FPE S596 Culminating Experience in Fire Protection – Evaluation of Centennial Station

Prepared for:

**Fire Protection Engineering
California Polytechnic State University
San Luis Obispo, CA 93407-0442**

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Final

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Life Safety

Smoke Control

ASET vs. RSET

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1.0 EXECUTIVE SUMMARY

The purpose of this analysis is for completion of FPE 596 Culminating Experience in Fire Protection Engineering course in the Fire Protection Engineering Program at California Polytechnic State University. This analysis has been compiled using previous design courses evaluating the egress analysis, suppression design, alarm and detection design, smoke control system design, and structural fire protection. The context of the courses studied both prescriptive and performance based design approaches.

The building chosen for the analysis is Centennial Station located approximately 15 miles south of Denver, Colorado at 12154 East Easter Avenue, Englewood, CO 80112. The facility was designed specifically for use by the government in 2008 and constructed throughout 2009. The facility is a 92,041 square feet, four-story, freestanding building consisting primarily of B, E, and S-1 occupancies.

Analysis of Centennial Station was completed with only the floor plans of the building. Mechanical, electrical, fire protection, and life safety drawings were not available during the completion of this analysis. The attached floor plans showing fire protection systems were created by Brandon Huffman and are not indicative of what is present at the building. Where noted certain assumptions were made to complete the design of the systems. All images of the systems are shown as a representation of systems installed in Centennial Station, but are not of the actual systems installed in the building.

The fire alarm and suppression systems were designed using prescriptive methods utilizing applicable NFPA codes. The smoke control system design provided in this analysis is hypothetical with information known about the building; the hypothetical system design is based performance-based design and industry best practices. Egress analysis was performed using prescriptive based design, as well as performance based evaluation. All systems were evaluated together to analyze the required safe egress time versus the available safe egress time, the analysis was used to determine the effectiveness of the design of all operating systems including alarm activation, sprinkler activation, effectiveness of smoke exhaust, and occupant travel paths and times.

Analysis of the building found that the prescriptive based designs of the alarm and suppression systems met the minimum code requirements for the building as shown in the drawings in Appendix C. Additionally, the building use and construction type was appropriate for the building height and area as constructed. In general, the egress components were code compliant with the exception of one instance of an exceeded common path of travel on the third floor in Open Office 312. Fire Dynamics Simulator was used to model the smoke exhaust system; it was determined that the smoke control system is adequate for the building as designed in this analysis.

2.0 INTRODUCTION

The following analysis is for completion of FPE 596 Culminating Experience in Fire Protection Engineering course in the Fire Protection Engineering Program at California Polytechnic State University. This analysis has been compiled from the completion of previous design courses completed in the Fire Protection Engineering program. The previous design courses included egress, suppression, alarm, smoke control and special hazard. The context of the courses studied both prescriptive and performance based design approaches.

The building to be studied is Centennial Station located in Englewood, CO. The facility is a four story office building constructed for use by a government agency. The office building has unique features including an atrium, vehicle storage, holding cells, a training center, and weapons storage.

Though the building was constructed in 2009 this analysis will be based on a facility which is currently being designed rather than constructed, the applicable code editions will be based on design in 2008. The exterior of the building is show in Image 1.

Image 1 – Centennial Station

Floor plans of the building were received from the architect. None of the electrical, mechanical, plumbing, or fire protection drawings were reviewed prior to this analysis. Where unknown information was necessary certain assumptions have been made, these will be described where needed.

The purpose of this analysis will be to provide code compliant fire protection systems. The following items will specifically be reviewed in detail:

- Life safety plans;
- Egress Components;
- Building construction types and methods;
- Timed egress analysis;
- Tenability criteria;
- Smoke and heat detection;
- Audible and visual notification;
- Fire alarm system wiring;
- Hazard classification;
- Suppression including sprinkler systems and special hazards;
- Hydraulic calculations;
- Smoke control;
- Fire modeling.

3.0 BUILDING DESCRIPTION

Centennial Station is located approximately 15 miles south of Denver, Colorado at 12154 East Easter Avenue, Englewood, CO 80112. The facility was designed specifically for use by the government in 2008 and constructed throughout 2009. The facility is a 92,041 square feet, four-story, freestanding building consisting primarily of B, E, and S-1 occupancies.

Based at the foothills of Rock Mountains the expected temperatures in the area include extreme highs and lows. The average monthly high temperature is 89°F in July, with an extreme high temperature of 108°F recorded in 1989. The average monthly low temperature is 18°F in both December and January. The lowest temperature recorded was -32°F recorded in 1963. The yearly average wind speed in the area is approximately 6 mph.

Though Centennial Station is in Englewood, the authority having jurisdiction is South Metro Fire Rescue Authority head quartered at 9195 East Mineral Avenue, Centennial, CO 80112. The nearest fire station is Station 35, located at 12080 E Briarwood Ave, Centennial, CO 80112 operated by South Metro Fire Rescue Authority. The fire station is approximately 0.4 miles to the north of Centennial Station.

Below is the site plan for Centennial Station. South Peoria Street is to the west of the building and East Easter Avenue is to the north. Because the DEA building is secure facility security fencing has been installed to limit access to the facility, the fencing is shown in black in Image 2. Two entrances through the fence are indicated on the site plan as well.

Image 2 – Site Plan

The first floor of the facility is to be used for storage, detention, vehicle parking, and a main lobby with a three story atrium. The storage in the building includes evidence, firearms, and general building storage. The detention area has direct access to a parking area inside the building and has three holding cells. In addition to parking reserved for four vehicles the first

floor has parking for an RV and a technical garage where vehicles are disassembled. The total area of the first floor is 23,724 square feet. Three exits are provided directly to the exterior of the building with one additional exit through the covered parking area; however, this exit will not be included in the egress analysis as it is through an adjoining space. An attached covered parking area is provided on the east side of the building, the parking area is 49,810 square feet, in addition to the building floor area. The parking garage will be considered a separate building and is not included in the analysis with exception to building separation requirements.

The second floor of the building is to be used for a press room, training, office space, technical storage, training, and a fitness center. The area of the second floor not including the atrium is 23,456 square feet. Two exit stairways are provided from the second floor. One of the exit stairways discharge into the main lobby and the other stairway discharges into an exit corridor.

The third floor of the building is to be comprised of office space and conference rooms. The total floor area of the third floor is 22,774 square feet. Two exit stairways are provided on the second floor exiting the building similarly to the second floor through the lobby and an exit corridor.

Lastly, the fourth floor of the building will be used for office space, conference rooms, and file storage. The total floor area of the fourth floor is 22,087 square feet. Two exit stairways are provided similarly to the second and third floors.

Though a sprinkler system is not specifically required for a four story, business occupancy building by the International Building Code, it has been chosen to install one because of the advantage of specific tradeoffs given to sprinklered buildings as well as the additional life safety associated with sprinklered buildings. In accordance with Section 903.4 of the IBC the building automatic sprinkler system is required to be monitored by a fire alarm system; therefore, a fire alarm control panel is required to be installed in the building.

A fire alarm system will be provided throughout the building to monitor the fire sprinkler water-flow switch, fire sprinkler control valves, atrium smoke detection, elevator recall, and provide occupant notification. The fire alarm system will be designed and installed in accordance with NFPA 72. Detection will be provided as required by code, specifically in the atrium and to protect the fire alarm control panel. A manual pull station will be provided at a normally attended location. The fire alarm system will provide audible notification throughout the building and visible notification in areas normally occupied by multiple occupants.

A smoke control system will be design to ensure tenable conditions can be maintained in the atrium during a fire event for a duration as required by code. The smoke control system will be comprised of detection, smoke exhaust and make-up air.

4.0 APPLICABLE CODES AND STANDARDS

The following analysis presented in this report is based on the following codes, standards, and industry references at the time of construction of the facility.

4.1 International Code Council (ICC)

- IBC – International Building Code, 2006 Edition;

4.2 National Fire Protection Association (NFPA)

- NFPA 1 – Fire Code, 2006 Edition;

- NFPA 10 – Standard for Portable Fire Extinguishers, 2007 Edition;
- NFPA 13 – Standard for the Installation of Sprinkler Systems, 2007 Edition;
- NFPA 24 – Standard for the Installation of Private Service Mains and Their Appurtenances, 2007 Edition;
- NFPA 25 – Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems, 2008 Edition;
- NFPA 70 – National Electrical Code, 2008 Edition;
- NFPA 72 – National Fire Alarm Code, 2007 Edition;
- NFPA 92 B – Standard for Smoke Management Systems in Malls, Atria, and Large Spaces, 2005 Edition;
- NFPA 101 – Life Safety Code, 2006 Edition;
- NFPA 170 – Standard for Fire Safety Symbols, 2006 Edition;
- NFPA 253 – Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source, 2006 Edition;
- NFPA 255 – Standard Method of Test of Surface Burning Characteristics of Building Materials, 2006 Edition;
- NFPA 286 – Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth, 2006 Edition;

4.3 American Society for Testing and Materials (ASTM)

- ASTM E 84 – Standard Test Methods for Surface Burning Characteristics of Building Materials, 01 Edition
- ASTM E 119 – Standard Test Methods for Fire Tests of Building Construction and Materials, 00a Edition

4.4 Manufacturer's Guides

- Hilti – Firestop Systems Specifier's Guide, Volume 12;
- CertainTeed – Gypsum Board Systems Manual, 2012 Edition;
- TFP181 – 5.6 K-Factor "Royal Flush II" Concealed Pendent Sprinklers Quick & Standard Response, Standard Coverage;
- TFP172 – 5.6 K-Factor Upright, and Recessed Pendent Sprinklers Quick Response, Standard Coverage;
- TFP176 – 5.6 K-Factor Horizontal and Vertical Sidewall Sprinklers Quick Response, Standard Coverage;
- TFP950 – Model CV-1FR Grooved-End Riser Check Valves 2 to 12 Inch;
- TFP1020 – Model DPV-1 Dry Pipe Valve, External Resetting 2-1/2 thru 6 Inch;
- ES-A-2000SS – Series 2000SS Double Check Valve Assembly;
- Silent Knight – Intelliknight 5820LX Addressable Fire System Installation and Operations Manual;
- Silent Knight – Model 5496 Intelligent Power Module Installation and Operations Manual;
- Silent Knight – SK-Beam Manufacturer Datasheet;

- Silent Knight – SK-Duct Manufacturer Datasheet;
- Silent Knight – SK-Heat Manufacturer Datasheet;
- Silent Knight – SK-Minimon Manufacturer Datasheet;
- Silent Knight – SK-Monitor Manufacturer Datasheet;
- Silent Knight – SK-Monitor-2 Manufacturer Datasheet;
- Silent Knight – SK-Photo Manufacturer Datasheet;
- Silent Knight – SK-Pull-DA Manufacturer Datasheet;
- Silent Knight – SK-Relay Manufacturer Datasheet;
- System Sensor – Ceiling Strobe and Horn/strobe Manufacturer Datasheet;
- System Sensor – Wall Horn, Strobe, and Horn/strobe Manufacturer Datasheet'

4.5 References

- Fire Protection Handbook, 20th Edition (2008)
- SFPE – Handbook of Fire Protection Engineering, 3rd Edition (2002)

It is noted that South Metro Fire Rescue does not have amendments to the ICC codes; therefore, the code will be applied as such.

5.0 BUILDING USE AND CONSTRUCTION

Generally, the Centennial Station office building will be used as office space. These types of buildings are expected to have mobile, coherent occupants capable of self-preservation. The first floor is expected to have a relatively light occupant load because of the low occupant loads associated with parking and storage areas; however, special area separations are to be expected because of the higher hazards associated with these areas. The second floor will have a high occupant load due to the large square footage of assembly use occupancies. Because of the high occupant load it will be critical to ensure adequate available exits. Both the third and fourth floors are largely used for business associated with light occupant loads and minimal special requirements. The building use is coordinated closely with the construction types, further information about the building construction types can be found in the structural portion of this analysis.

5.1 Occupancy Classification

All portions of the Centennial Station are to be classified with respect to occupancy as described in this section. The occupant classifications will define the use of each space of the building. The space and use will determine code requirements based on expected occupant load, occupant mobility, and fuel load.

The IBC Chapter 3 defines the following occupant classifications: assembly, business, education, factory, high hazard, institutional, mercantile, residential, storage, and miscellaneous.

Centennial Station will have multiple occupancies and be considered a mixed use building. The relevant occupancy classifications have been defined and discussed in the following subsections. Occupancy Classification drawings LS-1 through LS-4 are included in Appendix C showing the occupancy classification for each space in Centennial Station.

5.1.1 Accessory

Accessory occupancies are those occupancies which are subsidiary to the main occupancy of the building as defined in Section 508.3.1 of the IBC. This code section also limits the aggregate accessory floor area not to exceed of the 10 percent of the total floor area for each story. The accessory areas at Centennial Station include break rooms, restrooms, some waiting areas, and some assembly areas based on square footage limitations. Accessory areas, in general, are occupied by people from adjacent areas of the building, thus their occupant load may not always add to the total occupant load for a floor.

5.1.2 Assembly

Assembly occupancies are used of the gathering of people. These areas will have the highest occupant loads of any occupant classifications at Centennial Station. The assembly occupancy is separated into five sub-groups as follows:

- A-1 – uses with fixed seating, intended for viewing of performing arts or motion pictures including movie theaters, concert halls, and theaters;
- A-2 – uses intended for food and/or drink consumption including night clubs, restaurants, and bars;
- A-3 – uses intended for worship, recreation, or amusement including bowling alleys, places of religious worship, gymnasiums, lecture halls, libraries, museums, and pool halls;
- A-4 – uses intended for viewing of indoor sporting events including arenas, skating rinks, swimming pools, and tennis courts;
- A-5 – uses intended for participation in or viewing of outdoor activities including bleachers, grandstands, and stadiums.

Centennial Station will have assembly areas including: the training center, press room, and conference rooms. It is noted that the conference rooms which have an occupant load of less than 50 persons or is less than 750 square feet are not considered assembly, but rather, are areas accessory to the business occupancy.

5.1.3 Business

Business occupancies are for use of service-type transactions; specifically, banks, administration facilities, data processing, and professional services are included in this group. The group will have a moderate fuel load such as desks, chairs, printers, and tables are expected to be included in the space. Centennial Stations primary use is office space, the majority of the floor area will be used for business occupancy.

5.1.4 Institutional

Institutional use occupancies are specified for occupants who will required assistance or are not capable of exiting the building. The institutional occupancy group includes board and care facilities, drug centers, nursing homes, mental hospitals, prisons, jails, correctional facilities, and daycare facilities. Institutional groups are subdivided into the following subgroups:

- I-1 – intended for use by more than 16 persons, who require 24-hour care due to age or mental disability; these include assisted living facilities, halfway houses, group homes, and alcohol and drug centers;

- I-2 – intended for medical, surgical, psychiatric, nursing, or custodial care of more than five people that are not capable of self-preservation on a 24-hour basis. This occupancy group includes hospitals, nursing homes, mental hospitals, and detoxification facilities;
- I-3 – intended for use by occupants which are incapable of self-preservation due to security measurement. This group includes prisons, jails, detention centers, and correctional centers. I-3 occupancies are further divided into five subcategories based on the level of physical restraint of the occupants;
- I-4 – intended for use as a day care facility limited to use less than 24 hours per day by more than five persons.

Centennial station will house three holding cells on the first floor meeting the definition of an I-3, Condition 5 classification, for occupants which are physically restrained and movement is restricted to staff-controlled manual release. However, I-3 occupancies are specifically defined as having greater than five persons, thus the holding cells at Centennial Station are accessory to the business occupancy.

5.1.5 Incidental Use

As part of a mixed use building certain areas are required to be protected as a higher hazard than the rest of the building. These areas are often considered incidental use areas including furnace rooms, parking garages, laundry rooms, waste collection rooms, storage rooms, padded holding cells, and parking garages. These incidental use areas have specific separation and/or protection requirements in accordance with Table 508.2 of the IBC. Specifically, the parking garage will require 1-hour fire-resistance-rated separation and an automatic sprinkler system and storage rooms greater than 100 square feet are required to have automatic sprinkler protection. Where fire-resistance-rated separations are required by Table 508.2, they shall be constructed to meet the requirements of Section 706 of the IBC for fire rated construction assemblies.

5.1.6 Parking/Vehicle Storage

Parking garages are required to meet special requirements are detailed in Section 406.2 of the IBC. The parking garage on the east side of Centennial Station meets the definition of an open, attached parking garage and will be required to meet the requirements set forth by Section 406.2.

5.1.7 Special Use

Atriums are considered special use occupancies as defined by the IBC as an opening connecting two or more stories other than stairways, elevators, and mechanical shafts. The atrium located in the lobby of the Centennial Station, on the north side of the building, meets the definition of an atrium as it connects three stories. The atrium will require special installation methods related to the wet-pipe sprinkler system, fire alarm system, and a smoke control system as required by Section 404 of the IBC. The atrium can be seen in Image 3.

Image 3 – Atrium Exterior

5.1.8 Storage

Storage occupancies are specified for storage items which are not defined as hazardous materials. Storage occupancy classifications are further divided into two subcategories:

- S-1 – intended for storage of moderate-hazard storage including bamboos, baskets, books and paper, shoes, cardboard, furniture, furs, glues, grains, leather, lumber, and motor vehicle repair garages;
- S-2 – intended for storage of low-hazard items including beverages, electrical motors, empty cans, food products, frozen products, gypsum board, meats, metal cabinets, metals, mirrors, parking garages, stoves, and washers and dryers.

Centennial station will have various storage rooms located on each floor. The majority of the storage rooms will be classified as group S-1 storage; however, the parking and vehicle storage on the first floor will be classified as group S-2 storage.

5.2 Building Construction

All buildings are constructed of specific classifications as defined in Chapter 6 of the IBC. The construction classifications are based of the fire-resistance ratings of structural elements, bearing walls, nonbearing partitions, floor construction, and roof construction. The building construction classifications are divided into the following categories:

- Type IA an IB – constructed of noncombustible materials with structural frame and bearing walls having specific fire-resistance ratings;

- Type IIA and IIB – constructed of noncombustible materials, generally not requiring fire-resistance ratings of structural members or walls;
- Type IIIA and IIIB – constructed of noncombustible exterior walls and combustible or limited-combustible interior walls and roof;
- Type IV – constructed of heavy timber in which the exterior walls are constructed of noncombustible materials.
- Type VA and VB – construction of combustible materials throughout the structure.

The building construction classifications are further divided into subcategories A and B when specific elements are required to have fire-resistance ratings. The categories are defined by the fire-resistance rating of the building elements as indicated in the Table 1 below, Table 601 of the IBC.

Table 1 – Fire-Resistant Ratings of Building Elements

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A ^e	B	A ^e	B	HT	A ^e	B
Structural frame ^a	3 ^b	2 ^b	1	0	1	0	HT	1	0
Bearing walls									
Exterior ^g	3	2	1	0	2	2	2	1	0
Interior	3 ^b	2 ^b	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions	See Table 602								
Exterior									
Nonbearing walls and partitions	0	0	0	0	0	0	See Section 602.4.6	0	0
Interior ^f									
Floor construction									
Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction									
Including supporting beams and joists	1 1/2 ^c	1 ^{c, d}	1 ^{c, d}	0 ^{c, d}	1 ^{c, d}	0 ^{c, d}	HT	1 ^{c, d}	0

Centennial Station is constructed of type II-B construction. The structural frame, bearing walls, nonbearing partitions, floor, and roof are to be constructed of noncombustible materials. Because the subcategory is B, none of the building elements are required to have a fire-resistance rating.

Image 4 – Building Structure

Image 4 above shows the construction of Centennial Station. The picture is from the north looking south. The concrete structure in the center of the building is the stairway and elevator shaft near the lobby of the atrium. The steel columns can be seen on the corners of the building. The steel beams and girders can be seen supporting the poured concrete floors. This is a typical design philosophy for a building this height, of this use, and requiring Type II-B construction. Structural plans were not available; however, the columns are shown on the plans in the appendix.

Details of the floor construction are unknown; however, it is assumed that a typical design of poured light weight concrete with steel reinforcement poured on a ribbed metal deck. Image 5 shows the assumed construction method of the floor assemblies.

Image 5 – Typical Floor Construction

5.3 Allowable Height and Area

The IBC allows specific maximums with regards to the building height from grade, the number of stories, and the area per story for every building. The allowable height and area is based on construction type of a building and if the building is protected throughout by an automatic sprinkler in accordance with Section 903.3.1.1. Centennial Station is a B – business occupancy protected by an automatic sprinkler system throughout, is constructed of Type II-B construction, and has a maximum height of 48 feet above grade.

In accordance with section 503 of the IBC, Table 503 is applied to Centennial Station. The maximum building height is 55 feet and the maximum number of stories is four; however the building height is increased by 20% and the number of stories is increased by one for sprinklered buildings per Section 504.2 of the IBC. Therefore, the maximum building height is 66 feet and the maximum number of stories is five.

The maximum area of per story of the building is limited to 23,000 square feet per Table 503 of the IBC; however, the area is allowed to be increased in accordance with Section 506.1 of the IBC. The area increase is to be calculated using the following equation:

$$A_a = \{A_t + [A_t * I_f] + [A_t * I_s]\}$$

Where A_a is the allowable area per story in square feet, A_t is the tabular area per story in accordance with Table 503 in square feet, I_f is the area increase factor due to frontage as calculated in accordance with Section 506.2, and I_s is the area increase factor due to sprinkler

protection as calculated in accordance with Section 506.3. Section 506.3 specifies an I_s of two for sprinklered buildings greater than one story.

