2 Hand Calculations

The hand calculations were based on the method described in Section 4 Chapter 2 of the NFPA fire Protection Handbook. Two scenarios were evaluated; the first was exiting the hangar, and the second was exiting all the occupants on the second and third floors. The time to exit the ground floor, the exterior mechanical rooms, the machine shop and other ancillary areas was assumed to be not a limiting factor. The hangar was not thought to be a limiting factor either but since this is where a fire most likely would occur it was evaluated. The equations for the travel time were programed into MS Excel to simplify the calculations.

8.2.1 Evacuating the Second and Third floors

In order to calculate the travel time some assumptions needed to be made. 1) The occupancy for each floor was divided evenly between each of the exits. 2) The limiting factors would be cueing at the choke points in the flow, thus time to walk to an exit was considered minor compared to the time to exit. Since cueing was occurring the specific flow would be the maximum specific flow and the population density would be that for maximum flow. Since each of the three exit stairs in the building are configured differently each was evaluated separately. The north and south exit stairs exit directly outside and there is no additional personnel added from the ground floor. The center stair exits into an exit corridor on the ground floor which also sees occupants from the ground floor. In order to account for this additional flow the personnel from rooms 4, 10, 11, 12 & 13 were added prior to exiting the door on the ground floor. The results of this analysis showed that dividing the occupancy load evenly between the three stairs, the center stairs is the time limiting factor, taking 5.2 minutes. The north and south stairs take about 4.3 minutes each. If you optimize the occupancy load then when 28% of the second and third floor go to the center stairs and 36% go to the north and south stairs each the evacuation time becomes 4.6 minutes for each of the stairs (Figure 8-2).

	North				Center			South	
Stairs				**Stairs**			**Stairs**		
Width	45	in		Width	45	in	Width	45	in
Eff Wid	33	in		Eff Wid	33	in	Eff Wid	33	in
	2.75	ft			2.75	ft		2.75	ft
Max Specific flow Stairs	18.5	persons/min/ft	Ttable 4.2.8	Max Specific flow Stairs	18.5	persons/min/ft	Max Specific flow Stairs	18.5	persons/min/ft
flow	50.875	people/min		flow	50.875	people/min	flow	50.875	people/min
Door Top				**Door Top**			**Door Top**		
Width	36	in		Width	36	in	Width	36	in
Eff Wid	24	in		Eff Wid	24	in	Eff Wid	24	in
	2	ft			2	ft		2	ft
Max Specific flow Stairs	24	persons/min/ft	Ttable 4.2.8	Max Specific flow Stairs	24	persons/min/ft	Max Specific flow Stairs	24	persons/min/ft
flow	48	people/min		flow	48	people/min	flow	48	people/min
Door to outside				**Door to outside**			**Door to outside**		
Width	45	in		Width	36	in	Width	72	in
Eff Wid	33	in		Eff Wid	24	in	Eff Wid	60	in
	2.75	ft			2	ft		5	ft
Max Specific flow Stairs	24	persons/min/ft	Ttable 4.2.8	Max Specific flow Stairs	24	persons/min/ft	Max Specific flow Stairs	24	persons/min/ft
flow	66	people/min		flow	48	people/min	flow	120	people/min
Controling flow	50.875	people/min		Controling flow	48	people/min	Controling flow	50.875	people/min
Stairs				Exit of building			Stairs		
People above gnd floor	182			People above gnd floor	181		People above gnd floor	182	
				Additional from ground floor	67				
				Total	248				
Total time for one exit	3.577396	min using one exit		Total time for one exit	5.166667		Total time for one exit	3.577396	
# Exits	1			# Exits	1		# Exits	1	
	3.577396	Min			5.166667	Min		3.577396	Min
K	212		From Table 4.2.5	K	212		K	212	
A	2.86		From Equ 1	A	2.86		A	2.86	
D	0.175		Density for MAX flow	D	0.175		D	0.175	
Speed	105.894	ft/min	Equation 1	Speed	105.894	ft/min	Speed	105.894	ft/min
The choke point will be at the second floor where the flow from the third floor and second floor meet. Once choking ends need to add time from second floor to ground.				The choke point will be at the 36 inch door at the exit on the ground floor. This will see flow from the stairs (second and third floors) and the ground floor. Once choking ends no need to add additional time since it is at the building exit.			The choke point will be at the second floor where the flow from the third floor and second floor meet. Once choking ends need to add time from second floor to ground.		
Length of stairs	75.8	feet		Length of stairs	0	feet	Length of stairs	75.8	feet
time between floors	0.71581	min/floor		time between floors	0	min/floor	time between floors	0.71581	min/floor
Total Time	4.3	min		Total Time	5.2	min	Total Time	4.3	min

Figure 8-2: Travel time calculated for the office/support area.

8.2.2 Evacuating the Hangar Bay

The population in the hangar bay is very disperse and the time to reach the exit is believed to be the limiting factor rather than the exit itself. For the hangar the initial speed and specific flow was determined from the hangar population density. The speed was determined to be 273 ft/min. The maximum distance to an exit was estimated at 150 feet, half the length of the hangar, thus it would take 0.6 minutes to reach an exit. The initial flow through each exit was 8.7 people per minute which given 120 people would take 13.7 minutes. This meant that cueing would be occurring at the exit, thus the maximum specific flow rate was chosen rather than using the initial specific flow. With the maximum specific flow the time to exit 120 people was reduced to 0.3 minutes. The total time to exit the hangar would then be the 0.6 minutes to reach the exit then the 0.3 minutes to exit the hangar. Total time 0.9 minutes, less than that needed to empty the second and third floors as expected (Figure 8-3).

The total evacuation time would be the calculated movement time plus the pre-movement time. For the hangar the pre-movement time ranged from 5.5 to 7.5 minutes depending if mechanics were in a remote location inside an aircraft or not. Areas such electronic bays or the lower lobe of an aircraft might require a few minutes to get out of. Adding the 5.5 to 6.5 minutes to the 1 minute calculated provides a total evacuation time of 6.5 to 8.5 minutes. For the office area when NOT in a flight test configuration, which would be about 80% of the time, the evacuation time would be the 3.5 minute pre-movement time plus the 5.5 minute movement time for a total of 9 minutes. If in a flight test configuration the pre-movement time would be about 2.5 minutes longer or about 11.5 minutes total evacuation time.

Hangar floor			
Length	300	Feet	
Width	200	feet	Table 4.2.6
Area	60000	ft^2	
# Occupants	120		
Density	0.002	people/ft^2	
K	275		From Table 4.2.5
A	2.86		From Equ 1
D	0.002		Actual Density
Speed	273.427	ft/min	Equation 1
Longest distand to a exit	150	feet	1/2 the length
Time to reach exit	**0.5**	**Min**	
Fs Initial	0.546854	people/ft effective width/min	
Width	36	in	
Eff Width	24	in	
	2	ft	
Initail Rate out the door	1.093708	People/min/exit	
	8	# Exits	
	8.749664	People/ min	
	120	# Occupants	
Time to exit at initial rate	13.71481	Min	
Cueing will start at the exit and the rate will increase until the maximum rate is achieved. Use Fs Max to estimate time to exit hangar.			
Fs Max	24		
flow	48	people/min/per exit	
	8	# Exits	
	384	People/ min	
	120	# Occupants	
Time to exit	**0.3125**	**Min**	
Total time= Time to reach exit+ time to exit			
Total Time=	**0.9**	**min**	
	52	**Sec**	

Figure 8-3: Travel time calculated for the hangar bay

8.3 Pathfinder model

The AUTOCAD file that I had of the hangar was only a 2D drawing. The three floors were stacked in AUTOCAD at the correct level. Stair landings were then added. Once this was complete the DWG file was uploaded to Pathfinder. The rooms were separated automatically in Pathfinder. The stairs were manually added. The exterior mechanical and electrical rooms on the second floor were not added since they were not expected to be a limiting factor. The occupants of the building were added automatically using the population density option for each area based on the occupancy load factor for that area. The occupants used the default behaviors. The access control doors on the ground and third floors were added as one way doors. The doors into the hangar bay were also added as one way doors leading out of the hangar. The results of the model were surprising similar to the hand calculations. Figure 8-4 to Figure 8-6 show the view of the hangar at T=0, 30, and 50 seconds. It took 49 seconds to travel versus the 52 second estimated using the hand calculations. Figure 8-7 to Figure 8-14 show the view of the three floors of the office /support area at various times. This area took 279 seconds using "Pathfinder" versus the 311 seconds for the even 1/3 distribution of occupants or the 275 seconds for the optimized distribution of occupants using the hand calculation method.

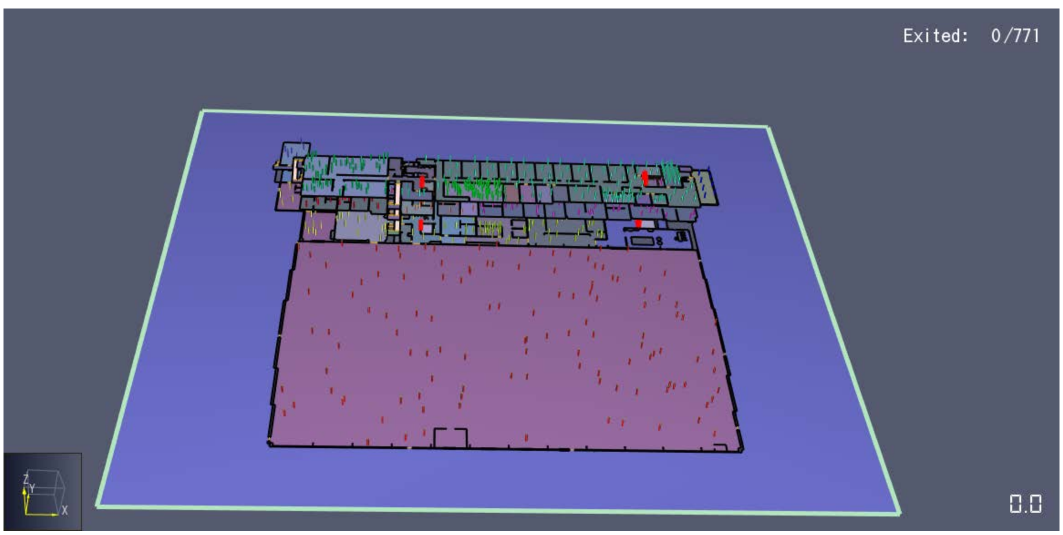


Figure 8-4: View of Hangar at T=0

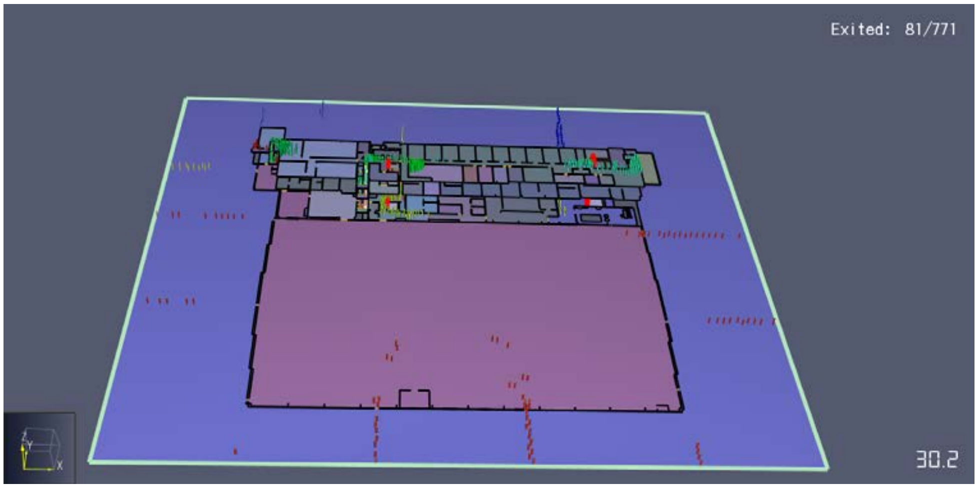


Figure 8-5: View of Hangar at T=30 Sec

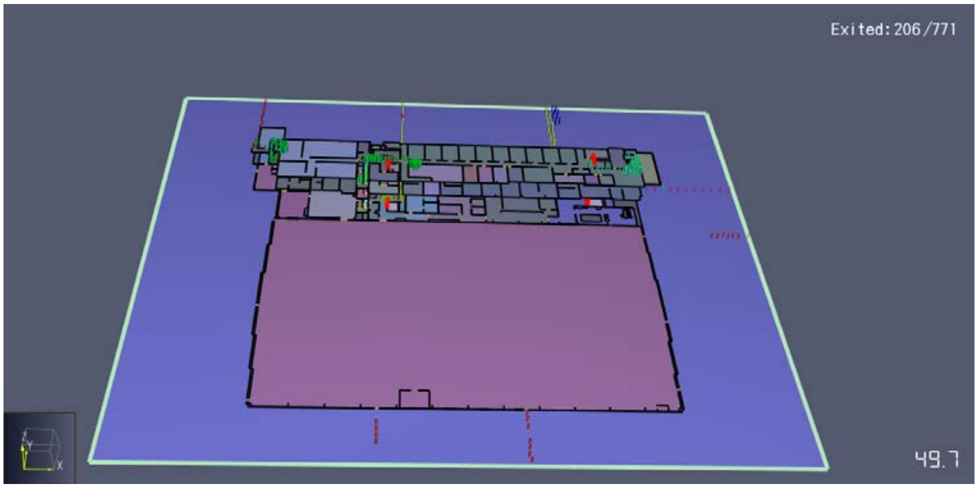


Figure 8-6: View of Hangar at T=50 Sec
(Last person exited the Hangar Bay)

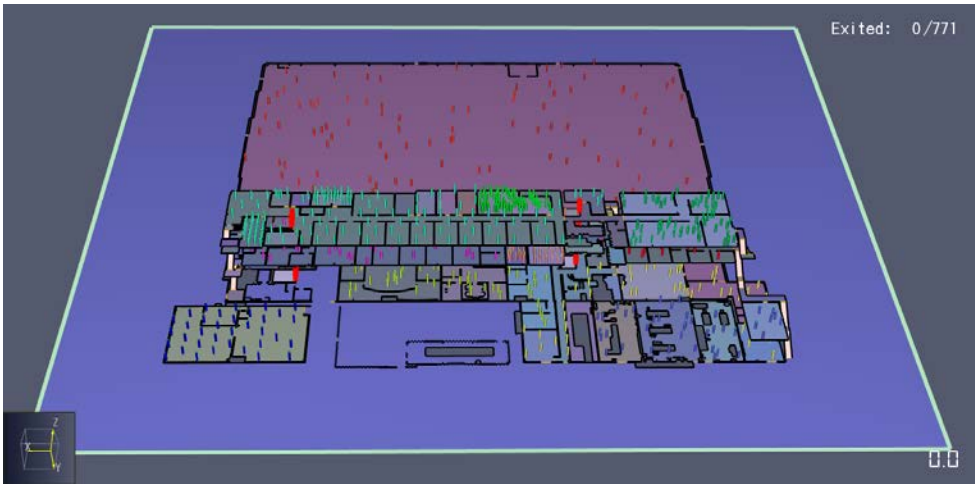


Figure 8-7: View of Office/Support Area at T=0

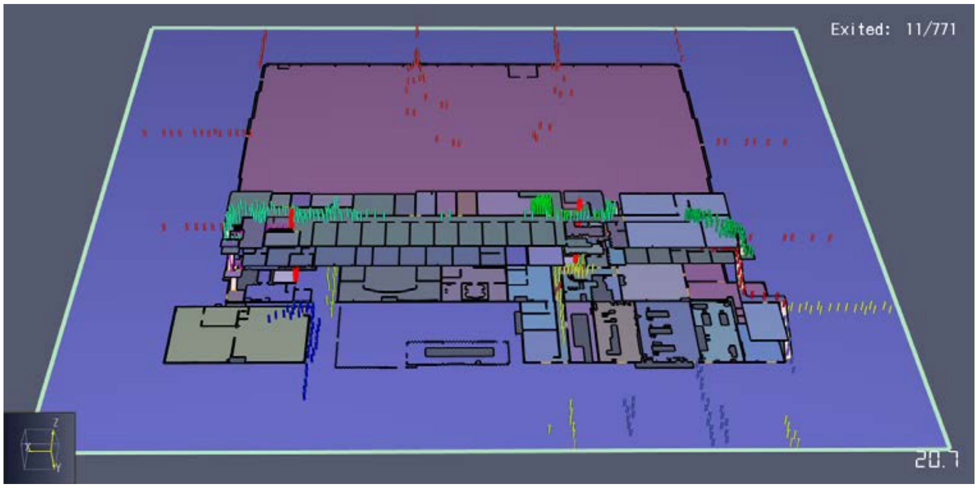


Figure 8-8: View of Office/Support Area at T=20 Seconds

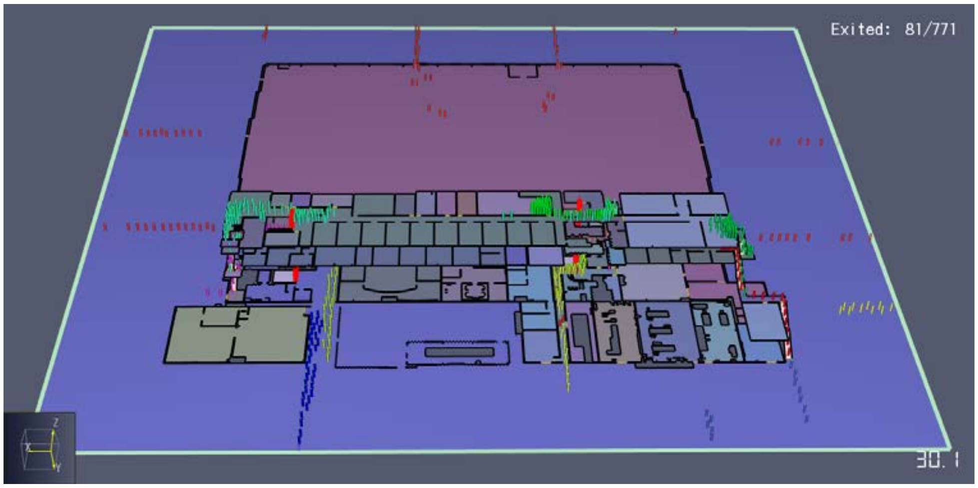


Figure 8-9: View of Office/Support Area at T=30 Seconds

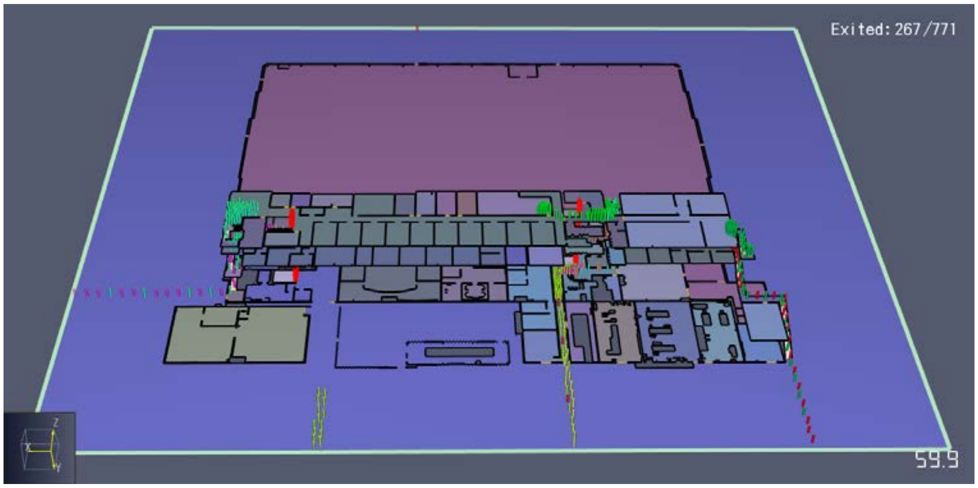


Figure 8-10: View of Office/Support Area at T=60 Seconds

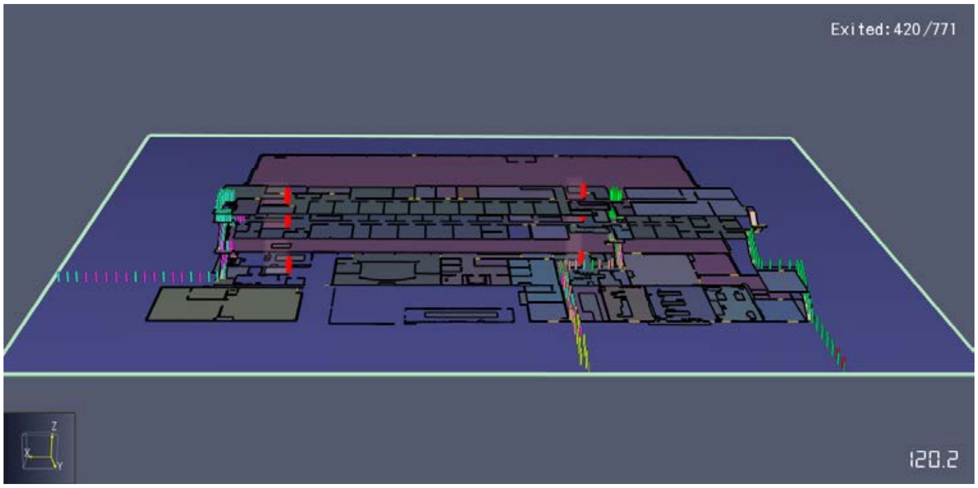


Figure 8-11: View of Office/Support Area at T=120 Seconds

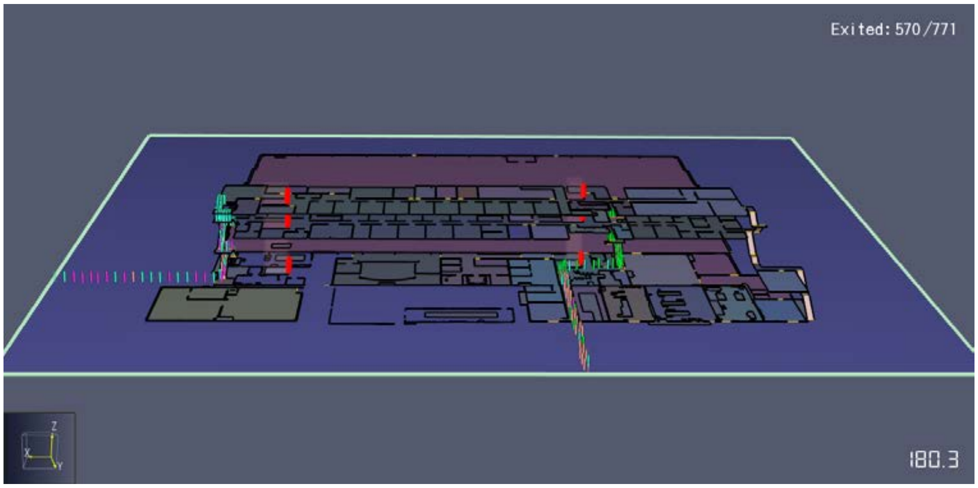


Figure 8-12: View of Office/Support Area at T=180 Seconds

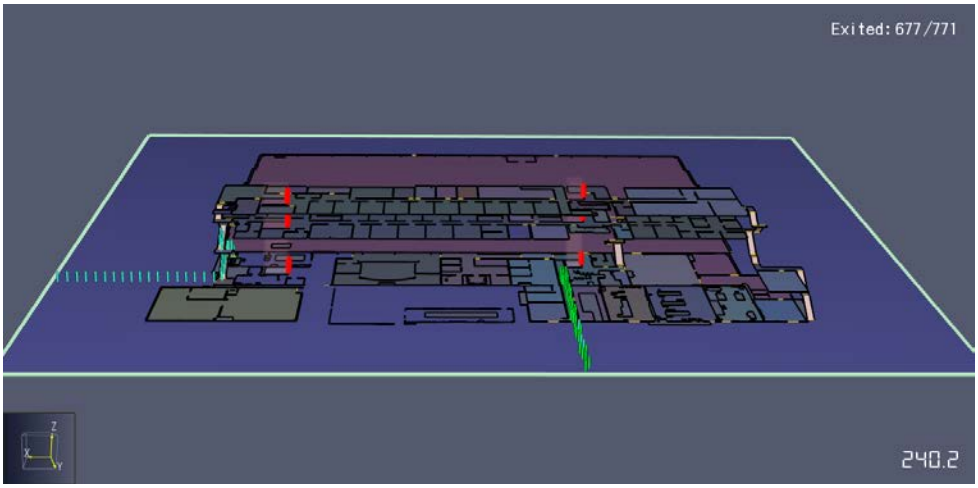


Figure 8-13: View of Office/Support Area at T=240 Seconds

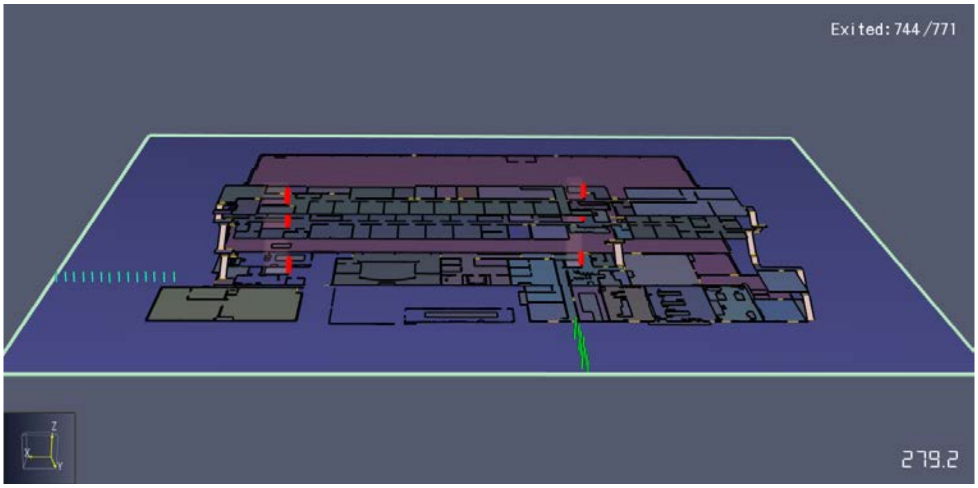


Figure 8-14: View of Office/Support Area at T=280 Seconds
(Last person exited the building)

8.4 Requires Safe Egress Time (RSET) and Evacuation Time Summary

As discussed in the beginning of this Section the Required Safe Egress Time (RSET) consists of the alarm time plus the evacuation time. The alarm time can't be determined without defining fire scenarios since it is dependent on how the alarm is activated. If the alarm is a pull station form an observer when the fire ignites the alarm time may be short. If the alarm is from a sprinkler riser flow switch the detection time could be several minutes then up to an additional minute prior to the notification devices activating. The Evacuation time on the other hand is less scenario oriented since it starts when the notification devices activate and consists of the pre-movement time and the travel time. Table 8-1 summarized the evacuation time determined from the calculations. The times have been rounded up to the nearest ½ minute to be conservative. In the next section these evacuation times will be added to the detection and alarm times as determined by the FDS modeling to determine the RSET. The RSET will then be compared to the ASET as determined by the modeling.

Table 8-1: Evacuation Time Summary (time in minutes)

	Hangar	**Office/Engineering Area**	**During-Flight Test**
Pre-movement time	6.5	3.5	6.0
Travel Time	1	5	5
Total Evacuation Time	7.5	8.5	11

9 Fire Modeling for ASET and Aircraft Damage Assessment

The primary occupant specific fire scenario for this building is a fuel spill in the hangar bay. The spill size could range from a few gallons to several hundred gallons. The fuel tanks for small fighter type aircraft vary between 600 and 2000 gallons. When aircraft are moved into the hangar the tanks are not generally full and it would not be expected that multiple tanks would spill at the same time. The design scenarios that will be investigated are 3.6 gallon and 8 gallon spills of jet fuel. These were chosen since they are the most likely to occur. A large pool fire would most definitely cause major damage to an aircraft in the hangar. The properties of the fuel are shown in Table 9-1.

Table 9-1: JP-5 Fuel Properties

Property	Value	Reference
Density	810 kg/m^3	Handbook of Aviation Fuel Properties, CRC Report #530, Fig 3
Surface Tension	23 dynes/cm	Handbook of Aviation Fuel Properties, CRC Report #530, Fig 15
Heat Release Rate/m^2	2043 kW/m^2	NFPA 72 Table B.2.3.2.6.2(a) For Diesel Oil

Based on the fuel surface tension and density a 3.6 gallon fuel spill would create a 4 m^2 pool of depth 0.34cm and the 8 gallon spill a 9 m^2 pool. In reality the hangar floor is not flat but has low spots thus the pool will be smaller, deeper, and potentially separated into multiple pools. This analysis will use 4 and 9 m^2 for the fire areas. NFPA 72 Table B.2.3.2.6.2(a) gives a value of 2043 kW/m^2 for the heat release rate per area for Diesel Oil which is very similar to JP-5. The fire in the hangar was modeled using the NIST Fire Dynamics Simulator (FDS). The fire was simulated as a square under the leading edge of a wing for both the 4 & 9 m^2 fires. Then the 9 m^2 pool was moved forward of the wing to look at the impact of a fire not in direct contact with the aircraft.