The frontage increase applies to all buildings which have access to a public way where a minimum of 25% of the buildings perimeter is open to a public way or open space having a minimum width of 20 feet. The frontage increase is calculated using the following equation:

$$I_f = \left[\frac{F}{P} - 0.25 \right] * \frac{W}{30}$$

Where F is the building parameter that fronts on a public way in feet, P is the perimeter of the building in feet, and W is the width of the public way. F and P were measured to be 340 feet and 690 feet respectively. Centennial Station fronts South Peoria Street to the west and East Easter Avenue to the north; South Peoria Street was measured to be 80 feet wide and East Easter Avenue was measured to be 40 feet. The value used for W was 60 feet, an average of the two public ways. The calculated area increase is shown in Table 2 below:

Table 2 – Area Increase Calculation

Area Increase Calculation		
A_a	80167	square feet
A_t	23000	square feet
I_f	0.49	-
I_s	2	-
F	340	feet
P	690	feet
W	60	feet

The calculated maximum area for the floor area per story is 80,167 square feet greatly exceeding the maximum area of 23,724 square feet, the area of the first floor. Centennial Station is within the allowable limits set by Table 503 of the building code.

5.4 Building Use and Construction Summary

The construction type met the requirements of the IBC for the expected use. This type of construction is very typical for a building of this use, business, and of this height, four floors. Section 7 will detail the sprinkler system which will affect the requirements of the building construction.

6.0 EGRESS ANALYSIS

Using the building use, construction type, and building floor plans, the egress systems will be analyzed in Section 6. A summary of the codes used for the life safety analysis is shown Table 3. The code requirements shown in Table 3 will be detailed throughout Section 6.

Table 3 – Code Analysis Summary

Code Analysis Summary			
Applicable Code			
International Building Code 2006 Edition			
Occupancy:	Code Section	Occupant Load Factor	
Assembly (Chairs and Tables)	Table 1004.1.1	15 Net	
Assessory Storage, Mech., and Elec.	Table 1004.1.1	20 Net	
B (Business)	Table 1004.1.1	100 Gross	
E (Education)	Table 1004.1.1	20 Gross	
S-1 (Parking)	Table 1004.1.1	200 Gross	
Height/Area Requirements	Code Section	Max Stories	Max Area per Floor
B (Business)	Table 503	4	80,167
Actual Height/Area	Code Section	Max Stories	Max Area per Floor
B (Business)	Table 503	4	23,456
Note: Increases in area are included based on sprinkler protection and building perimeter.			
Seperation Requirements	Code Section	Requirement	Provided
Seperation Between B and S-1	Table 508.3.3	None	None
Interior Finishes	Code Section	Requirement	Provided
Exit Enclosures	Table 803.5	B	B
Corridors	Table 803.5	C	C
All Other Areas	Table 803.5	C	C
Construction Type	Code Section	Requirement	Provided
II-B	Table 601	None	None
Fire Rated Construction	Code Section	Requirement	Provided
Exit Stairways	1020.1	2-Hour	2-Hour
Corridors	Table 1017.1	0	0
Egress Components	Code Section	Requirement	Provided
Corridor Width (inches)	Table 1017.2	44	60
Door Width (inches/person)	Table 1005.1	0.2	See Life Safety Plans
Stair Width (inches/person)	Table 1005.1	0.3	See Life Safety Plans
Common Path of Travel	Table 1014.3	100	See Life Safety Plans
Exit Access Travel Distance B (feet)	Table 1016.1	300	See Life Safety Plans
Exit Access Travel Distance S-1 (feet)	Table 1016.1	250	See Life Safety Plans
Dead End (feet)	1017.3(2)	50	See Life Safety Plans
Number of Exits	Table 1019.1	2	2
Exit Seperation	1015.2.1	1/3 Diagonal	> Minimum

The table above is not meant to be all inclusive, the following analysis will detail all codes applied to Centennial Station.

6.1 Egress Components

Means of egress are divided into the following components: exit access, the exit, and the exit discharge. Exit access includes the portion of a means of egress that lead an occupant from an occupied portion of the building to an exit, this includes rooms, open office areas, and corridors. The exit is the portion of a means of egress which connects the exit access to the exit discharge; these areas are built of fire-resistance rated constructions to separate the exit from the rest space. Exits include exterior exit doors at the ground level, exit passageways, and exit stairways. The exit discharge is the portion of the egress system which leads from the termination of the exit to a public way; where a public way is defined as a street or alley that has been dedicated to the public, for public use.

The egress components included in the means of egress system for Centennial Station are to be building in accordance with Chapter 10 of the IBC. The specific requirements of this chapter will be detailed in this section of the analysis.

6.1.1 General Means of Egress

All portions of means of egress system in buildings constructed in accordance with Chapter 10 of the IBC are to meet specific requirement with regards to egress. These requirements must be met to ensure that occupants will have a clear, unobstructed path through the building to reach an exit, within a specific travel distance. At a minimum the ceiling height of any building is to be 7 feet 6 inches, with no objects protruding lower than 6 feet 8 inches in accordance with Sections 1003.2 and 1003.3 of the IBC. The floor to floor elevation at Centennial Station is 12 feet; acoustic ceilings are to be installed at 9 feet above the finish floor, leaving 3 feet interstitial space above the acoustic ceilings and the bottom of the floor above. Therefore, the clearance throughout the building will be acceptable. The minimum door height will be 6 feet 8 inches, as low as allowable for protruding objects.

6.1.2 Occupant Load

Before the egress components can be designed, the occupant load must be known to verify that the capacity of the exits will be adequate for the maximum number of people in the building. The design occupant load is calculated based on the floor area needed by each occupant of a space, as specified for the use of the space. The required floor area per occupant is provided in Table 1004.1.1 of the IBC shown in Table 4 below.

Table 4 – Occupant Load Factor

FUNCTION OF SPACE	FLOOR AREA IN SQ. FT. PER OCCUPANT		
Accessory storage areas, mechanical equipment room	300 gross		
Agricultural building	300 gross	Exercise rooms	50 gross
Aircraft hangars	500 gross	H-5 Fabrication and manufacturing areas	200 gross
Airport terminal		Industrial areas	100 gross
Baggage claim	20 gross	Institutional areas	
Baggage handling	300 gross	Inpatient treatment areas	240 gross
Concourse	100 gross	Outpatient areas	100 gross
Waiting areas	15 gross	Sleeping areas	120 gross
Assembly		Kitchens, commercial	200 gross
Gaming floors (keno, slots, etc.)	11 gross	Library	
Assembly with fixed seats	See Section 1004.7	Reading rooms	50 net
Assembly without fixed seats		Stack area	100 gross
Concentrated (chairs only—not fixed)	7 net	Locker rooms	50 gross
Standing space	5 net	Mercantile	
Unconcentrated (tables and chairs)	15 net	Areas on other floors	60 gross
Bowling centers, allow 5 persons for each lane including 15 feet of runway, and for additional areas	7 net	Basement and grade floor areas	30 gross
Business areas	100 gross	Storage, stock, shipping areas	300 gross
Courtrooms—other than fixed seating areas	40 net	Parking garages	200 gross
Day care	35 net	Residential	200 gross
Dormitories	50 gross	Skating rinks, swimming pools	
Educational		Rink and pool	50 gross
Classroom area	20 net	Decks	15 gross
Shops and other vocational room areas	50 net	Stages and platforms	15 net
		Warehouses	500 gross

The floor area per occupant is determined by the use of the space. Uses where large numbers of people are expected to be in one space at a time will have lower areas per occupant. For example, assembly areas without fixed seating would expect a large amount of people in one space; however, storage space will have the majority of the floor space used for storage of items and would be expected to not be occupied by many people at one time, thus the floor area per occupant is much larger. When determining the occupant loads either the gross area or the net area of the space is used. The gross area is measured at the inside of the perimeter of the exterior walls of the building without deduction for corridors, stairways, closets, columns, and other features. The net area is measured as the actual occupied floor area not including unoccupied areas such as corridors, stairways, restrooms, and mechanical rooms.

Primarily, the occupant load factor used at Centennial Station is 100 square feet per occupant as specified for office spaces. This allows for furniture such as tables, chairs, file cabinets, and cubicles. An occupant load factor of 100 square feet was used for both offices and open office space. The assembly areas used an occupant load factor of 15 square feet per occupant because the assembly areas had unconcentrated seating using tables and chairs. Training Room 256 was calculated using the number of fixed seats, plus an occupant load factor of 15 square feet per person the front of the room for a “stage” use. Storage areas were calculated using 300 square feet per person. The restrooms, break rooms, locker rooms, and Fitness Area occupant loads were not included in the total occupant load calculation as these areas were determined to be accessory to the business occupancy and would not be occupied at the same time as the business

areas as permitted by Section 1004.1 of the IBC. The occupant load for each space in Centennial Station is shown in Appendix C on sheets LS-5 through LS-8 using the tag shown in Image 6 below:

ROOM USE	
AREA	OLF
OCCUPANCY	

Image 6 – Room Use Identification Tag

The top row of the tag identifies the uses of the space such as business, assembly, storage, education, or storage. The middle row of the tag indicates the floor area of the perimeter of the interior walls of the space and the occupant load factor (OLF) used from Table 1004.1.1 of the IBC. The bottom row of the tag indicates the total occupant load of the space. The occupant load is calculated by dividing the total area by the occupant load factor and rounding up to the nearest whole number. The combined occupant load for each space is shown for each floor is shown in Table 5 below.

Table 5 – Building Occupant Load Summary

Building Occupant Load Summary	
Floor	Occupant Load (persons)
1	103
2	250
3	230
4	261
Building Total:	844

6.1.3 Egress Width

The IBC specifies egress width factors per occupant for both egress doors and stairways. The exit doors and stairways are to be sized appropriately to accommodate the maximum occupant load as calculated in the previous section of this analysis. The egress width factors per occupant served are based on the occupancy of the building, whether or not the building is protected by a sprinkler system, and the egress component. Hazardous and institutional occupancies will have greater width factors compared to all other occupancies. Furthermore, nonsprinklered buildings will require greater width factors as specified by Table 1005.1 of the IBC. The egress width factors used for Centennial Station will be 0.2 inches per occupant for stairways and 0.15 inches per occupant for other egress components including doors. Each exit has been tagged on drawings LS-5 through LS-8 in appendix C. The tag is shown in Image 7 below:

ACTUAL WIDTH
REQUIRED WIDTH
ACTUAL CAPACITY
MAXIMUM CAPACITY

Image 7 – Exit Capacity Identification Tag

The top row is the actual clear width of the egress component in inches. The row below is the required width in inches, calculated by multiplying the occupant load served by the egress width factor. The next row down is the actual capacity, the number of occupants expected to use the egress component divided by the number of exit available. The bottom row is the maximum capacity, the actual width of the egress component divided by the egress factor. Note that the minimum door width is not to be less than 32 inches in accordance with Section 1008.1.1 of the IBC and the minimum width of stairways is not to be less than 44 inches in accordance with Section 1009.1 of the IBC.

The doors leading into the stairways at Centennial Station are 36 inches wide; however, the clear width used to calculate the exit capacity is 34 inches. The stairways have been measured to be 44 inches wide, the clear width between the hand rails is 40 inches. The south exit on the first floor is 34 inches and the two north exits are 70 inches each.

Additionally, where multiple means of egress are provided they shall be sized such that the loss of any means of egress will not reduce the available occupancy by less than 50 percent in accordance with Section 1005 of the IBC. Because Centennial Station is designed with two egress stairways the loss of one of the stairways will reduce the egress capacity by 50 percent in compliance with the IBC.

6.1.4 Egress Illumination and Signage

To ensure occupants are able to find an exit in the event of power outage and during emergencies egress pathways are required to be illuminated and exit signage is to be installed. The illumination for the means of egress is to be provided per Section 1006 of the IBC. Illumination shall be provided automatically in the event of power supply failure in the following locations:

- Spaces that require two or more means of egress;
- Corridors, exit enclosures, and exit passageways where two or more exits are required;
- Exterior landings for exit discharge doorways in buildings;

Centennial Station is equipped with an on-site generator on the southeast corner of the building to provide power to the building in the event of power failure. The generator shall be capable of providing power for a minimum duration of 90 minutes in accordance with Section 1006.3 of the IBC. The performance of the system shall be as defined by Section 1006.4 of the IBC:

Emergency lighting facilities shall be arranged to provide initial illumination that is at least an average of 1 foot-candle and a minimum at any point of 0.1 foot-candle measured along the path of egress at floor level. Illumination levels shall be permitted to decline to 0.6 foot candle average and a minimum at any point of 0.06 foot-candle at the end of the emergency lighting time duration. A maximum-to-minimum illumination uniformity ratio of 40 to 1 shall not be exceeded.

In the event of an emergency, such as fire, the exits and exit pathways are to be clearly marked by exit signage indicating exits and exit access doors. The exit signs are shown on the Life Safety plans LS-5 through LS-8. In addition to the exits and exit access doorways the exit signs shall be located in the corridor at intervals not greater than 100 feet and in rooms where more than one exit is required. The exit signs at Centennial Station are to be externally illuminated and comply with Section 1011.5 of the IBC. The letters on the sign are to be at least 6 inches in height and shall have an intensity of not less than 5 foot-candles. All exit signage shall be illuminated at all times and powered by a source with will ensure continued illumination for a

duration of at least 90 minutes when primary power is lost. Signs are permitted to have secondary power via batteries or the on-site generator.

6.1.5 Exit Access and Travel Distance

The required distance for an occupant to travel from the most remote point of any story to an entrance to an exit is limited in accordance with Section 1016 of the IBC. The travel distance shall be measured along the natural and unobstructed path of egress travel. Travel distances vary based on occupancy and sprinkler protection of the building as shown in Table 6 below, Table 1016.1 of the IBC.

Table 6 – Exit Access Travel Distance

OCCUPANCY	WITHOUT SPRINKLER SYSTEM (feet)	WITH SPRINKLER SYSTEM (feet)
A, E, F-1, I-1, M, R, S-1	200	250 ^b
B	200	300 ^c
F-2, S-2, U	300	400 ^c
H-1	Not Permitted	75 ^c
H-2	Not Permitted	100 ^c
H-3	Not Permitted	150 ^c
H-4	Not Permitted	175 ^c
H-5	Not Permitted	200 ^c
I-2, I-3, I-4	150	200 ^c

The maximum travel distance for the A and S-1 occupancies in the Centennial Station will be limited to 250 feet; the B occupancies are limited to 300 feet. The longest travel distance found in Centennial Station is 231 feet on the second floor exiting from Audio 250, through rooms Tech. Workroom and Open Office 246, continuing through the corridor to Stairway 1. The maximum travel distances and travel paths for all areas of the building are shown on the Life Safety plans, sheets LS-5 through LS-8. Though other travel paths are available only the longest paths are shown on the plans for clarity.

Where only one exit is provided from a space the common path of travel and shall be less than the distances specified in Section 1014 of the IBC. The common path of travel for A occupancies are limited to 75 feet, common paths of travel for Group B and S occupancies is not to exceed 100 feet for sprinkler buildings in accordance with Section 1014.3 of the IBC. Furthermore, dead end corridor distances are limited to ensure adequate, safe egress paths. Dead end corridors with lengths of 2.5 times greater than their width shall not exit 20 feet for A and S occupancies and 50 feet for B occupancies in accordance with Section 1017.3 of the IBC. The longest dead-end corridor is shown on the second floor of the Life Safety plans; the length of the dead-end corridor is 20 feet. The longest common path of travel was found in Open Office 312, measured to be 115 feet, exceeding the length allowed by the IBC. It is suggested that an additional path of egress through Break Room 310 be provided to eliminate the common path of travel through the open office. Lengths of other common paths of travel are shown on for all floors, though only the worst cases are shown on the plan for clarity.

To allow occupants adequate time to safely reach exit access the corridors and stairways are often required to be constructed of fire-resistance rated construction. The corridor construction is to be in accordance with Section 1017, specifically Table 1017.1. Table 1017.1 requires corridors serving more than 30 persons in A, B, and S occupancies be constructed of fire-resistance rated construction complying with Section 708 of the IBC; however, when the building is equipped with a sprinkler system the corridors are permitted to not be rated, thus the corridors at Centennial Station will not be of rated construction. Additionally, the corridors shall not be less than 44 inches wide. The corridors at Centennial Station are to be 60 inches wide, complying with Section 1017.2 of the IBC.

Stairways are to be constructed of fire-resistance rated construction as required for vertical enclosures per Section 1020 of the IBC as defined for vertical exit enclosures. Vertical exit enclosures are to be rated for not less than 1-hour when connecting less than four floors and not less than 2-hours when connecting four or more floors. The two exit stairways at Centennial Station will both serve four floors and shall be constructed with 2-hour fire-resistance rated construction per Section 1020.1. The construction of the fire rated barriers shall be in accordance with Sections 706 and 711 of the IBC. Because the stairway is to be rated for 2-hours the exit passageway from Stairway 2 leading to the exterior of the building shall also be a 2-hour fire rated barrier in accordance with Section 1021.3 of the IBC.

The path of egress travel is not to be interrupted. This may include doors opening into corridors, as indicated by the red arrow in Image 8 below in Corridor 257. The door from Training Room 256 is recessed such that the door opening will not protrude into the corridor.

Image 8 – Second Floor Corridor

Furthermore, the means of egress system is not to be diminished along the path of travel as specified by Section 1003.6, the egress component capacity is not to decrease as the occupants exit.

6.1.6 Number of Exits

It is necessary to have a minimum number of exits from each story to ensure occupants have adequate options to egress from the building. The minimum number of exits is specified by Table 1019.1 of the IBC where each story is to have a minimum of two exits for 1-500 occupants, three exits for 501-1,000 occupants and four exits when there are more than 1,000 occupants per story. Because no single floor occupant load exceeds 500 persons, two exits are acceptable for Centennial Station.

Furthermore, all rooms and spaces within each story shall be provided with the minimum number of exit access doorways as shown in Table 1015.1 of the IBC, Table 7 below.

Table 7 – Spaces with One Means of Egress

OCCUPANCY	MAXIMUM OCCUPANT LOAD
A, B, E ^a , F, M, U	49
H-1, H-2, H-3	3
H-4, H-5, I-1, I-3, I-4, R	10
S	29

Table 1015.1 indicates maximum occupant loads of a space permitted to have one exit. For A and B occupancies, one exit is allowed when the occupant load is less than 50. S occupancies are allowed to have one exit when there are less than 30 occupants.

None of the storage areas in Centennial Station exceed 29 occupants thus one exit access doorway is acceptable; however, Press Room 233, Training 256, and Executive Conference Room 402 all exceed 50 occupants requiring two exits. The three areas listed above do have two exits, but further codes requirements are to be met. In accordance with Section 1015.2.1 exception 2 – where two exit access doorways are required they must be separated by a distance of not less than one-third of the maximum overall diagonal of the area served.

Table 8 – Exit Access Doorway Separation

Space	Maximum Diagonal Dimension (feet)	One-Third Diagonal Dimension (feet)	Door Separation (feet)
Press Room 233	41	14	19.5
Training Room 256	66	22	42
Executive Conference Room 406	55	18	19.5

Table 8 shows the measure measurements of the maximum diagonal dimension and the door separation. The door separation must be greater than one-third the maximum diagonal dimension, as shown all three spaces are acceptable.

6.1.7 Exit Discharge

As previously defined the exit discharge is to allow egress from the building to a public way. Exit discharge at Centennial Station is provided on the first floor with two exits in the main entrance and one exit on the south side of the building. Exit discharge from the second through fourth floors is obtained through Stairways 1 and 2 shown on the plans. The stairways present special consideration as the discharge on the first floor is not directly to the exterior of the

building. Egress from Stairway 2 to the exterior is through an exit passageway constructed with a 2-hour fire rated barrier protected by the automatic sprinkler system. Egress through Stairway 1 is not through a protected exit passageway; this is permitted by Section 1024.1 exception 1 for a maximum of 50 percent of the number and capacity of the exit enclosures, though the egress path is to the exit is to be unobstructed, clearly visible, and protected by an automatic sprinkler system. Egress from Stairway 1 through the main lobby meets the requirements of exception 1.

Exit discharge is to lead directly to a public way with an unobstructed path. An unobstructed path is not available because of the security fencing around Centennial Station; however, the fence has a minimum separation from the building of 140 feet to the south and 320 feet to the north. In accordance with Section 1024.6 access to a public way is not required when a safe dispersal area is available further than 50 feet from the building. A walking path surrounding Centennial Station allows for adequate separation and necessary area for occupants to congregate at a safe distance from the building.

6.2 Egress Analysis Summary

Analysis of the egress systems of Centennial System found that most areas are compliant; however, it is suggested that an additional path of egress though Break Room 310 be provided to eliminate the excessive common path of travel though Open Office 312. Egress through the building is of a good design providing two separate exits provided the egress corridor on the south side of the building is maintained. It will be critical to maintain the rating of the corridor to ensure the system is compliant with the IBC. It will be critical that the sprinkler system and fire alarm system detailed in Sections 7 and 8 are designed appropriately based on requirements set forth by the egress analysis.

7.0 SUPPRESSION SYSTEM DESIGN CRITERIA

Centennial Station will be equipped with two independent sprinkler risers fed from the same underground supply. The supply will come from the city main running along South Peoria; the supply will run directly into the building and a sprinkler riser will be provided in the northeast corner of the building. The riser room will contain the backflow preventer and two sprinkler system risers. The fire alarm system will be designed as described in Section 8 based on the sprinkler systems designed.

One wet-pipe sprinkler system will be installed to protect the heated spaces of the building; this will include the majority of the first floor and all of the second, third, and fourth floors. Because the total floor area for each floor is less than 52,000 square feet one system is acceptable to protect the building in accordance with NFPA 13 Section 8.2.1 for light hazard systems. A control valve and water flow switch will be provided on each floor. Any concealed spaces above the ceiling in the building will not be required to be sprinkler in accordance with NFPA 13 Section 8.15.1.2.1 because the concealed spaces are constructed of noncombustible construction.

The second riser will be equipped with a dry-pipe valve to protect the parking areas, generator room, and loading dock within the facility. Because of the cold temperatures associated with the location of the facility these parking areas have the potential to be exposed to sub-freezing temperatures. To ensure the sprinkler system is not prone to failure from freezing the pipe in these areas will not normally be filled with water. The requirements for the dry-pipe sprinkler system differ from those of the wet-pipe system; these differences will be discussed in detail throughout this analysis.

In general, the wet-pipe sprinkler system will be a gridded system. There will be a 4-inch main running east to west on the north side of the building and there will be a 2 inch floating main running east to west on the south side of the building. The branchlines will connect the mains running north to south. The dry-pipe sprinkler system will be a tree system running north from the riser room to the south end of the building. The majority of the sprinkler heads will be quick response standard spray pendent sprinkler heads, where the ceiling is open to the structure quick response standard spray upright sprinkler heads will be used. The specific design criteria for the sprinkler heads will be included in detail in the following sections of this analysis.

The hydraulically most demanding areas are expected to be the light hazard areas on the fourth floor and the remote area for the dry system will be the largest parking area on the first floor. Hydraulic calculations will be performed both by hand and using the hydraulic calculation software SprinkCAD. The hydraulic calculations will be provided in this analysis.

7.1 Classification of Occupancies

Each area of the building will be classified as light hazard, ordinary hazard, extra hazard, or special hazard. The hazard classification is based on the intended use and expected fuel load in each area. Light hazard is associated with a relatively light load of combustibles. Ordinary hazard has a greater load of combustibles and may contain other more combustible materials. Extra hazard has the greatest possible fuel load and may also include combustible fuels or other hazardous materials based on quantity. Special hazard area include the storage based on specific heights and may also include other storage limitations; it is not likely that Centennial Station will include extra hazard or special hazard storage. The occupancy classifications have been identified for each area of the building on Sheets FS-1 through FS-4 in Appendix C. The sprinkler design will be based on the classification of the area; greater hazard areas will require a greater density of water applied to each square foot of the floor area. The density/area curves are found in Image 9 from NFPA 13 Section 11.2.3.1.1.

Image 9 – Density/Area Curves

The image above specifically defines the density of water in gallons per square foot (gpm/sf) and the area that density is required to be provided for each occupancy classification. In addition to the design density the occupancy will require specific hose stream requirements. The Table 9,

NFPA 13 Table 11.2.3.1.2, identifies the hose stream required as well as the duration the hose stream is required to be provided.

Table 9 – Hose Stream Allowance and Duration

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

The minimum hose stream will be applied to the hydraulic calculation when determining the required sprinkler application rate.

7.1.1 Light Hazard

The majority of Centennial Station will be designated as light hazard. Light hazard occupancies have a minimal fuel load including general office furniture and minimal storage. Section A.5.2. of NFPA 13 specifies the following uses as light hazard:

- Animal shelters;
- Churches;
- Educational
- Hospitals;
- Institutional;
- Museums;
- Offices;
- Unused attics.

The light hazard areas will be protected using a density of 0.10 gpm/sf over an area of 1,500 square feet in accordance with Table 11.2.3.1.2 of NFPA 13. Where allowed the area of application will be reduced in accordance with Figure 11.2.3.2.3.1 of NFPA 13. This reduction will be 40 percent for ceiling heights of 10 feet or less as found in Centennial Station. The required hose stream allowance will be 100 gpm for a minimum duration of 30 minutes.

7.1.2 Ordinary Hazard

Specific areas of Centennial Station are to be protected with a sprinkler system capable of controlling fires with greater heat release rates and greater fuel loads. These areas will be designated as ordinary hazard. Ordinary hazard groups are divided further into Groups 1 and 2.

7.1.2.1 Ordinary Hazard Group 1

Ordinary hazard group 1 will be used to classify the areas of the building which have low combustibility and fires with moderate heat release rates. Section A.5.3.1 of NFPA specifies these types of facilities as the following:

- Automobile parking and showrooms;
- Bakeries;
- Laundries;
- Restaurant service areas.

More specifically, the areas in Centennial Station that will be classified as Group 1 are the parking areas, storage areas with storage less than 8 feet, copy/shred areas, mechanical rooms, and electrical rooms. Small storage areas with Class I and II commodities will be classified as Group 1. Larger storage rooms with the potential for racks and Class III and IV commodities will be classified as Group 2 as discussed in the next section of this analysis. The ordinary hazard Group 1 areas will be protected using a density of 0.15 gpm/sf over an area of 1,500 square feet in accordance with Table 11.2.3.1.2 of NFPA 13. The required hose stream allowance will be 250 gpm for a minimum duration of 60 minutes.

7.1.2.2 Ordinary Hazard Group 2

Ordinary hazard Group 2 areas will have a greater risk because of the fuel load and potential heat release rates. Ordinary hazard Group 2 areas are expected to have moderate to high combustible materials and moderate heat release rates. Section A.5.3.1 of NFPA 13 specifies these types of facilities as the following:

- Barns;
- Mills;
- Dry cleaners;
- Libraries;
- Machine shops;
- Post offices;
- Stages;
- Manufacturing;
- Wood working.

Additionally, Group 2 areas will include storage rooms with storage heights greater than 8 feet and less than 12 feet, the generator room, and loading dock. The storage areas with the potential for rack storage and storage of Class III and IV commodities shall be classified as Group 2 as required by Table 13.2.1 of NFPA 13. The table defines storage of Class I through IV commodities on racks and palletized as Group 2 when stored less than 10 feet as expected in Centennial Station. Table 13.2.1 from NFPA 13 is shown in Table 10, the design criteria listed below meets the requirements for miscellaneous storage.

Table 10 – Discharge Criteria for Miscellaneous Storage

Commodity	Type of Storage	Storage Height		Maximum Ceiling Height		Design Curve Figure 13.2.1	Note	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
		ft	m	ft	m			gpm	L/min	gpm	L/min	
		Class I to IV										
Class I	Palletized, bin box, shelf, and rack	≤12	≤3.7	—	—	OH1		0, 50, or 100	0, 189, 379	250	946	90
Class II		≤10	≤3.05	—	—	OH1		0, 50, or 100	0, 189, 379	250	946	90
Class II		>10 to ≤12	>3.05 to ≤3.7	—	—	OH2		0, 50, or 100	0, 189, 379	250	946	90
Class III		≤12	≤3.7	—	—	OH2		0, 50, or 100	0, 189, 379	250	946	90
Class IV		≤10	≤3.05	—	—	OH2		0, 50, or 100	0, 189, 379	250	946	90
Class IV	Palletized, bin box, and shelf	>10 to ≤12	>3.05 to ≤3.7	32	—	OH2		0, 50, or 100	0, 189, 379	250	946	90
Class IV	Rack	>10 to ≤12	>3.05 to ≤3.7	32	—	EH1		0, 50, or 100	0, 189, 379	500	1893	120

The ordinary hazard Group 2 areas will be protected using a density of 0.20 gpm/sf over an area of 1,500 square feet in accordance with Table 11.2.3.1.2 of NFPA 13. The required hose stream allowance will be 250 gpm for a minimum duration of 60 minutes.

7.1.3 Extra Hazard

Extra hazard areas will contain highly combustible materials with high heat release rates. These types of areas will not be found in Centennial Station. Extra hazard occupancies have greater water demand requirements than those for ordinary and light hazard occupancies.

7.1.3.1 Extra Hazard Group 1

Extra hazard Group 1 occupancies are those which contain very high combustible materials with high heat release rates; however, flammable and combustible materials are not allowed in Group 1 areas. Section A.5.4.1 of NFPA 13 specifies these types of facilities as the following:

- Aircraft hangers;
- Hydraulic fluid use areas;
- Metal extruding;
- Upholstering with plastic foams.

Extra hazard Group 1 areas are protected using a density of 0.30 gpm/sf over an area of 2,500 square feet in accordance with Table 11.2.3.1.2 of NFPA 13. The required hose stream allowance will be 500 gpm for a minimum duration of 90 minutes.

7.1.3.2 Extra Hazard Group 2

Similar to extra hazard Group 1 areas the items in Group 2 areas are highly combustible and have high heat release rates, but Group 2 does include flammable and combustible liquids. It is noted that flammable liquids may be used in the Weapons Cleaning room, but the quantities of flammable liquids will be minimal, so a Group 2 designation is not warranted. Section A.5.4.2 of NFPA 13 specifies these types of facilities as the following:

- Asphalt saturating;
- Flammable liquids storage;
- Plastics manufacturing;
- Solvent cleaning;
- Varnish and paint dipping.

Extra hazard Group 2 areas are protected using a density of 0.40 gpm/sf over an area of 2,500 square feet in accordance with Table 11.2.3.1.2 of NFPA 13. The required hose stream allowance will be 500 gpm for a minimum duration of 90 minutes.

7.1.4 Special Hazard

NFPA 13 provides specific design criteria for special hazard areas. None of the special hazard items are expected at Centennial Station with the exception of miscellaneous storage which will be classified and protected as Ordinary Hazard Groups 1 and 2 as previously defined.

Protection of special hazards must be in accordance with the associated chapters listed below:

- Chapter 14 – Protection of Class I to Class IV Commodities That Are Stored Palletized, Solid Piled, Bin Boxes, or Shelf;
- Chapter 15 – Protection of Plastic and Rubber Commodities That Are Stored Palletized, Solid Piled, Bin Boxes, or Shelf Storage;
- Chapter 16 – Protection of Class I to Class IV Commodities That Are Stored on Racks;
- Chapter 17 – Protection of Plastic and Rubber Commodities That Are Stored on Racks;
- Chapter 18 – Protection of Rubber Tire Storage;
- Chapter 19 – Protection of Roll Paper;
- Chapter 20 – Special Designs of Storage Protection.

7.2 Water Supply

The water supply for the sprinkler system at Centennial Station will be from a 12 inch circulating main running along East Easter Avenue. The water is supplied by the Centennial Water District and has been determined to be adequate for the expected demand and reliable. A water flow test was performed on the locations shown in Image 10 below.

Image 10 – Hydrant Locations

The test was done by flowing water at the “Flow Hydrant” shown above. A gauge was installed on the “Test Hydrant”. The static pressure was determined to be 80 psi. A 2.5 inch orifice was opened on the flow hydrant and the residual pressure was documented. The residual pressure was measured to be 65 psi. While the water was flowing from the 2.5 inch orifice the velocity pressure was measured using a pitot tube. The pitot was determined to be 27. The flow from the hydrant was calculated using the equation: $Q = 29.83C_d D^2 \sqrt{P_v}$. Where Q is the flow in gpm, C_d is the discharge coefficient, D is the hydrant orifice diameter in inches, and P_v is the velocity pressure measured from the pitot tube. The discharge coefficient used was 0.9 for a rounded opening from the hydrant. The complete hydrant test summary is provided in Table 11.

Table 11 – Hydrant Test Summary

Hydrant Test Worksheet				
Project:	Centennial Station			
Project Address:	12154 East Easter Avenue, Englewood, CO 80112			
Tested By:	SMFR	Test Date:	May 6, 2008	
Witnessed By:	John Smith	Test Time:	1:00 pm	
Test Data				
Parameter	Flow Hydrant #1	Flow Hydrant #2	Flow Hydrant #3	
Size Opening	2.5			
Coefficient	0.9			
Pitot Reading	27			
Flow Rate (GPM)	871.9	0	0	
Total Flow for Test (GPM)	871.9			
Static Reading (psi)	80.0			
Residual Reading (psi)	65.0			
Equation for Flow: $Q = 29.83 \cdot C_d \cdot D^2 \cdot P^{(1/2)}$				
Note: The diameter coefficients are as follows - Rounded $C_d = 0.9$, Square $C_d = 0.8$, and Projected $C_d = 0.7$.				
Results				
Flow at 20 psi Residual	1843.2			
Flow at 0 psi	2153.0			
System Flow Demand				
System Pressure Demand				
Hydrant Flow Curve				

The table above shows the static pressure, residual pressure, and pitot. The flow is the calculated. The graph shows the static pressure with 0 gpm flow, the flow of 871.9 gpm at the residual pressure, and the expected flow at 20 psi. The flow to the sprinkler system is to be supplied without allowing the supply to be below 20 psi. The flow at 20 psi is calculated using the following equation:

$$Q = Q_T \left(\frac{P_S - 20}{P_S - P_R} \right)^{0.54}$$

Where Q_T is the flow at the residual pressure in gpm, P_S is the static pressure in psi, and P_R is the residual pressure in psi.

The supply will be provided to the building through a 4 inch PVC pipe as described in the underground portion of this analysis. The supply will rise into the building in the riser room as shown on the plans. The piping to the sprinkler system is required to be equipped with a backflow prevention device. A 4 inch Ames SS2000 double check backflow preventer has been chosen for this system. The backflow preventor will be installed horizontally before the risers for the wet-pipe and dry-pipe systems. The backflow preventor has two OS&Y gate valves on each side of the double check valve. The valve assembly is shown in Image 11.

Image 11 – Backflow Prevention Device

The backflow prevention device will decrease the pressure available in the system. It is necessary to include this pressure loss in the hydraulic calculations. The pressure loss associated with the valve is dependent on the quantity of water flowing through the valve. The flow through the valve for the wet-pipe sprinkler system is expected to be approximately 200 gpm, thus the pressure loss through the backflow preventer is expected to be 3 psi per the Ames SS2000 datasheet. The flow through the backflow preventer for the dry-pipe system is expected to be approximately 600 gpm with a pressure loss of approximately 6 psi.

Furthermore, a section of piping must be eliminated in the riser room to allow space in the pipe for the backflow prevention device. The length of the backflow preventer from flange to flange is 40 inches, this is to be accounted for in the design of the pipe through the riser room. The OS&Y gate valves on the backflow preventer are to be electronically monitored by the fire alarm system using tamper switches which will initiate a supervisory signal by the fire alarm panel of the valves are operated.

7.3 Sprinkler system installation requirements

The sprinkler system is to be designed and installed in accordance with NFPA 13, specifically chapters 6, 7, 8, and 11. These chapters will regulate the design of the risers, piping, head spacing, and head type. The system design for the wet-pipe riser, dry-pipe riser, and the sprinkler head locations will be detailed in this section. Furthermore, the requirements for the standpipe system will be addressed. The standpipe shall be designed in accordance with NFPA 14.

7.3.1 Sprinkler Head Requirements

There will be three different types of sprinkler heads installed at Centennial Station. All sprinkler heads will have K-Factors of 5.6 and ½ inch NPT threads. Pendent, concealed sprinklers have been chosen to protect the heated spaces of the building where drop ceilings, either gypsum board or acoustic ceiling tile, are installed. Brass upright sprinklers have been chosen to protect the unheated areas where the dry-pipe sprinkler system is installed as well as the heated areas where no ceiling is installed. The sidewall sprinkler heads will be used to protect specific unheated areas in the garage. All sprinkler heads will be quick response with 3 mm glass bulbs and are rated to be installed in light or ordinary hazard areas. All of the sprinklers installed will be ordinary temperature heads with an activation temperature of 155 degrees F with the exception of the generator room. The generator room will be protected by intermediate temperature heads with an activation temperature of 200 degrees F. The sprinkler system design is based on the Tyco TY3531 pendent sprinkler heads, the TY313 upright sprinkler heads, and the TY3331 sidewall sprinkler head.

The sprinklers in light hazard areas will be spaced in accordance with Table 8.6.2.2.1(a) for noncombustible construction. The sprinklers will be designed to have a maximum areas of protection of 225 square feet, utilizing sprinkler spacing of 15 feet. The maximum spacing of the sprinkler heads from any wall shall not be greater than 7 feet 6 inches unless permitted by NFPA 13. It should be noted that the sprinkler spacing in areas with a drop ceiling will be nominally 14 feet to allow the sprinkler heads to be evenly spaced in the center or quarter points of 2 feet by 4 feet acoustic ceiling tiles. Additionally, the sprinkler heads are to be separated by more than 6 feet and are not to be installed closer than 4 inches to a wall. The minimum head spacing is to prevent “cold soldering” between heads where the spray from a head less than 6 feet away would prevent the adjacent head from activating. The sprinkler system design is based on the Tyco TY3531, standard spray, pendent, quick response, ordinary temperature, concealed sprinkler.

The sprinklers protecting both the Group 1 and 2 ordinary hazard areas will be designed similarly to the light hazard areas; however, the maximum area of coverage will be 130 square feet.

The sprinkler head layout is shown in Appendix C. Because a full ceiling plan was not available potential obstructions are not possible to be designed around, but all obstruction rules are to be followed per Chapter 8 of NFPA 13. Clearance from obstructions is necessary to ensure the spray of the sprinkler will not be blocked shadowing parts of the floor area which are to be protected. Additionally, a minimum clearance from the sprinkler head deflector to storage is to be a minimum of 18 inches in accordance with Section 8.6.6.1 of NFPA 13.

Sprinklers have been installed along the glass separating the office area from the atrium. The sprinklers are to be spaced at 6 feet in accordance the Section 404.5 of the IBC. The sprinklers are provided in lieu of a 1-hour fire barrier required for the separation of atriums.

7.3.2 Wet-Pipe System Requirements

The wet-pipe sprinkler riser will be located in the Water Room 102 as shown on the sprinkler layout plans. The riser is to consist of a control valve, riser check valve, gauges, drain, hydraulic placard, spare sprinkler head box, and waterflow switch. An example of two wet-pipe sprinkler risers is shown in Image 12.

Image 12 – Typical Wet-Pipe Riser

The image above shows the supply from the floor. Above the supply is a butterfly control valve with a tamper switch and indicator showing the direction of the valve, note the control valves on both risers are in the closed position. The control valve will provide the ability to stop the flow of water to the system. The tamper switches on the control valve are to be monitored by the fire alarm control panel as required by Section 8.16.1.1.2.1 of NFPA 13. It should be noted that the riser at Centennial Station will have a fire department connection with a check valve before the control valve, the configuration above does not have an FDC connection in the riser. Directly above the control valve is the riser check valve which will allow water to only flow to the system and not back down the supply. The riser check valve is equipped with two gauges. One gauge is before the check valve and measures the supply pressure and the other gauge is above the check valve measuring the system water pressure. The check valve used will be a CV-1FR, this valve is also provided with a 2 inch drain – appropriate for a 4 inch riser in accordance with Table 8.16.2.4.2 of NFPA 13. A hydraulic placard is attached by a chain on the riser. The hydraulic placard is to indicate the original design parameters of the system including the maximum flow

and minimum required pressure to operate the system. Above the hydraulic placard is the paddle type water flow switch. The flow switch will monitor the sprinkler system for activation, water flowing through the pipe will move a paddle and initiate an alarm signal. The waterflow switch is to be monitored by the fire alarm control panel. To the left of the riser a spare head cabinet has been provided with a minimum of six of each type of sprinkler used in the building. The riser at Centennial Station will be similar to the orientation shown above.

The first floor will be supplied directly from the riser. The water supply will continue to a vertical riser routed through the stairwell to provide supply to the upper floors of the building. Each floor will have a floor control assembly. Each floor control assembly will have a control valve, drain, and waterflow switch. The control valve is to have a tamper switch monitored by the fire alarm control panel, the waterflow switch is to be monitored as well.

Continuing from the risers will be the feed main, the feed main for the wet-pipe system will be 4 inches. Because the system is gridded there will be a floating main on the opposite end of the building from the feed main, the floating main will be 2 inch pipe. The branchlines between the feed main and the floating main will be 1-1/2 inch pipe. All branchlines not between the mains will be sized based on the pipe schedule for light hazard areas shown in Table 12.

Table 12 – Pipe Schedule

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1¼ in.	3 sprinklers	1¼ in.	3 sprinklers
1½ in.	5 sprinklers	1½ in.	5 sprinklers
2 in.	10 sprinklers	2 in.	12 sprinklers
2½ in.	30 sprinklers	2½ in.	40 sprinklers
3 in.	60 sprinklers	3 in.	65 sprinklers
3½ in.	100 sprinklers	3½ in.	115 sprinklers
4 in.	See Section 8.2	4 in.	See Section 8.2

Because the sprinkler system will be hydraulically calculated it is not necessary for the entire system to follow the schedule above, but it was used for branchlines with 5 heads or less. The above table is from NFPA 13 Table 22.5.2.2.1.

The wet-pipe sprinkler system was calculated to provide 0.10 gpm/sf over 1035 square feet. To cover the design area eight heads operated. The minimum pressure at the sprinkler head was 16.1 psi. The maximum flow for the system is 282 gpm at a pressure of 51.4 psi. The hydraulic calculations will be discussed in detail in later sections of this analysis.

7.3.3 Dry-Pipe System Requirements

The dry-pipe sprinkler system will protect the unheated parking areas, the generator room, and the loading dock on the first floor of the building. The riser will be located adjacent to the wet-pipe riser in the Riser Room. The dry-pipe system will be supplied from the same underground piping, backflow preventer, and fire department connection as the wet-pipe sprinkler riser. The dry-pipe sprinkler system will have a riser similar to the risers shown in Image 13.

Image 13 – Typical Dry-Pipe Riser

The image above shows two dry-pipe sprinkler systems and one wet-pipe sprinkler system. The dry-pipe sprinkler systems are supplied from the horizontal pipe running along the bottom of the image. From the supply first is a butterfly control valve equipped with a tamper switch monitored by the fire alarm control panel. Above the control valve is the dry-pipe valve. The dry-pipe valve to be installed at Centennial Station is to be the Tyco DPV-1 four inch valve with all necessary trim. The dry-pipe valve uses differential pressure to control water flow into the pipe system, air pressure holds a clapper valve closed until the air is released from the dry-pipe system. The sprinkler piping will be pressurized with air from an air compressor to a pressure range of 20 – 28 psi for a water supply pressure of 80 psi per the datasheet for the DPV-1 valve. The valve trim includes gauges on the supply and discharge sides of the valve, an air pressure monitor, and a water pressure monitor – both of which will be monitored by the fire alarm control panel. The air pressure will be monitored for low pressure which may allow the valve to open inadvertently, the water pressure will be monitored for flow to the system. Above the dry-pipe valve is the hydraulic placard installed similarly to the wet-pipe system. Not seen in the image is the spare head cabinet which will house a minimum of six of each type of sprinkler head.