The heat release rate growth was determined from the flame spread rate for a liquid phase reaction. The rate was obtained from a plot of flame spread rate versus temperature, Figure 9-1 (White et al, 1997). Using a flame spread rate of 4.5 cm/s the HRR growth could be determined, Figure 9-2

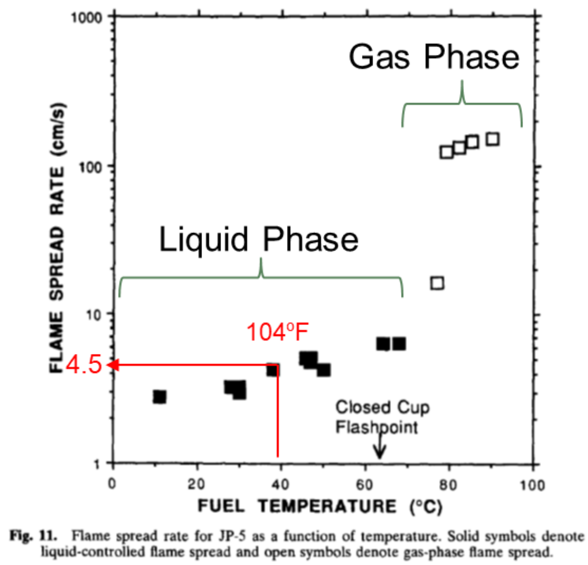


Figure 9-1: Flame Spread Rate versus Temperature

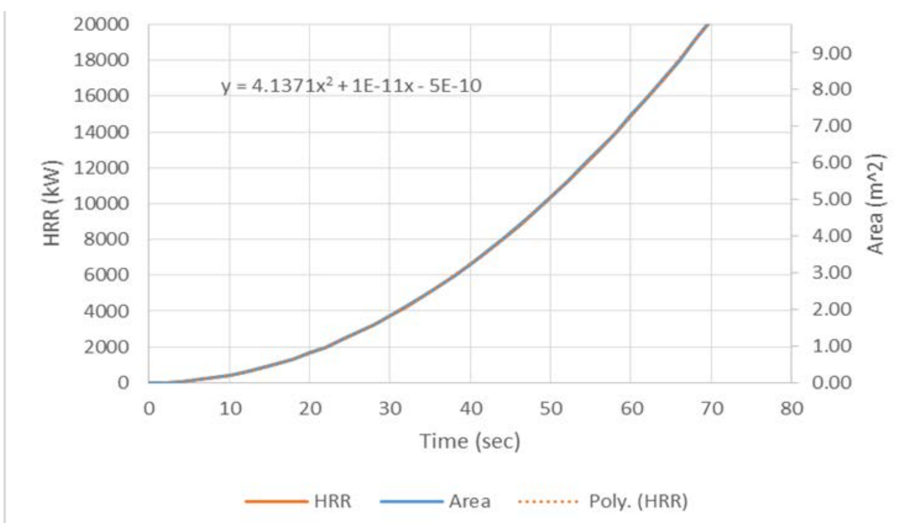


Figure 9-2: HRR Growth for JP-5 with a 4.5 cm/s Flame Spread Rate

The basic features of the hangar was modeled in FDS with smoke curtains shown in green and sprinklers located on several bays over the fire location. The doors were left open partially since this is a common occurrence. It also allows the smoke to exit and fresh air to enter. The hangar is not an air tight building thus this would simulate the real building. The aircraft was modeled as box obstructions in FDS with dimensions approximately those of a 767. There were thermocouples located on the wing and the side of the fuselage. The fire was modeled as a square partially under the leading edge of one wing. This would be a realistic scenario since the fuel is located in the wing and if a spill would occur it would be in this vicinity. The hangar was divided into 5 meshes. The mesh around the fire and through the wing adjacent to the fire had a grid size of 0.5 meters and the remainder of the hangar used a grid spacing of 1 m.

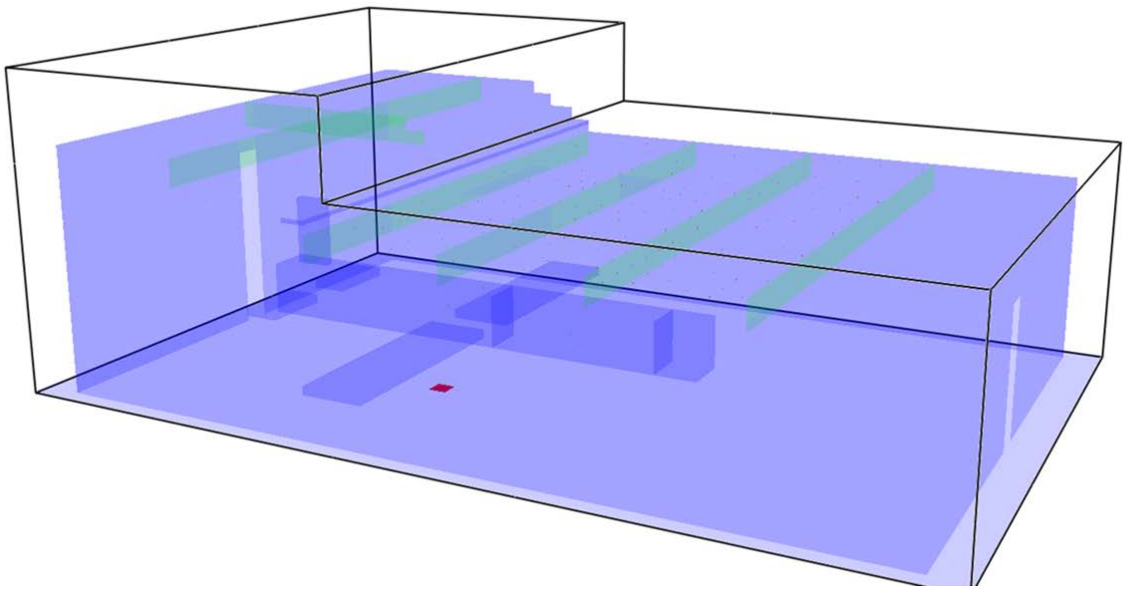


Figure 9-3: FDS Model Configuration

9.1 Under Wing Pool Fire Results

The first scenario was an 8 gallon jet fuel spill which formed a 9 m^2 pool and was located under the leading edge of the wing. The fire plume hit the wing and dispersed both under and in front of the wing. The heat release rate reached a steady state of 18.5 MW, Figure 9-4. The burner in the FDS model was set to run for a total of 200 seconds. Integrating the fuel consumption from FDS the 24.5 kg (8 gallons) was totally consumed in about 85 seconds (Figure 9-5) thus the fire would have gone out at this time. Having the burner run longer provided a worst case scenario in the model.

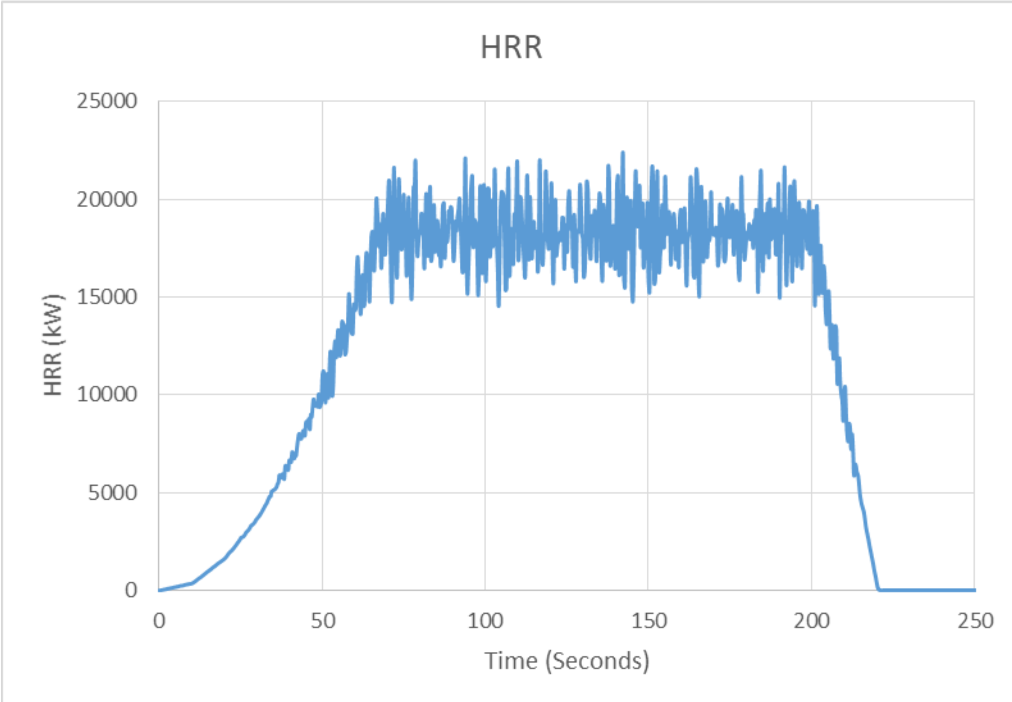


Figure 9-4: Heat Release Rate from the FDS model for the 3m x3 m pool fire

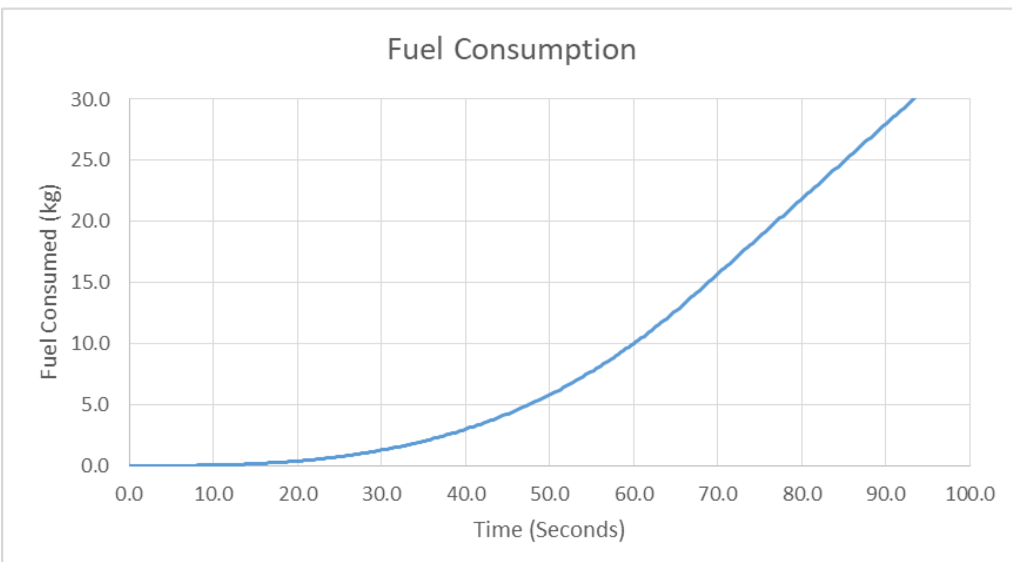


Figure 9-5: Fuel consumption as a function of time for a 3m x3 m pool fire

In this scenario the fire is first detected by theIR3 optical flame detectors (OFDs) and activate the alarm and notification devices. The detection time is approximately 10 seconds and the processing time another 10 seconds thus the alarm time is 20 seconds. The RSET is the 20 second alarm time plus the 7.5 minute evacuation time for a total RSET of approximately 8 minutes for the hangar.

Figure 9-6 to Figure 9-8 show the tenability requirements for visibility, carbon monoxide and temperature at 2 m above the floor level. As can be seen the tenability limits are not reached except in the vicinity of the fire. This shows that the ASET is unlimited for this scenario thus ASET is greater than RSET with a large margin of safety. The next performance criteria to evaluate is damage to an aircraft.

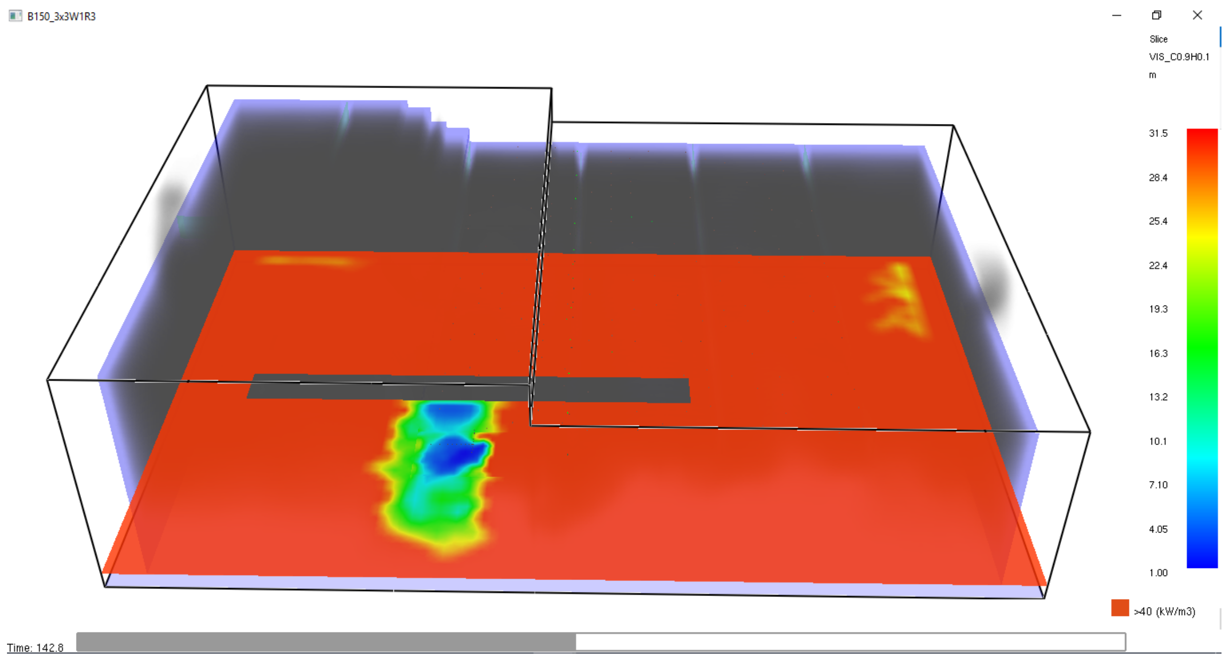


Figure 9-6: Visibility profile 2m above the floor for 3m x 3m pool fire

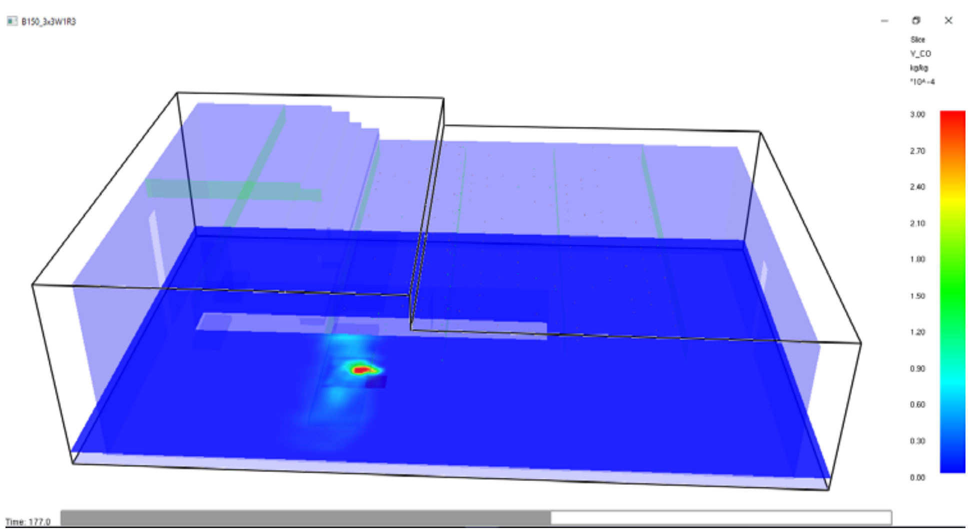


Figure 9-7: Carbon Monoxide profile 2m above the floor for 3m x 3m pool fire

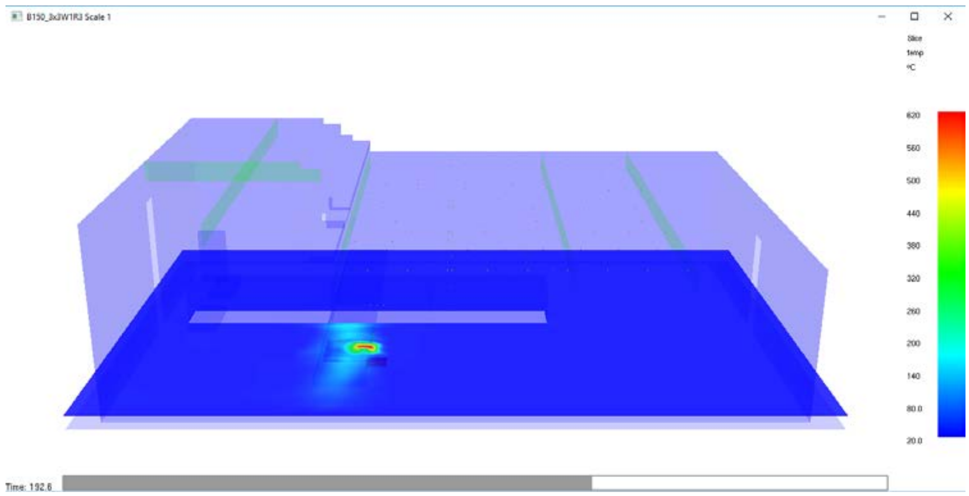


Figure 9-8: Temperature profile 2m above the floor for 3m x 3m pool fire

As the fire burns under the wing the underside and the leading edge rise in temperature and exceed the damage threshold temperature of 150°C. The amount of damage to the wing and fuselage is significant at 85 seconds when the fire burns itself out (Figure 9-9). The temperature along the leading edge and underside of the wing exceeds the melting temperature of 6061 alloy aluminum which is 585 °C (Figure 9-10). A smaller 2m x 2m pool fire was also modeled and showed similar results when in the vicinity of the wing (Figure 9-11) just not to the magnitude of the larger fire.

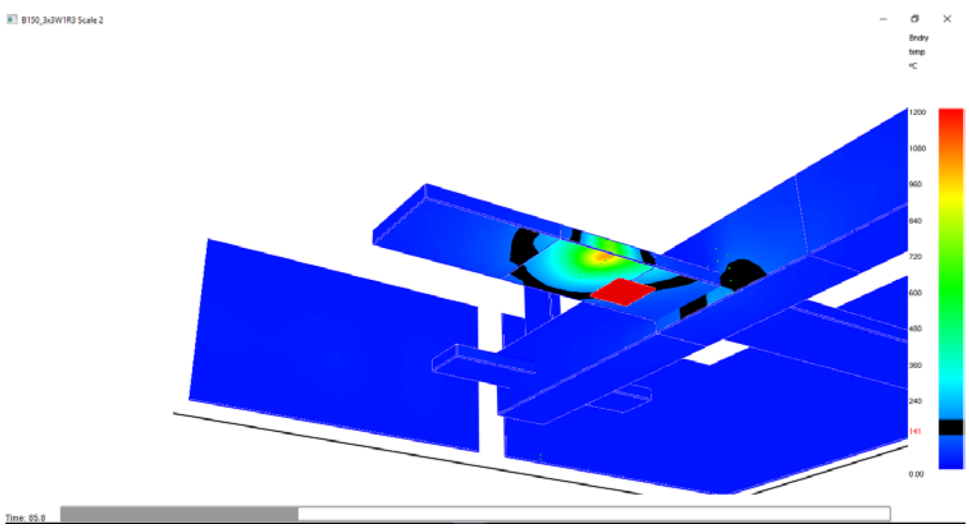


Figure 9-9: Aircraft temperature profile at 85 seconds for 3m x 3m fire (150°C highlighted)

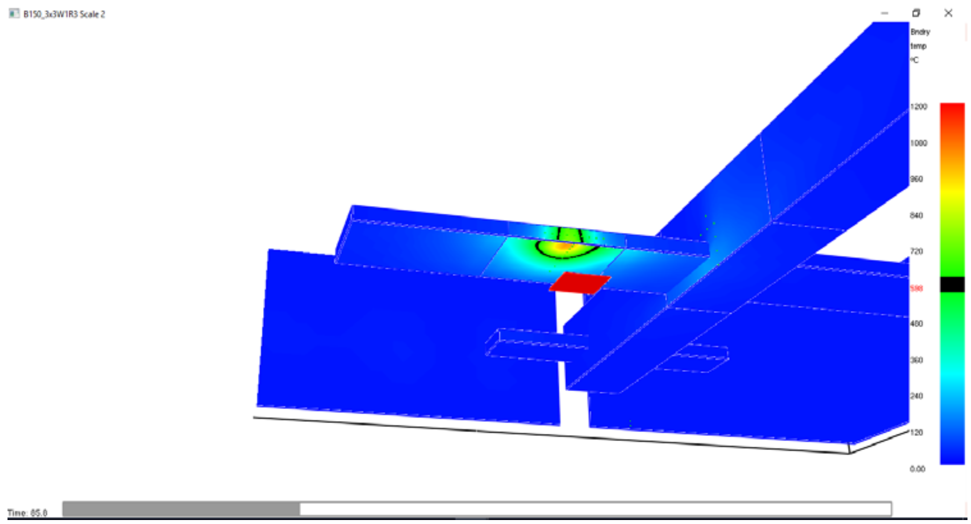


Figure 9-10: Aircraft temperature profile at 85 seconds 3m x 3m fire (585°C highlighted)

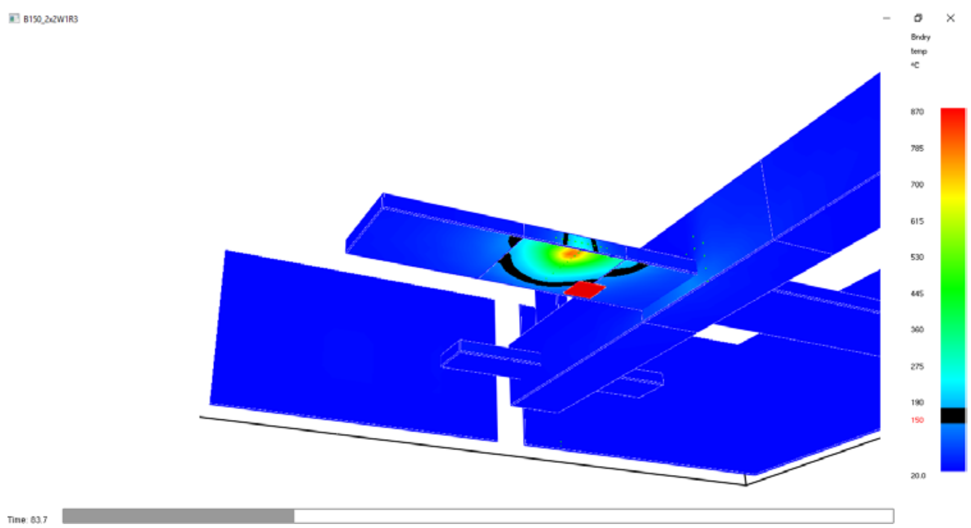


Figure 9-11: Aircraft temperature profile at 85 seconds for 2m x 2m fire (150°C highlighted)

As the fire burns under the front of the wing a portion of the heat and smoke rises to the ceiling and a portion is deflected under the wing Figure 9-12. The model also shows how the smoke curtain traps the smoke and heat such that the sprinklers will activate quicker. In this scenario the first sprinklers activates at 98 seconds, Figure 9-13.

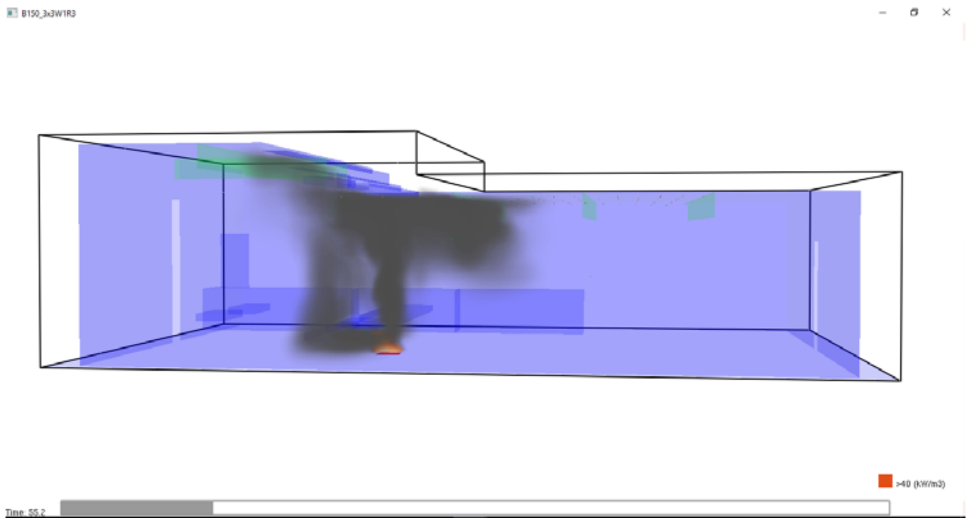


Figure 9-12: Smoke pattern for pool fire under leading edge of wing

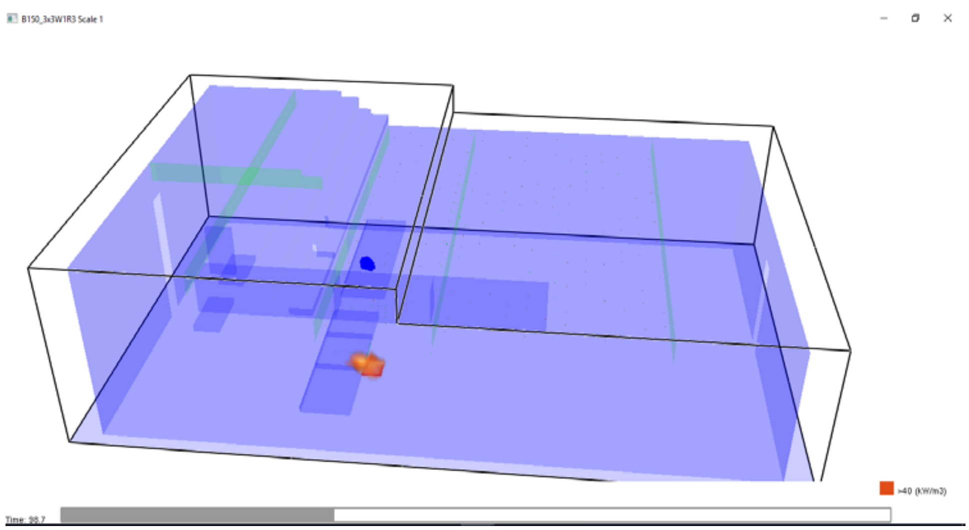


Figure 9-13: Activation of first sprinkler for 3m x 3m fire under wing

Once the sprinklers activate the riser flow switch trips and starts a 50 seconds mechanical timer prior to sending the signal to the fire alarm system and the high expansion foam system (Note: the fire alarm was previously activated by the IR3 OFDs). At the end of the 50 second delay the high expansion foam (HEF) fire suppression system activates. The alarm signal takes about 10 seconds to initiate the HEF system which then takes about 30 seconds prior to the foam dropping from the first generator. Once the foam starts to drop the floor is 80% covered in about 40 seconds. These times were measured during the HEF activation testing. The time line is summarized in Table 9-2. As can be seen the fire would have burned out by the time the HEF system activates using the sprinkler flow switch for activation. In the case of the smaller 2m x 2m pool fire the temperature at the ceiling never reached the activation temperature of the sprinklers and the fire would have burned itself out without ever activating the HEF system.

Table 9-2: High Expansion Foam Activation Timeline

T=0	Fire occurs
T=10	OFD detects fire and activates alarm
T=83	Sprinklers activate
T= 133	Flow Switch activates (50 sec delay timer)
T= 143	Hi Ex Foam suppression system activates (10 sec alarm delay)
T= 173	Foam exits first generator (determined from activation test)
T= 210	Foam covers silhouette of aircraft (~80% of floor)
T= 300	Floor 1 meter deep foam. Fire Suppressed

The current HEF system was installed following the guidelines of the AF ETL 02-15 which was in force at the time of installation. The new requirements for activating HEF system are defined in UFC 4-211-01 "Aircraft Maintenance Hangars" which was published on 13 April 2017. The new requirements require that the HEF system be activated by the simultaneous activation of two IR3 optical flame detectors. If this process is applied to the current fire scenario the HEF system would activate and have the floor 80% covered in about 70 seconds. The system would also activate on smaller fires that currently don't generate sufficient heat at the ceiling to activate the sprinklers.