The dry-pipe sprinkler system will be a “tree” system fed from only one side. The riser will be 4 inch, but the main will be 3 inch and reduce down to 2 inch. The pipe size will follow the schedule provide for the wet-pipe system; however, the table is not required to be followed exactly because the system will be hydraulically calculated. The pipe in the sprinkler system shall be hot-dipped galvanized pipe to prevent corrosion normally associated with dry-pipe systems.

Because the sprinkler system is not normally filled with water there will be a delay in the application of water after a head fuses. The system water delivery time is to be 60 seconds per Section 7.2.3.2 of NFPA 13. The system volume is 108.9 gallons therefore a quick opening device is not required per Section 7.2.3.4 requiring systems greater than 750 gallons to have a quick opening device. The quick opening device is used to release air pressure at the riser allowing water to fill the pipe quicker reducing the water delivery time.

The purpose of the dry-pipe system is to allow sprinkler piping to be installed in unconditioned areas where water would freeze in a wet-pipe system. To ensure water is not left in the system the pipe is to be sloped $\frac{1}{4}$ inch per 10 feet on the main and $\frac{1}{2}$ inch per 10 feet on the branchlines so that water will flow back to the system drain in accordance with NFPA 13 Section 8.16.2.3.1. Where water may be trapped in the system auxiliary drains are to be installed.

The sprinkler system is calculated to provide 0.15 gpm/sf over an area of 1,950 square feet. The required maximum flow is 602.4 gpm including the hose stream allowance at a minimum pressure of 54 psi. The detailed hydraulic analysis is provided in other sections of this analysis.

7.3.4 Standpipe System Requirement

A standpipe system is an extension of the automatic sprinkler system which will provide hose connections in locations as specified by code. Centennial Station is required by Section 905.3.1 of the IBC to have a Class III standpipe system because the floor level of the highest story is greater than 30 feet above grade. The standpipe system shall be an automatic, wet, Class III system having a 1-1/2 inch hose connection for use by building occupants and 2-1/2 inch connection for use by the fire department. A class III hose connection is shown in Image 14.

Image 14 – Class III Hose Station

The hose stations are to be located as shown on the plans in Appendix C. The IBC requires the hose stations to be located at the intermediate floor level landing between floors in the stairway for all floors; however, it has been previously approved by the fire marshal to install the hose stations on the floor level to coordinate with the installation of the building riser and control assemblies. Identical standpipes will be provided in each stairway at Centennial Station. The standpipe system will be fed from the automatic sprinkler system. In addition to the stairways the hose connections are to be provide in the egress corridor on the first floor.

7.4 Hangers and Bracing

The fire sprinkler piping will be required to be supported throughout the system in accordance with Chapter 9 of NFPA 13. All pipe supports and hangers are to be listed for the installed use and specifically designed for that use. Generally, the all piping will be supported from the bar joists and the riser supplying the upper floors will be supported using riser clamps.

Starting at the riser the horizontal backflow preventer will be supported by pipe stands. Pipe stands will also be provided below the two risers, supporting the vertical load of the risers. The sprinkler system in Centennial Station will be a gridded system. The main will run east to west on the north side of the building and a floating main will run east to west on the south side of the building. The branchlines will run north to south throughout the building connecting the main and floating main. This design approach was taken because the bar joists in the building run east to west between the beams as shown in the image below. Image 15 was taken from the north side of the building looking south, the concrete structure in the center of the building is the elevator shaft adjacent to the atrium. Routing the branchlines north to south will provide the most practical way of hanging the sprinkler piping.

Image 15 – Building Structure

The mains will be supported by the bar joists when possible or trapeze hangers when bar joists are not available for support. The trapeze hangers are to be installed in accordance with NFPA 13 Section 9.1.1.6. Trapeze hangers are to be specifically designed for the support of the 4 inch mains and the width between the trapeze supports. The main piping will be supported using clevis hangers which will have all thread rod running vertically to either the trapeze hanger or universal clamp, an example of a clevis hanger is shown in Image 16.

Image 16 – Clevis Hanger

Typically, the branchlines will be supported by adjustable swivel rings, all thread rod, and a universal clamp. Where possible the universal clamp will be mounted to the bar joists. An example of this installation is shown in Image 17.

Image 17 – Branchline Hanger

The pipe hangers are to be spaced appropriately for the size of pipe being supported. The hangers are required by NFPA 13 Section 9.2.1.3.1 to be capable of supporting

Table 13 – Hanger Spacing

	Nominal Pipe Size (in.)											
	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8
Steel pipe except threaded lightwall	N/A	12-0	12-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0
Threaded lightwall steel pipe	N/A	12-0	12-0	12-0	12-0	12-0	12-0	N/A	N/A	N/A	N/A	N/A
Copper tube	8-0	8-0	10-0	10-0	12-0	12-0	12-0	15-0	15-0	15-0	15-0	15-0
CPVC	5-6	6-0	6-6	7-0	8-0	9-0	10-0	N/A	N/A	N/A	N/A	N/A
Polybutylene (IPS)	N/A	3-9	4-7	5-0	5-11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Polybutylene (CTS)	2-11	3-4	3-11	4-5	5-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ductile iron pipe	N/A	N/A	N/A	N/A	N/A	N/A	15-0	N/A	15-0	N/A	15-0	15-0

7.5 Underground Piping

The underground piping supplying water to Centennial Station will be a PVC pipe listed for the intended use with pressuring rating of at least 175 psi such as AWWA C900 DR 18 water pipe. The C900 DR 18 pipe has a maximum pressure rating of 235 psi acceptable installation at Centennial Station. Preliminary hydraulic calculations indicate that 4 inch pipe will be acceptable for the sprinkler system supply, this will be justified in the hydraulic calculation section of this analysis. The underground pipe will be tied to the 12 inch city water main running east to west along East Easter Avenue. The underground will run approximately 220 feet to the south to the northwest corner of the building rising aboveground in Water Room 102. The supply piping will be equipped with a double check backflow preventer before supplying two fire sprinkler risers.

To adequately protect the pipe it must be buried by a specific distance below grade as specified by NFPA 13. The image below shows the recommended depth of cover in feet for the entire United States, the image is Figure A.10.4.1 from NFPA 13.

Image 18 – Recommended Depth of Cover

As seen in Image 18 the minimum cover for areas near Denver, Colorado is 6 feet. At Centennial Station the burial depth of the 4-inch underground water supply will be 6 feet 2 inches to the center of the pipe below grade to provide the minimum required burial depth. The minimum depth is required to prevent underground pipe from freezing. Minimum depth of cover is 2 feet 6 inches, found in the warmer climates of the southern United States. Moving further north into colder climates requires a greater burial depth to prevent freezing.

The underground pipe will include three underground fittings. A tapping tee is to be installed at the connection to the 12 inch underground, two 90 degree elbows will be installed to penetrate into the floor of the riser room. The fittings are to be provided with thrust blocks to ensure the pipe is secure. Thrust blocks will be required at the tapping tee and both 90 degree elbows. The thrust blocks shall be designed to withstand the expected thrust for the 4 inch fitting as specified in Table A.10.8.2(a) of NFPA 24. The area of the thrust block can then be calculated based on the thrust.

Prior to acceptance the underground piping is to be flushed in accordance with Section 10.10.2.1.3 of NFPA 13. The minimum flow rate during flushing shall be the flow hydraulically calculated for the demand of the sprinkler system or a 10 ft/sec – 390 gpm per Table 10.10.2.1.3 of NFPA 13. Flushing shall continue for a sufficient time to ensure the pipe is free of debris. Hydrostatic testing shall be performed at a minimum pressure of 200 psi for a minimum of 2 hours in accordance with Section 10.10.2.2.1 of NFPA 13. Upon completion of flushing and hydrostatically testing the system the “Contractor’s Material and Test Certificate for Underground Piping” is to be provided.

7.6 Hydraulic Calculations

The sprinkler system is required to be hydraulically calculated to ensure the system will perform as expected when activated. NFPA 13 Chapter 22 provides specific information required for the hydraulic calculations and associated working plans, also known as shop drawings. Hydraulic calculations have been performed for Centennial Station for both the wet-pipe and dry-pipe sprinkler systems. Before the hydraulic calculations can be completed the sprinkler heads must be laid out through the entire building. Once that is completed as shown in the plans in Appendix C the following information must be known:

- Type of system – wet-pipe or dry-pipe;
- Hazard Classification to determine the required density;
- Water flow test information – static pressure, residual pressure, flow;
- Protection area per sprinkler head;
- K-Factor of the sprinkler head;
- Outside hose stream allowance;
- Location of the remote area;
- Elevation above grade of the remote area.

The remote area for each system is where the sprinkler system will have the greatest flow and pressure demand; this will typically be the highest elevation of the system. The remote area for a tree system will be at the furthest point from the source and in a gridded system the remote area will likely be the center of the grid.

Once the above information is known the system can be hydraulically calculated. Both sprinkler systems have been hydraulically calculated using the computer program SprinkCAD as detailed below, the dry-pipe system has been calculated by hand as well. Both calculations methods are appropriate; however, a hand calculation for the gridded wet-pipe system is very difficult and not usually accepted by an authority having jurisdiction.

7.6.1 Hand Hydraulic Analysis

A hand calculation was performed for the dry-pipe sprinkler system protecting the garage areas of the first floor of the building. The remote area is shown as the hatched area on the first floor in the plans in Appendix C. It should be noted that though the remote area chosen is not the furthest from the sprinkler riser, it is the furthest space that has an area of 1,950 square feet. It is assumed that if the system is capable of protecting a large area then it will be adequate for the small spaces at the end of the tree system.

The nodes shown on the plan were automatically input by SprinkCAD; however, for convenience the same nodes were used for the hand calculation. The calculation will start at node N200. First, the flow through a single sprinkler head is calculated by multiplying the density required, 0.15 gpm/sq, by the area protected by a single head, 130 square feet. This yields a flow of 19.5 gpm. Then the required pressure to flow 19.5 gpm through the head is calculated using $P = (Q/P)^2$, thus the pressure required is 12.1 psi with a K-factor of 5.6. Next the friction loss resulting from the flow through the one inch pipe from node N201 to N200 is calculated using the Hazen-Williams equation:

$$p = \frac{4.52Q^{1.85}}{C^{1.85}d^{4.87}}$$

Where p is the friction loss per foot, Q is the flow through the pipe in gpm, C is the C-factor of the pipe, and d is the inside diameter of the pipe. The friction loss coefficient of the pipe is 100 for dry-pipe system, this accounts for the added friction loss associated with the corrosion in dry-pipe sprinkler systems. A similar calculation method is performed to calculate the flow of node N201 with the additional pressure; this is then repeated and added for nodes N202 and N203. Next the friction loss through the pipe between nodes 0064 and 0065 is calculated again using the Hazen-Williams formula. Then the flow is calculated at nodes N204, N205, N206, and N207 with the added pressure for the friction loss in the pipe between 0064 and 0065. This process is repeated for the remainder of the sprinkler heads. Then the added friction loss through the main is calculated and added to the required pressure. At the riser the friction loss through the double-check backflow preventer, dry-pipe valve, and elevation loss are added. Lastly, the friction loss through the underground is calculated using a C-factor of 150 for PVC pipe.

The resulting calculation determined the required flow for the dry-pipe sprinkler system was 345 gpm, including outside hose stream, at a minimum pressure of 50.1 psi. This compares well with the computer hydraulic analysis in the following section.

7.6.2 Computer Hydraulic Analysis

Due to the complexity of most sprinkler systems, specifically gridded sprinkler system, hydraulic calculations are to be completed by a trusted computer program to prove that the water supply is adequate for the sprinkler system design. For the analysis of the sprinkler systems at Centennial Station the computer program SprinkCAD was chosen. SprinkCAD is an AutoCAD based program supplied by Tyco International Ltd. The program was first developed in the mid 1990's.

To perform the hydraulic calculation, the sprinkler system including the riser, cross main, floating main, and branchlines were drawn in two dimensions in the AutoCAD based environment the pipes were sized as previously described in this analysis. After the sprinkler system was drawn the water supply data was input where the new underground is to intersect the existing main. Design criteria was input for both sprinkler system and the remote areas were defined. Once all of the needed data and information was provided into the drawing the systems are able to be calculated. SprinkCAD performs the hydraulic calculations utilizing methods identical to a hand calculation; however, the calculations are performed much faster and without mathematical error.

The data output from SprinkCAD or any other computer based hydraulic calculation program is to summarize the calculation and provide the information specified in Section 22.3.5 of NFPA 13. The following sheets are to be included in the calculation:

- Summary sheet;
- Graph sheet;
- Node analysis;
- Detailed worksheet.

The summary sheet will contain the building and building owner information, the sprinkler contractor's information, and the design criteria for the system. The format for the summary

sheet is shown in Figure 22.3.5.1(a) of NFPA 13. The graph sheet will show the available water supply, sprinkler system demand, and hose stream allowance all on a single $Q^{1.85}$ semi-exponential graph paper. A sample sheet of the graph paper is shown in Figure 22.3.5.1(b) of NFPA 13. On the shop drawings each flowing sprinkler head in the remote area will have a unique node; these nodes will be shown on the node analysis along with the elevation, node type, pressure, and discharge for each sprinkler head. The format for the node analysis is shown in Figure 22.3.5.1(c) of NFPA 13. The detailed worksheets will include the hydraulic calculation and all of the steps taken for the hydraulic calculation of the pressure demand and flow for the most remote sprinklers. The information included in the detailed worksheet needed to complete the hydraulic calculation will include the pipe diameter, roughness coefficient, pipe length, friction loss in each section of pipe, flow through each section of pipe, and the pressure in the pipe. A sample of the detailed worksheet is shown in Figure 22.3.5.1(d) of NFPA 13.

The wet-pipe and dry-pipe sprinkler systems have been hydraulically calculated using SprinkCAD software. The hydraulic analysis output data provided by SprinkCAD has been included in Appendix A. Image 19 shows the calculation graph for the dry-pipe system, the most demanding system. The summary sheet, graph sheet, node analysis, and detailed worksheets are attached as required.

Image 19 – Dry-Pipe System Demand Graph

The water supply is shown as the dark blue line, the green line is the sprinkler demand, and the red line is the hose demand. The flow in gpm is shown in the x-axis and the pressure in psi is shown in the y-axis.

Though the computer aided hydraulic programs are more efficient, faster, and less likely to have mathematical errors, the programs must be used by competent professionals trained in the use of the program to ensure the data is input properly. Just because the output looks accurate and complete it does not mean the information was input correctly into the analysis.

7.7 Sprinkler Activation Time

The sprinkler activation time will be calculated using the DETACT method which uses the Albert correlation to estimate detector activation time and will be compared to an FDS model of a work station fire on the fourth floor. The DETACT method calculates the velocity and temperature of the ceiling jet and the gas plume. This data is used to calculate the activation time based on the activation temperature and response time index (RTI) of the detector, which for this analysis will be the sprinkler head as selected for Centennial Station. The following equations have been used:

- $\Delta T_{g,pl} = 16.9 \frac{\dot{Q}^{2/3}}{H^{5/3}};$
- $u_{g,pl} = 1.0 \left(\frac{\dot{Q}}{H} \right)^{1/3};$
- $\frac{\Delta T_{g,cj}}{\Delta T_{g,pl}} = \frac{0.3}{(r/H)^{2/3}};$
- $\frac{u_{g,cj}}{u_{g,pl}} = \frac{0.2}{(r/H)^{5/6}}.$

Where r is the radial distance of the sprinkler head from the heat source, H is the height of the detector above the heat source, and Q is the heat release rate of the fire. The heat release rate of the fire will be based on data provided in the SFPE Handbook Figure 3-1.38 “Heat release rates for office workstations”. The graph of the test data is shown in Image 20.

Image 20 – Workstation Heat Release Rate

From the test data given in the SFPE Handbook test “D” was chosen. Test “D” is a modern workstation with three sides. This will be appropriate for the expected furniture in the open office areas of Centennial Station. This design fire will be used only to calculate the sprinkler activation time in an open office area. The test data shows a maximum heat release rate of 3,000 kW at 500 seconds. Using the heat release rate equation for a “t-squared” fire, Equation B.4 from NFPA 72, the fire growth coefficient can be calculated. That equation is as follows: $Q = \alpha t^2$, where Q is the heat release rate, α is the fire growth coefficient, and t is time. Using values from the test data the work station fire growth constant is calculated to be $\alpha = 0.012$. This is

classified as a “medium” growth fire as shown in Figure B.2.3.2.6.2 of Annex B of NPFA 72, shown below.

Image 21 – Fire Intensity Coefficients

The sprinkler head characteristics will be for a 3mm glass bulb, quick response, intermediate temperature, standard spray pendant sprinkler as described in the automatic wet-pipe sprinkler portion of this analysis. From the sprinkler head datasheet, the activation temperature has been determined to be 165°F and the RTI is 50 (m-s)^{1/2}. All input data has been inserted into Table 14.

Table 14 – DETACT Input Data

DETACT Model				
Description	Value	Units	English Units	
Ceiling Height (H)	1.8	m	6	Feet
Radial Distance (R)	2.1	m	7	Feet
Ambient Temp (T ₀)	22.2	C	72	F
Actuation Temperature (T _a)	73.9	C	165	F
Response Time Index (RTI)	50	(m-s) ^{1/2}		
Fire Growth Power (n)	2	-		
Fire Growth Coefficient (k)	0.012	kW/s ⁿ		
Time Step (dt)	2	s		
R/H	1.167	-		
dT _{ej} /dT _{pl}	0.271	-		
u _{ej} /u _{pl}	0.176	-		

The input data was used to calculate the detector temperature at time step intervals of two seconds. The output data for 300 seconds is shown in the graph in Image 22.

Image 22 – DETACT Graph

The data above shows the gas temperature, detector temperature, and the heat release rate versus time. The graph shows that the sprinkler activation temperature of 165°F (74°C), shown by the red lines, is achieved at 175 seconds, at this time the heat release rate is 365 kW, well below the expected maximum heat release rate for a modern three panel workstation. The FDS model of an identical fire on the fourth floor of the building showed an activation time of 178 seconds, comparing very well with the DETACT model. The heat release rate at the time of sprinkler activation was 290 kW, less than the DETACT model due to the input of the ramp function used for the fire growth model in the FDS model. Image 23 shows the FDS model.

Image 23 – FDS Sprinkler Application Image

7.8 Inspection, Testing, and Maintenance

Upon initial completion of the system the owner is required by Section 4.3 of NFPA 13 to provide an “Owner’s Certificate” indicating the intended use of the building, a preliminary plan of the building, and knowledge of the water supply. The owner is to sign the certificate indicating that any changes to the building that will affect the sprinkler system will be corrected to ensure proper operation of the sprinkler system.

Prior to acceptance of the sprinkler system the “Contractors Material and Test Certificate for Aboveground Piping” shall be provided completed by the installing contractor. The certificate provides the following information:

- Building name and address;
- Confirmation that the system is installed according to the shop drawings;
- Verification that NFPA 25 and installation manuals have been left on site;
- Make, model, year of manufacture, orifice size, quantity, and temperature rating for each sprinkler installed;
- Type of pipe and fittings installed;
- Type of alarm valve or flow indicator;
- Time delay for the water flow indicator;
- Dry pipe operating test including water pressure, air pressure, time to trip test, trip point pressure, and water delivery time;
- Hydrostatic test information including pressure and duration;
- Welding data if necessary;
- Hydraulic nameplate data;
- Date the system was left in service with all valves open;
- Signature of contractor and property owner or owner’s representative.

The aboveground test certificate is to be completed separately for both the wet-pipe and dry-pipe sprinkler systems. The test certificates shall be left on site for use during future testing and inspections.

NFPA 13 defers the requirements for continuing inspection, testing, and maintenance requirements to NFPA 25 – Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems. It shall be the owner’s responsibility to hire a licensed contractor to perform the necessary inspections, testing, and maintenance as required by NFPA 25. Table 5.1 of NFPA 25 specifies the durations at which the fire sprinkler equipment is to be tested. A summary of that table is provided in Table 15 for the equipment installed at Centennial Station.

Table 15 – IT&M Schedule

Sprinkler IT&M Schedule			
Item	Inspection	Maintenance	Test
Gauges	Monthly	As Needed	5 Years
Waterflow Device	Quarterly	As Needed	Quarterly
Control Valves	Monthly	Annually	NA
Valve Supervisory Device	Quarterly	As Needed	Semiannually
Hydraulic Nameplate	Quarterly	As Needed	NA
Hangers	Annually	As Needed	NA
Pipe and Fittings	Annually	As Needed	NA
Sprinklers	Annually	As Needed	At 50 Years
Spare Sprinklers	Annually	As Needed	NA
Fire Department Connection	Quarterly	As Needed	NA
Main Drain	NA	As Needed	Annually
Low-Point Drains	NA	Annually	NA

Inspections are to be done visually for excessive wear or damage. Testing is to be done by operating the device for proper operation. Maintenance is to be done as wear or damage is found. The inspections for the dry-pipe systems are to be specific for the season; a fall inspection is to be done prior to the first expected freeze and a spring inspection is to be provided after the last freeze. The fall inspection shall ensure the pipe is dry and free of water and test the functionality of the dry-pipe valve. The spring inspection is to inspect the pipe for damage and leaks as well as testing the dry-pipe valve.

Furthermore, the sprinkler inspection is to include inspection of the building for changes which may negatively affect the sprinkler system. Such changes may include addition or removal of walls, changes of use of a space, or storage of items which present a greater challenge than initially expected. This information shall be compared to the Owner's Certificate provided upon completion of the system. The water supply is to also be examined to ensure changes have not been made which may reduce the pressure or flow from what the sprinkler system was originally calculated.

7.9 Suppression System Design Summary

Wet-pipe and dry-pipe systems for the installation at Centennial Station are very common in the fire protection industry. The systems in Appendix C have been laid out and calculated using common methods for sprinkler systems. Because the installed system is unknown, the system could not actually be evaluated. Section 8 will detail the coordination between the fire sprinkler system and the sprinkler system. Specific code requirements are to be address to maintain code compliant systems.