If the HEF system extinguished the fire in 60 seconds then the temperature profile on the wing would be such that the damage would be localized to the leading edge and the underside of the wing which is in direct contact with the fire. (Figure 9-14).

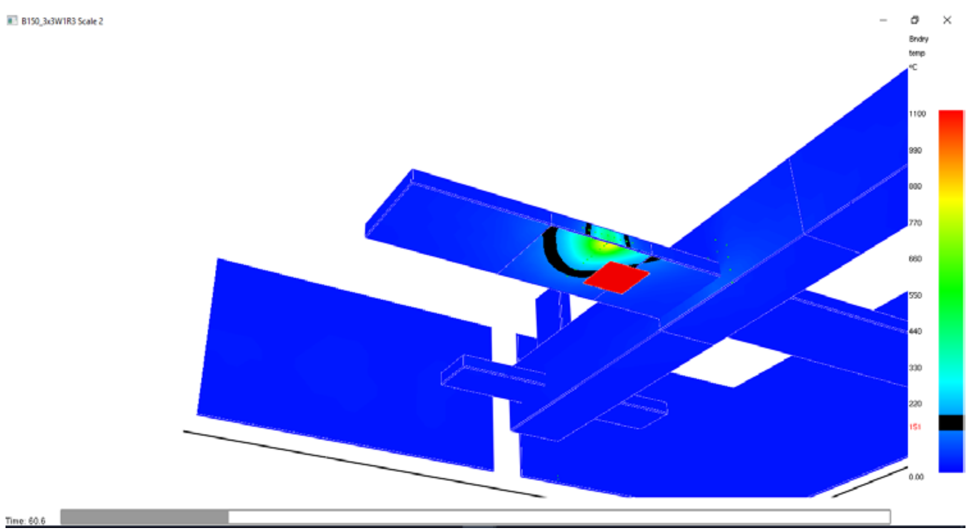


Figure 9-14: Temperature profile on aircraft at 60 seconds (150^{o}C highlighted)

9.2 Forward of Wing Pool Fire Results

The 3m x 3m pool fire that was under the leading edge of the wing was moved forward of the wing 3.5m. This would simulate a fuel spill from a servicing cart of a spill that flowed away from the aircraft before finding a low spot on the floor to pool. As can be seen in Figure 9-15 the skin temperature of the aircraft reaches a maximum of about 270 ^{o}C with only a small section over the 150 ^{o}C limit established as the level for damage. With the fire away from the wing the heat rises much faster and the sprinklers activate at 64 seconds and start to cool the wing and control the fire. The HEF system still does not activate until after the fire has burned itself out at 84 seconds.

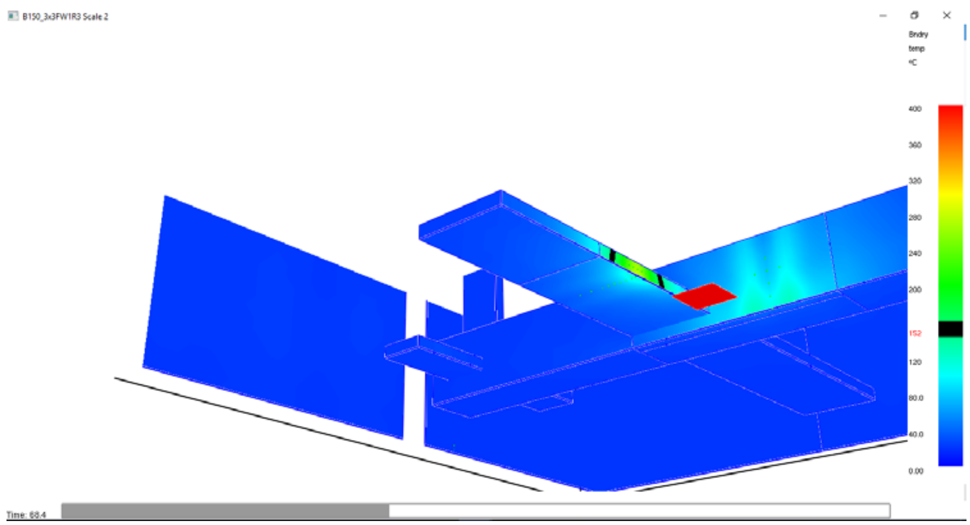


Figure 9-15: Aircraft temperature profile at 68 seconds for 3m x 3m fire 3.5 m forward of the wing

9.3 Performance Based Summary and Conclusion

A performance analysis was performed on the aircraft hangar evaluating both life safety and asset protection. For the fire scenario studies the life safety was not an issue. The available safe egress time (ASET) was greater than the required safe egress time (RSET) for the fire scenarios in the hangar that were modeled. The asset protection analysis showed that for the fire scenarios studied the aircraft would receive damage due to thermal loads. The magnitude of the damage depends greatly on the location of the fire to the asset and the size of the fire. For the small fires studies the high expansion foam system would be ineffective since the fire would burn itself out prior to the system activating. It is recommended that the activation sequence of the HEF system be changed to meet the current UFC 4-211-01 requirement to use optical flame detectors to activate the system rather than the flow switches form the sprinkler risers.

10 Conclusions and Recommendations

The hangar originally built in 1958 then modified and expanded over the years was evaluated using both the prescriptive requirements and a performance analysis. For the prescriptive analysis the building was evaluated against the 2015 International Building Code and the current NFPA codes and in a few cases the Department of Defense (DoD) Unified Facilities Criteria (UFC). The building has a three story area that has been modified over the years from an open area fabrication and support area to an office and computer area with multiple rooms. During the prescriptive analysis a few areas were identified that do not meet the current codes due to rooms being separated by security doors that only allow unobstructed travel in one direction. These modifications over the years have created a few areas that have a common travel paths and dead ends that exceed the requirements as set forth by the current Life Safety Code, NFPA 101. The hangar bay is compliant with the egress requirements of the Life Safety Code but due to the size of the hangar the notification devices installed do not meet the audibility or illumination requirements of Alarm Code NFPA 72. It is recommended that the rotating beacons and horns be installed per the new UFC 4-211-01 requirements which would provide better coverage.

For the performance analysis a pool fire created from jet fuel was ignited both under the aircraft and in the vicinity of an aircraft. The hangar was then evaluated for both life safety by verifying that the available safe egress time (ASET) was greater than the required safe egress time (RSET). The RSET was calculated using both hand calculations and a pathfinder computer model. The ASET was determined using a NIST Fire Dynamic Simulator (FDS). The FDS modeling showed that the ASET was significantly greater than the RSET thus there was no issue with life safety. Asset protection from the fire scenarios chosen was not as promising. For both fire scenarios chosen to be analyzed in the hangar the aircraft suffered damage. It was also determined, from the modeling, that the current activation sequence of the high expansion foam (HEF) system, using the sprinkler flow switches, would be ineffective due to the delay in activating the sprinklers at the 50 & 70 ft ceiling levels and the mechanical timer in the flow switch. A better way to activate the HEF system would be using multiple optical flame detectors as now required by UFC 4-211-01 dated April 2017.

10.1 Recommendations

1) Re-evaluate the ground floor exit paths and reconfigure some of the rooms and doors such that the common path and dead end distance meets the Life Safety Code.
2) Add a second door to the large conference room on the third floor. This room only meets code due to the large table that is currently located in the room reducing the "net area" of the room. If the table was removed then the room's occupancy would be greater than 50 people and would require two exit doors.
3) Add additional notification devices in the hangar bay for complete coverage. Blue 400+ cd rotating beacons at the corners of the hangar bay are now required by the UFC 4-211-01 for notification of high expansion foam system activation.

4) Re-evaluate the audibility of the horns in the hangar bay and add additional horns to ensure complete coverage.
5) Change the activation sequence of the High Expansion Foam (HEF) system to use two simultaneously activated optical flame detectors to activate the system. This would allow the foam to activate and suppress the fire within approximately 60 seconds of the fires ignition.

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15) UFC 4-211-01, UNIFIED FACILITY CRITERIA (UFC) Aircraft Maintenance Hangars, Department of Defense, 13 April 2017

Appendix A: Appendix A: Battery Calculations

Battery Calculations						
Main and Common Area FACP (Node 1)						
		Current (Amps)				
		Standby		Alarm		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-640	1	0.2500	0.2500	0.2500	0.2500	Amps
CPS-24	1	0.0400	0.0400	0.0000	0.0000	Amps
# NACs in use	2	0.0350	0.0700	0.0350	0.0700	Amps
NCA2	1	0.2000	0.2000	0.2000	0.2000	Amps
NCM-W, NCM-F	2	0.1100	0.2200	0.1100	0.2200	Amps
LEM-320 (SLC2)	1	0.1000	0.1000	0.1000	0.1000	Amps
B210LP	13	0.0000	0.0000	0.0000	0.0000	Amps
FSP-851	12	0.0003	0.0036	0.0000	0.0000	Amps
NBG-12LX	16	0.0004	0.0061	0.0000	0.0000	Amps
DNR	6	0.0000	0.0000	0.0000	0.0000	Amps
XP6-R	3	0.0015	0.0044	0.0000	0.0000	Amps
XP10-M	7	0.0035	0.0245	0.0000	0.0000	Amps
FST-851	1	0.0003	0.0003	0.0000	0.0000	Amps
FDM-1	3	0.0008	0.0023	0.0000	0.0000	Amps
FRM-1	9	0.0003	0.0023	0.0000	0.0000	Amps
FCO-851	1	0.0003	0.0003	0.0000	0.0000	Amps
SLC Activation Current	2	0.0000	0.0000	0.4000	0.8000	Amps
SPSCW15	4	0.0000	0.0000	0.0660	0.2640	Amps
SPSCW30	1	0.0000	0.0000	0.0940	0.0940	Amps
SPSCW75	1	0.0000	0.0000	0.1580	0.1580	Amps
Sub Total (amps)			0.92372		2.1560	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			44.33856		0.539	Amp-hrs
System Amp Hours				44.87756		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				8.975512		Amp-hrs
Total Amp-hours				**53.85307**		**Amp-hrs**

Battery Calculations						
Ground and 1st Mezzanine Common Area FCPS (Node 1)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
ACPS-610	1	0.13	0.13	0.25	0.25	Amps
SPSCW15	13	0	0	0.066	0.858	Amps
SPSCW110	4	0	0	0.202	0.808	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.13		1.916	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			6.24		0.479	Amp-hrs
System Amp Hours				6.719		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				1.3438		Amp-hrs
Total Amp-hours				**8.0628**		**Amp-hrs**

Battery Calculations						
Common Area 2nd Mezzanine FCPS (Node 1)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
ACPS-610	1	0.13	0.13	0.25	0.25	Amps
SPSCW15	6	0	0	0.066	0.396	Amps
SPSCW30	0	0	0	0.094	0	Amps
SPSCW75	0	0	0	0.158	0	Amps
SCW-CLR-ALERT15	0	0	0	0.0666	0	Amps
SCW-CLR-ALERT30	0	0	0	0.094	0	Amps
SCW-CLR-ALERT75	0	0	0	0.158	0	Amps
SCW15	0	0	0	0.066	0	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.13		0.646	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			6.24		0.1615	Amp-hrs
System Amp Hours				6.4015		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				1.2803		Amp-hrs
Total Amp-hours				**7.6818**		**Amp-hrs**

Battery Calculations						
Digital Voice Comand Panel (Node 2)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
DVC-EM	1	0.44	0.44	0.44	0.44	Amps
DVC-KD	1	0.06	0.06	0.06	0.06	Amps
RM-1	1	0.075	0.075	0.075	0.075	Amps
SPW	21	0	0	0.064	1.344	Amps
Sub Total (amps)			0.575		1.919	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			27.6		0.47975	Amp-hrs
System Amp Hours				28.07975		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				5.61595		Amp-hrs
Total Amp-hours				**33.6957**		**Amp-hrs**

Battery Calculations						
Secure Area G1 South (Node 4)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	2	0.035	0.07	0.035	0.07	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	6		0	0.066	0.396	Amps
SPSCW30	1	0	0	0.094	0.094	Amps
SPSCW75	4	0	0	0.158	0.632	Amps
SPSCW95	2		0		0	Amps
SCW-CLR-ALERT15	14	0	0	0.0666	0.9324	Amps
SCW-CLR-ALERT30	2	0	0	0.094	0.188	Amps
SCW-CLR-ALERT75	3	0	0	0.158	0.474	Amps
SCW-CLR-ALERT95	2		0		0	Amps
SCW15	4	0	0	0.066	0.264	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.36068		3.7004	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			17.31264		0.9251	Amp-hrs
System Amp Hours				18.23774		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				3.647548		Amp-hrs
Total Amp-hours				**21.88529**		**Amp-hrs**

Battery Calculations						
Secure Area G1 North (Node 5)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	4	0.035	0.14	0.035	0.14	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	14		0	0.066	0.924	Amps
SPSCW30	2	0	0	0.094	0.188	Amps
SPSCW75	3	0	0	0.158	0.474	Amps
SCW-CLR-ALERT15	14	0	0	0.0666	0.9324	Amps
SCW-CLR-ALERT30	2	0	0	0.094	0.188	Amps
SCW-CLR-ALERT75	3	0	0	0.158	0.474	Amps
SCW15	4	0	0	0.066	0.264	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.43068		4.2344	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			20.67264		1.0586	Amp-hrs
System Amp Hours				21.73124		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				4.346248		Amp-hrs
Total Amp-hours				**26.07749**		**Amp-hrs**

Battery Calculations						
Secure Area M1 South (Node 6)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	4	0.035	0.14	0.035	0.14	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	14		0	0.066	0.924	Amps
SPSCW30	2	0	0	0.094	0.188	Amps
SPSCW75	3	0	0	0.158	0.474	Amps
SCW-CLR-ALERT15	14	0	0	0.0666	0.9324	Amps
SCW-CLR-ALERT30	2	0	0	0.094	0.188	Amps
SCW-CLR-ALERT75	3	0	0	0.158	0.474	Amps
SCW15	4	0	0	0.066	0.264	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.43068		4.2344	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			20.67264		1.0586	Amp-hrs
System Amp Hours				21.73124		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				4.346248		Amp-hrs
Total Amp-hours				**26.07749**		**Amp-hrs**

Battery Calculations						
Secure Area M1 North (Node 7)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	2	0.035	0.07	0.035	0.07	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	3		0	0.066	0.198	Amps
SPSCW30	0	0	0	0.094	0	Amps
SPSCW75	2	0	0	0.158	0.316	Amps
SCW-CLR-ALERT15	3	0	0	0.0666	0.1998	Amps
SCW-CLR-ALERT30	0	0	0	0.094	0	Amps
SCW-CLR-ALERT75	2	0	0	0.158	0.316	Amps
SCW15	0	0	0	0.066	0	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.36068		1.7498	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			17.31264		0.43745	Amp-hrs
System Amp Hours				17.75009		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				3.550018		Amp-hrs
Total Amp-hours				**21.30011**		**Amp-hrs**

Battery Calculations						
Secure Area M1.5 North (Node 8)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	2	0.035	0.07	0.035	0.07	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	1		0	0.066	0.066	Amps
SPSCW30	0	0	0	0.094	0	Amps
SPSCW75	0	0	0	0.158	0	Amps
SCW-CLR-ALERT15	1	0	0	0.0666	0.0666	Amps
SCW-CLR-ALERT30	0	0	0	0.094	0	Amps
SCW-CLR-ALERT75	0	0	0	0.158	0	Amps
SCW15	0	0	0	0.066	0	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.36068		0.8526	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			17.31264		0.21315	Amp-hrs
System Amp Hours				17.52579		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				3.505158		Amp-hrs
Total Amp-hours				**21.03095**		**Amp-hrs**

Battery Calculations						
Secure Area M2 South (Node 9)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	4	0.035	0.14	0.035	0.14	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	4		0	0.066	0.264	Amps
SPSCW30	6	0	0	0.094	0.564	Amps
SPSCW75	7	0	0	0.158	1.106	Amps
SCW-CLR-ALERT15	4	0	0	0.0666	0.2664	Amps
SCW-CLR-ALERT30	6	0	0	0.094	0.564	Amps
SCW-CLR-ALERT75	7	0	0	0.158	1.106	Amps
SCW15	0	0	0	0.066	0	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.43068		4.6604	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			20.67264		1.1651	Amp-hrs
System Amp Hours				21.83774		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				4.367548		Amp-hrs
Total Amp-hours				**26.20529**		**Amp-hrs**

Battery Calculations						
Secure Area M2 North (Node 10)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	2	0.035	0.07	0.035	0.07	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	0		0	0.066	0	Amps
SPSCW30	5	0	0	0.094	0.47	Amps
SPSCW75	0	0	0	0.158	0	Amps
SCW-CLR-ALERT15	0	0	0	0.0666	0	Amps
SCW-CLR-ALERT30	5	0	0	0.094	0.47	Amps
SCW-CLR-ALERT75	0	0	0	0.158	0	Amps
SCW15	0	0	0	0.066	0	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.36068		1.66	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			17.31264		0.415	Amp-hrs
System Amp Hours				17.72764		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				3.545528		Amp-hrs
Total Amp-hours				**21.27317**		**Amp-hrs**

Battery Calculations

Electrical Substation B191 (Node 15)

		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	1	0.035	0.035	0.035	0.035	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
P2W15	1	0	0	0.091	0.091	Amps
P2W75	1	0	0	0.176	0.176	Amps
Sub Total (amps)			0.32568		0.952	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			15.63264		0.238	Amp-hrs
System Amp Hours				15.87064		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				3.174128		Amp-hrs
Total Amp-hours				**19.04477**		**Amp-hrs**

Battery Calculations						
Machine Shop B192 (Node 16)						
		Current (Amps)				
		Standby		**Alarm**		Units
Equipment	Quantity	Unit	Total	Unit	Total	Amps
FACP CPU-320	1	0.25	0.25	0.25	0.25	Amps
CPS-24	1	0.04	0.04	0	0	Amps
# NACs in use	2	0.035	0.07	0.035	0.07	Amps
B210LP	1	0	0	0	0	Amps
FSP-851	1	0.0003	0.0003	0	0	Amps
NBG-12LX	1	0.00038	0.00038	0	0	Amps
SLC Activation Current	1	0	0	0.4	0.4	Amps
SPSCW15	2		0	0.066	0.132	Amps
SPSCW30	0	0	0	0.094	0	Amps
SPSCW75	2	0	0	0.158	0.316	Amps
SCW-CLR-ALERT15	2	0	0	0.0666	0.1332	Amps
SCW-CLR-ALERT30	0	0	0	0.094	0	Amps
SCW-CLR-ALERT75	2	0	0	0.158	0.316	Amps
SCW15	0	0	0	0.066	0	Amps
			0	1.65	0	Amps
		0	0	1.65	0	Amps
Sub Total (amps)			0.36068		1.6172	
Duration (48 Hrs standby, 15 min alarm) Hours (UFC 3-600-01)			48		0.25	Hours
System Amp-hours			17.31264		0.4043	Amp-hrs
System Amp Hours				17.71694		Amp-hrs
20 % reserve (NFPA 72 Section 10.6.7.2.1.1)				3.543388		Amp-hrs
Total Amp-hours				**21.26033**		**Amp-hrs**

Appendix B: Riser Hydraulic calculations and supporting Information

B.1. Riser 1A Office/Support Area Wet Pipe System Hydraulic Calculations

0.1	GPM/ft^2
1500	FT62
150	GPM
1.25	GPM/Head

Project name: Riser 1A office area 2nd Mezzanine South End — Date:

Step No.	Nozzle Ident and Location			Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes
		Drop	q	12.0			L	19	C=	120	Pt	4.6	Pt		k=	5.6
1	1	Piping			1	2 - 90 L	F	4			Pe	-7.8	Pv			q = k * (Pt)^1/2
			Q	12.0	1.049		T	23	pf	0.051	Pf	1.2	Pn			Piping to drop below drop ceiling
											Pt	-2.0			k=	#NUM!
			q	12.0			L	9.5	C=	120	Pt	4.6	Pt		k=	5.60
3	1	BL1A			1		F				Pe		Pv			
			Q	12.0	1.049		T	9.5	pf	0.051	Pf	0.5	Pn			
			q	12.6			L	9.5	C=	120	Pt	5.1	Pt		k=	5.60
4	2	BL1A			1		F				Pe		Pv			
			Q	24.6	1.049		T	9.5	pf	0.191	Pf	1.8	Pn			
			q	14.7			L	14.5	C=	120	Pt	6.9	Pt		k=	5.60
2	3	BL1A			1.25	1-90L	F	9			Pe		Pv			
			Q	39.3	1.38	1-T	T	23.5	pf	0.119	Pf	2.8	Pn			
			q	0.0			L	0	C=	120	Pt	9.7	Pt		k=	
2	**A**	BL1			1.25		F	0			Pe		Pv			
			Q	39.3	1.38		T	0	pf	0.119	Pf	0.0	Pn			
			q	13.2			L	9.5	C=	120	Pt	5.5	Pt		k=	5.60
3	1	BL1			1		F				Pe		Pv			
			Q	13.2	1.049		T	9.5	pf	0.060	Pf	0.6	Pn			
			q	13.8			L	9.5	C=	120	Pt	6.1	Pt		k=	5.60
4	2	BL1			1		F				Pe		Pv			
			Q	27.0	1.049		T	9.5	pf	0.226	Pf	2.2	Pn			
			q	16.1			L	9.5	C=	120	Pt	8.2	Pt		k=	5.60
5	3	BL1			1.25		F				Pe		Pv			
			Q	43.1	1.38		T	9.5	pf	0.141	Pf	1.3	Pn			
			q	17.3			L	3	C=	120	Pt	9.6	Pt		k=	5.60
5	4	BL1			2		F				Pe		Pv			
			Q	60.4	2.067		T	3	pf	0.037	Pf	0.1	Pn			
			q	0.0			L	6.5	C=	120	Pt	9.7	Pt		k=	
5	**A**	BL1			2		F				Pe		Pv			
			Q	60.4	2.067		T	6.5	pf	0.037	Pf	0.2	Pn			
			q	17.7			L	3.5	C=	120	Pt	9.9	Pt		k=	5.60
5	5	BL1			2	Tee	F	10			Pe		Pv			
			Q	78.0	2.067		T	13.5	pf	0.059	Pf	0.8	Pn			
			q	0.0			L		C=	120	Pt	10.7	Pt		k=	
5	B	BL1			2		F				Pe		Pv			
			Q	78.0	2.067		T	0	pf	0.059	Pf	0.0	Pn			
			q	17.5			L	4.5	C=	120	Pt	9.8	Pt		k=	5.60
1	1	BL1B			1	Tee	F	5			Pe		Pv			
			Q	17.5	1.049		T	9.5	pf	0.102	Pf	1.0	Pn			
			q	0.0			L	0.5	C=	120	Pt	10.7	Pt		k=	0.00
2	B	BL1			2	Tee	F	10			Pe	2.2	Pv			drop 6" into CM
			Q	95.5	2.067		T	10.5	pf	0.086	Pf	0.9	Pn			Add flow from both sides of CM
											Pt	13.8			k=	25.71
															K for Branch BL1	

Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	13.0			L	9.5	C=	120	Pt	5.4	Pt		k=	5.60
4	1	BL2			1		F				Pe		Pv			
			Q	13.0	1.049		T	9.5	pf	0.059	Pf	0.6	Pn			
			q	13.7			L	9.5	C=	120	Pt	5.9	Pt		k=	5.60
4	2	BL2			1		F				Pe		Pv			
			Q	26.7	1.049		T	9.5	pf	0.221	Pf	2.1	Pn			
			q	15.9			L	9.5	C=	120	Pt	8.0	Pt		k=	5.60
4	3	BL2			1.25		F				Pe		Pv			
			Q	42.5	1.38		T	9.5	pf	0.138	Pf	1.3	Pn			
			q	17.1			L	7	C=	120	Pt	9.4	Pt		k=	5.60
4	4	BL2			1.5	Tee	F	8			Pe		Pv			
			Q	59.7	1.61		T	15	pf	0.122	Pf	1.8	Pn			
			q	0.0			L	0	C=	120	Pt	11.2	Pt		k=	0.00
4	A	BL2			2		F				Pe		Pv			
			Q	59.7	2.067		T	0	pf	0.036	Pf	0.0	Pn			
			q	16.5			L	5	C=	120	Pt	8.7	Pt		k=	5.60
4	1	BL2			1		F				Pe		Pv			
			Q	16.5	1.049		T	5	pf	0.091	Pf	0.5	Pn			
			q	17.0			L	1	C=	120	Pt	9.2	Pt		k=	5.60
4	2	BL2			1	Tee	F	5			Pe		Pv			
			Q	33.5	1.049		T	6	pf	0.338	Pf	2.0	Pn			
			q	0.0			L	0.5	C=	120	Pt	11.2	Pt		k=	0.00
4	A	BL2			2	Tee	F	10			Pe	0.2	Pv			drop 6" into CM
			Q	93.2	2.067		T	10.5	pf	0.082	Pf	0.9	Pn			Add flow from both sides of CM
												12.3			k=	26.59
															K for Branch BL2	
			q	13.0			L	9.5	C=	120	Pt	5.4	Pt		k=	5.60
4	1	BL3			1		F				Pe		Pv			
			Q	13.0	1.049		T	9.5	pf	0.059	Pf	0.6	Pn			
			q	13.7			L	9.5	C=	120	Pt	5.9	Pt		k=	5.60
4	2	BL3			1		F				Pe		Pv			
			Q	26.7	1.049		T	9.5	pf	0.221	Pf	2.1	Pn			
			q	13.7			L	9.5	C=	120	Pt	5.9	Pt		k=	5.60
4	3	BL3			1.25		F				Pe		Pv			
			Q	40.3	1.38		T	9.5	pf	0.125	Pf	1.2	Pn			
			q	15.9			L	9.5	C=	120	Pt	8.0	Pt		k=	5.60
4	4	BL3			1.5		F				Pe		Pv			
			Q	56.2	1.61		T	9.5	pf	0.109	Pf	1.0	Pn			
			q	16.9			L	5	C=	120	Pt	9.1	Pt		k=	5.60
4	5	BL3			2	Tee	F	10			Pe		Pv			
			Q	73.1	2.067		T	15	pf	0.053	Pf	0.8	Pn			
			q	0.0			L	0	C=	120	Pt	9.9	Pt		k=	0.00
4	A	BL3			2		F				Pe		Pv			
			Q	73.1	2.067		T	0	pf	0.053	Pf	0.0	Pn			
			q	16.2			L	4.5	C=	120	Pt	8.4	Pt		k=	5.60
4	1	BL3			1	Tee	F	5			Pe		Pv			
			Q	16.2	1.049		T	9.5	pf	0.088	Pf	0.8	Pn			
			q	0.0			L	0.5	C=	120	Pt	9.2	Pt		k=	0.00
4	A	BL3			2	Tee	F	10			Pe		Pv			drop 6" into CM
			Q	89.3	2.067		T	10.5	pf	0.076	Pf	0.8	Pn			Add flow from both sides of CM
												10.0			k=	28.23
															K for Branch BL3	

Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
		Cross Main														
			q	95.5			L	12.25	C=	120	Pt	13.8	Pt		k=	25.71
4	1	BL1			2.5		F				Pe		Pv			
			Q	95.5	2.469		T	12.25	pf	0.036	Pf	0.4	Pn			
			q	100.4			L	12.25	C=	120	Pt	14.3	Pt		k=	26.59
4	2	BL2			2.5		F				Pe		Pv			
			Q	195.9	2.469		T	12.25	pf	0.137	Pf	1.7	Pn			
			q	106.6			L	86	C=	120	Pt	14.3	Pt		k=	28.23
4	3	BL3			3		F				Pe		Pv			
			Q	302.5	3.068		T	86	pf	0.106	Pf	9.2	Pn			
			q	0.0			L	53	C=	120	Pt	15.9	Pt		k=	0.00
4	4				4	Tee	F	20			Pe		Pv			
			Q	302.5	4.026		T	73	pf	0.028	Pf	2.1	Pn			
		GND	q	0.0			L	77	C=	120	Pt	18.0	Pt		k=	0.00
4	5	Flr			6	1-90L	F	20			Pe	29.9	Pv			drop 69' to gnd floor
		Riser	Q	302.5	60.65		T	97	pf	0.000	Pf	0.0	Pn			
		Valves	q	0.0			L	0	C=	120	Pt	47.9	Pt		k=	0.00
	6				6		F	20			Pe		Pv			
			Q	302.5	60.65		T	20	pf	0.000	Pf	0.0	Pn			
			q	0.0		1-90L	L	86	C=	140	Pt	47.9	Pt		k=	0.00
	6	POC			8	Tee	F	53			Pe		Pv			
			Q	302.5	7.981		T	139	pf	0.001	Pf	0.1	Pn			
												48.0				
								Sprinkler		302.506	gpm	48.0	psi			
								Hose		250.000	gpm					
								Total		552.506	gpm					

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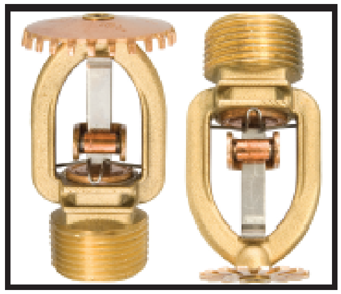
Series TY-L — 5.6 and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers Standard Response, Standard Coverage



General Description

The TYCO Series TY-L, 5.6 and 8.0 K-factor, Upright, Pendent, and Recessed Pendent Sprinklers described in this data sheet are standard response, standard coverage, solder type spray sprinklers designed for use in light, ordinary, and extra hazard, commercial occupancies such as banks, hotels, shopping malls, factories, refineries, chemical plants, etc.