8.0 FIRE ALARM AND DETECTION SYSTEMS

The fire alarm system will be installed in accordance with IBC Section 907.2.2 for Group B business occupancies. These occupancies are required to have a manual fire alarm system for buildings with greater than 500 occupants; however, the manual pull stations can be omitted when the building is equipped throughout with a sprinkler system which will activate occupant notification upon water flow. The occupant notification will be provided in accordance with IBC Section 907.9 requiring visual notification in public and common areas and audible alarms throughout the building at a sound pressure level of 15 dBA greater than ambient conditions.

The audible and visual notification appliances are to be installed in accordance with NFPA 72 per Section 907.9 of the IBC. Furthermore, Section 903.4.2 of the IBC requires the sprinkler system be monitored by a fire alarm control panel which will activate occupant notification on the interior of the building as well as an approved location on the exterior of the building, this will be above the fire department connection. A manual pull station will be provided at the fire alarm control panel. Point smoke detection will be provided above the fire alarm control panel, power supplies, and in the elevator lobbies and elevator control room. Beam smoke detection will be installed in the atrium which will activate the smoke control system. Tamper switches will monitor the position of the sprinkler control valves to ensure the sprinkler systems are operational.

8.1 Fire Alarm Control Panel

The fire alarm control panel to be installed in the Centennial Station will be a non-proprietary, addressable control panel. The control panel will monitor the alarm and supervisory ancillary devices located throughout the facility and power notification appliances which will notify occupants of a fire in the building. The control panel will have a signaling line circuit which will poll all of the addressable devices. Power supplies will be installed to support the power demand of the notification appliances; the power supplies will be controlled by the control panel. For this project a Silent Knight 5820XL fire alarm control panel has been chosen to protect the facility. The panel is seen in Image 24.

Image 24 – Fire Alarm Control Panel

As seen above the panel will have a red cabinet with an annunciator on the front panel. The annunciator will have push buttons for silence, acknowledge, and limited programming

functionality as well as an LCD display which will show all pertinent information for the system. Many installations will require an auxiliary annunciator; however, because the fire alarm control unit will be near the main entrance to Centennial Station only the annunciator on the control panel will be necessary. The location of the fire alarm control panel is in the lobby near the main entrance as shown on the plans in Appendix C.

The Silent Knight fire alarm control panel is built to support 99 SK detectors and 99 SK modules, which is expandable to 396 detectors and modules; however, the expansion will not be necessary for Centennial Station. The panel has a built in digital alarm communication transmitter (DACT) which will be used to relay all signals to a monitoring station, the supervising station monitoring will be discussed in more detail later in this analysis. Six programmable notification appliance circuits (NAC) are available providing 6 amps total and no more than 3 amps per circuit. The NAC circuits can be programmed to power notification appliances or provide constant auxiliary 24 VDC power. Two form C on board relays are provided for control of auxiliary functions such as door closure. A detail from the fire alarm control panel is shown in Image 25 showing all of the terminals on the mother board.

Image 25 – FACP Motherboard Detail

The terminals on the top right of the mother board are to be supplied from a dedicated 20 amp service breaker. The breaker is to be mechanically locked and marked to indicate that it is supplying the fire alarm system. The panel and breaker number is to be labeled inside the fire alarm control panel. The terminals below the annunciator are for the SLC and the phone lines. The terminals along the bottom of the mother board are for panel trouble, two programmable form C relays, an SBUS for auxiliary annunciators or intelligent power supplies, and six programmable NAC circuits. The terminal block to the left of the annunciator is for the

connection to the batteries for standby power. Two 12 volt batteries will be wired in series to provide 24 volt back up power for the system, the batteries will be installed in the bottom of the cabinet. The circuiting will be discussed in detail in further sections of this analysis. A smoke detector will be installed above the fire alarm control panel to protect the panel. It should be noted that this is not required by the 2007 Edition NFPA 72, but is required by the 2002 and 2010 Editions.

8.1.1 Fire Alarm Power Supplies

Power supplies will be installed on the second, third, and fourth floors to power the horn/strobes and strobes on each floor. The power supplies will be Model 5496 Intelligent Power Modules manufactured by Silent Knight. The power supplies will be circuited to the fire alarm control panel by an RS-485 data bus. This will allow easy programming to activate synchronized notification throughout the building. Each power supply is capable of supplying 6 amps over four NAC circuits. An image of the power supply motherboard is shown in Image 26.

Image 26 – Power Supply Motherboard Detail

The power supply is powered by a 120 volt, dedicated 20 amp breaker similarly to the fire alarm control panel at the terminal on the top left corner. The battery terminal block is provided on the bottom left corner, the batteries are installed in the cabinet. Four supervised NAC circuits are shown along the bottom of the motherboard. The SBUS data connection is shown on the bottom terminal block on the furthest contacts to the right. The SBUS will be routed from the fire alarm

control panel to the power supply on the second floor, then rise to the third and fourth floors where the SBUS will terminate.

8.2 Circuiting and Pathways

Four types of circuits will be used in Centennial Station. A signaling line circuit (SLC) will be used to connect all addressable modules, smoke detectors, heat detectors, and pull stations to the fire alarm control panel. Initiating device circuits (IDC) will connect non-addressable devices to the fire alarm control panel; the IDCs will run from monitor modules to water flow switches and tamper switches and from relay modules to control functions on ancillary equipment.

Notification appliance circuits (NAC) are used to power the the horn/strobes and strobes. The last types of circuit used will be an RS-485 SBUS; this type of circuit will connect intelligent power supplies to the fire alarm control panel. The full riser diagram showing the routing of the circuiting between devices is shown on the plans in Appendix C.

8.2.1 Initiating Device Circuit

Initiating device circuits are defined by NFPA 72 Section 3.3.89 as a component which monitors a change of state condition. This will include the circuits from all monitor modules. These types of circuits are classified as either Class A or Class B. Class A circuits will be wired from the monitor module to a normally open set of contacts then return to the monitor module. Class A circuits are capable of operating with a single open; however, a single open will initiate a trouble signal. Class B circuits, which will be used at Centennial Station, are wired from the monitor module to a normally open pair of contacts then to an end of line resistor. When the normally open contacts on the monitored component closes a signal is initiated as programmed at the fire alarm panel. The signals are to perform as defined in Table 6.5 from NFPA 72 shown below. T-tapping of IDCs will not be allowed as circuit integrity cannot be monitored on a Class B t-tapped circuit. The wiring of the IDC will be accomplished using 2 conductor 18 AWG FPL cable. This type of cable is not permitted to be installed without conduit above the drop ceiling; however, this is not necessary as the circuits will be run relatively short distances from the monitor modules to water flow and tamper switches. The IDCs, which are wired to control devices for the atrium smoke control system are to be protected and installed in conduit as required for smoke control system wiring.

Table 16 – Performance of IDCs

Class	B			A		
	Alm	Trbl	ARC	Alm	Trbl	ARC
Abnormal Condition	1	2	3	4	5	6
Single open	—	X	—	—	X	R
Single ground	—	X	R	—	X	R

Alm: Alarm. Trbl: Trouble. ARC: Alarm receipt capability during abnormal condition. R: Required capacity.
X: Indication required at protected premises and as required by Chapter 8.

8.2.2 Signaling Line Circuit

The signaling line circuit is defined by NFPA 72 Section 3.3.173 as a circuit path between addressable devices and the control unit. A single SLC will be wired throughout the building to all addressable devices. The circuit integrity of the SLC is to be in accordance with Table 6.6.1 of NFPA 72 shown below. SLC circuits are designated at either Class A, Style 6 or Style 7 or

Class B Style 4. Class A Style 6 circuits are wired in a single continuous loop to all devices and then return to the fire alarm control panel. This type of circuit allows functionality of all devices with a single open. Class A Style 7 is wired similarly to Style 6; however, isolation modules are installed on both sides of each device allowing circuit operation with a wire-to-wire short. A Class B Style 4 circuit is a single circuit in which a single open will initiate a trouble signal, but will not allow devices to operate downstream of a single open. The SLC at Centennial Station will be Class B Style 4 circuit allowing easier wiring and the use of “t-tapping” of circuits. The SLC will be limited only by the number of devices on the SLC; the SK-5820XL is limited to 99 detectors and 99 modules on a single SLC. The SLC wiring is to be 2 conductor 16 AWG FPLP cable. This type of cable is permitted to be installed above the drop ceiling in open air without conduit.

Table 17 – Performance of SLCs

Class	B			A			A		
Style	4			6			7		
	Alm	Trbl	ARC	Alm	Trbl	ARC	Alm	Trbl	ARC
Abnormal Condition	1	2	3	4	5	7	8	9	10
Single open	—	X	—	—	X	R	—	X	R
Single ground	—	X	R	—	X	R	—	X	R
Wire-to-wire short	—	X	—	—	X	—	—	X	R
Wire-to-wire short & open	—	X	—	—	X	—	—	X	—
Wire-to-wire short & ground	—	X	—	—	X	—	—	X	—
Open and ground	—	X	—	—	X	R	—	X	R
Loss of carrier (if used)/channel interface	—	X	—	—	X	—	—	X	—

Alm: Alarm. Trbl: Trouble. ARC: Alarm receipt capability during abnormal condition. R: Required capability.
X: Indication required at protected premises and as required by Chapter 8.

8.2.3 Notification Appliance Circuit

Notification appliance circuits are defined as the circuiting from a fire alarm control panel to notification appliances powering horn/strobes or strobes. The NAC circuits are Class B Style Y or Class A Style Z as shown Table 6.7 of NFPA 72 shown below. Class A Style Z circuit are wired in a single continuous loop from the panel to all notification appliances then returns to the panel allowing operation with a single open. Class B Style Y, as will be installed in Centennial Station, are wired in a single continuous circuit ending at an end of line resistor. If there is a single open in the circuit a trouble signal will be initiated, but operation of devices downstream of the open will not operate. The NAC circuits installed at Centennial Station will be 2 conductor 14 AWG FPLP cable. This cable is permitted to be installed between devices above the drop ceiling without conduit. Voltage drop calculations will be required for the NAC circuits to ensure a minimum of 16 volts is provided at the last device on each circuit. The calculations are completed in a further section of this analysis.

Table 18 – Performance of NACs

Class	B		A	
	Trouble Indication at Protected Premises	Alarm Capability During Abnormal Conditions	Trouble Indication at Protected Premises	Alarm Capability During Abnormal Conditions
Abnormal Condition	1	2	3	4
Single open	X	—	X	R
Single ground	X	R	X	R
Wire-to-wire short	X	—	X	—

| X: Indication required at protected premises. R: Required capability.

8.2.4 RS-485 Circuit

The RS-485 circuit is an intelligent circuit which will be wired between the fire alarm control panel and the power supplies. The circuit will run vertically between electrical rooms to connect the power supplies. Programming is defined in the fire alarm control panel to initiate alarm notification throughout the building. The RS-485 circuit will be 2 conductor 16 AWG FPLP which will be allowed to be run vertically in a riser or in the return plenum above the acoustic ceiling tile. The wiring is to be installed in conduit in the electrical rooms. Though an annunciator is not installed in Centennial Station, annunciators are also wired to the fire alarm control panel via an RS-485 circuit. Additionally, the RS-485 circuit is to be shielded. The shielding protects the wire from interference from other signals. The shielding is incorporated into the jacket of the wire and is to be drained to ground at the control panel.

8.2.5 Circuit Protection

The circuits are to be installed in open air in the return plenum space above the drop ceiling. In general, the wiring installed in stairways and in electrical rooms will be protected by conduit. The conduit fill shall be calculated in accordance with NFPA 70; however, typical conduit size will be minimum $\frac{3}{4}$ inch and greater when necessary. Back boxes are to be 4 inch by 4 inch boxes without extension rings. Furthermore, low voltage wiring is not to be installed in conduit with voltage greater than 24 VDC to ensure interference from high voltage wiring does not occur in the low voltage wire as specified by NFPA 70.

8.3 Initiating Devices

The initiating devices will be monitored by the fire alarm control panel to indicate either alarm or supervisory signals. The alarm signals will be from smoke detectors, heat detectors, manual pull stations, and water flow switches which are monitored by monitor modules. Additionally, supervisory signals will be initiated from valve position monitors called tamper switches and duct smoke detectors. Device mounting heights and acceptable locations are shown on the plans in Appendix C.

8.3.1 Monitor/Relay Modules

The fire alarm system will protect the building primarily via water flow monitoring. A water flow switch will be installed in the riser room and at the floor control assembly on each floor. These devices do not have the capability to communicate directly to the fire alarm control panel; therefore, a monitor module is used to monitor these devices. An example of an SK-Monitor is shown in Image 27.

Image 27 – Monitor Module

The monitor modules are tied to the fire alarm via the SLC, contacts from the water flow switch are wired to the other contacts on the module. The wiring from the monitor module to the water flow switch is an IDC. The IDC must land on normally open contacts on the water flow switch with an end of line resistor wired after the contacts. Upon activation, the water flow switch will close the normally open contacts eliminating the end of line resistor initiating an alarm signal to the monitor module. Each monitor module is given a unique address, when a signal is received at the fire alarm control panel the address, device type, and location will be displayed on the annunciator on the fire alarm control panel. These types of modules are also available with two IDC circuits, these are known as dual monitor modules. The dual monitor modules will be used at Centennial Station to monitor the water flow switch and tamper switch for each floor control assembly. The wiring from the module to the tamper switch is identical to that of the water flow switch; however, the programming in the fire alarm control panel will be such that the tamper switch initiates a supervisory signal at the panel. A complete sequence of operations is provided in the plans in Appendix C showing all functions associated with water flow and tamper signals.

The relay modules look identical to the monitor modules and they are wired to the SLC similarly. Relay modules will be used to performed air handler unit (AHU) shutdown, fire/smoke damper closure, elevator recall, or security override. Each relay module is given a unique address. The address is used in the programming of the fire alarm control panel. The relay on each modules is a Form C dry-contact relay with three terminations: common, normally open and normally closed. As programmed the relay will change state initiating the desired function as specified in the sequence of operations shown in the plans in Appendix C. For example, if the duct smoke detector detects smoke the relay will be programmed to change state shutting down the associated AHU, AHU control wiring must be wired through the relay.

8.3.2 Manual Pull Stations

A single manual pull station will be provided at the fire alarm control panel, this location works well because it is adjacent to the lobby which is a normally occupied area. Where manual pull stations are required by the IBC they must be installed within 5 feet of the exit they are protecting and not have a travel distance greater than 200 feet in accordance with Section 907.3.1. Because manual pull stations are not required at Centennial Station the requirements of

Section 907.3.1 will not be applied; however, Section 907.3.2 requires manual pull stations be installed between 42 and 48 inches above the floor, this will be applied at Centennial Station.

Image 28 – Manual Pull Station

The manual pull station in Image 28 is the SK-Pull-DA double action pull station. The pull station is operated by pushing the lever in and then down, the double action pull station is less likely to have accidental operation; therefore, it is preferred over single action pull station. The pull station is resettable by using a key to open the face of the pull station and then a switch is reset into the normal operating position. The pull station is a conventional device with an IDC, so a mini-monitor module will be installed in the back box of each pull station to give the device a unique address which will be identified by the fire alarm control panel. The mini-monitor is shown in the image below. The yellow and purple wires are the IDC that will go to the manual pull station, the red and black wires will be tied to the SLC.

Image 29 – Mini-monitor Module

8.3.3 Smoke Detection

Smoke detection will be provided at the fire alarm control panel, in the atrium, and in the elevator lobbies and control room for elevator recall functions. Several types of smoke detection will be installed based on the location of the detector and the purpose of the detector.

8.3.3.1 Point Smoke Detector

Photoelectric smoke detection will be installed at the fire alarm control panel and in the elevator lobbies and control room for elevator recall functions. Point type smoke detectors will be installed using a prescriptive based approach and are permitted to protect a maximum of 900 square feet with a nominal spacing of 30 feet in accordance with Section 5.7.3.2.3.1 of NFPA 72. The spot type smoke detection will be installed with specific objectives; therefore, in Centennial Station the spacing between detectors will not be critical. The point smoke detectors will be installed within 15 feet of the fire alarm control panel and the elevator cab which the detector is protecting. Photoelectric smoke detectors where chosen as ionization smoke detectors are not suitable for the elevation in Englewood, Colorado.

The point type smoke detectors are wired directly to the SLC, each detector will have a unique address to indicate the location of the detector. Furthermore, each detector will be programmed with functions specific to their location. The smoke detector above the fire alarm control panel will simply initiate an alarm signal. The smoke detectors in the elevator lobbies and elevator control room will initiate an alarm signal in addition to elevator recall functions. Additionally, two smoke detectors will be installed on both sides of a held open door which is the boundary of a 2-hour fire rated wall. Detection by the smoke detectors near the rated door will cause a relay to activate and disconnect 24 VDC power to magnetic door holders. The smoke detectors will be required on both sides of the door frame in accordance with Figure 5.16.6.5.1 of NFPA 72 for a distance greater than 24 inches between the door frame and the ceiling.

Image 30 – Smoke Detector

Detection by smoke detectors in the elevator lobby will initiate elevator recall. The smoke detectors on the second through fourth floors will cause the elevator cab to return to the first floor, smoke detection on the first floor will recall the elevator cab to the second floor. Elevator recall is done to ensure occupants are not exposed by the elevator cab to a floor with untenable conditions due to smoke. Furthermore, the smoke detector in the elevator machine room will recall the elevator to the first floor. The elevator recall functionality is detailed graphically in the sequence of operations in the plans in Appendix C.

8.3.3.2 Beam Smoke Detector

A single beam smoke detection will be installed to protect the atrium. The beam smoke detector consists of a transmitter and reflector. The transmitter projects light to the reflector, then measures the amount of light which returns to the transmitter from the reflector. Based on the amount of light which is received the detector determines whether or not smoke is present. An alarm signal will be initiated when light obscuration is 25%. If obscuration is 100% indicating beam blockage a trouble signal will be initiated. The beam smoke detector is a conventional device, therefore, it will be wired to the SLC via an IDC. Because the beam smoke detector will be installed in an inaccessible location at the top of the atrium a remote test station will be installed on the third floor in the office adjacent to the detector. The test station will allow the detector to be put into an alarm condition without directly accessing the detector.

The beam smoke detector is capable of detecting a maximum line of sight distance of 328 feet long and 30 feet wide. A verification of the detector protection will be done using a performance based approach based on an anticipated fire size, smoke plume width, and smoke plume height within the atrium. The smoke detector will be used to initiate an alarm signal as well as the smoke control system in the atrium. The smoke control system will be discussed in later analysis of the building. The SK-Beam smoke detector is shown in Image 31.

Image 31 – Beam Smoke Detector

8.3.3.3 Duct Smoke Detector

Duct smoke detection will be installed in accordance with Section 6.4.2.1 of NFPA 90A. The duct smoke detectors are required to be installed on the supply side of the AHU downstream of air filters and before any branch connections on units with a flow greater than 2,000 cfm. The return side of the air system will require duct smoke detectors at each story prior to recirculation of fresh air for systems with a capacity greater than 15,000 cfm. The building is supplied by two AHU's, each will have one duct smoke detector installed on the return plenum and several smoke detectors installed on the supply side, one at each floor level. A single relay module will

be used to shut down each AHU ensuring smoke is not spread throughout the building by the air distribution system. An image of the SK-Duct is shown in Image 32.

Image 32 – Duct Smoke Detector

The duct smoke detector is attached directly to the duct which it is to protect. Two air tubes penetrate the duct and connect to the housing. One air tube flows air to the detector and one air tube flow are back to the duct. The inlet tubes flow air across a standard point type smoke detector. The housing is also equipped to contain a relay module when the desired function is to shut down an associated AHU. The relay will not be installed at Centennial Station as several duct smoke detectors are shutting down a single AHU.

8.3.4 Heat Detection

A single heat detector will be installed in the elevator machine room to initiate shunt trip. The heat detector will be 135 degree F, fixed temperature detector. The heat detector is shown in Image 33, but is nearly identical to the smoke detectors installed.

Image 33 – Heat Detector

The heat detector is to be installed within 24 inches of the sprinkler head in the elevator machine room. Upon detection the heat detector will initiate an alarm signal throughout the building and activate shunt trip of the elevator power. The purpose of this is to ensure all elevator circuiting is de-energized prior to sprinkler activation. The full sequence of operations for the heat detector and elevator recall is shown on the plans in Appendix C.

8.3.5 Tamper Switch

A control valve for the sprinkler system is shown in Image 34. The control valve is required to be monitored by the fire alarm system to initiate a supervisory signal if the valve is closed

indicating that the sprinkler system is potentially non-operational. The control valves will be located on the sprinkler system as described in Section 7 of this analysis.

Image 34 – Sprinkler Control Valve

Image 34 above shows a control valve which is not yet wired to the fire alarm system, this is indicated by the loose wires at the bottom of the valve. The valve is required to initiate a supervisory signal during a maximum of the first two rotations of the valve in accordance with Section 5.15.1.2 of NFPA 72.

8.4 Notification Appliances

The notification appliances will include horn/strobes and strobes to provide occupant notification throughout the building when an alarm signal is initiated. The alarm notification appliances are to be installed to provide occupant notification in accordance with Section 907.9 of the IBC.

Visible notification is to be provided as described in Sections 907.9.1 through 907.9.4 of the IBC which specifically requires visual notification in public and common areas. At Centennial Station these locations will include the following:

- Corridors;
- Restrooms;
- Conference rooms;
- Break rooms;
- Open office areas;
- Waiting areas;
- Multi-occupant offices.

The visual notification will be achieved by using xenon strobe lights. The strobes are to be installed in accordance with Section 7.5 of NFPA 72. The strobes chosen for Centennial Station are manufactured by System Sensor, which are listed for use with the Silent Knight system. The majority of the strobes will be ceiling mounted and are shown in Image 35.