The recessed version of the Series TY-L Pendent Sprinkler, where applicable, is intended for use in areas with a finished ceiling. It uses a two-piece Style 20 (1/2 inch NPT) or Style 30 (3/4 inch NPT) Recessed Escutcheon. The Recessed Escutcheon provides 1/4 in. (6,4 mm) of recessed adjustment or up to 1/2 in. (12,7 mm) of total adjustment from the flush pendent position. The adjustment provided by the Recessed Escutcheon reduces the accuracy to which the fixed pipe drops to the sprinklers must be cut.

Corrosion resistant coatings, where applicable, are utilized to extend the life of copper alloy sprinklers beyond that which would otherwise be obtained when exposed to corrosive atmospheres. Although corrosion resistant coated sprinklers have passed the standard corrosion tests of the applicable approval agencies, the testing is not representative of all possible corrosive atmospheres. Consequently, it is recommended that the end user be consulted with respect to the suitability of these coatings for any given corrosive environment. The effects of ambient temperature, concentration of chemicals, and gas/chemical velocity, should be considered, as a minimum, along with the corrosive nature of the chemical to which the sprinklers will be exposed.

An intermediate level version of the Series TY-L Pendent Sprinkler can be obtained by utilizing the Series TY-L Pendent Sprinkler in combination with the Model S Shield.

IMPORTANT

Always refer to Technical Data Sheet TFP700 for the "INSTALLER WARNING" that provides cautions with respect to handling and installation of sprinkler systems and components. Improper handling and installation can permanently damage a sprinkler system or its components and cause the sprinkler to fail to operate in a fire situation or cause it to operate prematurely.

NOTICE

The TYCO Series TY-L, 5.6 and 8.0 K-factor, Upright and Pendent Sprinklers described herein must be installed and maintained in compliance with this document, as well as with the applicable standards of the National Fire Protection Association, in addition to the standards of any other authorities having jurisdiction. Failure to do so may impair the performance of these devices.

The owner is responsible for maintaining their fire protection system and devices in proper operating condition. Contact the installing contractor or product manufacturer with any questions.

Sprinkler Identification Number (SIN)

TY3111. . . . . .Upright 5.6K, 1/2" NPT
TY3211 . . . .Pendent 5.6K, 1/2" NPT
TY4111. . . . . Upright 8.0K, 3/4" NPT
TY4211. . . . .Pendent 8.0K, 3/4" NPT
TY4811 . . . . .Upright 8.0K, 1/2" NPT
TY4911 . . . .Pendent 8.0K, 1/2" NPT

TY3111 is a re-designation for S1800 and G3111.
TY3211 is a re-designation for S1801 and G3112.
TY4111 is a re-designation for S1810 and G3101.
TY4211 is a re-designation for S1811 and G3102.
TY4811 is a re-designation for S1805.
TY4911 is a re-designation for S1806.

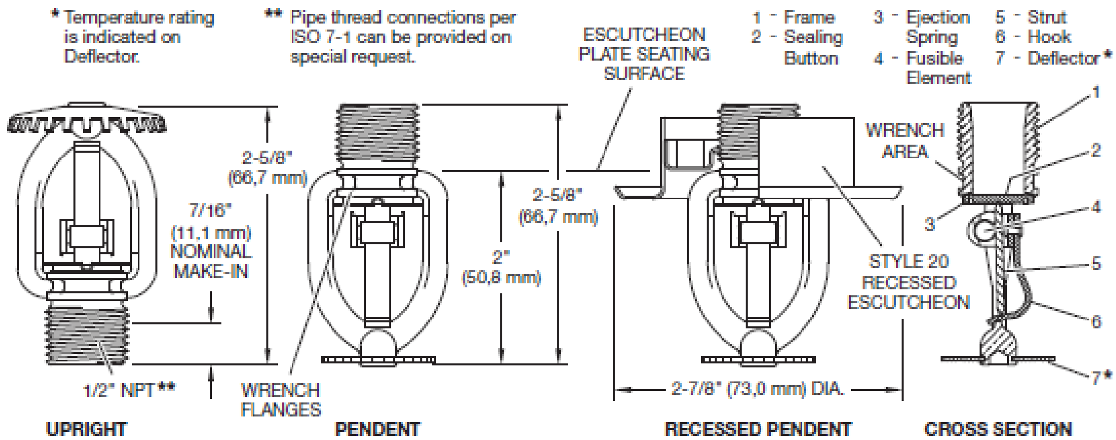


FIGURE 3
STANDARD RESPONSE SERIES TY-L UPRIGHT (TY4811) AND PENDENT (TY4911) SPRINKLERS
8.0 K-FACTOR, 1/2 INCH NPT

Technical Data

Approvals
UL and C-UL Listed. FM, and LPCB Approved. (Refer to Table A for complete approval information including corrosion resistant status.)

Maximum Working Pressure
175 psi (12,1 bar)

Discharge Coefficient
K=5.6 GPM/psi^{½} (80,6 LPM/bar^{½})
K=8.0 GPM/psi^{½} (115,2 LPM/bar^{½})

Temperature Ratings
Refer to Table A

Finishes
Sprinkler: Refer to Table A Recessed

Escutcheon: White Coated, Chrome Plated, or Brass Plated

Physical Characteristics

Frame	Brass
Sealing Button	Bronze w/TEFLON
Ejection Spring	Stainless Steel
Strut	MONEL
Hook	Bronze/MONEL
Deflector	Bronze
Fusible Element	Solder, Copper, Stainless Steel

Operation

A copper tube sealed by two stainless steel balls holds a fusible alloy. When the rated temperature is reached, the alloy melts, the balls are forced toward each other releasing the tension mechanism, allowing the sprinkler to operate.

Design Criteria

The TYCO Series TY-L, 5.6 and 8.0 K-factor, Upright, Pendent, and Recessed Pendent Sprinklers are intended for fire protection systems designed in accordance with the standard installation rules recognized by the applicable Listing or Approval agency (e.g., UL Listing is based on the requirements of NFPA 13, and FM Approval is based on the requirements of FM's Loss Prevention Data Sheets). Only the Style 20 or 30 Recessed Escutcheon, as applicable, are to be used for recessed pendent installations.

Installation

The TYCO Series TY-L, 5.6 and 8.0 K-factor, Upright, Pendent, and Recessed Pendent Sprinklers must be installed in accordance with this section:

A leak tight 1/2 inch NPT sprinkler joint should be obtained with a torque of 7 to 14 ft.-lbs. (9,5 to 19,0 Nm). A leak tight 3/4 inch NPT sprinkler joint should be obtained with a torque of 10 to 20 ft.-lbs. (13,4 to 26,8 Nm). Higher levels of torque may distort the sprinkler inlet and cause leakage or impairment of the sprinkler.

Do not attempt to make-up for insufficient adjustment in the escutcheon plate by under- or over-tightening the sprinkler. Readjust the position of the sprinkler fitting to suit.

Series TY-L Pendent and Upright Sprinkler Installation
The Series TY-L Pendent and Upright Sprinklers must be installed in accordance with this section.

Pendent sprinklers are to be installed in the pendent position, and upright sprinklers are to be installed in the upright position.

Step 1. With pipe thread sealant applied to the pipe threads, hand tighten the sprinkler into the sprinkler fitting.

Step 2. Tighten the sprinkler into the sprinkler fitting using only the W-Type 9 Sprinkler Wrench (Ref. Figure 7), except that an 8 or 10 inch adjustable Crescent wrench is to be used for wax coated sprinklers. With reference to Figures 1, 2, and 3, the W-Type 9 Sprinkler Wrench is to be applied to the wrench area, or as applicable, the adjustable Crescent wrench is to be applied to the wrenching flanges.

When installing wax coated sprinklers with the adjustable Crescent wrench, additional care needs to be exercised to prevent damage to the wax coating on the sprinkler wrench flats or frame arms and, consequently, exposure of bare metal to the corrosive environment. The jaws of the wrench should be opened sufficiently wide to pass over the wrench flats without damaging the wax coating. Before wrench tightening the sprinkler, the jaws of the wrench are to be adjusted to just contact the sprinkler wrench flats. After wrench tightening the sprinkler, loosen the wrench jaws before removing the wrench.

Close

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Fire Products

Model AV-1

Model AV-1 Alarm Check Valve, 300 psi (20,7 bar) 2-1/2, 4, 6, & 8 Inch

(TFP910)

Features and Benefits

- *Full Comprehensive Line of Alarm Valves*
- *Lightweight Ductile Iron Bodies*
- *UL & CUL Listed, as well as FM Approved*
- *Compatible with RC-1 Retarding Chamber*
- *Can be Installed in Vertical & Horizontal Position*
- *Flanged x Flanged, Flanged x Grooved & Grooved x Grooved Available*

AV-1 (300 psi) Alarm Valve Family

General Description

The Model AV-1 Alarm Check Valves are divided seat ring, rubber faced clapper, waterflow alarm check valves that are intended for use in wet pipe (automatic sprinkler) fire protection systems. They may be installed vertically or horizontally, and they are designed to automatically actuate electric and/or hydraulic alarms when there is a steady flow of water into the system that is equivalent to the discharge rate of one or more sprinklers.

A separately ordered, Model RC-1 Retard Chamber (TFP920) is required for installations subject to variable pressures. It is used to help prevent false alarms associated with pressure variations in public water supplies.

The AV-1-300 Alarm Check Valve Trim includes pressure gauges to monitor system pressure conditions, a by-pass check valve, a main drain valve, and an alarm test valve. The bypass check valve reduces the possibility of false alarms by permitting slow as well as small transient increases in water supply pressure to be passed through to the system without opening the waterway clapper.

Technical Data

Approvals

UL and C-UL Listed, as well as FM Approved.

Working Water Pressure Range

20 to 300 psi (1,4 to 20,7 bar).

Physical Characteristics

The body is ductile iron, the handhole cover is ductile iron or cast iron, and the seat ring is bronze. The clapper for the 2-1/2 inch (DN65) valve size is stainless steel. The clapper for the larger valve sizes is either cast or ductile iron. All valve sizes utilize an EPDM clapper facing. Threaded port connections for the AV-1 Valves are available NPT threaded or threaded per ISO 7/1 as detailed in the Ordering Procedure section.

	● End Connection Available		
	Inlet x Outlet		
Nominal Valve Size	Groove x Groove	Flange x Groove	Flange x Flange
2-1/2 Inch (DN65)	● 22 lbs. (10,0 Kg)	● 28 lbs. (12,7 Kg)	N/A
4 Inch (DN100)	● 45 lbs. (20,4 Kg)	● 51 lbs. (23,1 Kg)	● 62 lbs. (28,1 Kg)
6 Inch (DN150)	● 68 lbs. (30,9 Kg)	● 78 lbs. (35,4 Kg)	● 93 lbs. (42,2 Kg)
8 Inch (DN200)	● 129 lbs. (58,6 Kg)	● 148 lbs. (67,1 Kg)	● 167 lbs. (75,8 Kg)

(Always refer to Technical Data Sheet [TFP910] for complete description of all Listing criteria, design parameters, installation instructions, care and maintenance guidelines, and our limited warranty).

Ordering Procedure

Standard AV-1-300 Alarm Check Valve (American Standard Flange Drilling, American Threaded Ports, and American Groove Outside Diameter, as applicable):

Specify: (specify size inch) Model AV-1-300 Alarm Check Valve with (specify end connections), P/N (specify).

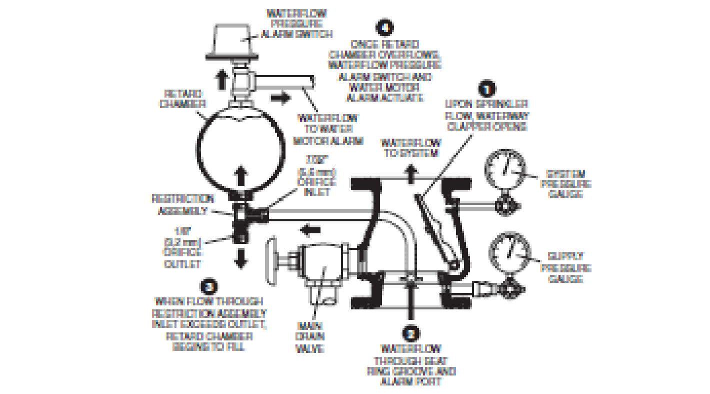
2-1/2 Inch G x G
  2.88 inch (73,0 mm)
  Groove O.D. x 2.88
  inch (73,0 mm)
  Groove O.D. . . . . .P/N 52-203-1-110
2-1/2 Inch F x G
  ANSI Flange x
  2.88 inch (73,0 mm)
  Groove O.D. . . . . .P/N 52-203-1-210
4 Inch G x G
  4.50 inch (114,3 mm)
  Groove O.D. x 4.50
  inch (114,3 mm)
  Groove O.D. . . . . .P/N 52-203-1-113
4 Inch F x G
  ANSI Flange x
  4.50 inch (114,3 mm)
  Groove O.D. . . . . .P/N 52-203-1-413
4 Inch F x F
  ANSI Flange x
  ANSI Flange . . . . .P/N 52-203-1-013
6 Inch G x G
  6.62 inch (168,3 mm)
  Groove O.D. x 6.62
  inch (168,3 mm)
  Groove O.D . . . . .P/N 52-203-1-115
6 Inch F x G
  ANSI Flange x
  6.62 inch (168,3 mm)
  Groove O.D . . . . .P/N 52-203-1-615
6 Inch F x F
  ANSI Flange x
  ANSI Flange . . . . .P/N 52-203-1-015
8 Inch G x G
  8.62 inch (219,1 mm)
  Groove O.D x 8.62
  inch (219,1 mm)
  Groove O.D . . . . .P/N 52-203-1-916
8 Inch F x G
  ANSI Flange x
  8.62 inch (219,1 mm)
  Groove O.D . . . . .P/N 52-203-1-816
8 Inch F x F
  ANSI Flange x
  ANSI Flange . . . . .P/N 52-203-1-016

Standard Order AV-1-300 Valve Trim:

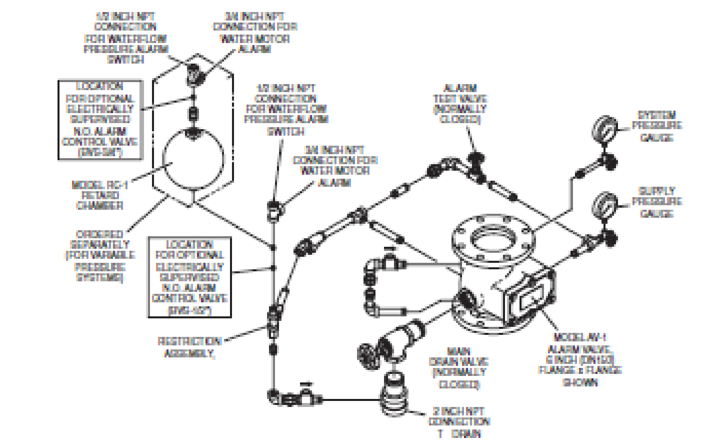
Specify: Vertical, Closed Drain Galvanized Trim for (specify size) Model AV-1-300 Alarm Check Valve, P/N (specify).

Vertical Closed Drain, Galvanized

2-1/2 inch . . . . .P/N 52-204-2-050
4 or 6 inch . . . . .P/N 52-204-2-951
8 inch . . . . .P/N 52-204-2-952



OPERATION



VERTICAL CLOSED DRAIN TRIM - STANDARD ORDER - SEMI-PREASSEMBLED

Accessories

Order the following accessories, as applicable:

Model RC-1
  Retard Chamber
  (required for variable pressure water supply conditions) . . . . .P/N 52-211-2-002
Alarm Vent Trim
  (required when a water motor alarm is not installed) . . . . .P/N 52-201-2-012
Model PS10-2A
  Potter Electric Waterflow Pressure Alarm Switch
  (required for electric signal indicating waterflow) . . . . .P/N 54-281-1-002
Model WMA-1
  Water Motor Alarm (required for a mechanical waterflow alarm) . . .P/N 52-630-1-001

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B.2. Riser 1B Exterior Covered Storage Dry Pipe System Hydraulic Calculations

		Total	Design	
Ordinary Hazard Group 2		0.15	0.15	GPM/ft^2
0.2	gpm/ft^2	2250	1950	FT^2
1500.0	ft^2	337.5	292.5	GPM
Dry Pipe Add 30%		30	11.25	GPM/Head
		11.25	26	Heads

t name: 5.2 Exterior covered storage Riser 1B Dry Pipe system — Date:

Nozzle Ident and Location			Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes
	West Side of BL								Use C=100 for Dry pipe system						
		q	12.0			L	10	C=	100	Pt	4.6	Pt		k=	5.62
1	BL1			1		F				Pe		Pv			
		Q	12.0	1.049		T	10	pf	0.071	Pf	0.7	Pn			
		q	12.9			L	10	C=	100	Pt	5.3	Pt		k=	5.62
2	BL1			1		F				Pe		Pv			
		Q	24.9	1.049		T	10	pf	0.273	Pf	2.7	Pn			
		q	15.9			L	5	C=	100	Pt	8.0	Pt		k=	5.62
3	BL1			1.25		F				Pe		Pv			
		Q	40.8	1.38		T	5	pf	0.179	Pf	0.9	Pn			
		q	0.0			L	13	C=	100	Pt	8.9	Pt		k=	0.00
A	BL1			1.5	2- Tee	F	16			Pe	0.4	Pv			1 ft drop to CM
		Q	40.8	1.61		T	29	pf	0.085	Pf	2.5	Pn			
	East Side of BL								Use C=100 for Dry pipe system						
		q	12.3			L	5	C=	100	Pt	4.8	Pt		k=	5.62
1	BL1			1		F				Pe		Pv			
		Q	12.3	1.049		T	5	pf	0.074	Pf	0.4	Pn			
		q	12.7			L	10	C=	100	Pt	5.1	Pt		k=	5.62
2	BL1			1		F				Pe		Pv			
		Q	25.0	1.049		T	10	pf	0.276	Pf	2.8	Pn			
		q	15.8			L	5	C=	100	Pt	7.9	Pt		k=	5.62
3	BL1			1.25		F				Pe		Pv			
		Q	40.8	1.38		T	5	pf	0.179	Pf	0.9	Pn			
		q	0.0			L	13	C=	100	Pt	8.8	Pt		k=	0.00
A	BL1			1.5	2- Tee	F	16			Pe	0.4	Pv			1 ft drop to CM
		Q	81.6	1.61		T	29	pf	0.305	Pf	8.8	Pn			Flow for Both sides
											18.1			k=	19.20
														K for Branch	
	Cross Main								Use C=100 for Dry pipe system						
		q	112.4			L	10	C=	100	Pt	34.3	Pt		k=	19.20
1	BL1			2		F				Pe		Pv			5 Heads
		Q	112.4	2.067		T	10	pf	0.163	Pf	1.6	Pn			
		q	115.1			L	10	C=	100	Pt	35.9	Pt		k=	19.20
2	BL2			2.5		F				Pe		Pv			5 Heads (10 Total)
		Q	227.5	2.469		T	10	pf	0.253	Pf	2.5	Pn			
		q	119.1			L	10	C=	120	Pt	38.5	Pt		k=	19.20
3	BL3			3		F				Pe		Pv			3 Heads (13 Total)
		Q	346.5	3.068		T	10	pf	0.137	Pf	1.4	Pn			
		q	121.2			L	10	C=	120	Pt	39.8	Pt		k=	19.20
4	BL4			3		F				Pe		Pv			
		Q	467.7	3.068		T	10	pf	0.238	Pf	2.4	Pn			
		q	124.7			L	93	C=	120	Pt	42.2	Pt		k=	19.20
5	BL5			4	5-90 L	F	50			Pe		Pv			
		Q	592.4	4.026		T	143	pf	0.098	Pf	14.0	Pn			
	Top	q	0.0			L	2	C=	120	Pt	56.3	Pt		k=	
6	Riser			4		F				Pe		Pv			
	Valve	Q	592.4	4.026		T	2	pf	0.098	Pf	0.2	Pn			
		q	0.0			L	2	C=	120	Pt	56.5	Pt		k=	
6	Dry Valve			4		F				Pv	3.0	Pv			3 PSI loss across valve
		Q	592.4	4.026		T	2	pf	0.098	Pf	0.2	Pn			
		q	0.0		Gate	L	20	C=	120	Pt	59.7	Pt		k=	
6	OS&Y			4	Valve	F	12			Pe		Pv			
		Q	592.4	4.026	Tee	T	32	pf	0.098	Pf	3.1	Pn			
		q	0.0		1-90L	L	32	C=	120	Pt	62.8	Pt		k=	
6	POC			8	1-Tee	F	53			Pe	4.3	Pv			
		Q	592.4	7.98		T	85	pf	0.004	Pf	0.3	Pn			
											67.4				

Sprinkler	592	gpm	67.4	psi
Hose	250	gpm		
Total	842	gpm		

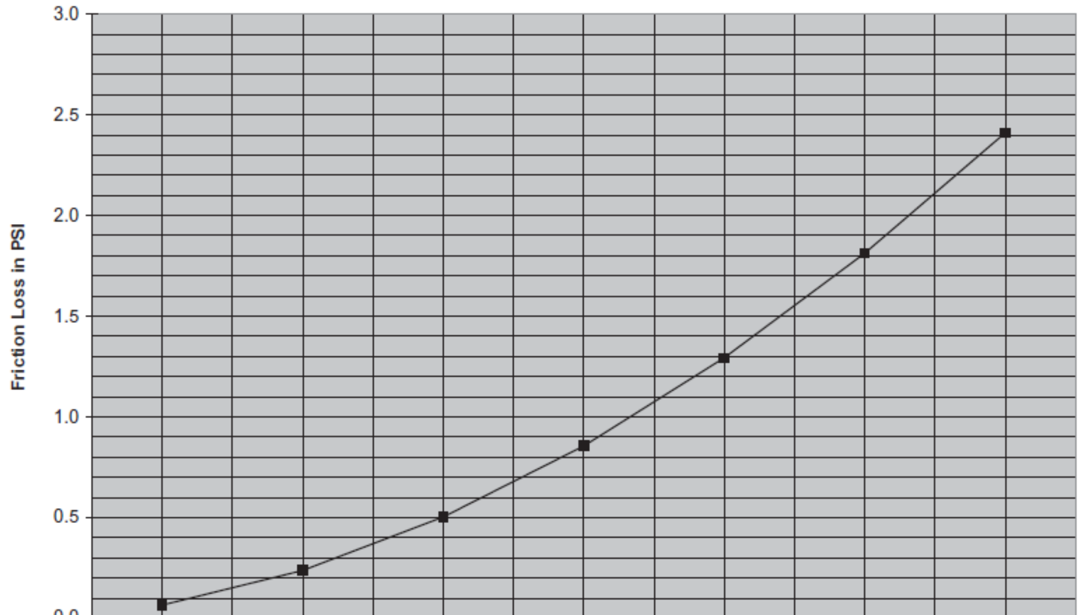
May 18, 2009

VIKING | **TECHNICAL DATA** | **4" MODEL F SERIES DRY VALVES FRICTION LOSS CHART**

The Viking Corporation, 210 N Industrial Park Drive, Hastings MI 49058
Telephone: 269-945-9501 Technical Services 877-384-5464 Fax: 269-818-1680 Email: techsvcs@vikingcorp.com

FOR USE WITH ENGLISH PRACTICAL SYSTEM
Where Flow is Measured in GPM and Pressure is Measured in PSI

Graph is for reference purposes.



	200	400	600	800	1000	1200	1400
Total PSI Loss	0.07	0.24	0.50	0.86	1.29	1.81	2.41

Flow in GPM
(C = 120)

Friction Loss for the 4" Viking Model F Series Dry Valves is equivalent to 5 feet of 4" Schedule 40 (id = 4.026") Pipe (C = 120).

To calculate friction loss for the 4" (id = 4.026") Viking Model F Series Dry Valves at a specific flow, use the following formula:

$$P_{PSI} = \left(\frac{4.52 \times Q^{1.85}}{C^{1.85} \times 4.026^{4.87}}\right) \times 5$$

Where P = Friction Loss (PSI)
Q = Flow in GPM
C = Constant (=120)

Form No. F_061709

New friction loss chart, issued May 18, 2009.

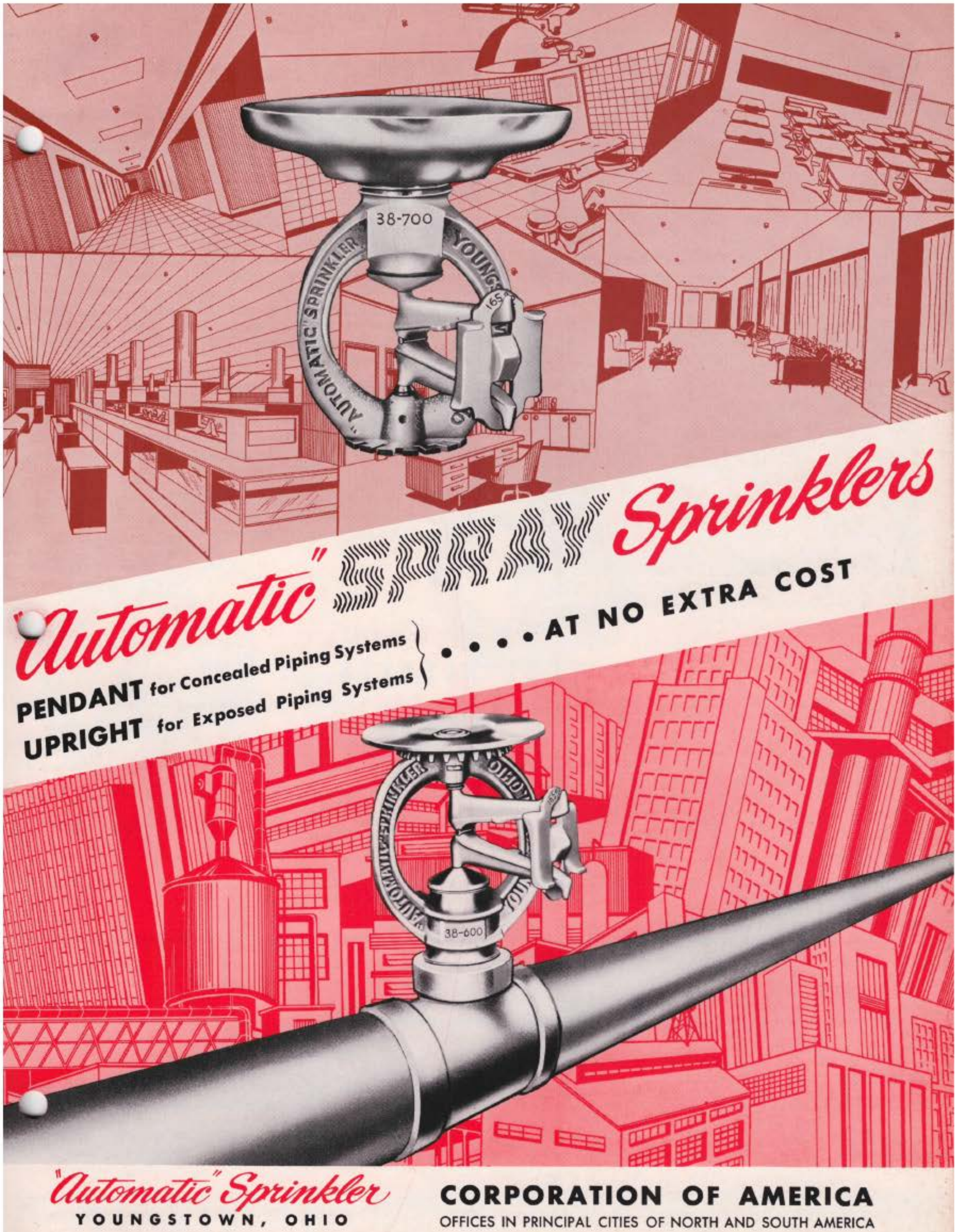
B.3. Riser 2 East Overhang Deluge System Hydraulic Calculations

					0.25	GPM/ft^2										
					10000	FT62										
					2500	GPM										
					20.83333	GPM/Head										

Project name:			Riser 2 Deluge											Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	21.0			L	10	C=	120	Pt	15.5	Pt		k=	5.34
1	1	BL1			1.25		F				Pe		Pv			q = k * (Pt)^1/2
			Q	21.0	1.38		T	10	pf	0.037	Pf	0.4	Pn		Pt=	
			q	21.3			L	10	C=	120	Pt	15.8	Pt		k=	5.34
2	2	BL1			1.5		F				Pe		Pv			
			Q	42.3	1.61		T	10	pf	0.064	Pf	0.6	Pn			
			q	21.7			L	8	C=	120	Pt	16.5	Pt		k=	5.34
3	3	BL1			2		F				Pe		Pv			
			Q	63.9	2.067		T	8	pf	0.041	Pf	0.3	Pn			
			q	0.0			L	0	C=	120	Pt	16.8	Pt		k=	5.34
4	A	CM			1.5		F				Pe		Pv			
			Q	63.9	1.61		T	0	pf	0.139	Pf	0.0	Pn			
			q	21.5			L	10	C=	120	Pt	16.1	Pt		k=	5.34
2	4	BL1			1.25		F				Pe		Pv			
			Q	21.5	1.38		T	10	pf	0.039	Pf	0.4	Pn			
			q	21.7			L	2	C=	120	Pt	16.5	Pt		k=	5.34
3	5	BL1			1.25		F				Pe		Pv			
			Q	43.2	1.38		T	2	pf	0.142	Pf	0.3	Pn			
			q	0.0			L	0	C=	120	Pt	16.8	Pt		k=	5.34
4	A	CM			1.5		F				Pe		Pv			
			Q	43.2	1.61		T	0	pf	0.067	Pf	0.0	Pn			
			q	0.0			L	1	C=	120.000	Pt	18.4	Pt			Branch K
	B				2.5	2-Tee	F	24			Pe	0.4	Pv			24.98868354
			Q	107.1	2.469		T	25	pf	0.045	Pf	1.1	Pn			

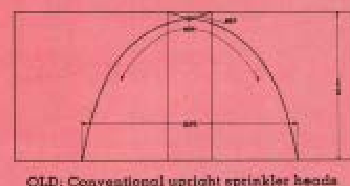
Project name:			Riser 2											Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	21.0			L	10	C=	120	Pt	15.5	Pt		k=	5.34
1	1	BL2			1.25		F				Pe		Pv			q = k * (Pt)^1/2
			Q	21.0	1.38		T	10	pf	0.037	Pf	0.4	Pn		Pt=	
			q	21.3			L	10	C=	120	Pt	15.8	Pt		k=	5.34
2	2	BL2			1.5		F				Pe		Pv			
			Q	42.3	1.61		T	10	pf	0.064	Pf	0.6	Pn			
			q	21.7			L	2	C=	120	Pt	16.5	Pt		k=	5.34
3	3	BL2			2		F				Pe		Pv			
			Q	63.9	2.069		T	2	pf	0.041	Pf	0.1	Pn			
			q	0.0			L	0	C=	120	Pt	16.6	Pt		k=	5.34
4	A	CM			2		F				Pe		Pv			
			Q	63.9	2.067		T	0	pf	0.041	Pf	0.0	Pn			
			q	21.1			L	10	C=	120	Pt	15.7	Pt		k=	5.34
2	4	BL2			1.25		F				Pe		Pv			
			Q	21.1	1.38		T	10	pf	0.038	Pf	0.4	Pn			
			q	21.4			L	8	C=	120	Pt	16.0	Pt		k=	5.34
3	5	BL2			1.5		F				Pe		Pv			
			Q	42.5	1.61		T	8	pf	0.065	Pf	0.5	Pn			
			q	0.0			L	0	C=	120	Pt	16.6	Pt		k=	5.34
4	A	CM			1.5		F				Pe		Pv			
			Q	42.5	1.61		T	0	pf	0.065	Pf	0.0	Pn			
			q	0.0			L	1	C=	120.000	Pt	18.1	Pt			Branch K
	B				2.5	2-Tee	F	24			Pe	0.4	Pv			25.01697813
			Q	106.5	2.469		T	25	pf	0.044	Pf	1.1	Pn			

					0.25	GPM/ft^2										
					10000	FT62										
					2500	GPM										
					20.83333	GPM/Head										
Project name:			B150 Deluge											Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure			Notes
			q	107.1			L	8	C=	120	Pt	18.4	Pt		k=	24.98868354
1	1	BL1			3		F				Pe		Pv			q = k * (Pt)^1/2
			Q	107.1	3.068		T	8	pf	0.016	Pf	0.1	Pn		Pt=	
			q	107.6			L	8	C=	120	Pt	18.5	Pt		k=	25.01697813
2	2	BL2			3		F				Pe		Pv			
			Q	214.7	3.068		T	8	pf	0.056	Pf	0.5	Pn			
			q	108.8			L	8	C=	120	Pt	18.9	Pt		k=	24.98868354
3	3	BL3			3.5		F				Pe		Pv			
			Q	323.4	3.548		T	8	pf	0.059	Pf	0.5	Pn			
			q	110.2			L	8	C=	120	Pt	19.4	Pt		k=	25.01697813
4	4	BL4			4		F				Pe		Pv			
			Q	433.7	4.026		T	8	pf	0.055	Pf	0.4	Pn			
			q	111.4			L	8	C=	120	Pt	19.9	Pt		k=	24.98868354
2	5	BL5			4		F				Pe		Pv			
			Q	545.0	4.026		T	8	pf	0.084	Pf	0.7	Pn			
			q	113.4			L	8	C=	120	Pt	20.5	Pt		k=	25.01697813
3	6	BL6			5		F				Pe		Pv			
			Q	658.4	5.047		T	8	pf	0.040	Pf	0.3	Pn			
			q	114.1			L	8	C=	120	Pt	20.9	Pt		k=	24.98868354
4	7	BL7			5		F				Pe		Pv			
			Q	772.5	5.047		T	8	pf	0.053	Pf	0.4	Pn			
			q	115.4			L	8	C=	120	Pt	21.3	Pt		k=	25.01697813
	8	BL8			6		F				Pe		Pv			
			Q	887.9	6.065		T	8	pf	0.028	Pf	0.2	Pn			
			q	115.9			L	8	C=	120	Pt	21.5	Pt		k=	24.98868354
	9	BL9			6		F				Pe		Pv			
			Q	1003.8	6.065		T	8	pf	0.035	Pf	0.3	Pn			
			q	116.8			L	8	C=	120	Pt	21.8	Pt		k=	25.01697813
	10	BL10			6		F				Pe		Pv			
			Q	1120.6	6.065		T	8	pf	0.043	Pf	0.3	Pn			
			q	117.6			L	8	C=	120	Pt	22.1	Pt		k=	24.98868354
	11	BL11			6		F				Pe		Pv			
			Q	1238.1	6.065		T	8	pf	0.052	Pf	0.4	Pn			
			q	118.8			L	4	C=	120	Pt	22.6	Pt		k=	25.01697813
	12	BL12			6	Tee	F	30			Pe		Pv			
			Q	1356.9	6.065		T	34	pf	0.062	Pf	2.1	Pn			
		Top of	q	0.0			L	83	C=	120	Pt	24.7	Pt			
	B	Deluge Valve			8	3-90L	F	54			Pe	27.3	Pv			63' Elevation
		24 BLs	Q	2713.9	7.981		T	137	pf	0.059	Pf	8.0	Pn			
			q	0.0			L	4	C=	120	Pt	60.0	Pt			
	C	Deluge Valve			8		F				Pc	4.0	Pv			Sprecification sheet
			Q	2713.9	7.981		T	4	pf	0.059	Pf	0.2	Pn			
			q	0.0			L	85	C=	120	Pt	64.2	Pt			
	B	POC			8	1- 90L	F	18			Pe	2.6	Pv			Below grade to POC
			Q	2713.9	7.981		T	103	pf	0.059	Pf	6.0	Pn			
												72.8	POC			
				Sprinklers	2714	gpm										
				Hose	500	gpm										
				Total	3214	gpm										

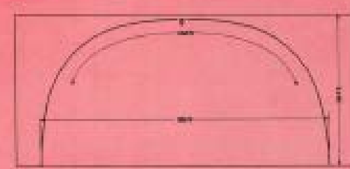

38-700
"Automatic" SPRAY Sprinklers
PENDANT for Concealed Piping Systems
UPRIGHT for Exposed Piping Systems
. . . . AT NO EXTRA COST
38-600
"Automatic" Sprinkler
YOUNGSTOWN, OHIO
CORPORATION OF AMERICA
OFFICES IN PRINCIPAL CITIES OF NORTH AND SOUTH AMERICA

"Automatic" SPRAY Sprinklers

NO BETTER FIRE PROTECTION AT ANY PRICE!



OLD: Conventional upright sprinkler heads work like this.



NEW: Now upright spray sprinkler works like this.

DESIGN FEATURES

For many years, conventional approved sprinkler heads have been designed so that in operation, a high percentage of discharged water is directed at the ceiling. The reasoning behind this has been that direct application of water against ceiling structures is necessary to control and extinguish fire. Unfortunately, this method of application does not permit the most efficient use of the water available to combat fire. In operation, the water, deflected off the ceiling, falls in coarse drops or fine streams, and maximum cooling effect is thereby surrendered.

Notwithstanding the satisfactory performance record of conventional sprinklers, a revolutionary idea for improved fire protection has brought about the development of our "Automatic" SPRAY Sprinkler. The deflector arrangement of this new device breaks up water into an evenly distributed spray. All water discharge is directed laterally and downward in a wide pattern, thereby cooling and dissipating the hot, fiery gases as they rise. Moderate fires are quickly extinguished before ceiling temperatures become critical. Severe fires develop on updraft of gases which force the finely divided spray against the ceiling for effective protection. At the same time, the fire area is cooled below the ignition temperature and the wide, solid pattern of water spray reduces surrounding temperatures at the ceiling so that heads adjacent to the fire area are not needlessly opened.

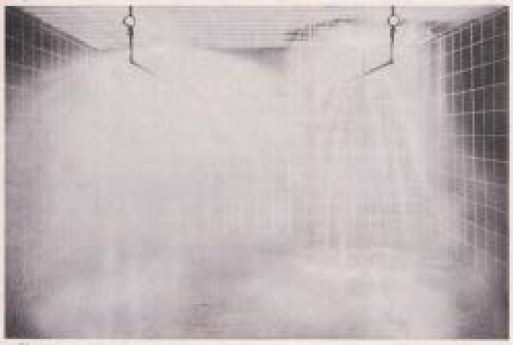
The "Automatic" SPRAY Sprinkler is unsurpassed for—**simplicity of design — sturdiness of construction — dependability of performance — speed in action — efficiency in fire extinguishment.**

As the character of the discharge of spray sprinklers is such that heads cannot be inverted, two distinct designs are necessary. The Model 38-600 "Automatic" SPRAY Sprinkler is approved for upright installation on all fixed temperature and Rate-of-Rise fire protection systems. Model 38-700 "Automatic" SPRAY Sprinklers are approved for installation in the pendant position on all types of concealed piping systems, or for installation in pendant position on exposed piping systems. Both styles of SPRAY sprinklers are available in all temperature ratings and finishes.

Like all components used in our fire protection systems, "Automatic" SPRAY Sprinklers are manufactured under close supervision in our modern plant facilities and the raw materials used in production are of the finest quality.

First APPROVED UPRIGHT SPRAY SPRINKLER

"Automatic" SPRAY Sprinklers discharging water at moderate pressures provide good lateral and downward coverage.



Note superior distribution and breakup of pattern between SPRAY Sprinkler, left and conventional sprinkler, right. Heavy water droplets from regular sprinkler form distinct pattern on floor.

PERFORMANCE AND ADAPTABILITY

The performance of "Automatic" SPRAY Sprinklers is exceedingly better than that of conventional approved sprinkler heads. They have the advantage of being applicable for installation on all existing sprinkler systems, thus avoiding costly rearrangement of piping systems when substituted for less efficient extinguishing devices.

Based on approval tests, "Automatic" SPRAY Sprinklers provide considerably better protection for any type of ceiling construction. This is evidenced by the fact that in Ordinary Hazard occupancies having clear, non-combustible, smooth ceilings, one "Automatic" SPRAY Sprinkler provides adequate protection for 130 square feet. Old style heads are approved for a maximum of only 100 square feet. Thus, with fewer SPRAY heads needed, the cost of sprinkler installations can be substantially reduced.

The "Automatic" SPRAY Sprinkler provides equal or better control of fire in all classes of hazard. In approval tests, fewer heads operated, even when the total volume of water discharged was substantially lower than from approved conventional upright and pendant sprinklers. (See performance tables).

Proved by test to be more effective as Extra Hazard Protection, the superiority of "Automatic" SPRAY Sprinklers for both Light and Ordinary hazards is now recognized.

TEST RESULTS

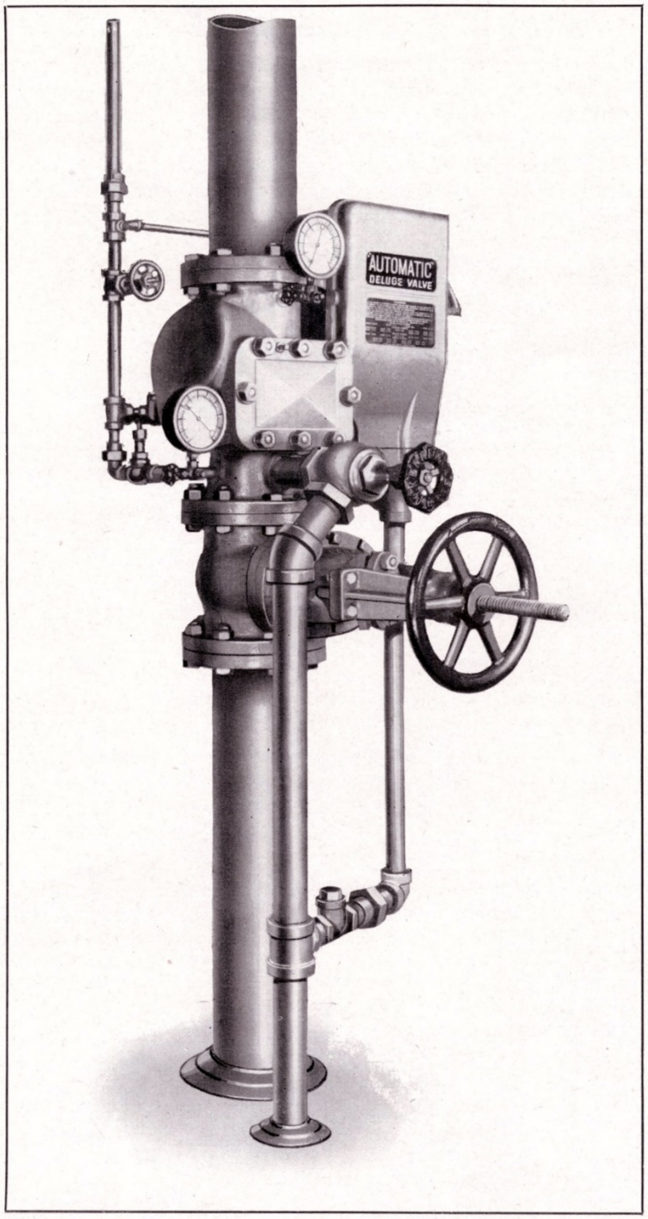
The "Automatic" SPRAY Sprinkler has been thoroughly tested by the Factory Mutual Laboratories and Underwriters' Laboratories, Inc., and the test results shown here give evidence of the superiority of this improved device.

Test fires in Class B combustibles consisted of atomized gasoline released at a constant rate. Test fires in Class A materials consisted of a measured amount of wood augmented by a measured amount of gasoline. Protection was compared between approved conventional 165° rated sprinklers and our new SPRAY Sprinkler. Every test showed the superiority of the new device over the conventional sprinkler head. The following tables give comparable results between the standard sprinkler and the "Automatic" SPRAY Sprinkler.

	Type Head	Head Spacing	Water		Gas Flow GPM	Ceiling Destroyed Sq. Feet	1/8" or More Depth of Ceiling Charred	Wood Loss Lbs.	No. Heads Opened	Total GPM	Ceiling Temp.
			Pressure	GPM							
CLASS A FIRE	Standard Sprinkler	10 x 10	5	13.5	0.73	8.5	3.75	150	17	229	1000°
	SPRAY Sprinkler	10 x 10	2.75	9	0.73	*	*	*	7	63	400°
CLASS A FIRE	Standard Sprinkler	10 x 10	15	23.5	0.91	15	8	171	11	259	1210°
	SPRAY Sprinkler	10 x 10	9	16	0.89	0	0	19	10	160	300°
CLASS A FIRE	Standard Sprinkler	10 x 10	33	30.75	1.31	25	12.5	155	10	308	1200°
	SPRAY Sprinkler	10 x 10	18	22.75	1.31	0	0	25	11	250	560°
CLASS B FIRE	Standard Sprinkler	10 x 10	50	38	1.92	47.5	17	(Gasoline Fire)	11	418	1270°
	SPRAY Sprinkler	10 x 10	28	28.25	1.92	0	0	(Gasoline Fire)	10	283	850°

*Test discontinued after 6 minutes because Class A materials were no longer burning and gasoline fire was not causing damage to ceiling.

"Automatic" Deluge Valve - - Model C



"AUTOMATIC" OF AMERICA

"AUTOMATIC" SPRINKLER RATE OF RISE CORPORATION OF AMERICA

"Automatic" Sprinkler

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA

P. O. BOX 360 . . . . YOUNGSTOWN 1, OHIO

Bulletin No. 59 OFFICES IN PRINCIPAL CITIES OF NORTH AND SOUTH AMERICA

"AUTOMATIC" DELUGE VALVE—MODEL C

The Model C Deluge Valve is a mechanical type valve operating on the Rate-of-Rise of temperature principle. The valve is controlled by Heat Actuated Devices installed over the protected area and connected by means of copper air tubing to the "Automatic" Release attached to the Deluge Valve. The water supply is normally restrained by the Valve Clapper which is held in a closed position by a Latch.

The heat of a fire will increase the air pressure within the Heat Actuated Devices and act upon the diaphragm of the "Automatic" Release. The movement of this diaphragm disengages the Release Levers whereupon a Weight is dropped, releasing the Latch and allowing the water pressure to force open the Clapper and enter the System. The operation of the Release will also allow for the instantaneous sounding of a Fire Alarm.

The Model C Deluge Valve was developed in the early 1930's and has been installed and in constant use since 1931.

OPERATION OF THE DELUGE VALVE

(See Fig. 1)

The Clapper No. 3 is held in a set position by the Clapper Latch No. 6, which is attached to the Latch Arm No. 12A and the Weight Guide Rod No. 46. Weight No. 11 holds Weight Guide Rod No. 46 in a set position by contacting with the Taper Pin No. 80-30 when the Weight Latch No. 14C is at rest on the Releasing Lever Cap No. 56B. The Releasing Lever Cap No. 56B is held in a set position by Release No. 81-100A.

When the Release operates, the Releasing Lever Cap No. 56B rotates around the Releasing Lever Screw No. 43 and disengages the Weight Latch No. 14C. Weight No. 11 falls against the Latch Arm No. 12A and disengages the Clapper Latch No. 6 and Clapper No. 3. The Clapper No. 3 is then free to rotate on the Clapper Hinge Pin No. 26 and allows free passage of water through the Valve.

The Clapper Latch No. 6 is provided with a flexible rubber Latch Facing No. 33A which closes the Latch Seat Ring No. 36 at the time the Valve operates. When the Valve is in a set position, the Latch Seat Ring No. 36 serves as a Drip Valve.

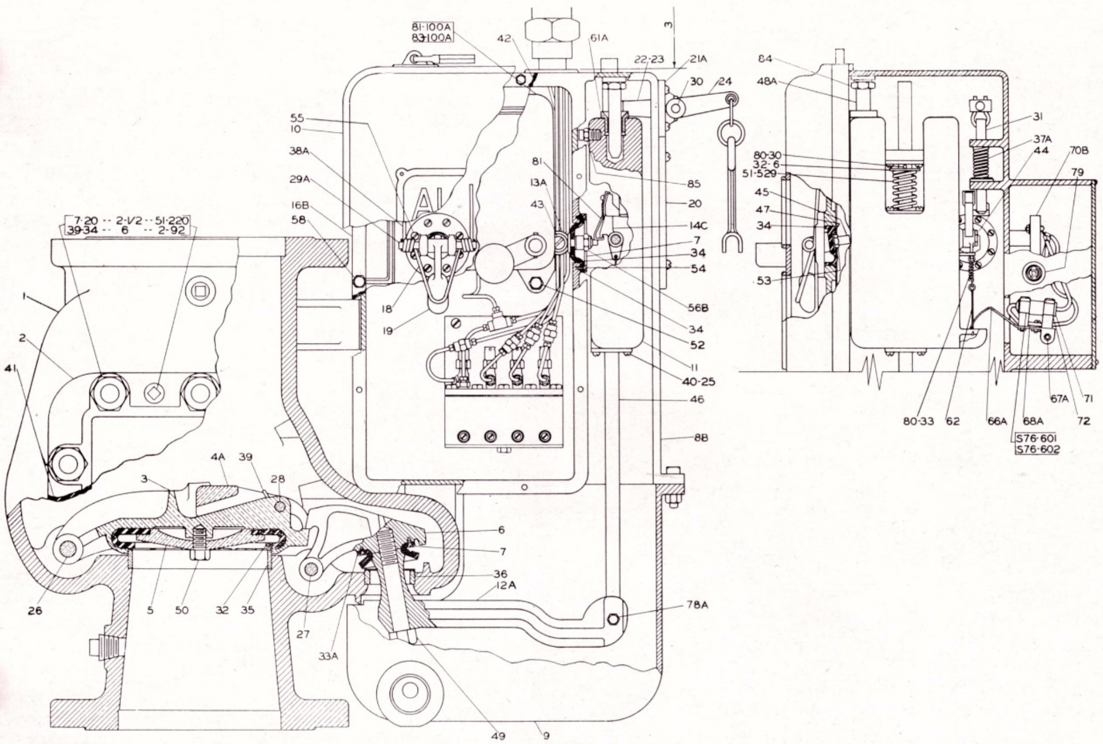
TO SET VALVE

To set the Valve after operation, close the Main Gate Valve (or Post-Indicator Valve), drain Piping System by opening the main Draw-off. Also, completely drain all the low portions of the Piping System by opening auxiliary Drain Valves (or Drain Plugs). If Pendant Automatic Sprinklers are used on the Piping System, these must be renewed, emptied of water and replaced.

After thoroughly draining the Piping System, close the main Draw-off Valve and all other Drain Openings. Remove the Handhold Cover No. 2 (Fig. 1) and inspect the rubber Clapper Facing No. 32 (Fig. 1) and the Clapper Seat Ring No. 35 (Fig. 1). The Clapper No. 3 (Fig. 1) will be found held in a partly opened position by the Clapper Stop No. 4A (Fig. 1) engaging with stops on the body casting. Raise the Clapper No. 3 (Fig. 1) to a wide open position and carefully wipe the surface of the Clapper Facing No. 32 (Fig. 1), and also the tinned surface of the Clapper Seat Ring No. 35 (Fig. 1), removing foreign matter if found. **Use no oil, grease or other compound on either rubber Clapper Facing or on Clapper Seat Ring.** Lower the Clapper No. 3 to the Clapper Seat Ring No. 35 by holding the long arm of the Clapper Stop No. 4A so that the short arm passes the stops on the Valve Body No. 1 (Fig. 1). Press Clapper No. 3 firmly to the Clapper Seat Ring No. 35 (Fig. 1). Remove Cover No. 10 and reset the "Automatic" Release No. 81-100A by pulling outward on the Reset Handle No. 19 (Fig. 1). Lift Weight No. 11 (Fig. 1) until it engages and is held in "up" position by the Releasing Lever Cap No. 56B (Fig. 1). Examine the Handhole Cover Gasket No. 41 on the Handhole Cover No. 2. Be sure it is not damaged and that it will make a water-tight joint when the Handhole Cover is replaced.

Replace the Handhole Cover No. 2 and bolt thoroughly. Tighten down on the holding nuts uniformly as the Hand-hole Cover must make a tight joint and permit no leakage when the Valve next operates. Open the Main Gate Valve slightly and note the pressure on the Water Gauge. When the Water Gauge shows full pressure, make sure that the Clapper does not leak. If a leak is evident, water will show at the Latch Seat Ring No. 36 (Fig. 1). If a water leak shows, close Main Gate Valve, open the Main Draw-off, remove the Handhole Cover No. 2 (Fig. 1), and find and correct the trouble. If no leakage shows at the Latch Seat Ring No. 36 (Fig. 1), open completely the Main Gate Valve and lock or seal in position. Replace the Cover No. 10 (Fig. 1) and lock in position.

A 3/16" hole, located in the Flange on the Valve Body, is provided for the passage of a thin spurt of water in the event the Main Gate Valve is opened before the Handhole Cover has been secured to the Valve Body.



VALVE BODY ASSEMBLY—FIG. 1

2½″ Valve—Overall Length from Flange to Flange— 9″

6 ″ Valve—Overall Length from Flange to Flange—18″

2½″ AND 6″ MODEL "C" DELUGE VALVE—LIST OF PARTS

DRAWING SYMBOL	DESCRIPTION	VALVE SIZE 2½″	6″
2	Handhole Cover	76-202	76-602
3	Clapper	76-203	76-603
4A	Clapper Stop	76-204	76-604A
5	Face Retaining Plate	76-205	76-605
26	Clapper Hinge Pin	76-226	76-626
28	Stop Hinge Pin	76-228	76-628
32	Clapper Facing	76-232	76-632
39	Clapper Stop Spring	76-239	76-639
41	Handhole Cover Gasket	76-241	76-641
50	Clapper Facing Screw	76-250	76-650
7-20 / 39-34	Handhole Cover Nut	7-20	39-34
51-220 / 2-92	Handhole Cover Set Screw	51-220	2-92
6	Clapper Latch	76-206A	76-606A
7	Facing Retaining Ring	76-607	76-607
12A	Latch Arm	76-212A	76-612A
27	Latch Hinge Pin	76-227	76-627
33A	Latch Facing	76-633A	76-633A
49	Latch Screw	76-249	76-649
11	Weight	76-211A	76-611A
13A	Weight Releasing Lever	76-613A	76-613A
14C	Weight Latch	76-614C	76-614C
20	Side Cover Plate	76-620	76-620
21A	Manual Pull Bracket	76-621A	76-621A
22	Manual Pull Cable Clamp	76-622	76-622
23	Manual Pull Cable Clamp Cap	76-623	76-623
24	Manual Pull Arm	76-624	76-624
30	Manual Pull Hinge Pin	76-630	76-630
31	Manual Pull Rod	76-631	76-631
34	Rubber Sealing Bushing	79-634	79-634
37A	Manual Pull Spring	76-637A	76-637A
43	Releasing Lever Screw	76-643	76-643

DRAWING SYMBOL	DESCRIPTION	VALVE SIZE 2½″	6″
44	Weight Latch Screw	76-644	76-644
46	Weight Guide Rod	76-246	76-646
48A	Guide	76-248A	76-648A
56B	Releasing Lever Cap	76-656B	76-656B
62	Tie Rod	76-662	76-662
78A	Guide Rod Bolt & Nut	76-678A	76-678A
81	Weight Latch Spring	76-681	76-681
84	Guide Lock Nut	76-684	76-684
85	Weight Clearance Pin	76-685	76-685
32-6	Guide Rod Washer	32-6	32-6
40-25	Guide Plate Screw	40-25	40-25
51-529	Guide Rod Spring	51-529	51-529
80-30	Taper Pin	80-30	80-30
80-33	Weight Releasing Spring	80-33	80-33
10	Cover	76-210	76-610
16B	Sealing Plate	76-216B	76-616B
18	Reset Bracket	76-618	76-618
19	Reset Handle	76-619	76-619
29A	Reset Handle Hinge Pin	76-629A	76-629A
38A	Reset Handle Spring	76-638A	76-638A
42	Sealing Plate Gasket	79-242A	79-642
45	Reset Handle Stud	76-645	76-645
47	Reset Lever Stud Washer	79-647	79-647
52	Release Fastening Screw	76-652	76-652
53	Reset Stud Check Nut	76-653	76-653
54	Retaining Ring Screw	76-654	76-654
55	Reset Bracket Screw	76-655	76-655
58	Sealing Plate Screw	76-658	76-658
81-100A	Release Assembly (Suprotex—Deluge and Deluge)	81-100A	81-100A
83-100A	Release Assembly (Suprotex)	83-100A	83-100A
S76-601	Mercury Switch Assembly (Open)	S76-601	S76-601
S76-602	Mercury Switch Assemb. (Closed)	S76-602	S76-602

TO INSPECT VALVE

Open wide the Main Draw-off Valve and note the action of the Water Gauge. This will prove the condition of the water supplies. If Supply Pipes are obstructed, or Water Gates wholly or partially closed, the Water Gauge Hand will drop decidedly. If this occurs, investigate and remedy the cause. Remove Cover No. 10 (Fig. 1), see that Weight No. 11 (Fig. 1), is in the "up" or set position.