Image 35 – Notification Devices

The strobes are a white xenon lights with selectable candela ratings from 15 candela to 115 candela. Candela ratings are a calculation method for determining light intensity. The light intensity required per area per strobe is define by Table 7.5.4.3.1(b) for ceiling mounted devices. The necessary candela ratings per rooms size will be as follows:

- 15 candela – 20 ft by 20 ft;
- 30 candela – 30 ft by 30 ft;
- 60 candela – 40 ft by 40 ft;
- 75 candela – 44 ft by 44 ft;
- 95 candela – 50 ft by 50 ft;
- 110 candela – 53 ft by 53 ft;
- 115 candela – 55 ft by 55 ft;

Strobes with greater light intensities require a greater amount of energy to power; therefore, the intensities a limited for the space they are protecting to limit the amount of power needed for each circuit. This will also allow a greater number of devices to be installed per power supply. Ceiling mounted devices were chosen because of their ease of installation in acoustic ceiling tile; however, spaces like the atrium with high ceilings will have wall mounted devices for ease of access and maintenance. The wall mounted devices will have similar candela ratings as the ceiling mounted devices, but will be specified in accordance with Table 7.5.4.3.1(a) of NFPA 72. The wall mounted devices are to be mounted such that the entire lens is greater than 80 inches and less than 96 inches above the floor in accordance with Section 7.5.4.1 of NFPA 72.

Audible notification will be provided throughout the building as described by 907.9.2 of the IBC. Audible notification is to be 15 dBA greater than ambient conditions throughout the building. The expected ambient noise level in the business occupancy is 55 dBA, thus a minimum noise level of 70 dBA will be provided throughout the building. In areas with ambient noise conditions greater than 105 dBA audible notification shall not exceed 120 dBA and visual devices will be installed rather than audible notification. To simplify the installation

combination horn/strobes will be installed where audible notification is needed, horn only devices are not expected at Centennial Station. The maximum sound output from the horns is 88 dBA per the manufacturer's datasheet. The expected sound pressure loss through a closed door is approximately 15 dBA; therefore, the sound pressure level with a closed door near a horn will be 73 dBA and horn will not be needed in each office. In general, the horns in the corridors will provide sound pressure levels high enough to provide adequate notification in single occupant offices.

A single exterior rated horn/strobe will be installed on outside of the building above the fire department connection. The exterior horn/strobe will function similarly to a water gong, following water flow only. The exterior device is rated for the extreme low temperatures and high temperatures associated with the location in Colorado. The device will have a NEMA 4X box with a gasket around the back box.

To allow the exterior horn/strobe to function as required following only water flow it must be supplied by a single dedicated NAC circuit. It will operate independently and must be wired as such. Programming within the fire alarm control panel will power the associated NAC circuit only when the address of the monitor module monitoring the water flow switch is in the alarm condition. The exterior device is shown in Image 36.

Image 36 – Exterior Notification Devices

The circuits powering the notification appliances are required to be calculated to ensure the minimum operating voltage of 16 volts is provided at the last device. The resistance in the wire will cause voltage loss across the circuit; therefore, the circuits will be limited in length based on the resistance in the wire and the total power required by all of the devices. This type of calculation is known as the voltage drop calculation and is provided later in this analysis.

8.5 System Monitoring

The fire alarm system at Centennial Station will be a protected premises system. In addition to fire detection and occupant notification the system is required to be monitored such that all signals are reported at a listed monitoring facility. There are three possible types of listed supervising stations; central supervising station, proprietary supervising station, and remote supervising station. All three types of supervising stations are required to dispatch appropriate

responses to signals received; however, the requirements of the supervising stations vary and the responses to the signals may vary. Proprietary station systems are most suitable for companies with many buildings where the owner would be capable of providing a listed central station which is manned 24 hours and capable of providing responses to all signals received. Central station supervision will monitor all signals, but the owner of the building will not own the central station and will contract out the responsibilities of monitoring. The central station will be notified of all signals via copper telephone lines and a dialer which can call the remote station. A remote supervising station will be used to monitor the fire alarm system at Centennial Station. The fire alarm system is equipped with a Digital Alarm Communicator Transmitter (DACT) which is tied to the fire alarm system via RS-485 data communication. The DACT then has two redundant phone lines, one primary and one secondary, which will communicate with a Digital Alarm Communicator Receiver (DACR) at the supervising station.

Each supervising station is required to meet the specifications of NFPA 72, specifically Chapter 8. Remote supervising stations are to have a detailed contract with the building owner which define the responsibilities of the supervising station – the details of the contract are provided in Section 8.3.3 of NFPA 72. The supervising station contracted by Centennial Station must also meet requirements for the facility, equipment, and personnel. Section 8.3.5 of NFPA 72 specifies the requirements of the facility; however, in general the facility is to be provided with restricted access, emergency lighting, intrusion system, fire alarm system, and backup power. In accordance with 8.3.6.2.1 the supervising station is to be manned by not less than two persons 24 hours per day.

When signals are received by the DACR at the supervising station from the DACT at Centennial Station they must have an appropriate response as dictated by NFPA 72 Section 8.3.7. Three types of signals will be sent to the supervising station, alarm, supervisory, and trouble. All signals are associated with the fire alarm equipment as shown in the sequence of operations in the plan drawings in Appendix C. Alarm signals are most critical and will have negative consequences to slow reaction, thus they are to have the following actions:

- Immediately retransmit the alarm signal to the public fire service;
- Dispatch a runner or technician to the protected premises to arrive within 2 hours after receipt of the alarm signal;
- Notify the subscriber or building owner.

Supervisory signals are less critical than alarm signals and must be responded to as follows:

- Communicate immediately with the subscriber or building owner and notify the fire department;
- Dispatch a runner to arrive within 2 hours to investigate the signal.

Lastly, trouble signals are the least critical and are indicative of system deficiencies, therefore, they have the longest allowable response times. The signals are to be responded to as follows:

- Communicate immediately with the subscriber or building owner and notify the fire department;
- Dispatch personnel to arrive within 4 hours to initiate maintenance if necessary;
- If an interruption lasts longer than 8 hours, provide notice to the subscriber and the fire department.

In conjunction with supervising the fire alarm systems it is customary for a contractor to also provide a maintenance and inspection program for the fire alarm and automatic fire sprinkler systems. This type of program is often completed by a licensed contractor to ensure proper maintenance of the fire protection systems. The inspection, testing, and maintenance durations are to be as described in further sections of this analysis.

8.6 System Calculations

Fire alarm system calculations must be performed to ensure the electrical systems will work as designed. The battery calculations will ensure the system will function as desired under backup power as required by NFPA 72. The voltage drop calculations will ensure each power circuit is not overloaded and that the minimum required voltage is provided at the last device on each power circuit.

8.6.1 Battery Calculations

NFPA 72 requires that all fire alarm systems have reliable back-up power such that there will be no interruption of service in the event of loss of 120 VAC. The back-up power is supplied by two 12 VDC batteries wired in series to provide 24 VDC to the system. Most fire alarm systems will require a minimum capacity to operate the fire alarm under quiescent load for 24 hours and alarm load for 5 minutes in accordance with NFPA 72 Section 4.4.1.5.3. The quiescent load at Centennial Station will be reduced to 4 hours as permitted by Section 4.4.1.5.2.1(2) because the building is equipped with an automatic starting, engine-driven generator.

The calculations are provided in Appendix B of this analysis. It was found that minimum 7 amp-hour batteries are appropriate for all panels, this size is common for fire alarm systems and will fit the cabinets of each panel. Excel spreadsheets have been created to automatically calculate the required battery capacity after populating the necessary cells. To begin the quantities of all devices powered by the fire alarm control panel is summarized, this does not include the equipment powered by the remote power supplies. Next, using the manufacturer's datasheets for all devices the quiescent and alarm load in amps is input into the spreadsheet. The spreadsheet will automatically sum the loads, but the minimum quiescent and alarm durations must be input as described above. Lastly, the calculation will indicate the minimum battery size required in amp-hours, which is the product of the total load and duration for both quiescent and alarm conditions. A battery size in amp-hours must be selected which is greater than the value calculated. All batteries to be installed are 12 VDC.

The battery calculations for the power supplies will be completed identically to the fire alarm control panel; however, only the notification devices which are powered directly by that power supply will be included in the calculation.

The battery sizes for the fire alarm control panel and power supplies installed at Centennial Station will all be small enough to fit within the cabinet of the panel they are supplying. This is not always case. For example, voice evacuation systems are required to have 24 hours standby quiescent power and 15 minutes of alarm power, if the fire alarm system was large enough the battery calculations may yield a battery size that would not fit in the cabinet. If this was the case a separate dedicated battery cabinet is installed to house only the batteries.

8.6.2 Voltage Drop Calculations

The fire alarm system will operate at 24 VDC under normal operating conditions, this power is supplied by 120 VAC from the building electrical system then transformed in the panel to 24

VDC. The notification appliances operate at a minimum of 16 VDC, the loss of voltage through the wire from the power supply (or fire alarm control panel) must be calculated to ensure the voltage will operate all of the devices on a circuit. These calculations are attached in Appendix B of this analysis. Because the addressable devices do not operate simultaneously a voltage drop calculation is not necessary for the SLC or any of the IDCs.

The voltage drop has been calculated using the “end of line” method where the voltage drop for a circuit is calculated using the sum of the current for all notification appliances at the end of the circuit. The method was chosen as it is the most conservative approach because the total current is calculated at the furthest distance rather than distributed throughout the circuit as actually installed. This will allow for field deviations in wire routing which may lengthen circuits, without exceeding the minimum voltage at the last device. To calculate the voltage drop the equation $V=IR$ is used, where V is the voltage drop, I is the current in the circuit, and R is the resistance through the wire. The current is given from the manufacturer’s datasheet shown Tables 19 and 20.

Table 19 – Strobe Current Draw

UL Max. Strobe Current Draw (mA RMS)					
	Candela	8–17.5 Volts		16–33 Volts	
		DC	FWR	DC	FWR
Standard Candela Range	15	123	128	66	71
	15/75	142	148	77	81
	30	NA	NA	94	96
	75	NA	NA	158	153
	95	NA	NA	181	176
	110	NA	NA	202	195
	115	NA	NA	210	205
High Candela Range	135	NA	NA	228	207
	150	NA	NA	246	220
	177	NA	NA	281	251
	185	NA	NA	286	258

Table 20 – Horn/Strobe Current Draw

UL Max. Current Draw (mA RMS), 2-Wire Horn Strobe, Standard Candela Range (15–115 cd)									
DC Input	8–17.5 Volts		16–33 Volts						
	15	15/75	15	15/75	30	75	95	110	115
Temporal High	137	147	79	90	107	176	194	212	218
Temporal Medium	132	144	69	80	97	157	182	201	210
Temporal Low	132	143	66	77	93	154	179	198	207
Non-Temporal High	141	152	91	100	116	176	201	221	229
Non-Temporal Medium	133	145	75	85	102	163	187	207	216
Non-Temporal Low	131	144	68	79	96	156	182	201	210

The current is selected for each notification appliance based on the audible and visual characteristics of the device. The resistance in the wire is calculated by multiplying the length of the circuit multiplied by two, multiplied by the resistance in the wire per thousand feet. The resistance is taken from NFPA 70 for various wire sizes and types. The calculations in Appendix B use 3.07 Ohms/1000 feet for 14 AWG, uncoated conductor. Once the voltage drop is calculated it is subtracted from 20.4 volts to ensure the voltage at the last device is greater than 16 volts. NFPA 72 requires an 85% de-rating of the voltage to account for weak batteries, thus

20.4 volts was used though the nominal system voltage is 24 volts. The calculations in Appendix B determined that 14 AWG conductor was acceptable for all of the notification appliance circuits throughout Centennial Station maintaining greater than 16 VDC at the last device of each circuit. The minimum voltage calculated at the last device as found to be 18.13 VDC.

8.7 Inspection, Testing, and Maintenance

Having a thorough inspection, testing, and maintenance program is critical to having a trusting and reliable fire alarm system. The fire alarm system is required to remain unused for many years then must operate as designed to protect life safety and property. To ensure the equipment is reliable it must be tested regularly. The testing, maintenance, and inspection frequencies and procedures are given in NFPA 72 Chapter 10. It is suggested that Centennial Station employ a local contractor to complete the inspection, testing, and maintenance duties.

To ensure the system remains as installed and is unchanged equipment is required to be visually inspected regularly in accordance with Table 10.3.1. The testing frequencies are to be in accordance with Table 10.4.4. The testing procedures are to be completed as specified by Table 10.4.2.2 and the fire alarm system manufacturer's instructions. A table of the frequencies is shown in Table 21.

Table 21 – Inspection, Maintenance, and Testing Frequencies

Fire Alarm IT&M Schedule			
Item	Inspection	Maintenance	Test
Fire Alarm Panel	Annually	As Needed	Annually
Fire Alarm Power Supply	Annually	As Needed	Annually
Automatic Detector	Semiannually	As Needed	Annually
Manual Pull Station	Semiannually	As Needed	Annually
Notification Appliances	Semiannually	As Needed	Annually
Alarm Communication Equip.	Annually	As Needed	Annually
Batteries	Semiannually	As Needed	Annually

The maintenance of the system and peripherals is to be completed as needed. Generally, as a contractor identifies deficiencies with the system during inspection or testing they will suggest items which are to be maintained to ensure the fire alarm system is fully functional.

8.8 Fire Alarm and Detection Design Summary

The fire alarm system at Centennial Station provides limited automatic detection because the building is sprinkler, but the fire alarm system does provide important functions with regard to the elevator control, smoke control, and notification. The limited detection makes the fire alarm system rather simple, but notification will be extensive throughout the building as required. The actual system installed is unknown, but it is assumed that a relatively similar system was installed. Section 7 provides specific information for the sprinkler system that will affect the design of the fire alarm system. These systems must be designed with close coordination.

9.0 STRUCTURAL FIRE PROTECTION

The Structural Fire Protection analysis will thoroughly examine the construction components, building requirements, construction methods, and structural features of the Centennial Station office building with regards to structural fire protection.

9.1 Fire-Resistance-Rated Construction

Fire-resistance-rated construction is governed by Chapter 7 of the IBC. The fire-resistance ratings are used to safeguard against the spread of fire and smoke within the building as well as between buildings. The ratings at Centennial Station will be used for corridors, stairways, egress passageways, and mixed use separation. Each rated wall will indicate the period of time which the building element will be able to confine a fire as determined by specific test methods. The rated walls are indicated on the plans LS-1 through LS-4 in Appendix C.

The test procedures for determining the fire-resistance rating of a building element are to be as described in ASTM E 119 “Standard Test Methods for Fire Tests of Building Construction and Materials” required by Section 703.2 of the IBC. Using a furnace, the building elements are exposed to temperatures expected during a fire, greater fire-resistance ratings are required to withstand greater temperatures. The Time-Temperature Curve is shown in the Table 22.

Table 22 – Time-Temperature Curve

Time-Temperature Curve	
Temperature (°F)	Time
1000	at 5 min
1300	at 10 min
1550	at 30 min
1700	at 1 hour
1850	at 2 hour
2000	at 4 hour
2300	at 8 hour

When required for the conditions of approval the test specimens are also to be subjected to a hose stream test where a hose stream is used to evaluate the impact, erosion, and cooling effects on the building element at a specified pressure and duration. The conditions for the hose stream test are shown in Table 23.

Table 23 – Conditions for Hose Stream Test

Conditions for Hose Stream Test		
Resistance Period	Water Pressure at Base of Nozzle (psi)	Duration of Application (min/100 ft² exposed area)
8 hour and over	45	6
4 hour and over if less than 8 hour	45	5
2 hour and over if less than 4 hour	30	2.5
1-1/2 hour and over if less than 2 hour	30	1.5
1 hour and over if less than 1-1/2 hour	30	1
Less than 1 hour	30	1

Test details are specific for each building element including walls, partitions, columns, beams, and roof and floor assemblies; each element has defined conditions of acceptance. The conditions of acceptance for nonbearing walls and partitions used at Centennial Station will be as defined by Section 18 of ASTM E 119:

“18.1.1 The wall or partition has withstood the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.”

“18.1.2 The wall or partition has withstood the fire and hose stream test as specified in 10, without passage of flame, of gases hot enough to ignite cotton waste, or of passage of water from the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.”

“18.1.3 Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F above its initial temperature.”

Because the building construction Centennial Station is Type II-B no fire-resistance ratings are required for any of the building elements; however, fire-resistance rated barriers are necessary for specific life safety objectives and occupancy separation. The locations of the fire barriers are further discussed in this analysis where required.

Fire barriers are defined as a fire-resistance-rated wall assembly of materials designed to restrict the spread of fire and are to be installed in accordance with Section 706 of the IBC. Fire barriers are suitable for construction of shaft enclosures, exit enclosures, exit passageways, atriums, incidental use areas, and separation of mixed occupancies. Fire barriers are required by Section of 706.5 to extend from the top of the floor/ceiling assembly below to the underside of the floor or roof slab or deck above and shall be securely attached thereto. The fire barriers shall be continuous through suspended ceilings. The fire barriers used at Centennial Station will be fire-resistance-rated for either 1-hour or 2-hours as shown on the plans in Appendix C. There are several different construction methods that are acceptable for the construction of fire-resistance-rated walls. The construction of the walls will depend on varying factors including if the walls are interior or exterior, load bearing or non-load bearing, and made of wood or steel. The majority of the rated walls at Centennial Station will be interior non-load bearing walls constructed of steel supports and drywall without insulation. One method of construction of the 1-hour fire-resistance-rated walls is shown below as an example.

Image 37 – 1-Hour Rated Wall Assembly

The wall assembly shown in Image 37 is System WPC138 from the CertainTeed “Gypsum Board Systems Manual” 2012 Edition. The assembly shown is constructed of one layer of 5/8 inch gypsum board on each side of 2-1/2 inch steel studs. The gypsum board is to be fastened to the studs vertically every 8 inches and along the floors and ceilings every 12 inches. This assembly is listed in accordance with UL U465.

Image 38 – 2-Hour Rated Wall Assembly

The walls assembly shown in Image 38 is System WPB245 from the CertainTeed manual. The assembly is constructed of two layers of 5/8-inch gypsum board on each side of 2-1/2-inch steel studs. The base and face layer of the gypsum board is to be fastened vertically every 12 inches. The seams between the two layers of gypsum board need to be offset. This assembly meets the listing of UL U411. It should be noted that had fire-resistance rating been required for columns, beams, or other structural member UL provides similar guidance on the construction and application of the fire resistance protection.

Through penetrations used for plumbing, piping, conduit, cable tray, ducting, or any other equipment of fire rated wall assemblies including fire barriers, shall be protected in accordance with Section 712 of the IBC. Penetrations are to be protected using an approved method, including a fire-resistance-rated assembly or a firestop system. Firestop systems shall be installed as tested in accordance with ASTM I814 or UL 1479. An example of a UL listed firestop system is shown in the Image 39.

Image 39 – Penetration Detail

Image 39 is from the Hilti “Firestop Systems Specifiers Guide – U.S. Volume 14”. The image shows one of many protection methods for a metal pipe penetrating concrete floor/wall or block wall using an optional sleeve. The concrete is tight against the sleeve; the pipe runs through the sleeve leaving a gap subject to passage of smoke and heat. The gap is packed with mineral wool and then covered with intumescent firestop sealant. All penetrations through fire barriers are to be protected using similar methods in accordance with manufacturer’s specifications.

All openings in fire rated wall assemblies, including doors and windows, shall comply with Section 715 of the IBC. The fire door ratings are based on the ratings of the walls they are installed in. The door rating for various wall ratings are shown in Table 715.4 Fire Door and Fire Shutter Fire Protection Ratings from the IBC, shown in Image 24.

Table 24 – Fire Door and Fire Shutter Fire Protection Ratings

TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE DOOR AND FIRE SHUTTER ASSEMBLY RATING (hours)
Fire walls and fire barriers having a required fire-resistance rating greater than 1 hour	4	3
	3	3 ^a
	2	1½
	1½	1½
Fire barriers having a required fire-resistance rating of 1 hour: Shaft, exit enclosure and exit passageway walls Other fire barriers	1	1
	1	¾
Fire partitions: Corridor walls Other fire partitions	1	⅓ ^b
	0.5	⅓ ^b
	1	¾
	0.5	⅓
Exterior walls	3	1½
	2	1½
	1	¾
Smoke barriers	1	⅓ ^b

In addition, door assemblies in corridors are required to have a minimum fire protection rating of 20 minutes tested in accordance with NFPA 252 without the hose stream test. All rated door assemblies are to be labeled in accordance with Section 715.4.5.1 indicating the name of manufacturer, inspection agency, fire protection rating, and the maximum transmitted temperature end point when required. The door assemblies shall be side-hinged, equipped with a latching mechanism, and self-closing per Section 715.4.7 of the IBC. Doors which close automatically upon detection of smoke are considered self-closing and are to be installed in accordance with Sections 715.4.7.3 and 907.10 of the IBC.

Fire window assemblies are permitted to be installed in smoke barriers and fire partitions. The fire window assemblies shall be tested in accordance with NFPA 257 and installed in accordance with Section 715.5 of the IBC. Minimum fire window assembly ratings are to be in accordance with Table 715.5 of the IBC shown in Table 25.

Table 25 – Fire Window Assembly Protection Ratings

TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE WINDOW ASSEMBLY RATING (hours)
Interior walls:		
Fire walls	All	NP ^a
Fire barriers	> 1	NP ^a
Smoke barriers	1	³ / ₄
and fire partitions	1	³ / ₄
Exterior walls	> 1	1 ¹ / ₂
	1	³ / ₄
Party wall	All	NP

The fire window assemblies are to be labeled indicating the name of the manufacturer, the test standard, and the rating. These types of assemblies will be installed between the atrium and the second and third floors.