Replace Cover No. 10 (Fig. 1) and lock or seal in position. See that the Main Gate Valve is fully opened and sealed or locked. Test Water Motor Alarm by opening Manual Test Valve. Note the operation of the Alarm Gong and if proper, close Test Valve. Test the Electric Alarm by pressing the Push Button. If the Electric Alarm rings satisfactorily, release pressure. If not, locate and correct the trouble and repeat the test. Note if the water that has passed to the Bell (Alarm) Line Pipe is draining into the Drip Cup No. 9 (Fig. 1), and that the Drip Line is carrying the drainage off properly. If water does not drain from the Bell Line, probe the restricted opening in the end of the Bell Line with a small piece of wire. See that all manual pulls are accessible and are not gagged or obstructed.

TO OPERATE VALVE BY HEAT

Use the Electric Test Set and follow the instructions attached thereto.

The Main Gate Valve must be closed before making tests on Deluge Systems. When the Electric Test Set is fully heated, apply to a Heat Actuated Device on the System, and within one minute, the Valve should trip when Weight No. 11 (Fig. 1) drops.

If the System is a Suprotex or a Pre-Action type with Automatic Sprinklers and the Gate Valve is open, be sure to drain the System completely after testing.

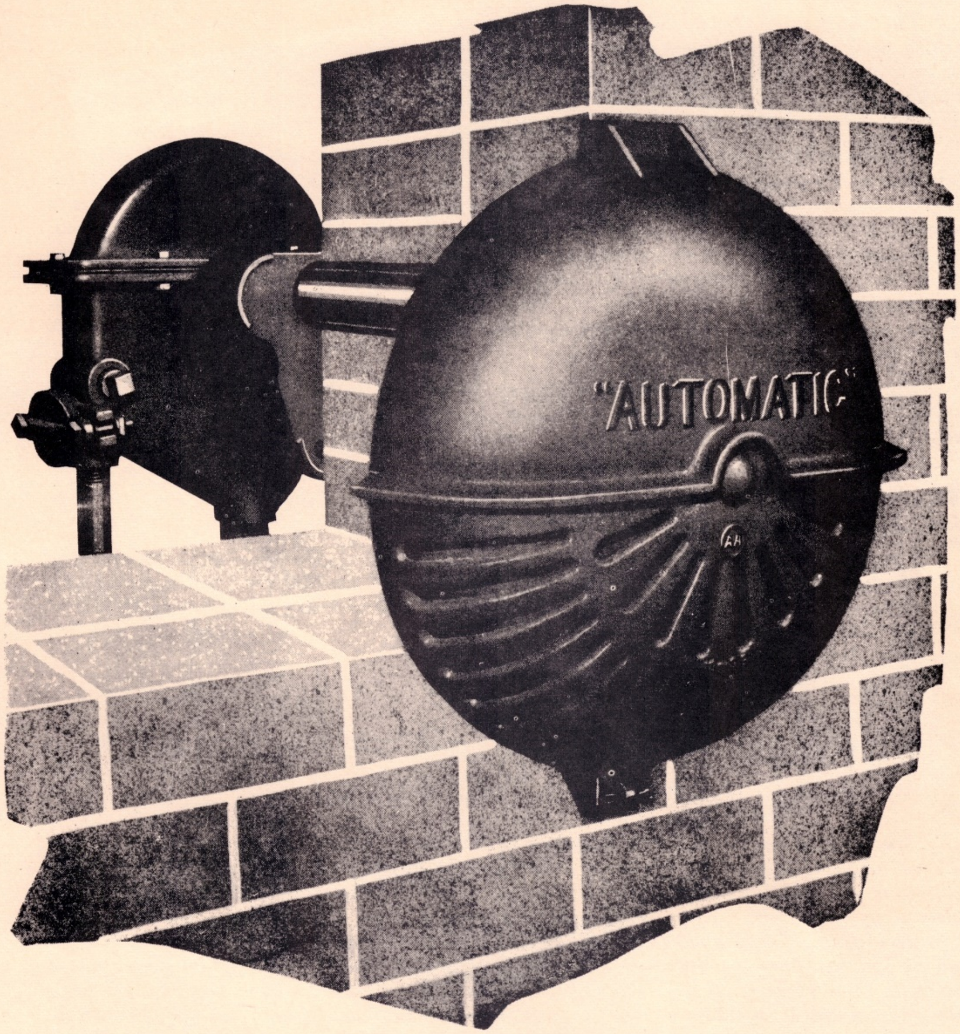
Hot water must be used in lieu of the Electric Test Set where explosive vapors or flash hazards exist. Wait at least ten minutes for Thermo-Pneumatic System to reach normal condition before making a successive heat test of the Heat Actuated Devices.

Where conditions do not warrant the full operation of the Deluge Valve in a test involving the discharge of water, the Control Valve may be closed and the Valve operated thermally only. If this type of test is made, the Deluge Valve should be opened, the Seat Rings and Clapper faces cleaned and all moving parts manipulated to make sure that all parts are undamaged and free to function.

Note: **Pendant Sprinklers in a Suprotex or Pre-Action System should always be removed, drained and replaced whenever water enters the System.**

After the test, reset the Valve as instructed and restore all apparatus to normal condition.

"AUTOMATIC" WATER MOTOR ALARM



"Automatic" Sprinkler

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA

YOUNGSTOWN 1, OHIO

Offices in Principal Cities of North and South America

Bulletin No. 57

THE "AUTOMATIC" WATER MOTOR AND ALARM GONG

The "Automatic" Water Motor Alarm is a rugged, simply formed device having relatively few moving parts which are designed and arranged for efficient and positive operation. The several moving parts in the Water Motor Alarm are arranged so that they may be readily inspected and removed if necessary, thereby facilitating the maintenance of the Alarm. Ease of access to the moving parts of the Water Motor Alarm makes periodic inspection and lubrication an easy task.

The Rotator is formed from a stamping, to assure a uniformly smooth and balanced construction. The nozzle directing the water against the blades of the Rotator is designed and positioned for effective operation and is provided with an adjacently located cylindrical screen of a size sufficiently large enough to avoid clogging. The screen is positioned so as to be self-cleaning between operations, and the nozzle and screen are readily accessible in the Water Motor Alarm so that periodic inspections can be easily made. The Water Motor Rotator is connected with the alarm portion of the alarm gong by means of an operating shaft which is enclosed in a pipe. The pipe passes through the buildng wall. Housings are provided to close the inner and outer ends of the wall pipe for the protection of the operating shaft.

The gong portion of the Water Motor Alarm is provided with revolvable striking hammers which are mounted on the wall plate of the gong assembly and connected to the operating shaft with a universal joint to preclude the binding of either the shaft or striking hammers.

The gong, which is fastened to the gong case, can be readily removed for inspection and easily assumes proper position when replaced. The gong case is of compact design and may be finished so as to harmonize with the building upon which it is installed.

The striking hammers are of generous size and are balanced in all positions as they revolve. They do not engage the gong while at rest, thus permitting the Water Motor to begin revolving with no load and attain considerable speed before assuming the load necessary for giving an alarm.

●

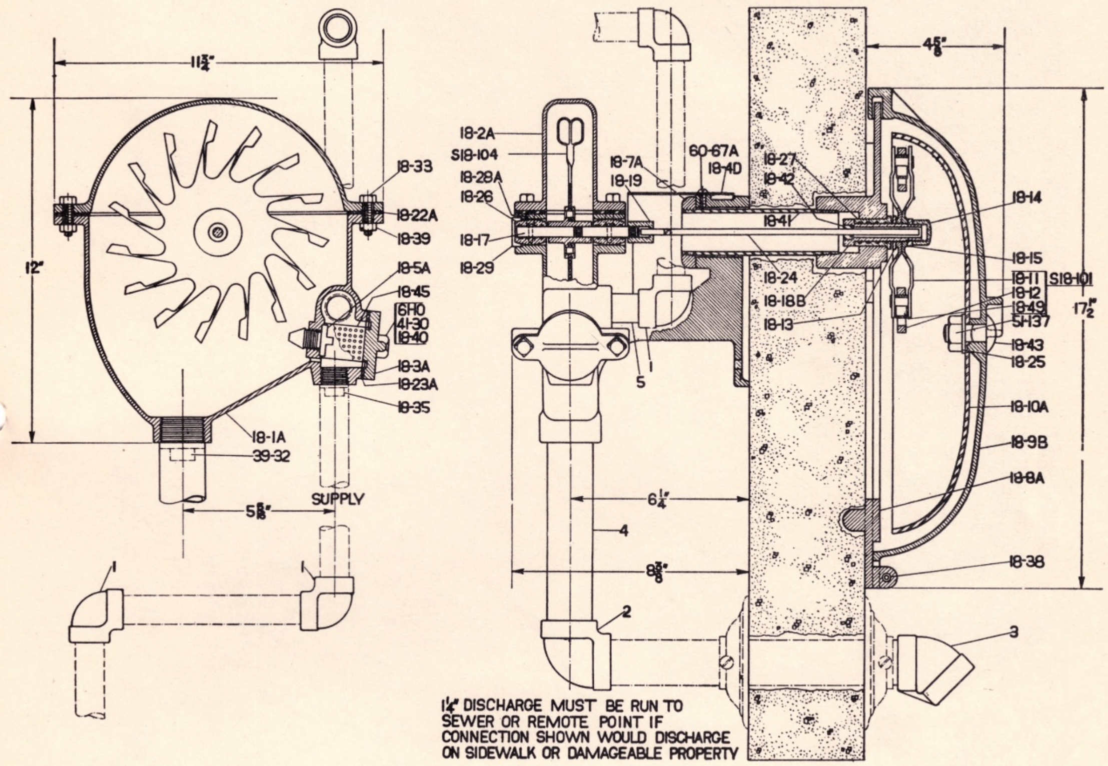
INSTRUCTIONS FOR INSTALLING THE "AUTOMATIC" WATER MOTOR ALARM

The Water Motor Alarm should be located as near the Sprinkler Valve as practicable in order to avoid long runs or many fittings in the pipe. The total length of the pipe should not exceed 75 feet nor should the Water Motor Alarm be located over 20 feet above the Sprinkler Valve. If absolutely necessary to exceed 75 feet, the pipe line to the Water Motor Alarm must be increased one or more sizes to compensate for loss of pressure due to hydraulic friction. The piping must be galvanized and not less than three-quarters of an inch in size. Larger sized pipe should be used for longer runs of piping or where pressures are low. The piping must be arranged so as to drain properly. No single Water Motor Alarm should be connected to more than three Sprinkler Valves, and the systems controlled by the valves should be in the same fire area.

When the Water Motor Alarm is installed on either brick or concrete walls, it should be located on the panel between the pilasters so that the connecting shaft between the motor and the gong can be as short as possible. When installed on frame buildings, it is preferable to block in between the joists of the building with substantial timber so as to supply an adequate support for the device. Care should be taken to see that the motor and gong have an even bearing on the supporting wall and are installed directly in line with each other.

When the discharge from the motor is drained to the outside of the building, the pipe should be provided with an angle elbow facing down so that sleet and ice will not form in the end of the discharge pipe.

When installing water motors, the filter screen should be examined and any foreign matter removed. The several moving parts should be lubricated and the device tested. Periodic tests and lubrications are recommended. It is advisable to inspect the screen following any operation of the alarm so that obstructions deposited by the water may be removed.



Assembly Drawing of the "Automatic" Water Motor and Alarm Gong Showing the Relation of the Different Parts

18—	1A	Body
18—	2A	Body Cover
18—	3A	Inlet Cover
18—	4D	Joint Cover
18—	5A	Nozzle
18—	7A	Lock Nut
18—	8A	Back Plate
18—	9B	Gong Cover
18—	10A	14" Gong
18—	13	Shaft Bushing Washer
18—	14	Shaft Bushing Cap
18—	15	Shaft Bushing Nut
18—	17	Shaft for Water Wheel
18—	18B	Shaft Bearing
18—	19	Motor Shaft Coupling
18—	22A	Body Cover Gasket
18—	23A	Inlet Cover Gasket
18—	24	Connecting Shafting
18—	25	Lock Washer
18—	26	Motor Bearings
18—	27	Back Plate Bearing
18—	28A	Motor Bearing Screws
18—	29	Outer Bearing Cap
18—	33	Screws
18—	38	Brass Cotter Pin
18—	39	¼" Hex Nut
18—	40	Inlet Cover Machine Bolt Nut
18—	41	Wall Sleeve
18—	42	Shaft Bearing Insert
18—	43	Carriage Bolts
18—	45	Nozzle Strainer
S18—	101	Knocker Assembly
S18—	104	Bucket Wheel
41—	30	Inlet Cover Machine Bolts
51—	137	Hex Nut
60—	67A	#8 - 32x¼ Machine Screw
61—	10	Inlet Cover Machine Bolt Washers

B.4. Risers 3 to 7 & 9 Hangar Wet Pipe System Hydraulic Calculations

		Extra Hazard Group 1														
				0.2	GPM/ft^2	Per AF ETL										
				5000	ft^2	Per AF ETL										
				1000	GPM											
				60	Heads											
				16.66667	GPM/Head											
Project name:			Hanger riser 3 North End Worst case											Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	17.0			L	10	C=	120	Pt	9.2	Pt		k=	5.6
1	1	BL1U			1.25		F				Pe	0.2	Pv			q = k * (Pt)^1/2
			Q	17.0	1.38		T	10	pf	0.025	Pf	0.3	Pn		Elev=	
			q	17.4			L	10	C=	120	Pt	9.7	Pt		k=	5.6
2	2	BL1U			1.25		F				Pe	0.2	Pv			
			Q	34.4	1.38		T	10	pf	0.093	Pf	0.9	Pn			
			q	18.4			L	10	C=	120	Pt	10.8	Pt		k=	5.6
3	3	BL1U			1.5		F				Pe	0.2	Pv			
			Q	52.9	1.61		T	10	pf	0.098	Pf	1.0	Pn			
			q	19.4			L	10	C=	120	Pt	12.0	Pt		k=	5.6
4	4	BL1U			2		F				Pe	0.2	Pv			
			Q	72.3	2.067		T	10	pf	0.052	Pf	0.5	Pn			
			q	20.0			L	8	C=	120	Pt	12.8	Pt		k=	5.6
5	5	BL1U			2		F				Pe	0.0	Pv			
			Q	92.3	2.067		T	8	pf	0.081	Pf	0.6	Pn			
			q	0.0			L	0	C=	120	Pt	13.5	Pt		k=	5.6
A					2		F				Pe		Pv			
			Q	92.3	2.067		T	0	pf	0.081	Pf	0.0	Pn			
			q	18.7			L	10	C=	120	Pt	11.2	Pt		k=	5.6
1	1	BL1L			1.25		F				Pe	-0.2	Pv			
			Q	18.7	1.38		T	10	pf	0.030	Pf	0.3	Pn			
			q	18.8			L	10	C=	120	Pt	11.3	Pt		k=	5.6
2	2	BL1L			1.25		F				Pe	-0.2	Pv			
			Q	37.6	1.38		T	10	pf	0.110	Pf	1.1	Pn			
			q	19.5			L	10	C=	120	Pt	12.2	Pt		k=	5.6
3	3	BL1L			1.5		F				Pe	-0.2	Pv			
			Q	57.1	1.61		T	10	pf	0.112	Pf	1.1	Pn			
			q	20.3			L	10	C=	120	Pt	13.1	Pt		k=	5.6
4	4	BL1L			2		F				Pe	-0.2	Pv			
			Q	77.3	2.067		T	10	pf	0.058	Pf	0.6	Pn			
			q	20.5			L	2	C=	120	Pt	13.4	Pt		k=	5.6
5	5	BL1L			2		F				Pe	-0.2	Pv			
			Q	97.9	2.067		T	2	pf	0.090	Pf	0.2	Pn			
			q	0.0			L	0	C=	120	Pt	13.5	Pt		k=	BL connection
A		BL1L			2		F				Pe		Pv			Top
			Q	190.2	2.067		T	0	pf	0.309	Pf	0.0	Pn			
			q	0.0			L	1	C=	120	Pt	13.5	Pt		k=	Branch K
B		BL1			3		F	30			Pe	1.1	Pv			47.64207726
			Q	190.2	3.068		T	31	pf	0.045	Pf	1.4	Pn			CM Connection
												15.9				

Project name:			Hanger riser North End Worst case											Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	17.0			L	10	C=	120	Pt	9.2	Pt		k=	5.6
1	1	BL2U			1.25		F				Pe	0.2	Pv			q = k * (Pt)^1/2
			Q	17.0	1.38		T	10	pf	0.025	Pf	0.3	Pn		Elev=	
			q	17.4			L	10	C=	120	Pt	9.7	Pt		k=	5.6
2	2	BL2U			1.25		F				Pe	0.2	Pv			
			Q	34.4	1.38		T	10	pf	0.093	Pf	0.9	Pn			
			q	18.4			L	10	C=	120	Pt	10.8	Pt		k=	5.6
3	3	BL2U			1.5		F				Pe	0.2	Pv			
			Q	52.9	1.61		T	10	pf	0.098	Pf	1.0	Pn			
			q	19.4			L	10	C=	120	Pt	12.0	Pt		k=	5.6
4	4	BL2U			2		F				Pe	0.2	Pv			
			Q	72.3	2.067		T	10	pf	0.052	Pf	0.5	Pn			
			q	20.0			L	2	C=	120	Pt	12.8	Pt		k=	5.6
5	5	BL2U			2		F				Pe	0.0	Pv			
			Q	92.3	2.067		T	2	pf	0.081	Pf	0.2	Pn			
			q	0.0			L	0	C=	120	Pt	13.0	Pt		k=	5.6
A					2		F				Pe		Pv			
			Q	92.3	2.067		T	0	pf	0.081	Pf	0.0	Pn			
			q	18.4			L	10	C=	120	Pt	10.8	Pt		k=	5.6
1	1	BL2L			1.25		F				Pe	-0.2	Pv			
			Q	18.4	1.38		T	10	pf	0.029	Pf	0.3	Pn			
			q	18.5			L	10	C=	120	Pt	10.9	Pt		k=	5.6
2	2	BL2L			1.25		F				Pe	-0.2	Pv			
			Q	36.9	1.38		T	10	pf	0.106	Pf	1.1	Pn			
			q	19.2			L	10	C=	120	Pt	11.7	Pt		k=	5.6
3	3	BL2L			1.5		F				Pe	-0.2	Pv			
			Q	56.1	1.61		T	10	pf	0.109	Pf	1.1	Pn			
			q	19.9			L	10	C=	120	Pt	12.6	Pt		k=	5.6
4	4	BL2L			2		F				Pe	-0.2	Pv			
			Q	76.0	2.067		T	10	pf	0.057	Pf	0.6	Pn			
			q	20.2			L	8	C=	120	Pt	13.0	Pt		k=	5.6
5	5	BL2L			2		F				Pe	-0.2	Pv			
			Q	96.2	2.067		T	2	pf	0.087	Pf	0.2	Pn			
			q	0.0			L	0	C=	120	Pt	13.0	Pt		k=	BL connection
A		BL2L			2		F				Pe		Pv			Top
			Q	188.4	2.067		T	0	pf	0.303	Pf	0.0	Pn			
			q	0.0			L	1	C=	120	Pt	13.0	Pt		k=	Branch K
B		BL2L			3		F	30			Pe	1.1	Pv			47.98317078
			Q	188.4	3.068		T	31	pf	0.044	Pf	1.4	Pn			CM Connection
												15.4				

Step No.	Nozzle Ident and Location			Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes
Project name:		Riser 3 Cross Main												Date:		
			q	190.2			L	8.75	C=	120	Pt	15.9	Pt		k=	47.64207726
1	1	A			3		F				Pe		Pv			q = k * (Pt)^1/2
			Q	190.2	3.068		T	8.75	pf	0.045	Pf	0.4	Pn		Pt=	
			q	193.9			L	8.75	C=	120	Pt	16.3	Pt		k=	47.98317078
2	2	B			4		F				Pe		Pv			
			Q	384.0	4.026		T	8.75	pf	0.044	Pf	0.4	Pn			
			q	194.8			L	4.375	C=	120	Pt	16.7	Pt		k=	47.64207726
3	3	A			5		F				Pe		Pv			
			Q	578.8	5.047		T	4.375	pf	0.031	Pf	0.1	Pn			
			q	0.0			L	0	C=	120	Pt	16.8	Pt		k=	47.98317078
AA		Main			6		F				Pe		Pv			
			Q	578.8	4.026		T	0	pf	0.094	Pf	0.0	Pn			
			q	191.5			L	8.75	C=	120	Pt	15.9	Pt		k=	47.98317078
4	6	B			3		F				Pe		Pv			
			Q	191.5	3.068		T	8.75	pf	0.046	Pf	0.4	Pn			
			q	192.5			L	8.75	C=	120	Pt	16.3	Pt		k=	47.64207726
5	5	A			4		F				Pe		Pv			
			Q	384.0	4.026		T	8.75	pf	0.044	Pf	0.4	Pn			
			q	196.2			L	4.375	C=	120	Pt	16.7	Pt		k=	47.98317078
6	4	B			5		F				Pe		Pv			
			Q	580.1	5.047		T	4.375	pf	0.031	Pf	0.1	Pn			
			q	0.0			L	0	C=	120	Pt	16.8	Pt		k=	47.64207726
AA		Main			6		F	15			Pe		Pv			
			Q	580.1	6.065		T	15	pf	0.013	Pf	0.2	Pn			
			q	0.0			L	1	C=	120	Pt	17.0	Pt		k=	Branch K
B		BL1L			6	1- Tee	F	30			Pe	1.1	Pv			262.0690443
			Q	1159.0	6.065		T	31	pf	0.046	Pf	1.4	Pn			CM Connection
												19.6				

Step No.	Nozzle Ident and Location			Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes
Project name:		Hanger riser 3 North End Worst case												Date:		
			q	1159.0			L	100	C=	120	Pt	19.6	Pt		k=	262.0690443
1	East CM				6		F	14			Pe	0.4	Pv			1 elbow
			Q	1159.0	6.065		T	114	pf	0.046	Pf	5.3	Pn		Pt=	
			q	0.0			L	134	C=	120	Pt	25.3	Pt		k=	0
2	West CM				8		F	0			Pe	37.7	Pv			Elevation 80'
			Q	1159.0	8.249		T	134	pf	0.010	Pf	1.4	Pn			
			q	0.0			L	0	C=	120	Pt	64.3	Pt		k=	
3	CV				8		F	0			Pe	2.0	Pv			From Specs
			Q	1159.0	8.249		T	0	pf	0.010	Pf	0.0	Pn			
			q	0.0			L	0	C=	120	Pt	66.3	Pt		k=	2940
	Butterfly Valve				8		F				Pe	0.2	Pv			Butterfly Valve
			Q	1159.0	8.249		T	0	pf	0.010	Pf	0.0	Pn			
			q	0.0			L	7	C=	120	Pt	66.5	Pt		k=	0
4	Base of Riser				8		F				Pe	3.0	Pv			
			Q	1159.0	8.249		T	7	pf	0.010	Pf	0.1	Pn			
			q	0.0			L	90	C=	120	Pt	66.5	Pt		k=	0
5	POC				8		F				Pe		Pv			
			Q	1159.0	8.249		T	90	pf	0.010	Pf	0.9	Pn			
												67.5				
								Sprinkler		1159	gpm	67.5	psi			
								Hose		500	gpm					
								Total		1659	gpm					

tyco

Worldwide Contacts | www.tyco-fire.com

Series TY-FRB, 5.6 K-factor Upright, Pendent, and Recessed Pendent Sprinklers Quick Response, Standard Coverage

General Description

The TYCO Series TY-FRB, 5.6 K-factor, Upright (TY313) and Pendent (TY323) Sprinklers described in this data sheet are quick response, standard coverage, decorative 3 mm glass bulb-type spray sprinklers designed for use in light or ordinary hazard, commercial occupancies such as banks, hotels, and shopping malls.

The recessed version of the Series TY-FRB Pendent Sprinkler, where applicable, is intended for use in areas with a finished ceiling. This recessed pendent sprinkler uses one of the following:

- A two-piece Style 15 Recessed Escutcheon with recessed adjustment up to 5/8 inch (15,9 mm) from the flush pendent position.
- A two-piece Style 20 Recessed Escutcheon with recessed adjustment up to 1/2 inch (12,7 mm) from the flush pendent position.

The adjustment provided by the Recessed Escutcheon reduces the accuracy to which the fixed pipe drops to the sprinklers must be cut.

Intermediate level versions of Series TY-FRB Sprinklers are described in Technical Data Sheet TFP357. Sprinkler guards and shields are described in Technical Data Sheet TFP780.

IMPORTANT

Always refer to Technical Data Sheet TFP700 for the "INSTALLER WARNING" that provides cautions with respect to handling and installation of sprinkler systems and components. Improper handling and installation can permanently damage a sprinkler system or its components and cause the sprinkler to fail to operate in a fire situation or cause it to operate prematurely.

NOTICE

The TYCO Series TY-FRB Sprinklers described herein must be installed and maintained in compliance with this document, as well as with the applicable standards of the National Fire Protection Association, in addition to the standards of any other authorities having jurisdiction. Failure to do so may impair the performance of these devices.

The owner is responsible for maintaining their fire protection system and devices in proper operating condition. The installing contractor or sprinkler manufacturer should be contacted with any questions.

Sprinkler Identification Number (SIN)

TY313 . . . . Upright 5.6K, 1/2" NPT
TY323 . . . . . . Pendent 5.6K, 1/2" NPT

Technical Data

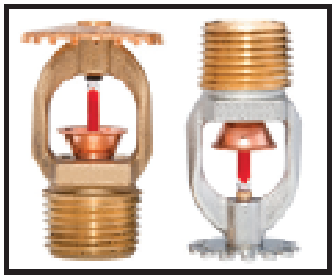
Approvals
UL and C-UL Listed
FM and VdS Approved
CE Certified

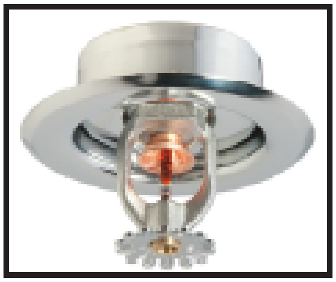
Maximum Working Pressure
175 psi (12,1 bar)
250 psi (17,2 bar)*

* The maximum working pressure of 250 psi (17,2 bar) only applies to the listing by Underwriters Laboratories, Inc. (UL).

Discharge Coefficient
K=5.6 GPM/psi$^{1/2}$ (80,6 LPM/bar$^{1/2}$)

Temperature Rating
135°F (57°C)
155°F (68°C)
175°F (79°C)
200°F (93°C)
286°F (141°C)





Finishes
Sprinkler: Natural Brass, Chrome Plated, Pure White (RAL 9010) and Signal White (RAL 9003).
Recessed Escutcheon: White Coated, Chrome Plated, or Brass Plated

Physical Characteristics
Frame . . . . Bronze
Button. . . . . Brass/Copper
Sealing Assembly . . . . Stainless Steel w/TEFLON
Bulb . . . . Glass
Compression Screw. . . . . Bronze
Deflector. . . . . Bronze

FireLock® Check Valves

cULus FM VdS LPCB

SEE VICTAULIC PUBLICATION 10.01 FOR DETAILS

SERIES 717 – cULus, FM, VdS, LPCB

SERIES 717H HIGH PRESSURE – cULus, FM, VdS, LPCB

The FireLock Series 717 Check Valve and Series 717H High Pressure Check Valves are CAD-designed for hydrodynamic efficiency and available in 2"/50mm – 3"/80mm (Series 717H) and 2½"/65mm – 12"/300mm (Series 717) sizes.

Series 717H valves are cULus Listed and FM Approved for service up to 365psi/2517kPa. See chart below for approved services for the Series 717 valves.

In both valve designs, the single-disc mechanism incorporates a spring-assisted feature for non-slamming operation. This spring-assisted, single-disc design achieves a leak-free seal with as little as 5ft /1.5m of head. Series 717 and 717H FireLock Check Valves can be installed either vertically (flow upwards only) or horizontally. A cast flow arrow indicator is provided to assist with proper valve orientation. Both valves include upstream and downstream pressure taps. Each valve is factory-tested to the rated working pressure. For systems requiring a Riser Check option, refer to publication 10.09.

Grooved ends allow fast, easy installation with just two Victaulic couplings or the valve may be mounted to flanged (ANSI CL.150) equipment using either to Victaulic Style 741 Vic-Flange® or Style 744 FireLock flange adapters on either end.

Series 717
(2½ – 3"/65 – 80mm)

Series 717
(4 – 12"/100 – 300mm)

Series 717H High Pressure Check Valve
(2 – 3"/50 – 80mm)

Size	Approval/Listing Service Pressures			
	Series 717H			
	cULus	FM	LPCB	Vds
2"/50mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa
2½"/65mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa
76.1mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa
3"/80mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365psi/2517kPa
4"/100mm	n/a	n/a	n/a	n/a
5"/125mm	n/a	n/a	n/a	n/a
139.7mm	n/a	n/a	n/a	n/a
6"/150mm	n/a	n/a	n/a	n/a
165.1mm	n/a	n/a	n/a	n/a
8"/200mm	n/a	n/a	n/a	n/a
10"/250mm	n/a	n/a	n/a	n/a
12"/300mm	n/a	n/a	n/a	n/a

Size	Approval/Listing Service Pressures			
	Series 717			
	cULus	FM	LPCB	VdS
2"/50mm	n/a	n/a	n/a	n/a
2½"/65mm	up to 250psi/1725kPa	n/a	up to 365 psi/2517kPa	n/a
76.1mm	up to 250psi/1725kPa	n/a	up to 365 psi/2517kPa	up to 16bar/232psi
3"/80mm	up to 250psi/1725kPa	n/a	up to 365 psi/2517kPa	up to 16bar/232psi
4"/100mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365 psi/2517kPa	up to 16bar/232psi
5"/125mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365 psi/2517kPa	n/a
139.7mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365 psi/2517kPa	up to 16bar/232psi
6"/150mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365 psi/2517kPa	up to 16bar/232psi
165.1mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 365 psi/2517kPa	n/a
8"/200mm	up to 365psi/2517kPa	up to 365psi/2517kPa	up to 348 psi/2400kPa	up to 16bar/232psi
10"/250mm	up to 250psi/1725kPa	up to 250psi/1725kPa	up to 1725kPa/250psi	n/a
12"/300mm	up to 250psi/1725kPa	up to 250psi/1725kPa	up to 1725kPa/250psi	n/a

JOB/OWNER	CONTRACTOR	ENGINEER
System No. ______	Submitted By ______	Spec Sect ______ Para ______
Location ______	Date ______	Approved ______
		Date ______

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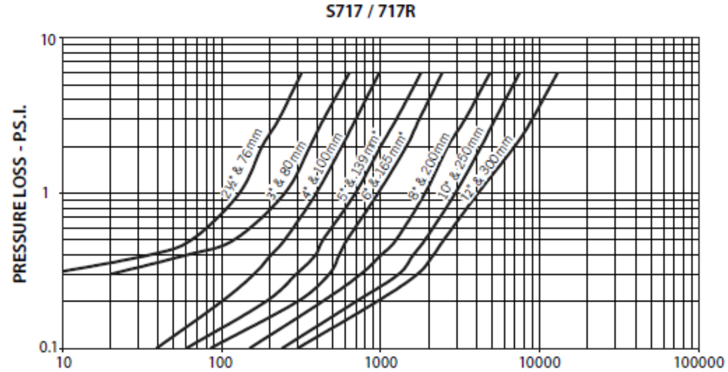
FireLock® Check Valves

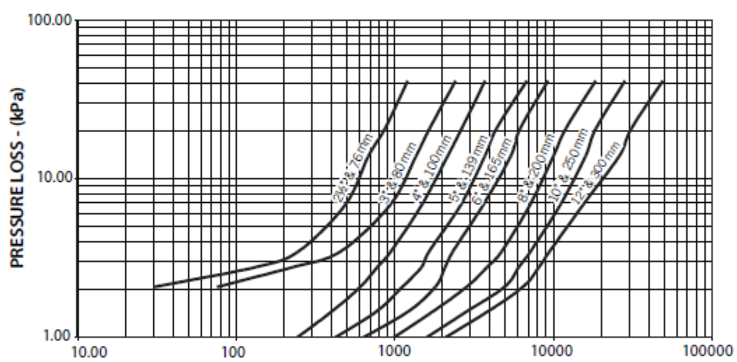
SERIES 717 – cULus, FM, VdS, LPCB

SERIES 717H HIGH PRESSURE – cULus, FM, VdS, LPCB

FLOW CHARACTERISTICS

The charts below express the flow of water at 60°F/16°C through valve.





B.5. Riser 8 High Expansion Foam System Hydraulic Calculations

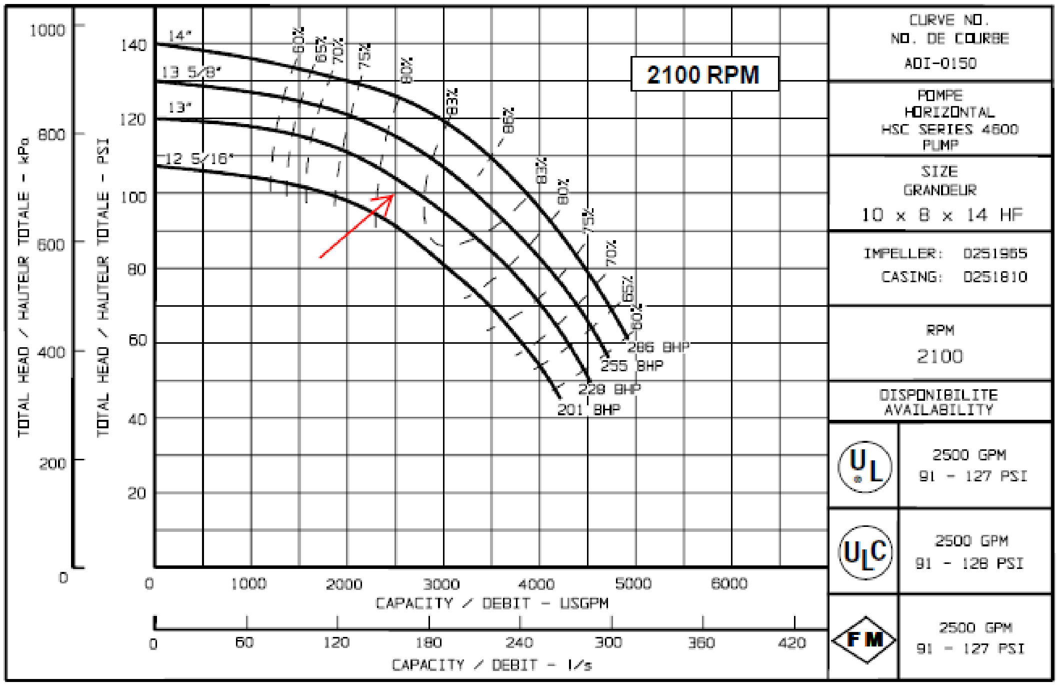
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure			Notes
Project name:			High Expansion Foam (North)											Date:		
			q	177.689			L	50	C=	120	Pt	40.0	Pt		k=	Flow based on Spec
1	1	North			2		F				Pe	0.2	Pv			Sheet for Foam
			Q	177.7	2.067		T	50	pf	0.272	Pf	13.6	Pn		Elev=	Generators
			q	200.796			L	60	C=	120	Pt	53.8	Pt		k=	Flow based on Spec
2	2	North			3		F				Pe	0.2	Pv			Sheet for Foam
			Q	378.5	3.068		T	60	pf	0.161	Pf	9.7	Pn			Generators
			q	215.064			L	119	C=	120	Pt	63.7	Pt		k=	Flow based on Spec
3	3	North			4		F				Pe	0.2	Pv			Sheet for Foam
			Q	593.5	4.026		T	119	pf	0.099	Pf	11.7	Pn			Generators
			q	0			L	0	C=	120	Pt	75.7	Pt		k=	
4	A				4		F				Pe	0.2	Pv			
			Q	593.5	4.026		T	0	pf	0.099	Pf	0.0	Pn			
			q	182.219			L	50	C=	120	Pt	42.5	Pt		k=	Flow based on Spec
5	4	North			2		F				Pe	0.2	Pv			Sheet for Foam
			Q	182.2	2.067		T	50	pf	0.285	Pf	14.3	Pn			Generators
			q	205.613			L	60	C=	120	Pt	57.0	Pt		k=	Flow based on Spec
6	5	North			3		F				Pe	0.0	Pv			Sheet for Foam
			Q	387.8	3.068		T	60	pf	0.169	Pf	10.1	Pn			Generators
			q	219.626			L	62	C=	120	Pt	67.2	Pt		k=	Flow based on Spec
7	6	North			4	Tee	F	20			Pe	0.0	Pv			Sheet for Foam
			Q	607.5	4.026		T	82	pf	0.103	Pf	8.4	Pn			Generators
			q	0.0			L	63	C=	120	Pt	75.7	Pt		k=	
8	A				6	2- 90 Ls	F	42			Pe	27.3	Pv			63 feet elevation
			Q	1201.0	6.065	2- 45 Ls	T	105	pf	0.049	Pf	5.2	Pn			
			q	-23.5			L	0	C=	120	Pt	108.1	Pt		k=	Remove foam soultion
5	Inductor				6		F				Pe	1.5	Pv			Graph
			Q	1177.5	6.065		T	0	pf	0.048	Pf	0.0	Pn			
			q				L	12	C=	120	Pt	109.6	Pt		k=	
5	BB				6	1 L	F	44			Pe	0.0	Pv			
			Q	1177.5	6.065	1 90	T	56	pf	0.048	Pf	2.7	Pn			
											Pt	112.3				

Project name:		High Expansion Foam (South)												Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	215.862			L	75	C=	120	Pt	64.3	Pt		k=	Flow based on Spec
1	7	South			2		F				Pe	0.2	Pv			Sheet for Foam
			Q	215.9	2.067		T	75	pf	0.390	Pf	29.3	Pn		Elev=	Generators
			q	246.948			L	102	C=	120	Pt	93.8	Pt		k=	Flow based on Spec
2	8	South			3	L	F	7			Pe	0.2	Pv			Sheet for Foam
			Q	462.8	3.068		T	109	pf	0.234	Pf	25.5	Pn			Generators
			q	0			L	0	C=	120	Pt	119.5	Pt		k=	
4	A				4		F				Pe	0.2	Pv			
			Q	462.8	4.026		T	0	pf	0.062	Pf	0.0	Pn			
			q	218.239			L	82	C=	120	Pt	66.1	Pt		k=	Flow based on Spec
5	9	South			2		F				Pe	0.2	Pv			Sheet for Foam
			Q	218.2	2.067		T	82	pf	0.398	Pf	32.6	Pn			Generators
			q	250.692			L	70	C=	120	Pt	99.0	Pt		k=	Flow based on Spec
6	10	South			3	Tee	F	15			Pe	0.0	Pv			Sheet for Foam
			Q	468.9	3.068		T	85	pf	0.239	Pf	20.4	Pn			Generators
			q	0			L	42	C=	120	Pt	119.4	Pt		k=	
4	A				4	Tee	F	20			Pe	0.2	Pv			
			Q	931.7	4.026		T	62	pf	0.227	Pf	14.1	Pn			
			q	0			L		C=	120	Pt	133.6	Pt		k=	
7	B				6		F				Pe	0.0	Pv			
			Q	931.7	6.065		T	0	pf	0.031	Pf	0.0	Pn			
			q	218.888			L	102	C=	120	Pt	66.6	Pt		k=	Flow based on Spec
5	11	South			2		F				Pe	0.2	Pv			Sheet for Foam
			Q	218.9	2.067		T	102	pf	0.400	Pf	40.8	Pn			Generators
			q	255.806		1-90 L	L	84	C=	120	Pt	107.6	Pt		k=	Flow based on Spec
6	12	South			3	1-T	F	22			Pe	0.0	Pv			Sheet for Foam
			Q	474.7	3.068		T	106	pf	0.245	Pf	26.0	Pn			Generators
			q	0			L	47	C=	120	Pt	133.6	Pt		k=	
4	B				4		F				Pe	20.4	Pv			
			Q	1406.4	4.026		T	47	pf	0.486	Pf	22.9	Pn			
			q	-27.6			L	0	C=	120	Pt	107.6	Pt		k=	Remove foam soultion
5	Inductor				6		F				Pe	1.5	Pv			Graph
			Q	1378.9	6.065		T	0	pf	0.064	Pf	0.0	Pn			
			q				L	12	C=	120	Pt	109.1	Pt		k=	
5	BB				6	1 L	F	44			Pe	0.0	Pv			
			Q	1378.9	6.065	1 90	T	56	pf	0.064	Pf	3.6	Pn			
											Pt	112.8				

Project name:		High Expansion Foam Riser feeding North and South												Date:		
Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	0			L	2	C=	120	Pt	112.8	Pt		k=	
1	BB				6		F				Pe		Pv			
			Q	2556.3	6.065		T	2	pf	0.200	Pf	0.4	Pn			
			q	0			L	0	C=	120	Pt	113.2	Pt		k=	
2		Control			8	Valve	F	57			Pc		Pv			From Spec Sheet
		Valve	Q	2556.3	8.249		T	57	pf	0.045	Pf	2.5	Pn			
			q	0			L	5	C=	120	Pt	115.7	Pt		k=	
											Pc	0.8				Valve Spec Sheet
4		Butterfly			8	L	F	18			Pe	2.2	Pv			Pc=(Q/Kv)^2
		Valve	Q	2556.3	8.249		T	23	pf	0.045	Pf	1.0	Pn			Kv=2940
			q	0			L	0	C=	120	Pt	119.6	Pt		k=	
5		Strainer			10		F				Pc	4.0	Pv			Spec Sheet
			Q	2556.3	10.37		T	0	pf	0.015	Pf	0.0	Pn			
			q	0			L	0	C=	120	Pt	123.6	Pt		k=	
											Pc	0.3				Valve Spec Sheet
6		Butterfly			10		F	0			Pe	0.0	Pv			Pc=(Q/Kv)^2
		Valve	Q	2556.3	10.37		T	0	pf	0.015	Pf	0.0	Pn			Kv=5020
			q	0			L	90	C=	120	Pt	123.7	Pt		k=	
4		To POC			10	5- 90L	F	55			Pe	0.2	Pv			
			Q	2556.3	10.37		T	145	pf	0.015	Pf	2.1	Pn			
											Pt	126.0				

ARMSTRONG®

2500 USGPM



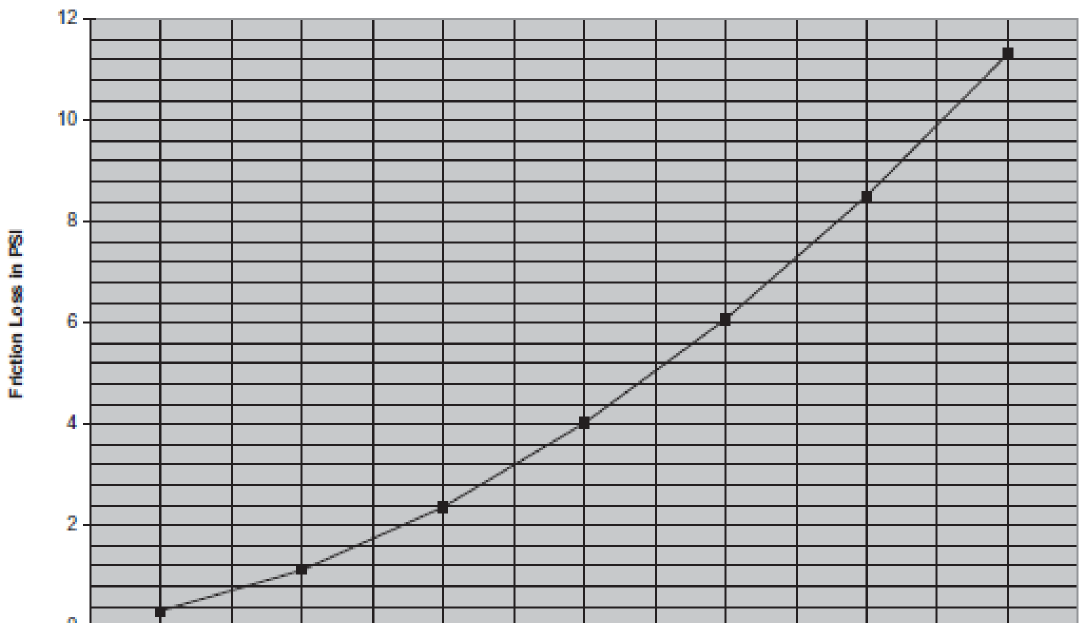
May 18, 2009

VIKING | TECHNICAL DATA | 8" MODEL J SERIES FLOW CONTROL VALVES FRICTION LOSS CHART

The Viking Corporation, 210 N Industrial Park Drive, Hastings MI 49058
Telephone: 269-945-9501 Technical Services 877-384-5464 Fax: 269-818-1680 Email: techsvcs@vikingcorp.com

FOR USE WITH ENGLISH PRACTICAL SYSTEM
Where Flow is Measured in GPM and Pressure is Measured in PSI

Graph is for reference purposes.



	750	1500	2250	3000	3750	4500	5250
Total PSI Loss	0.31	1.12	2.36	4.02	6.07	8.51	11.32

Flow in GPM
(C = 120)

Friction Loss for the 8" Viking Model J Series Flow Control Valves is equivalent to 57 feet of 8" Schedule 40 (id = 7.981") Pipe (C = 120).

To calculate friction loss for the 8" (id = 7.981") Viking Model J Series Flow Control Valves at a specific flow, use the following formula:

$$P_{PSI} = \left(\frac{4.52 \times Q^{1.85}}{C^{1.85} \times 7.981^{4.87}}\right) \times 57$$

Where P = Friction Loss (PSI)
Q = Flow in GPM
C = Constant (=120)

Form No. F_060409

New friction loss chart, issued May 18, 2009.

WATER POWERED HIGH EXPANSION FOAM GENERATORS

Chemguard Standard Model Water Powered (WP) High Expansion Foam Generators are designed to expand foam solution into millions of tiny stable bubbles. Expansion rates up to 880 gallons of expanded foam for every one gallon of foam solution can be achieved depending on the generator selected solution flow rate and operating pressure.

The Chemguard WP High Expansion Generators require no other source of power such as electricity or gasoline engines. They are powered by the foam solution driving a hydraulic (water) motor. The expansion of the foam solution is achieved by spraying the solution onto a stainless steel screen, and then an air stream created by the fan attached to the motor forces air through the screen to produce a mass of foam bubbles. The continuous flow of the foam solution and the movement of air through the screen will generate large volumes of foam.

FEATURES

- Seven different models available.
- No outside source of power required – only the foam solution under pressure.
- Standard units supply from 1,350 to 26,400 cfm.
- UL Listed* to operate at foam solution pressures as low as 40 psi.
- Stainless steel perforated screens.
- Easy installation with units capable of being mounted in horizontal or vertical configuration.
- Generator housing constructed from mild steel and painted in red polyurethane enamel paint (Custom colors available).
- NO STRAINER REQUIRED - Foam solution piping and discharge nozzles are of open design allowing passage of particles of up to ¼" in diameter.

PROPORTIONING

Chemguard High Expansion Foam Generators can be used with the following types of proportioning equipment.

- Fixed or portable eductors.
- Bladder tank balanced pressure-proportioning system.
- In-line balanced pressure or positive displacement foam pump-proportioning skid.

TYPICAL HAZARDS

Typical hazards where Chemguard High Expansion Foam Generators may be used to supply fire protection are:

- LNG Tank Farms/Loading Facilities
- Flammable Liquid Storage Areas
- Hazardous Waste Storage Facilities
- Shipboard Engine Rooms, Bilges and Holds
- Roll Paper Warehouse
- Chemical Storage Facilities
- Flammable Liquid Packaging Areas
- Cable Tunnels
- Aircraft Hangars

ORDERING INFORMATION

When ordering please provide the following information:

- Hazard to be protected
- Available residual water flow and pressure
- Method of proportioning required

CHEMGUARD
204 S. 6th Ave • Mansfield, Tx 76063 • (817) 473-9964 • FAX (817) 473-0606
www.chemguard.com

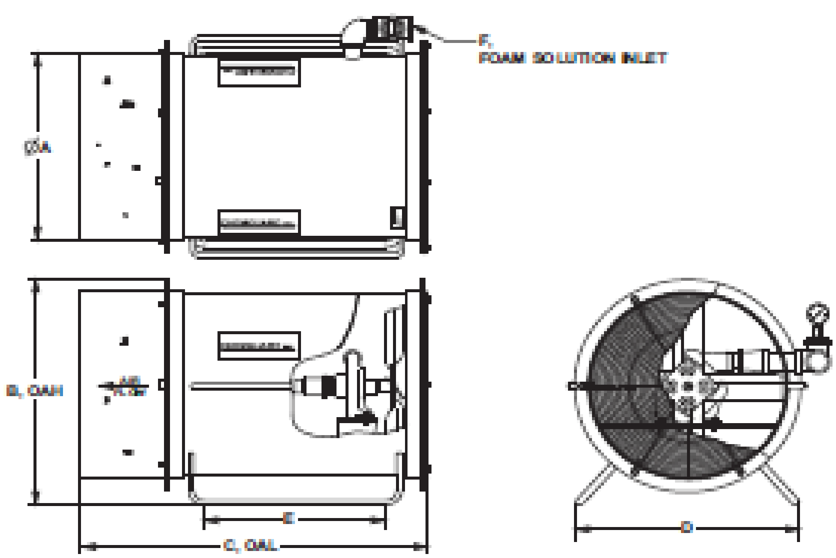
WATER POWERED HIGH EXPANSION FOAM GENERATORS - DIMENSIONAL CHART

Model/Part Number	Foam Output CFM (CMM)	Inlet Pressure PSI (Bar)	Dimensions, In. (mm) A	B	C	D	E	F	Weight Lbs (KG)
1500WP	1350 - 2050 (38 - 58)	40 - 100 (2.8 -6.9)	15.3 (389)	20 (508)	28 (711)	16 (406)	7.8 (198)	**1" FNH	75 (34)
*3000WP	3200 - 4500 (91 - 127)	40 - 80 (2.8 - 5.5)	19.5 (495)	23.8 (605)	34.3 (871)	22 (559)	15 (381)	**1.5" FNH	115 (52)
*6000WP	3300 - 5500 (93 - 156)	40 - 80 (2.8 - 5.5)	25.5 (648)	28.8 (732)	48.3 (1227)	28 (711)	24.5 (622)	**1.5" FNH	225 (102)
*15000WP	12200 - 17000 (345 - 481)	50 - 100 (3.4 - 6.9)	42 (1067)	44 (1118)	85.8 (2179)	42 (1067)	36 (914)	***2" Grvd	441 (200)
*18000WP	11300 - 18000 (320 - 510)	40 - 80 (2.8 - 5.5)	42.3 (1074)	48 (1219)	74.3 (1887)	46 (1168)	32.5 (826)	2.5" FNPT	535 (242)
*18000WP-SS-LNG	11300 - 18000 (320 - 510)	40 - 80 (2.8 - 5.5)	42.3 (1074)	48 (1219)	74.3 (1887)	46 (1168)	32.5 (826)	2.5" FNPT	535 (242)
*25000WP	15500 - 26400 (439 - 748)	40 - 90 (2.8 - 6.2)	54 (1372)	59 (1499)	91.5 (2324)	46 (1168)	38.25 (972)	***2" Grvd	627 (284)

*UL Listed Unit
**Units Supplied with Eductor
***Grooved

Note:

1. Other inlet threads/types available.
2. Dimensions are approximate and subject to change.



MODELS: 1500WP, 3000WP, 6000WP, 18000WP, 18000WP-SS-LNG

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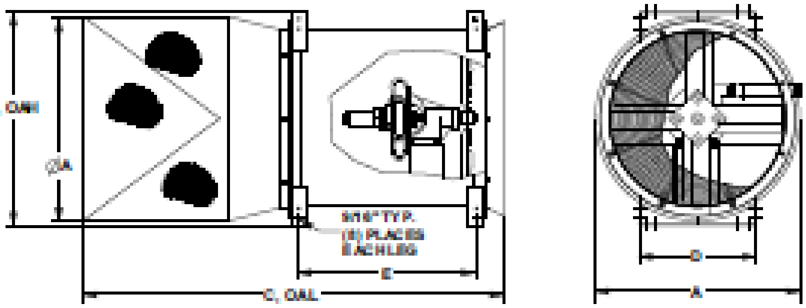
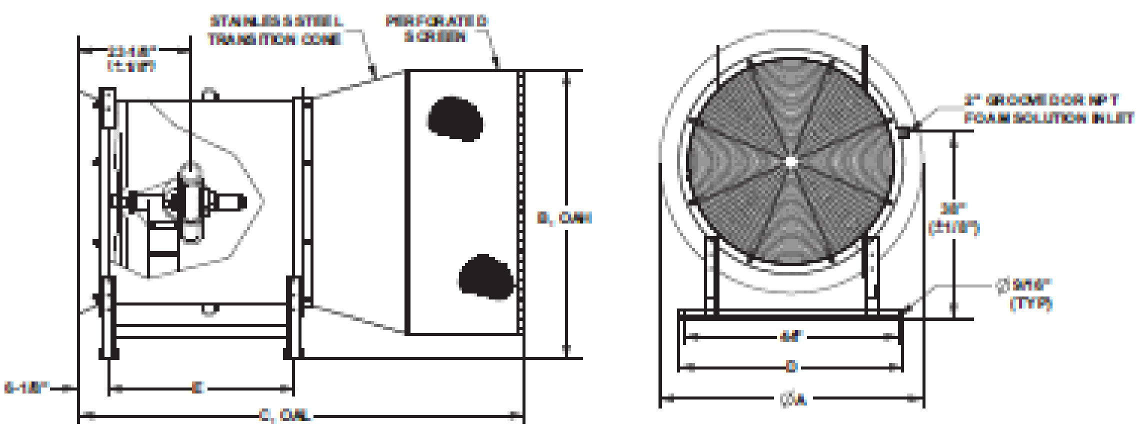


MODEL: 15000WP



MODEL: 25000WP

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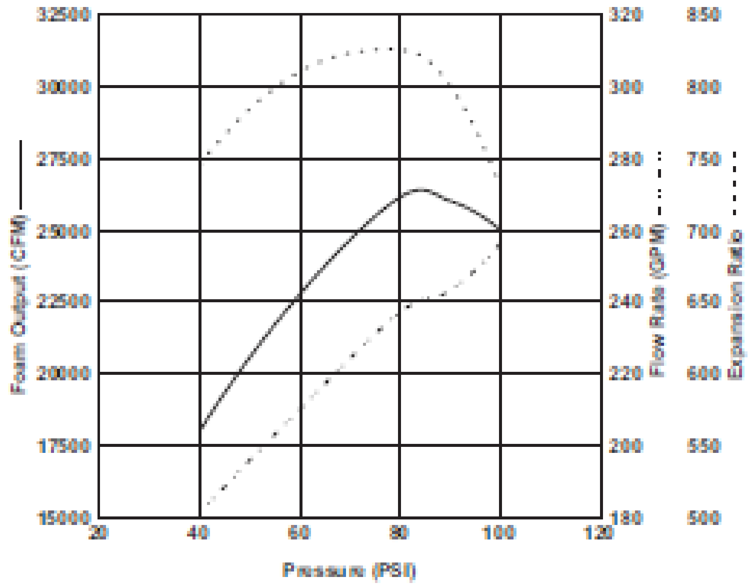
25000WP Performance Curve



25000WP						
PRESSURE		FOAM OUTPUT		FLOW RATE		EXPANSION
PSI	BAR	CFM	CMM	GPM	LPM	RATIO
40	2.8	18,000	510	181	685	744:1
50	3.4	20,250	573	195	738	777:1
60	4.1	22,750	644	210	795	810:1
70	4.8	25,000	708	225	852	831:1
80	5.5	26,100	739	237	895	826:1
90	6.2	26,000	736	243	920	800:1
100	6.9	25,000	708	256	969	731:1
Foam Breakdown Constant: S = 5.1 CFM/GPM (0.0382 CMM/LPM)						

ETL 02-15 vs. NFPA 409

Description	***ETL 02-15***	***Group I (NFPA 409)***	***Group II (NFPA 409)***
Foam Depth	1 Meter (3.28 ft.)	3 ft.	3 ft.
Discharge Time (to meet required depth)	4 Minutes	1 Minute	1 Minute
Rs	Density = .20 Sq. ft. = 5,000 Breakdown = 10	Density = .17 Sq. ft. = 15,000 Breakdown = Test Data	Density = .17 Sq. ft. = 5,000 Breakdown = Test Data
Leakage (CL)	If < = 15,000 then 2.0 If > 15,000 and < = 30,000 then 2.5 If > 30,000 then 3.0	1.0 to 1.2	1.0 to 1.2
Total Discharge Time	15 Minutes	12 Minutes	12 Minutes
Outside Air	No	Required	Required
Supplementary Handlines	No	Required(2 min) 60 gpm 20 min.	Required(2 min) 60 gpm 20 min.
Concentrate Redundancy	No	Required	Required
Bladder Tank Specifications	Must be Horizontal	Vertical or Horizontal	Vertical or Horizontal
Concentrate Piping	Must be Stainless Steel		

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RATIO FLOW CONTROLLERS

The Chemguard ratio flow controller is a device designed to meter the correct amount of Chemguard foam concentrate into the water stream over a wide range of flows and pressures with minimal pressure loss. These devices are used in conjunction with either a bladder tank or a foam pump proportioning system. Chemguard ratio flow controllers are UL Listed and FM Approved with certain Chemguard foam concentrates. Typical applications include flammable liquid storage tanks, loading racks, aircraft hangars, and heliports or anywhere flammable liquids are used, stored, processed or transported.