When ducts and air transfer openings penetrate fire-resistance-rated wall assemblies they shall be installed in accordance with Section 716 of the IBC. Fire dampers are listed devices installed in ducts to automatically close upon detection of heat to resist the passage of flame. The fire dampers can operate using a fusible link or an actuator controlled by the fire alarm system. The fire dampers described in this section will be for the penetration of rated wall assemblies, smoke dampers associated with the atrium smoke control system are specified in other sections of this analysis. The fire dampers for the Centennial Station are required to have a minimum rating of 1.5 hours per Table 716.3.1 for assemblies rated less than 3-hours. Fire dampers will be required specifically in the fire barriers in the corridors and where occupancies are separated. The fire dampers shall automatically close upon detection of heat, the operating temperature is required to be 50°F above the normal temperature within the duct system, but not less than 160°F.

It is noted that in accordance with Section 716.5.2 exception 3 – fire-resistance-rated wall assemblies of 1 hour penetrated by duct systems constructed of minimum 26 gauge steel are not required to have fire dampers. This is only allowed for duct system conveying supply, return or exhaust air.

There are various compliant fire damper assembly manufacturers and configurations. One such assembly is shown in Image 40.

Image 40 – Fire Damper Detail

In the image above an accordion type fire/smoke damper is shown. During a fire the fusible link will release the damper vanes closing the damper.

While fire dampers will be necessary in the fire-resistance-rated wall assemblies, fire/smoke dampers will be required for the smoke control system in the atrium. An example of a fire/smoke damper is shown in Image 41.

Image 41 – Fire/Smoke Damper Detail

The fire/smoke damper is constructed of several blades, a jackshaft, sleeve, actuator, and thermal sensor. The thermal sensor is set to a temperature a similar to the fire damper; upon detection of the preset temperature, the actuator will mechanically move the jackshaft closing the blades preventing the spread of flame. The fire/smoke damper is also controlled by detection of smoke, when smoke is detected the actuator will automatically close the damper; the damper closure is

to be controlled by the fire alarm system. Fire/smoke dampers will be discussed further in the requirements for the smoke control system in the atrium.

9.1.1 Fire Resistance Calculations

The floor assemblies and columns are not required to be designed to meet specific fire resistance ratings; however, they are required to be non-combustible. Furthermore, by the nature of the materials used and construction methods utilized, the floor assemblies have an inherent fire resistance rating. The rating for the floor system constructed of poured concrete on a metal deck can be determined by applying Table 26, Table 721.2.2.1 of the IBC.

Table 26 – Minimum Slab Thickness (inches)

CONCRETE TYPE	FIRE-RESISTANCE RATING (hour)				
	1	1½	2	3	4
Siliceous	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

Assuming a nominal slab thickness of 3.5 inches for the poured concrete and metal deck it can be determined that the fire-resistance rating is 1-1/2 hours when light weight concrete is used.

Additionally, had the columns been required to have a minimum fire-resistance rating several methods can be used. The IBC defines two specific methods for protecting steel columns; the first is gypsum wallboard protection and the second is spray-applied fire-resistant materials. The resistance provided by gypsum wallboard protection can be calculated using the following equation:

$$R = 130 \left[\frac{h(W'/D)}{2} \right]^{0.75}$$

Where R is the resistance in minutes, h is the thickness of the gypsum wallboard, D is the heated perimeter, W' is equal to $W + 50hD/144$. The wallboard is to be installed as directed by the IBC Chapter 7. An example of two methods of constructing gypsum board protection are shown in Image 42.

Image 42 – Gypsum Wallboard Protection

The resistance from the spray-applied fire-resistant material is calculated similarly using the following equation from the IBC:

$$R = [C_1(W/D) + C_2]h$$

Where R is the fire resistance in minutes, h is the thickness of the spray-applied material, D is the heated perimeter, C₁ and C₂ are material dependent constants, and W is the weight of the structural steel. An example of the application of spray-applied fire-resistant material is shown in Image 43.

Image 43 – Spray-Applied Fire-Resistance Rated Material

The method of fire-resistance protection would likely be based on if the beams are exposed or not. For example, the beams and columns in the parking area could be protected by spray-applied fire-resistance materials because the beams are exposed. The columns in the office area would likely be protected with gypsum wall board for aesthetic purposes.

9.2 Occupancy Separation

Occupancy separations for buildings with mixed uses are to be provided with occupancy separation as specified in Section 508 of the IBC. Building occupancy separations are used to separate higher hazard areas from lower hazard areas. Table 508.2 of the IBC indicates several incidental use areas which require separation. The only applicable incidental use separation at Centennial Station is from the parking garage and parking areas. Parking areas and the parking garage are required to have a minimum 2-hour separation or 1-hour separation for sprinklered buildings. These incidental use areas will be provided with 1-hour fire-resistive-rated separation.

In addition to incidental use areas specific occupancies must be separated by 1-hour, 2-hour, 3-hour, or 4-hour fire-resistance-rated assemblies. The separations are to be in accordance with Table 27, Table 508.3.3 of the IBC.

Table 27 – Required Separation of Occupancies (hours)

OCCUPANCY	A ^e , E		I		R ^d		F-2, S-2 ^{c,d} , U ^d		B ^b , F-1, M ^b , S-1		H-1		H-2		H-3, H-4, H-5	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A ^e , E ^e	N	N	1	2	1	2	N	1	1	2	NP	NP	3	4	2	3 ^a
I	—	—	N	N	1	NP	1	2	1	2	NP	NP	3	NP	2	NP
R ^d	—	—	—	—	N	N	1	2	1	2	NP	NP	3	NP	2	NP
F-2, S-2 ^{c,d} , U ^d	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3 ^a
B ^b , F-1, M ^b , S-1	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2 ^a
H-1	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP
H-3, H-4, H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP

Note that S indicates a sprinklered building, NS indicates a nonsprinklered building, N indicates no separation required, and NP indicates not permitted. Using the Table 508.3.3 it is shown that B and S-2 occupancies do not need to be separated; however, B and S-1 are required to be separated by a 1-hour fire barrier from A and E occupancies. Thus the meeting rooms, conference rooms, and training rooms are required to be separated from the B occupancy by a 1-hour fire rated wall, unless the assembly area is deemed to be accessory to the rest of the building per Section 508.3.1.3. Assembly occupancies are considered accessory when the aggregate accessory occupancy does not occupy more than 10 percent of the floor area of the story in which it is located per Section 508.3.1 or where assembly areas have a floor area of less than 750 square feet.

Training Room 256 on the second floor of Centennial Station is 2107 square feet. The aggregate sum of the floor area for the Training Room, Pressroom, and two meeting rooms is 3,400 square feet, equal to 14 percent of the floor area. Because the Pressroom and meeting rooms do not exceed 750 square feet rated wall assemblies are not required; however, the Training Room will require 1-hour separation. All other meeting rooms and assembly areas on other floors do not exceed the limit of 10 percent of the floor area on all other floors.

The fire-resistance-rated wall assemblies are shown on plans LS-1 through LS-4 in the Appendix C.

9.3 Structural Fire Protection Summary

Structure fire protection at Centennial Station is rather limited because of the Type II-B construction type; however, several systems are required. Specifically, the rated exit passage way, separation between the parking areas and the business use areas, and the stairways and elevator shafts. It is important that these ratings be constructed utilizing UL listed assemblies and these assemblies are maintained through any potential future tenant improvements.

10.0 SMOKE CONTROL

The atrium in the lobby of the Centennial Station extends from the first floor to the third floor. The atrium can be seen through windows on the second and third floors and there is a balcony in the atrium from the second floor. This section will detail the requirements of the smoke control system, the exhaust rate as calculated by NFPA 92, and an FDS simulation showing the effectiveness of the smoke control system. The design of the smoke control system will be a performance based design ensuring tenable conditions are maintained for a duration suitable for egress from the building. For the purpose of this analysis the smoke exhaust system will be sized

based on equations from NFPA 92B. Exhaust and make-up air rates would likely be reduced for the actual system installed to reduce the cost of the system providing value engineering principles.

10.1 Code Requirements

IBC Section 404.1.1 defines an atrium as a space that connects more than two stories in a building, not including elevator shafts and stairways. Section 404.5 of the IBC requires atriums have a smoke control system designed in accordance with Section 909 of the IBC. Because the atrium technically only connects two stories IBC Section 404.5 exception 1 permits the lobby in Centennial Station not be considered an atrium. Exception 1 requires a glass wall between occupied floors and the atrium to have a glass wall forming a smoke partition with automatic sprinklers spaced not greater than 12 inches from the glass wall and not separated by more than six feet. The sprinkler system at Centennial Station has been designed such that this exception is met.

Section 909 of the IBC requires an engineering analysis of the smoke control system to evaluate the following items:

- Stack effect;
- Temperature effect of the fire;
- Wind effect;
- HVAC systems;
- Climate;
- Duration of operation.

The smoke control system will be designed as specified by Section 909.8 of the IBC requiring smoke exhaust systems to be designed in accordance with NFPA 92B to maintain a minimum smoke layer height of six feet above the highest occupied floor level. The atrium balcony floor level is 12 feet above the first floor; therefore, the maximum smoke layer height would be 18 feet above the first floor.

10.2 Design Fire

Two design fire scenarios will be used to evaluate the smoke control system.

10.2.1 Design Fire One

Design fire one will be based on a wood desk being provided in the center of the lobby. Based on the architectural plans this is the only expected furniture that will be placed in the atrium. Image 44, Figure 3-1.59 from the SFPE Hand book was used to determine the heat release rate of a fire for a wood desk. The image below shows testing data for several office furniture layouts, line A for wooden furniture was used. A maximum heat release rate of 3,300 kW at 500 seconds was used for the design fire. Using the peak heat release rate and time to that peak it was determined that the design fire was a medium growth fire with a fire growth rate constant $\alpha = 0.0132 \text{ kW/sec}^2$. A soot yield of 0.015 per SFPE Table 3-4.14 was used in the model. Additionally, a carbon monoxide yield of 0.004 will be used per SFPE Table 3-4.14.

Image 44 – HRR of Wood Desk

10.2.2 Design Fire Two

Design fire two will be based on a polyurethane chair being placed in the space near the elevator lobby, while this is not shown on the architectural plans it is a possible location for a chair. Image 45, Table B.2.3.2.6.2.e was used to determine the maximum heat release rate of a fire from a polyurethane chair. The image below shows testing data for a polyurethane chair. A maximum heat release rate of 950 kW at 60 seconds was used for the design fire. The design fire is classified as an ultra-fast fire. A soot yield of 0.198 per SFPE Table 3-4.14 was used in the model. Additionally, a carbon monoxide yield of 0.042 will be used per SFPE Table 3-4.14.

Image 45 – HRR of Polyurethane Chair

10.3 Exhaust Rate

The maximum necessary exhaust rate was calculated based on the smoke mass production as calculated in NFPA 92B. The following equations were used:

- $z_l = 0.166Q_c^{2/5}$
- $m = (0.071Q_c^{1/3}z^{5/3}) + 0.018Q_c$

The resulting mass smoke production rate was multiplied by the density of air to calculate the volumetric flow rate. This was converted from kg/m^3 to cfm as shown in Table 28.

Table 28 – Exhaust Rate Calculation

Atrium Exhaust Rate		
Q =	3300	kW
$\chi_c =$	0.7	-
$Q_c =$	2310	kW
$z_l =$	3.7	m
$z =$	9.1	m
$m =$	41.4	kg/s
$\rho =$	1.2	kg/m^3
$V =$	34.5	m^3/s
$V =$	73076	cfm

10.4 Atrium HVAC

The atrium smoke control system will consist of a two exhaust fans located at the center of the ceiling of the atrium having a volumetric flow rate of 36,500 cfm each. Several make-up air vents will be provided on the first and second floor to provide make up air. The make-up flow rate will be 85% of the exhaust rate as recommended by NFPA 92B. The make-up air vents will be supplied by the building air handlers, upon smoke detection dampers will close directing all supply air to the atrium. Eight vents have been installed in the atrium, each vent will supply 7,700 cfm to provide 85% of the exhaust rate. The FDS simulation will be used to ensure the velocity of the make-up air near the design fire does not exceed 200 ft/min (1.02 m/s)

10.5 FDS Simulation

The FDS simulation was ran for up to 1000 seconds using the design fires and smoke exhaust system described above to determine the adequacy of the smoke control system. Pryosim, an external input user interface for FDS, was used to create the model shown in Image 46.

Image 46 – FDS Simulation Screenshot

For clarity the glass wall on the front of the atrium has been hidden. In the model the blue dots on the ceiling are sprinkler heads, the pink squares are the makeup air vents, green vents can be seen on the ceiling that are the exhaust vents, and green dots on the third floor are measuring the temperature, fractional effective dose, and temperature of the third floor. Not shown in the model is a measurement of the smoke layer height in the atrium, a beam detector at the ceiling of the atrium and slice files measuring the air velocities in the atrium. The beam detector will activate the smoke control system at 30% obscuration. The model will be ran assuming the sprinkler activation does not reduce the heat release rate of the fire. Because of the relatively low height of the atrium it was determined that stack effect would not affect the activation of the smoke control system. The tenability conditions resulting from the model are discussed in Section 11.2.2.

10.6 Smoke Control Design Summary

The smoke control system will have two design fires evaluated to analyze the effectiveness of the system. A FDS simulation will be used to evaluate the system design using NFPA 92B smoke exhaust rate calculations. The design fire scenario results are described in Section 11.2.2.1 and 11.2.2.2 of this analysis.

11.0 ASET VERSUS RSET

It is critical that in the event of a fire all occupants are allowed enough time to safely exit the building. To ensure sufficient egress time is allowed the available safe egress time (known herein as ASET) must be greater than the required safe egress time (known herein as RSET). ASET has been evaluated using the design fires described in Section 10. The results for tenability conditions are shown in Sections 11.2.2.1 and 11.2.2.2. The RSET will be evaluated using performance-based design modeling the egress time using Pathfinder and SFPE hand calculations to determine the travel time for occupants to egress the building.

ASET is defined as the duration of time from the ignition of a fire to the time when conditions in the building become untenable and occupants are no longer able to move to a safe location. RSET is defined as the time required for an occupant to travel from an initial location to a safe location. The safe location for the Centennial Station will be outside building, though with specific construction methods, such as the addition of areas of refuge, this is not necessarily required.

11.1 Required Safe Egress Time

RSET is the sum of the time from ignition to detection, time to notification, pre-evacuation time, and movement time – the time needed to escape the building. For the purpose of the egress portion of this analysis the time from ignition to detection will not be included; this will be added for the culminating project. ASET is the time available to escape. Figure 3.11.4 from the Fire Protection Handbook, shown in Image 47 provides a visual representation of ASET and RSET.

Image 47 – RSET Visual Diagram

11.1.1 Detector Activation Time

In order to calculate the necessary required safe egress time (RSET) the detector activation time is to be calculated. The beam smoke detector activation time was modeled in FDS in Section 10 using the design fire used for the smoke control system. Image 48 shows the simulation of the atrium fire, the image was taken at the time of beam detector activation, 30 seconds.

Smokeview 6.2.2 - Apr 10 2015

Frame: 25
Time: 31.5

0.05 (0.0000)

0.0001

Image 48 – Beam Smoke Detection Activation

11.1.2 Time to Notification

It is assumed that the first occupant notification will be from the fire alarm system. Upon activation of the beam smoke detector the fire alarm system will provide notification throughout the building via horns and strobes. No delay between detection and alarm activation is expected.

11.1.3 Pre-movement Time

The pre-movement time allots for the time occupants will use to investigate the alarm signal. Pre-movement time is based on the occupants as well as the type of fire alarm system installed in the building. Generally, office building, schools, and commercial buildings will have occupants which are awake, coherent and capable of self-preservation; these facilities will require the shortest pre-movement times. Shops, museums, sport centers, and assembly buildings will have require a longer pre-movement time because the occupants may be unfamiliar with the building. Hotels and boarding houses will require even longer pre-movement times as the occupants could be asleep. Lastly, hospitals, nursing homes and institutional facilities will require the longest pre-movement times as occupants will likely require assistance. Furthermore, the pre-movement times are based on the types of alarms installed in the building. Three alarm systems are accounted for: emergency voice/alarm communication with live directives, emergency voice/alarm communication with recorded voice messages, and a warning system with a coded temporal signal. The shortest pre-movement times are found using live voice messages, while the longest pre-movement times are from a standard fire alarm system. Pre-movement times for Centennial Station was determined to be 1 minute per PF 7974-6:2004 was used as recommended by the SFPE Handbook, 4th Edition. It is noted that the SFPE Handbook, 3rd Edition recommended 4 minutes, but recent testing has shown improved pre-movement times.

Furthermore, it is anticipated that the holding cells on the first floor will temporarily hold occupants, any person in the holding cell will be monitored and offered immediate assistance in the case of a fire or evacuation.

11.1.4 Travel Time First-Order Approximation

The travel time is defined as the time needed to move from the building to a safe location. For the Centennial Station the maximum travel time will be to egress from the fourth floor down three flights of stairs and egress to the exterior of the building. The occupant load and area for each floor are given in Table 29.

Table 29 – Occupant Load and Area

Building Occupant Load and Area		
Floor	Occupant Load (persons)	Area (square feet)
1	103	23724
2	250	23456
3	230	22774
4	261	22087
Building Total:	844	92041

A first-order approximation will be used to calculate the travel time as described in the Fire Protection Handbook Chapter 4-2. To calculate the estimated travel time it is assumed that all occupants will begin egressing at the same time resulting in a prime controlling factor, either the doorway leading to the stairway or the stairway itself. The controlling factor will lead to

queuing at a specific location. The specific flow, F_s , through the controlling egress components is calculated to determine where queuing will occur.

The estimated flow capability for a single stairway is calculated by first finding the effective width, W_e , of the stairway. The effective width of the stairway is the width of the stairway minus a boundary layer, which clearance required from the wall and handrails while using the stairway. The stairway in Centennial Station is 44 inches wide, using Table 4.2.4 of the Fire Protection Handbook, the boundary layer for the stairway is found to be 6 inches on each side. The maximum specific flow, F_{sm} , through the stairway is 18.5 persons/min/ft found in Table 4.2.8 of the Fire Protection Handbook. The maximum specific flow is the quantity of people that can pass through a stairway per minute per effective width (feet) of the stairway. The calculation for a single stairway at Centennial Station is shown in Table 30.

Table 30 – Flow Capability of a Stairway

Estimated Flow Capability of a Stairway		
Stairway Effective Width	Stairway Specific Flow	Stairway Flow
W_e	F_{sm}	F_s
(feet)	(persons/min/ft)	(persons/min)
2.67	18.5	49.3

Similarly to the stairway, the door way flow capability is to be calculated. The clear width of the doorways entering the stairways in Centennial Station are 2 feet 10 inches; the boundary layer through the door is 6 inches on each side. The maximum specific flow through the doorway is 24 persons/min/ft. The calculation for the flow capability of a doorway is shown in Table 31.

Table 31 – Flow Capability of a Doorway

Estimated Flow Capability through a Door		
Door Effective Width	Door Specific Flow	Door Flow
(feet)	(persons/min/ft)	(persons/min)
1.83	24	44.0

Because the flow from the doorway is less than that of the stairway, the doorway will be the controlling factor for egress from the building.

Next the estimate of the speed of movement for the stairway flow is calculated. The speed of movement is calculated using Equation 4-2(1), shown below:

$$S = k - akD$$

Where S is the speed of exiting individuals, k is the evacuation speed constant found in Table 4.2.5, “ a ” is 2.86 used for calculations using British measurements, and D is the density (persons/area). The evacuation speed constant is given in Table 4.2.5 of the Fire Protection Handbook; 212 is used for stairways with 7 inch risers and 11 inch treads. The density is found using Figure 4.2.7 of the Fire Protection Handbook; the density is found to be 0.175 persons/square foot for a stairway with a specific flow of 24 persons/min/ft. The speed calculation is shown in Table 32.

Table 32 – Estimated Speed of Movement

Estimated Speed of Movement for Stairway Flow			
D (persons/square foot)	k	a	S (ft/min)
0.175	212	2.86	105.9

The time to travel between floors is needed to be added to the total evacuation time. The distance between floors at Centennial Station is 12 feet. A conversion factor of 1.85, given in Table 4.2.6 of the Fire Protection Handbook, is used to calculate the actual travel distance between floors. A resulting travel distance of 22.2 feet is found when the conversion factor is applied. Additionally, each stairway is provided with a landing between each floor, the travel distance on the landing is 4 feet; therefore, the total travel distance between floors is 26 feet. The time to travel between floors is calculated using the speed calculated previously. The travel time between floors is shown in Table 33.

Table 33 – Floor to Floor Travel Time

Floor to Floor Travel Time			
Travel Distance Between Floors (feet)	Landing Distance (feet)	Floor to Floor Travel Distance (feet)	Travel Time per Floor (min)
22.2	4	26.2	0.2

Finally, the building evacuation time is calculated. This is calculated using the time for one-half of the total building occupant load, because two stairways are provided, to egress through the doorway plus the time to egress from the second floor to the exit. The total egress time is given in Table 34.

Table 34 – Building Evacuation Time Estimate

Building Evacuation Time Estimate			
Doorway Discharge (persons/min)	Stairways	Stairway Travel Time (min)	Total Evacuation Time (min)
44.0	2	0.2	8.7

The total estimated egress time to evacuate the floors above the first floor is 8.7 minutes. Note that the occupant load of the first floor is not included in the time to evacuate as the first floor occupants would not experience the crowding at the exit doors because of the relatively low occupant load on the first floor and additional exits provided.

11.1.5 Travel Time Using Pauls' Data

Two empirically based evacuation time equations are given in Figure 4.2.2 of the Fire Protection Handbook. These equations are shown below:

$$T = 0.70 + 0.0133p \text{ for } p > 800 \text{ persons/m}$$

$$T = 2.00 + 0.01173p \text{ for } p < 800 \text{ persons/m}$$

Where T is the total evacuation time in minutes and p is the evacuation populations in persons per meter of effective width. The calculation for the evacuation time using Pauls' data was completed using two exits with a width of 34 inches and an effective width of 22 inches, the calculation is shown in Table 35.