The operating principle of the controller is based upon the use of a modified venturi. As water passes through the inlet nozzle, pressure is reduced in the annular area of the nozzle. This reduction allows the metering of foam concentrate into the water stream through a foam concentratemetering orifice.

SPECIFICATIONS

Chemguard offers the ratio flow controller body in five models. The 2-1/2" ratio flow controller is a threaded controller designed with a 2-1/2" female NPT threaded inlet and 2-1/2" male NPT threaded outlet. The 3", 4", 6" and 8" ratio flow controllers are "between the flanges" units designed to fit between two ANSI 150 lb. pipe flanges. Only the recovery section protrudes into the system water piping. To ensure a complete gasket seal when installing between flanges, each face of the controller is machined with 20 grooves per inch.

The ratio flow controller body is cast from ASTM UNS-C84400 Brass. The inlet nozzle and metering orifice are machined from SAE #72 Brass. The inlet nozzle set screws and metering orifice retaining ring are of stainless steel.

The inlet nozzle is secured by two stainless steel set screws. This allows the nozzle to be removed from the controller for cleaning and/or repair.

Metering orifices are sized appropriately for each specified type and percentage foam concentrate. A stainless steel retaining ring secures the metering orifice in place.

The controller body is clearly marked with a flow direction arrow and label to identify the type of foam concentrate and injection percentage ratio.

FLOW RANGE

The Ratio Flow Controller Flow Range Table on page 4 lists the flow range for each ratio flow controller with respect to foam concentrate type. Please consult the Chemguard Engineering Department for specific applications or other foam concentrate types.

DESIGN INFORMATION

1. To ensure correct operation of a ratio flow controller when used with a bladder tank, the pressure of the foam concentrate at the controller must be within 2 psi of the incoming water pressure.

2. To ensure accurate proportioning over the flow range of the controller, minimum water inlet pressure of 30 psi must be available during operation of the system. A rule of thumb should include the water supply pipe to bladder tank and the concentrate supply pipe from bladder tank to controller foam inlet. The equivalent length of pipe including elbows, fittings and valve should be approximately 50 equivalent feet of the same pipe size as the foam inlet connection "D" on page 2.

3. Please review the controller dimension table for information on the minimum recommended length of straight pipe required upstream and downstream from the controller.

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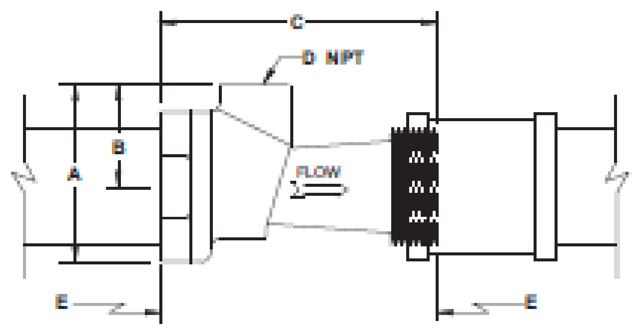
RATIO FLOW CONTROLLER DIMENSION TABLE

Ratio Flow Controller Size (Model)	Dimensions										
	A		B		C		D	***E		F	
	In.	(cm.)	In.	(cm.)	In.	(cm.)	In.	In.	(cm.)	lb.	(kg)
2-1/2" (CPC2.5)	4.3	10.9	2.40	6.10	6.9	17.5	1 NPT	12	31	8	3.6
3" (CPC3.0)	5.3	13.5	2.50	6.35	6.3	16.0	1-1/4 NPT	15	39	12	5.4
4" (CPC4.0)	6.8	17.3	2.75	6.99	8.0	20.3	1-1/2 NPT	20	51	22	10.0
6" (CPC6.0)	8.5	21.6	3.25	8.26	12.4	31.5	2 NPT	30	77	38	17.2
8" (CPC8.0)	10.9	27.7	3.55	9.02	12.4	31.5	2-1/2 NPT	40	102	73	33.1

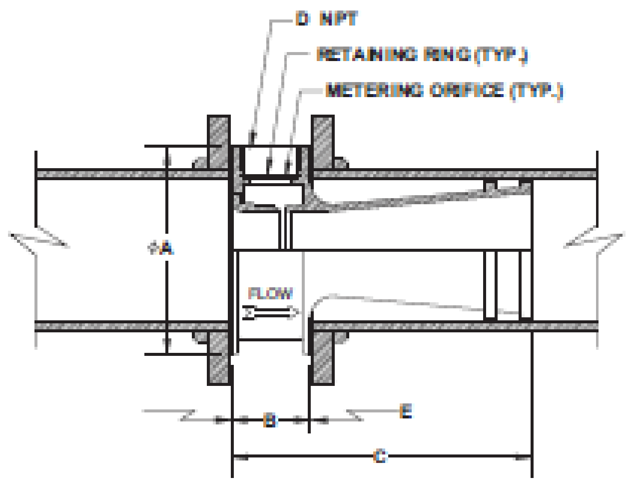
*** Straight pipe length required upstream and downstream.

Special Installation Note: A minimum of five (5) pipe diameters shall be allowed at the inlet and outlet of the proportioner.

Model:
CPC2.5



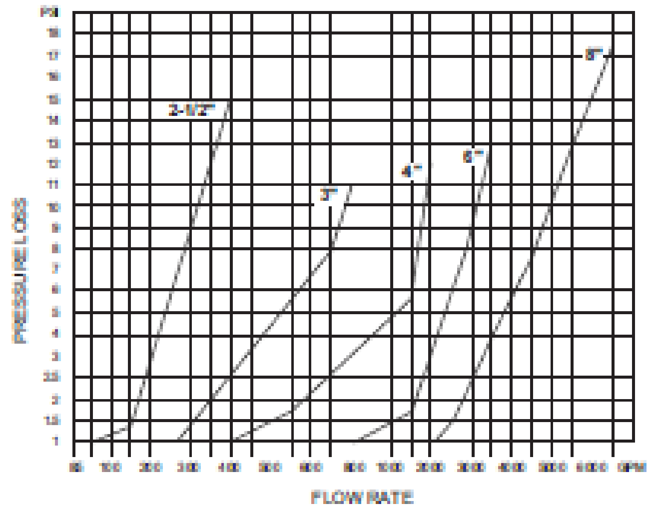
Models:
CPC3.0, CPC4.0
CPC6.0, CPC8.0



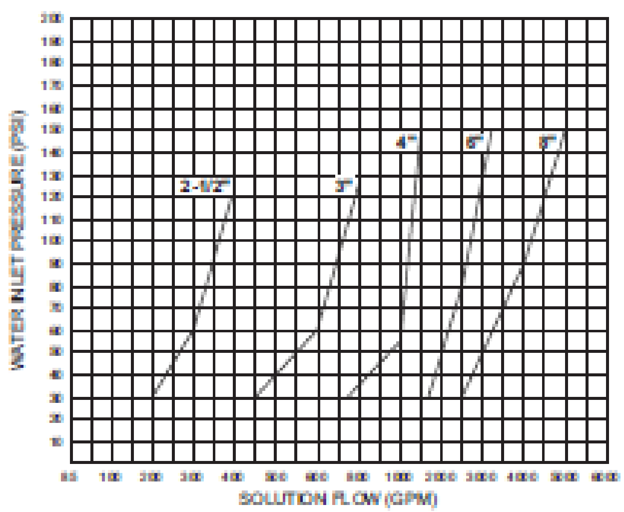
RATIO FLOW CONTROLLER - FLOW AND FRICTION LOSS CHARACTERISTICS

The following flow and friction loss characteristics are typical curves. For specific friction or flow in formation requirements please contact Chemguard.

FRICTION LOSS CURVES



MINIMUM INLET PRESSURE VERSUS FLOW



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VIKING® TECHNICAL DATA

FLOW CONTROL VALVE MODEL J-2 HALAR® COATED 1-1/2" & 2" (DN40 & DN50)

The Viking Corporation, 210 N Industrial Park Drive, Hastings MI 49058
Telephone: 269-945-9501 Technical Services: 877-384-5464 Fax: 269-818-1680 Email: techsvcs@vikingcorp.com

1. DESCRIPTION

The Viking Flow Control Valve is a quick opening, differential diaphragm flood valve with a spring loaded floating clapper. The Flow Control Valve can be used to facilitate manual or automatic on/off control. It can also be used to control water pressure or flow rates. As an on/off control valve it is used on Deluge Systems, Sprinkler Systems or to automatically fill tanks or reservoirs. The Flow Control Valve can be used as a pressure reducing valve to limit or conserve water flow. The valve is an integral part of the Viking Firecycle® System.

Features

A. VALVE:
1. Field replaceable Diaphragm and Seat Rubbers
2. Designed for installation in the horizontal or vertical position
3. Compatible with Hydraulic (See figure 2), Pneumatic, and/or Electric Detection Systems
4. Designed to be reset without opening the valve.
5. Can be trimmed to automatically reset electrically or manually.

B. HALAR® COATING:
1. Exceeds performance of Epoxy Coating or Kynar Coating
2. Mechanical strength and toughness
3. High thermal stability
4. High dielectric strength
5. Resistant to most chemicals and solvents
6. Resistant to cobalt 60 radiation
7. All wetted surfaces are coated including pipe threads

2. LISTINGS AND APPROVALS:

UL Listed - Guide No. VLFT & VLLA
C-UL Listed
FM Approved - On-Off Multi Cycle Sprinkler Systems
ABS Certificate number - 04-CH557068-X
MEA Approved - 89-92-E Vol. XXXI

3. TECHNICAL DATA

Viking Technical Data may be found on The Viking Corporation's Web site at http://www.vikinggroupinc.com. The Web site may include a more recent edition of this Technical Data Page.

Specifications:

Style: Straight through pattern
Connections available: Grooved inlet with grooved outlet
Pressure Rating - 250 PSI (17.2 bar) Working water pressure
Hydrostatically tested to 500 PSI (34.5 bar) at factory
Priming Chamber supply restriction (required): 0.125" (3.1 mm)
Color of Halar® Coated Valve: Black
Friction Loss: 1-1/2" - 7 ft. (2.1 m); 2" - 13 ft. (3.9 m)
C_V Factor: 1-1/2" - 66, 2" - 93

$$Q = C_V \sqrt{\frac{\Delta P}{S}}$$

Q = Flow
C_V = Flow Factor (GPM/1 PSI ΔP)
ΔP = Pressure Loss through Valve
S = Specific Gravity of Fluid

Material Standards:

Refer to Figure 4.
Halar® Coating Specification (SPF-2-Q06): **Refer to Figure 3.**
Electroless Nickel and Tin Plating Specifications (SPF02-J07): **Refer to Figure 3.**
Teflon Coating Specification (SPF02-N05): **Refer to Figure 3.**

Ordering Information:

Part Numbers: **1/2" - 12131Q/B; 2" - 12062Q/B**
Shipping Weight: 1/2" - 36 lbs. (13.3 kg.); 2" - 36.5 lbs. (16.5 kg.)

Form No. F_040404

Revised page replaces page 507a-h dated February 27, 2009. (Revised the Replacement Parts list. Revised Valve Disassembly and Reassembly instructions.)

B.6. Riser 10 Wet Pipe System for Pump Building Hydraulic Calculations

Project name:	Pump Building	0.2	GPM/ft^2
Classification:	Ordinary Hazard Group 2	Bld Size 1000	ft^2
		200	GPM
		8	
		25	GPM/Head

Date:

Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
			q	25.0			L	10	C=	120	Pt	19.9	Pt		k=	5.60
3	1	BL1			1		F				Pe		Pv			
			Q	25.0	1.049		T	10	pf	0.197	Pf	2.0	Pn			
			q	26.2			L	10	C=	120	Pt	21.9	Pt		k=	5.60
4	2	BL1			1		F				Pe		Pv			
			Q	51.2	1.049		T	10	pf	0.741	Pf	7.4	Pn			
			q	30.3			L	10	C=	120	Pt	29.3	Pt		k=	5.60
2	3	BL1			1.25		F				Pe		Pv			
			Q	81.5	1.38		T	10	pf	0.461	Pf	4.6	Pn			
			q	32.6			L	5	C=	120	Pt	33.9	Pt		k=	5.60
3	4	BL1			1.5		F				Pe		Pv			
			Q	114.1	1.61		T	5	pf	0.405	Pf	2.0	Pn			
			q	0.0			L	0	C=	120	Pt	35.9	Pt		k=	0.00
4	A	BL1			1.5	Tee	F	8			Pe		Pv			
			Q	114.1	1.61		T	8	pf	0.405	Pf	3.2	Pn			
												39.2			k=	18.23
															K for Branch	
			q	114.1			L	12.6	C=	120	Pt	39.2	Pt		k=	18.23
1	A	BL1			2		F				Pe		Pv			
			Q	114.1	2.067		T	12.6	pf	0.120	Pf	1.5	Pn			
			q	116.3			L	4	C=	120	Pt	40.7	Pt		k=	18.23
2	2	BL2			2		F				Pe		Pv			
			Q	230.4	2.067		T	4	pf	0.440	Pf	1.8	Pn			
		Top	q	0.0			L	6	C=	120	Pt	42.4	Pt		k=	0.00
3	B	Riser			2.5	1-90L	F	6			Pe	2.6	Pv			
		CV	Q	230.4	2.469		T	12	pf	0.185	Pf	2.2	Pn			
			q	0.0			L	13	C=	120	Pt	47.3	Pt		k=	0.00
4	4	Valve			2.5	Butterfly	F	7			Pe		Pv			
			Q	230.4	2.469		T	20	pf	0.185	Pf	3.7	Pn			
			q	0.0			L	2	C=	120	Pt	51.0	Pt		k=	0.00
5		POC			2.5	1-Tee	F	12			Pe		Pv			
			Q	230.4	2.469		T	14	pf	0.185	Pf	2.6	Pn			
											Pt	53.6				
								Sprinkler		230	gpm	53.6	psi			
								Hose		250	gpm					
								Total		480	gpm					

B.7. Riser 11 Wet Pipe System for Machine Shop Hydraulic Calculations

		Total	Design	
		Total	Design	
Ordinary Hazard Group 2		0.2	0.2	GPM/ft^2
0.2	gpm/ft^2	3555	1500	FT^2
1500.0	ft^2	711	300	GPM
		30	23.7	GPM/Head
		23.7	13	Heads

Project name: B192 Machine Shop Date:

Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
		Drop	q	24.0			L	2.25	C=	120	Pt	18.2	Pt		k=	5.62
1	1	Piping			1	2 - 90 L	F	4			Pe	-0.6	Pv			q = k * (Pt)^1/2
			Q	24.0	1.049		T	6.25	pf	0.182	Pf	1.1	Pn			Piping to drop below drop ceiling
											Pt	18.7			k=	5.55
																To be conservative used the higher K factor
			q	24.0			L	13	C=	120	Pt	18.2	Pt		k=	5.62
3	1	BL1			1		F				Pe		Pv			
			Q	24.0	1.049		T	13	pf	0.182	Pf	2.4	Pn			
			q	25.5			L	13	C=	120	Pt	20.6	Pt		k=	5.62
4	2	BL1			1		F				Pe		Pv			
			Q	49.5	1.049		T	13	pf	0.696	Pf	9.0	Pn			
			q	30.6			L	13	C=	120	Pt	29.7	Pt		k=	5.62
2	3	BL1			1.25		F				Pe		Pv			
			Q	80.1	1.38		T	13	pf	0.446	Pf	5.8	Pn			
			q	33.5			L	13	C=	120	Pt	35.5	Pt		k=	5.62
3	4	BL1			1.5		F				Pe		Pv			
			Q	113.6	1.61		T	13	pf	0.402	Pf	5.2	Pn			
			q	35.8			L	2	C=	120	Pt	40.7	Pt		k=	5.62
4	5	BL1			1.5		F				Pe		Pv			
			Q	149.4	1.61		T	2	pf	0.667	Pf	1.3	Pn			
			q	0.0			L	0	C=	120	Pt	42.0	Pt		k=	5.62
5	A	BL1			2	Tee	F	10			Pe		Pv			
			Q	149.4	2.067		T	10	pf	0.198	Pf	2.0	Pn			
												44.0			k=	22.53
																K for Branch with 5 open sprinkler
			q	24.0			L	13	C=	120	Pt	18.2	Pt		k=	5.62
1	1	BL2			1		F				Pe		Pv			
			Q	24.0	1.049		T	13	pf	0.182	Pf	2.4	Pn			
			q	25.5			L	13	C=	120	Pt	20.6	Pt		k=	5.62
2	2	BL2			1		F				Pe		Pv			
			Q	49.5	1.049		T	13	pf	0.696	Pf	9.0	Pn			
			q	30.6			L	13	C=	120	Pt	29.7	Pt		k=	5.62
3	3	BL2			1.25		F				Pe		Pv			
			Q	80.1	1.38		T	13	pf	0.446	Pf	5.8	Pn			
			q	0.0			L	13	C=	120	Pt	35.5	Pt		k=	5.62
4	4	BL2			1.5		F				Pe		Pv			Not Open
			Q	80.1	1.61		T	13	pf	0.211	Pf	2.7	Pn			
			q	0.0			L	2	C=	120	Pt	38.2	Pt		k=	5.62
5	5	BL2			1.5		F				Pe		Pv			Not Open
			Q	80.1	1.61		T	2	pf	0.211	Pf	0.4	Pn			
			q	0.0			L	0	C=	120	Pt	38.6	Pt		k=	5.62
	B	BL2			2	Tee	F	10			Pe		Pv			
			Q	80.1	2.067		T	10	pf	0.062	Pf	0.6	Pn			
												39.2			k=	12.79
																K for Branch with 4 open sprinkler

Project name:			B192 Machine Shop												Date:		
Step No.	Nozzle Ident and Location			Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length			Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes
		Cross Main															
			q	132.0				L	9	C=	120	Pt	34.3	Pt		k=	22.53
1	1	BL1			3			F				Pe		Pv			5 Heads
		5	Q	132.0	2.469			T	9	pf	0.066	Pf	0.6	Pn			
			q	133.1				L	9	C=	120	Pt	34.9	Pt		k=	22.53
2	2	BL2			3			F				Pe		Pv			5 Heads (10 Total)
		5	Q	265.0	2.469			T	9	pf	0.240	Pf	2.2	Pn			
			q	77.9				L	9	C=	120	Pt	37.1	Pt		k=	12.79
3	3	BL3			3			F				Pe		Pv			3 Heads (13 Total)
		4	Q	342.9	3.068			T	9	pf	0.134	Pf	1.2	Pn			
			q	0.0				L	9	C=	120	Pt	38.3	Pt		k=	0.00
4	4	BL4			3			F				Pe		Pv			
		4	Q	342.9	3.068			T	9	pf	0.134	Pf	1.2	Pn			
			q	0.0				L	9	C=	120	Pt	39.5	Pt		k=	0.00
	5	BL5			4			F				Pe		Pv			
			Q	342.9	4.026			T	9	pf	0.036	Pf	0.3	Pn			
		Top	q	0.0				L	20	C=	120	Pt	39.8	Pt		k=	0.00
	6	Riser			4	3-90L		F	30			Pe		Pv			
		CV	Q	342.9	4.026			T	50	pf	0.036	Pf	1.8	Pn			
			q	0.0				L	20	C=	120	Pt	41.6	Pt		k=	0.00
	6	CV			4			F	22			Pe		Pv			
			Q	342.9	4.026			T	42	pf	0.036	Pf	1.5	Pn			
			q	0.0		Gate		L	20	C=	120	Pt	43.1	Pt		k=	0.00
	6	OS&Y			4	Valve		F	2			Pe		Pv			
			Q	342.9	4.026			T	22	pf	0.036	Pf	0.8	Pn			
			q	0.0		1-90L		L	32	C=	120	Pt	43.9	Pt		k=	0.00
	6	POC			6	2-Tee		F	74			Pe	4.3	Pv			
			Q	342.9	6.065			T	106	pf	0.005	Pf	0.5	Pn			
													48.7				
									Sprinkler		343	gpm	48.7	psi			
									Hose		250	gpm					
									Total		593	gpm					

Reliable®

Model G Automatic Sprinklers Spray Upright, Spray Pendent And Conventional

Bulletin 110 Rev. W

Product Description

The Reliable Model G Automatic Sprinkler utilizes the center strut solder in compression principle of construction. The fusible alloy is captured in the cylinder of the solder capsule by a stainless steel ball. When the fusible alloy melts, the ball moves into the cylinder allowing the cylinder to fall away from the sprinkler. When this happens, the lever is released to spring free from the sprinkler so that all of the operating parts clear from the waterway allowing the deflector to distribute the discharging water.

Except for the parts in the cylinder as mentioned above, the sprinkler components are made from copper based alloys for maximum corrosion protection. Lead plated, wax coated or wax over lead plated sprinklers are available for specially severe environments. Chrome plated sprinklers are available for decorative purposes.

All sprinklers are individually hydrostatically tested. All sprinklers are identified as to their fusing point by markings that appear on several of the operating parts and by an identifying color that appears on the frame.

Upright

Pendent

Small Orifice Upright

Conventional

Sprinkler Types

Standard Upright – This deflector configuration is normally used with exposed piping installations. Water is distributed laterally and downward in a wide pattern approximating a hemisphere which is completely and uniformly filled with water in the form of small drops or spray.

Standard Pendent – This deflector configuration is normally used where the space above the piping is limited or where a concealed piping installation is employed. The discharge characteristics of the standard pendent are virtually identical to the standard upright as described above.

Large and Small Orifice — By varying the orifice size, a large or small orifice sprinkler is created that will distribute as much as 40% more water or 65% less water than the normal ½" (15mm) orifice sprinkler.

Conventional — This deflector configuration is used primarily in those countries where the LPC installation rules have precedence. The sprinkler is designed to distribute a portion of its water discharge upward against the ceiling with the balance downward. It may be installed in either the upright or the pendent position. Sprinklers with conventional deflectors are available with orifice sizes corresponding to light, ordinary and extra–high hazard installations.

Application and Installation

Standard sprinklers are used in fixed fire protection systems: Wet, Dry, Deluge or Preaction. Care must be exercised that the orifice sizes, temperature ratings, deflector styles and sprinkler spacings are in accordance with the latest published standards of the National Fire Protection Association or the approving authority having jurisdiction.

The sprinklers must be installed with the Reliable Model D Sprinkler Wrench. Any other type of wrench may damage the sprinkler.

The approvals or listings of Reliable Automatic Sprinklers by major approving organizations are shown in the tabulated list provided on the back of this bulletin.

Reliable Automatic Sprinkler Co., Inc., 103 Fairview Park Drive, Elmsford, New York 10523

Technical Data

Sprinkler Type	"K" Factor		Sprinkler Height	Approvals	Sprinkler Identification Number (SIN)	
	US	Metric			SSU	SSP
Standard–Upright (SSU) and Pendent (SSP) Deflectors Marked to Indicate Position						
1/2" (15 mm) Standard Orifice with 1/2" NPT (R1/2) Thread	5.62	81.0	2 7/8" (73 mm)	1, 2, 3, 4, 5, 6, 7	R1025	R1015
7/16" (11 mm) Small Orifice with 1/2" NPT (R1/2) Thread	4.24	61.0	2 7/8" (73 mm)	1, 5	R1023	R1013
3/8" (10 mm) Small Orifice with 1/2" NPT (R1/2) Thread	2.82	40.6	2 7/8" (73 mm)	1, 2, 5	R1021	R1011
5/16" (8 mm) Small Orifice with 1/2" NPT (R1/2) Thread	1.98	28.5	2 7/8" (73 mm)	1, 5	R1022	R1012
17/32" (20 mm) Large Orifice with 1/2" NPT (R1/2) Thread	7.96	114.7	2 7/8" (73 mm)	1, 2, 5	R1026	R1016
17/32" (20 mm) Large Orifice with 3/4" NPT (R3/4)Thread	8.20	118.2	2 15/16" (75 mm)	1, 2, 5	R1027	R1017
20 mm XHH with 20 mm Thread	8.20	118.2	75.4 mm	3, 4, 5	R1027	R1017
10 mm XLH with 10 mm Thread	4.10	59.1	73 mm	3, 4, 5	R1024	R1014
Conventional—Installed in Upright or Pendent Position						
10mm XLH with 10mm Thread	4.10	59.1	73 mm	4	R1074	
15mm Standard Orifice with (R1/2) Thread	5.62	81.0	73 mm	3, 4, 5, 7	R1075	
20mm XHH with (R3/4) Thread	8.20	118.2	75.4 mm	3, 4	R1077	

Temperature Ratings

Classification	Sprinkler Rating		Maximum Ambient Temperature		Frame (1) Color
	°F	°C	°F	°C	
Ordinary	135	57	100	38	Black
Ordinary	165	74	100	38	Uncolored
Intermediate	212	100	150	66	White
High	286	141	225	107	Blue

(1) Frame color does not apply to painted or plated sprinklers –Use sprinkler rating as identified on operating parts.

Finishes (1)

Standard Finishes	
Bronze	—All Temperature Ratings
Chrome	—All Temperature Ratings
White (2)	—All Temperature Ratings Only Frame and Deflector are Painted
Special Application Finishes	
Bright Brass Plated	—Only frame, deflector and cap are plated. 135°F (57°C), 165°F (74°C), 212°F (100°C) Temp. Rating.
Black Plated	—Only frame, deflector and cap are plated. All Temp. Ratings.
Polyester Coated (2)(4)	—Only frame and deflector are coated.
Lead Plated	—165°F (74°C), 212°F (100°C) and 286°F (141°C) Temp. Ratings.
Wax-Coated (3)	—165°F (74°C) Clear Wax, 212°F (100°C) Brown Wax.
Wax-Coated Over Lead Plated (3)	—165°F (74°C) Clear Wax, 212°F (100°C) Brown Wax.

(1) Other colors and finishes are available. Consult factory for details.
(2) UL listed and NYC MEA Approved only.
(3) 212°F (100°C) brown wax may be used on 286°F (141°C) sprinklers when maximum ambient temperatures do not exceed 150°F (66°C). UL Listed, FM Approved, NYC MEA 258-93-E.
(4) FM Approved for R1027 only.

Maintenance

Model G Sprinklers should be inspected and the sprinkler system maintained in accordance with NFPA 25. Do not clean sprinklers with soap and water, ammonia or any other cleaning fluids. Remove any sprinkler that has been painted (other than factory applied) or damaged in any way. A stock of spare sprinklers should be maintained to allow quick replacement of damaged or operated sprinklers. Prior to installation, sprinklers should be maintained in the original cartons and packaging until used to minimize the potential for damage to sprinklers that would cause improper operation or non-operation. Use only the Model D Sprinkler Wrench for sprinkler removal and installation. Any other type of wrench may damage the sprinkler.

Approval Organizations

1. Underwriters Laboratories, Inc. and UL Certified for Canada (cULus).
2. Factory Mutual Research Corporation
3. Loss Prevention Council
4. Pleniere Assemblee
5. VdS Schadenverhütung GmbH
6. N.Y.C. BS&A No. 587–75–SA or N.Y.C. MEA 258-93-E
7. EC Certificate: 1438-CPD-0054 (R1015)
   1438-CPD-0053 (R1025)
   1438-CPD-0052 (R1075)
   1438-CPD-0056 (R1077)

Ordering Information
Specify

1. Model G
2. Deflector
   - Upright
   - Pendent
   - Conventional
3. Nominal Orifice
4. Inlet Thread
5. Temperature Rating
6. Finish

The equipment presented in this bulletin is to be installed in accordance with the latest published Standards of the National Fire Protection Association, Factory Mutual Research Corporation, or other similar organizations and also with the provisions of governmental codes or ordinances whenever applicable. Products manufactured and distributed by Reliable have been protecting life and property for over 90 years, and are installed and serviced by the most highly qualified and reputable sprinkler contractors located throughout the United States, Canada and foreign countries.

Manufactured by
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