Table 35 – Pauls’ Data Evacuation Estimate

Pauls Method		
Door Width	34	inch
Effective Door Width	22	inch
Effective Door Width	0.5588	m
Occupant Load	844	persons
Number of Exits	2	-
P	755.2	Persons/meter
Egress Time	10.8	min

The estimated evacuation time is 2.1 minutes longer than that calculated using the first-order approximation. Note that this method is no longer used as the input data has been questioned for its validity in varying egress scenarios.

11.1.6 Pathfinder Simulation

Many computer based egress simulators are currently available, including Evacnet4, BuildingExodus, Simulex, Mass Motion, and Pathfinder, to estimate the egress time required from buildings. The computer based program Pathfinder, version 2014.3.1020, has been used in this analysis. Pathfinder was developed in the mid-2000’s by Thunderhead Engineering. In addition to Pathfinder Thunderhead has developed Pyrosim, a graphical user interface to be used with Fire Dynamics Simulator, a computation fluid dynamic calculator used for modeling specific fire scenarios. Pathfinder is ideal for use because it can simulate models used in Pyrosim.

Pathfinder is an agent based model that utilizes a 3D, triangulated mesh to match the real dimensions of the building to be evaluated. Walls are represented as impassable gaps in the navigation mesh, while doors are represented as mesh edges used for passage. Stairways are specified for riser height and tread depth. Elevators can be included in the simulation; however, because of the elevator recall functionality at Centennial Station elevators will not be included in the model.

To create the Pathfinder simulation, the AutoCAD files for each background were input into the graphical user interface separated by 12 feet in the vertical direction. The navigation geometry for each floor was automatically input by Pathfinder, and then each doorway in every room, corridor, and stairway was input manually. All rooms and tenable areas of the building were assigned an occupant load matching those shown drawings LS-5 through LS-8 in Appendix C of this analysis. The travel speed of occupants is set at 3.2 feet/second as given in Table 4.2.3 of the Fire Protection Handbook for the average walking speed under normal conditions; note that this is less than the Pathfinder default travel speed of 3.9 feet/second. The default width of each occupant, 18 inches, was used for the simulation. Additionally, the following default occupant parameters were used: acceleration time – 1.1 seconds, comfort distance – 1.0 feet, and collision response time – 1.5 seconds. A snapshot from the Pathfinder graphic user interface is shown in Image 45.

Image 49 – Pathfinder Graphic User Interface

All four floors are shown stacked vertically with connecting stairways, seen on the left side of the image. The floors are separated by 12 feet. All dimensions of rooms, doors, corridors, and stairways are to scale. The stair rise and tread have been input to be 7 inches and 11 inches respectively. The blue cylinders are the agents, where the quantity is as calculated for each specific area based on use.

There are two available behavior modes for use when running the Pathfinder simulation, both modes were simulated for comparison in this analysis. The first mode is the SFPE mode which uses door flow rates and stairway flow rates to limit the rate of egress by the agents where an equal distribution of occupants will use each exit. The SFPE mode is calculated using the same parameters as discussed for the SFPE hand calculation performed above. The total egress time for the SFPE mode simulation was 10.7 minutes, this compares relatively well with the hand calculated value of 8.7 minutes found using the SFPE equations. The second simulation option is the steering mode. The steering mode is a more complex calculation which allows agents to make decisions on which exit to use based on availability. Flow rates are limited by available densities through exits. The steering mode calculated the egress time for 844 occupants to exit Centennial Station to be 8.1 minutes.

The following four images, Images 50 through 53, show the plan view of the results output file from Pathfinder indicating the starting position of every agent; the starting positions have been randomized by Pathfinder. The text in the top right corner of the images show the quantity of agents that have egressed through an exit to the exterior of the building out of the initial occupant load of 844. The text in the bottom right of the image shows the running time of the simulation.

Image 50 – Pathfinder First Floor

Image 51 – Pathfinder Second Floor

Image 52 – Pathfinder Third Floor

Image 53 – Pathfinder Fourth Floor

Pathfinder steering mode optimizes egress by estimating the behavior of occupants rather than simply dividing the total number of occupants by the number of exits and assuming equal distribution as is done in the first-order approximations. In the simulation for Centennial Station two of the three main exits were used, the exit door on the north-east corner was not chose by the agents because the north-west door was closer to the stairway through the lobby. The graph of the door usage provided from the Pathfinder output file is shown in Image 54.

Image 54 – Pathfinder Door Use Graph

Door 120 is the exit on the west side of the main lobby and Door 141 is the exit on the south side of the building. A total of 393 occupants exited through Door 141 and the remaining 451 occupants exited through Door 120, varying from the first-order approximation which assumed equal use of the exits. The usage through Stairways 1 and 2 on each floor were found using the data from Pathfinder. A summary for each floor is shown in Table 36.

Table 36 – Stairway Use

Stairway Use Distribution		
Floor	Stairway 1	Stairway 2
2	129	121
3	121	109
4	108	153

The complete verification and validation document for the Pathfinder program can be found at the Thunderhead Engineering website. Verification ensures the software is operating properly as specified by the Pathfinder Technical Reference. Validation measures how well the simulation captures real behavior based on experimental data or experience. Thunderhead Engineering has run simulations to compare the software times to experimental data to ensure the program calculated results as expected. It has been determined that based on the testing information available the Pathfinder software is appropriate for the egress simulation performed at Centennial Station.

A comparison of the three types of egress calculations are as follows: SFPE Method 8.7 minutes, Pauls' Method 10.7, and the Pathfinder Simulation 8.1 minutes. Using this information, the

Pathfinder method was determined to be in-line with other calculation methods and will be used for the travel time analysis.

To determine the egress time from Centennial Station during an atrium fire a second Pathfinder scenario was simulated. The simulation was ran not allowing egress through the atrium to determine the delay caused by loss of egress capacity. The rerun of this simulation indicated that without egress through the atrium the travel time will be 14.75 minutes.

A summary of the RSET calculation is provided in Table 37.

Table 37 – RSET Calculation Summary

RSET Summary	
Activity	Time (minutes)
Detection	0.5
Pre-movement	1
Travel Time	14.75
Total:	16.3

11.2 Available Safe Egress Time

ASET is the time interval from ignition of the fire until the time at which conditions in the building become untenable. As calculated in the previous section, the RSET is a minimum of 16.3 minutes; the ASET must be greater than this time. ASET can be evaluated by the tenability conditions within the building from heat or products of combustion generated by a fire, the shortest time to untenable conditions shall be used for the ASET. Typically smoke inhalation by the occupants leading to incapacitation will provide the most conservative ASET. Section 11 indicated that the conditions in the atrium will be tenable for the duration of the model.

11.2.1 Tenability Requirements

Untenable conditions from a fire can occur due to five primary reasons, lack of visibility, lack of oxygen, excess carbon dioxide, excess carbon monoxide, or excessive heat. Furthermore, other toxins could be present based on the chemical composition of the fuel; however, this will not be discussed further because the potential fuel load is not expected to have unusual materials.

Because of the effects on the human body of carbon monoxide it is lethal at relatively low levels and is the leading cause of death from fire events. For this reason, lack of oxygen and excessive heat are not normally sole factors for untenable conditions because for a fire to reach a size in which the temperature or oxygen level reach untenable levels it is likely that carbon monoxide poisoning has already occurred. During a fire carbon monoxide is introduced into the human body by inhalation. Once in the body the carbon monoxide combines with hemoglobin in the blood to create carboxyhemoglobin. Elevated levels of carboxyhemoglobin in blood result in asphyxiation by limiting the amount of oxygen that can be delivered to the brain by blood. Carbon dioxide does not directly affect the body in concentrations emitted by a fire; however, the increased carbon dioxide levels will increase the breathing rate of occupants during exposure resulting in increased inhalation of carbon monoxide.

The time to incapacitation from carbon monoxide alone is dependent on the concentration of carbon monoxide. Exposure to high concentrations will lead to incapacitation in shorter times and low concentrations will lead to incapacitation in longer times. Haber's rule will be applied for the exposure to carbon monoxide using the following equation:

$$W = C \times t$$

Where W is the constant dose, C is the concentration in parts per million (ppm), and t is the exposure time. A concentration of 27,000 ppm-min is used as a baseline for incapacitation. Tenable conditions used for the ASET analysis will be 1,400 ppm for a duration of 20 minutes.

Oxygen depletion from a fire can lead to low-oxygen hypoxia when occupants are subjected to low oxygen levels. Normal atmospheric conditions have an oxygen concentration of approximately 20.9 percent. As shown in the SFPE Handbook low oxygen levels have the following effects on occupants based on concentration:

- 20.9 – 14.4 percent: no significant effects, slight loss of exercise tolerance;
- 14.4 – 11.8 percent: slight effects on memory and mental task performance, reduced exercise tolerance;
- 11.8 – 9.6 percent: severe incapacitation, lethargy, euphoria, loss of consciousness;
- 9.6 – 7.8 percent: loss of consciousness, death

The minimum threshold for low-oxygen levels will be 15%.

During a fire the temperatures near the origin of the fire are expected to increase, occupants will likely be exposed to elevated temperatures. The high temperatures put the occupants in danger of incapacitation from hyperthermia. The table below provides tolerance times for various temperatures. Because the egress times at Centennial Station are low it is not expected that occupants would be subjected to high temperatures for durations longer than shown below; however, the maximum temperature threshold for sustained heat exposure will be 248°F (120°C) as described in Table 2-6.16 of the SFPE Handbook.

Visibility will be limited to a minimum distance of 13 feet for occupants familiar with the building per SFPE Handbook Table 2-4.2.

11.2.2 FDS Results

The two design fires used for the ASET analysis have been described in Section 10.2.1 and 10.2.2 of this analysis.

The simulation was performed twice to determine the tenability conditions of the atrium on the first and second floors for both fire scenarios. The tenability conditions were determined to be visibility of 13 feet for occupants familiar with the building per SFPE Handbook Table 2-4.2 and maximum temperature threshold for sustained heat exposure of 248°F (120°C) per SFPE Handbook Table 2-6.16. Carbon monoxide concentration will be limited to 1,400 ppm for 20-minute exposure using Haber's Rule described by the SFPE Handbook. A screen shot of the smoke view simulation is shown in Image 55 for design fire one.

SmokeView 6.2.2 - April 10, 2015

Frame 553
Time 417.7

max 1

Image 55 – Smoke View Simulation

11.2.2.1 Design Fire One Results

The FDS simulation provided the following conditions on the second floor balcony, it is noted that the first floor conditions were less than the second floor balcony.

- Smoke detector activation time: 30 seconds
- Maximum temperature: 90°
- Minimum visibility: 48 feet
- Maximum CO concentration: 7×10^{-9}
- Tenable conditions maintained

Image 56 below shows the horizontal slice files for the carbon monoxide concentrations six feet above the first floor and six feet above the second floor. The red in the image indicates carbon monoxide levels of 1×10^{-9} , the conditions on the second floor were much lower than the concentration allowed.

Time: 666.3

Image 56 – CO Concentration Slice File

Image 57 below shows the horizontal slice files for the temperature in the lobby six feet above the first floor and six feet above the second floor. The red indicates temperatures of approximately 220°F. The temperatures modeled on the second floor showed the conditions on the balcony were tenable with regards to temperature.

Image 57 – Temperature Slice File

These results will be compared to the allowable tenable conditions described in Section 11. Tenable requirements will determine the available safe egress time for the atrium.

11.2.2.2 Design Fire Two Results

The FDS simulation provided the following conditions on the second floor balcony, it is noted that the first floor conditions were less than the second floor balcony.

- Sprinkler activation time: 70 seconds
- Smoke detector activation time: 52 seconds
- Maximum temperature: 70°
- Minimum visibility: 69 feet
- Maximum CO concentration: 1×10^{-9}
- Tenable conditions maintained

Image 58 below shows the horizontal slice files for the carbon monoxide concentrations six feet above the first floor and six feet above the second floor. The red in the image indicates carbon monoxide levels of 1×10^{-9} , the conditions on the second floor were much lower than the concentration allowed.

Image 58 – CO Concentration Slice File

Image 59 below shows the horizontal slice files for the temperature in the lobby six feet above the first floor and six feet above the second floor. The red indicates temperatures of approximately 90°F. The temperatures modeled on the second floor showed the conditions on the balcony were tenable with regards to temperature.

Image 59 – CO Concentration Slice File

11.3 ASET vs RSET Summary

It can be seen that tenable conditions were maintained on the first floor with the activation of the smoke control system allowing safe egress from the building with all occupants egressing to the

south exit or with use of the atrium exit. This analysis of ASET vs. RSET shows the close coordination of all building fire and life safety systems. The fire alarm must be designed to quickly activate and initiate the smoke control system. The sprinkler system design is critical to ensure fire control and suppression. The building egress components must be designed to allow for unobstructed travel of all occupants to allow for egress in a timely manner. Lastly, the smoke control system must perform to ensure tenable conditions are provided in the atrium for a duration long enough for occupants to egress the building. The analysis of the building has shown that these systems work together to meet specific code objectives and meet the performance based design criteria.

12.0 CONCLUSIONS

The fire protection analysis of the Centennial Station building has concluded that the fire protection systems designed for the building are generally code compliant with the exception of the common path of travel from Open Office 312. This code violation could be remedied with the addition of a travel path through an office or breakroom. With regards to the other fire protection systems, the building meets structural requirements, the fire alarm system meets code requirements from Section 907 of the IBC, and the fire sprinkler system meets the requirements of Section 903 of the IBC, and the atrium smoke control system meets the requirements of Section 909 of the IBC. Though the actual systems are unknown the acceptability of the fire protection designs is based on the systems shown in Appendix C. The FDS scenarios determined that the smoke control system coordinated with the smoke detection system maintains a tenable environment on the first floor and the second floor balcony for the duration of the fire in both scenarios.

APPENDIX A – SPRINKLER CALCULATIONS

CALCULATION SUMMARY

Project Name : Centennial Station

Project Location: 12154 East Easter Ave

Drawing No. : 15-001

City: Centennial, CO 80112

Design Areas

Design Area Name	Calc. Mode (Model)	Occupancy	Area of Application	Total Water	Pressure @ Source	Min. Density	Min. Pressure	Min. Flow	Calculated Heads	Hose Streams	Margin To Source
			(ft ²)	(gpm)	(psi)	(gpm/ft ²)	(psi)	(gpm)	#	(gpm)	(psi)
2	Demand (HW)	OH1	1950	602.4	Required 54	0.15	12.1	19.5	17	250	10.4

HYDRAULIC CALCULATIONS for

Job Information

Project Name : Centennial Station

Contract No. : 15-001

City: Centennial, CO 80112

Project Location: 12154 East Easter Ave

Date: 3/12/2015

Contractor Information

Name of Contractor: Cal Poly

Address: 123 Margaret Street

City: Neptune Beach, FL 32266

Phone Number: 303-905-2196

E-mail: brhuffma@calpoly.edu

Name of Designer: BAH

Authority Having Jurisdiction: CPFPE

Design

Remote Area Name	2
Remote Area Location	Parking
Occupancy Classification	OH1
Density (gpm/ft ²)	0.15
Area of Application (ft ²)	1950
Coverage per Sprinkler (ft ²)	130
Number of Calculated Sprinklers	17
In-Rack Demand (gpm)	0
Special Heads	
Hose Streams (gpm)	250
Total Water Required (incl. Hose Streams) (gpm)	602.4
Required Pressure at Source (psi)	54
Type of System	Dry
Volume - Downstream DPV (gal)	108.9 gal

Water Supply Information

Date	05/06/2008
Location	Easter and Quentin
Source	W1

Notes

**Diagram for Design Area : 2
(Optimized Hvdraulic Simplified)**

Hydraulic Analysis for : 2**Calculation Info**

Calculation Mode
 Hydraulic Model
 Fluid Name
 Fluid Weight, (lb/ft³)
 Fluid Dynamic Viscosity, (lb·s/ft²)

Demand
 Hazen-Williams
 Water @ 60F (15.6C)
 N/A for Hazen-Williams calculation.
 N/A for Hazen-Williams calculation.

Water Supply Parameters

Supply 1 : W1

Flow (gpm)	Pressure (psi)
0	72
872	57

Supply Analysis

Node at Source	Static Pressure (psi)	Residual Pressure (psi)	Flow (gpm)	Available Pressure (psi)	Total Demand (gpm)	Required Pressure (psi)
W1	72	57	872	69.2	602.4	54

Hoses

Inside Hose Flow / Standpipe Demand (gpm)

Outside Hose Flow (gpm)

Additional Outside Hose Flow (gpm) 250

Other (custom defined) Hose Flow (gpm)

Total Hose Flow (gpm) 250**Sprinklers**

Ovehead Sprinkler Flow (gpm) 352.4

InRack Sprinkler Flow (gpm) 0

Other (custom defined) Sprinkler Flow (gpm) 0

Total Sprinkler Flow (gpm) 352.4**Other**

Required Margin of Safety (psi) 0

W1 - Pressure (psi) 54

W1 - Flow (gpm) 352.4

Demand w/o System Pump(s) N/A

Hydraulic Analysis for : 2

Hydraulic Analysis for : 2

Graph Labels

Label	Description	Values	
		Flow (gpm)	Pressure (psi)
S1	Supply point #1 - Static	0	72
S2	Supply point #2 - Residual	872	57
D1	Elevation Pressure	0	7.4
D2	System Demand	352.4	54
D3	System Demand + Add.Out.Hose	602.4	54

Curve Intersections & Safety Margins

Curve Name	Intersection		Safety Margin	
	Pressure (psi)	Flow (gpm)	Pressure (psi)	@ Flow (gpm)
Supply	68.3	407.2	10.4	602.4

Open Heads

Head Ref.	Head Type	Coverage	K-Factor	Required			Calculated		
				Density	Flow	Pressure	Density	Flow	Pressure
		(ft ²)	(gpm/psi ^{1/2})	(gpm/ft ²)	(gpm)	(psi)	(gpm/ft ²)	(gpm)	(psi)
N203	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.15	19.5	12.1
N204	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.15	19.6	12.2
N205	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.161	20.9	13.9
N206	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.161	20.9	13.9
N207	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.15	19.6	12.2
N208	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.152	19.8	12.5
N209	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.163	21.1	14.3
N210	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.163	21.1	14.3
N211	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.152	19.8	12.5
N212	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.156	20.2	13.1
N213	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.166	21.6	14.9
N214	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.166	21.6	14.9
N215	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.156	20.2	13.1

N216	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.194	25.2	20.2
N200	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.15	19.5	12.1
N201	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.16	20.8	13.9
N202	Overhead Sprinkler	130	5.6	0.15	19.5	12.1	0.16	20.8	13.9

Node Data

Node# Elev	Type Hgroup	K-Fact. Open/Closed	Discharge Overdischarge	Coverage Density	Tot. Pres. Elev. Pres.	Req. Pres. Req. Discharge
ft		gpm/psi ^{1/2}	gpm gpm	ft ² gpm/ft ²	psi psi	psi gpm
N203 11	Overhead Sprinkler HEAD	5.6 Open	19.5 0	130 0.15	12.1 -7.4	12.1 19.5
N200 11	Overhead Sprinkler HEAD	5.6 Open	19.5 0	130 0.15	12.1 -7.4	12.1 19.5
N204 11	Overhead Sprinkler HEAD	5.6 Open	19.6 0.1	130 0.15	12.2 -7.4	12.1 19.5
N207 11	Overhead Sprinkler HEAD	5.6 Open	19.6 0.1	130 0.15	12.2 -7.4	12.1 19.5
N208 11	Overhead Sprinkler HEAD	5.6 Open	19.8 0.3	130 0.152	12.5 -7.4	12.1 19.5
N211 11	Overhead Sprinkler HEAD	5.6 Open	19.8 0.3	130 0.152	12.5 -7.4	12.1 19.5
N215 11	Overhead Sprinkler HEAD	5.6 Open	20.2 0.7	130 0.156	13.1 -7.4	12.1 19.5
N212 11	Overhead Sprinkler HEAD	5.6 Open	20.2 0.7	130 0.156	13.1 -7.4	12.1 19.5
N201 11	Overhead Sprinkler HEAD	5.6 Open	20.8 1.3	130 0.16	13.9 -7.4	12.1 19.5
N202 11	Overhead Sprinkler HEAD	5.6 Open	20.8 1.3	130 0.16	13.9 -7.4	12.1 19.5
N205 11	Overhead Sprinkler HEAD	5.6 Open	20.9 1.4	130 0.161	13.9 -7.4	12.1 19.5
N206 11	Overhead Sprinkler HEAD	5.6 Open	20.9 1.4	130 0.161	13.9 -7.4	12.1 19.5
N209 11	Overhead Sprinkler HEAD	5.6 Open	21.1 1.6	130 0.163	14.3 -7.4	12.1 19.5
N210 11	Overhead Sprinkler HEAD	5.6 Open	21.1 1.6	130 0.163	14.3 -7.4	12.1 19.5
N214 11	Overhead Sprinkler HEAD	5.6 Open	21.6 2.1	130 0.166	14.9 -7.4	12.1 19.5
N213 11	Overhead Sprinkler HEAD	5.6 Open	21.6 2.1	130 0.166	14.9 -7.4	12.1 19.5
N216 11	Overhead Sprinkler HEAD	5.6 Open	25.2 5.7	130 0.194	20.2 -7.4	12.1 19.5
0064 11	Node NODE				19.6 -7.4	
0065 11	Node NODE				19.7 -7.4	
0069 11	Node NODE				20.1 -7.4	
0070 11	Node NODE				21 -7.4	
0002 11	Node NODE				22.6 -7.4	
0006 11	Node NODE				33.6 -7.4	
0075-O 11	Node NODE				33.6 -7.4	
0075-I 11	Node NODE				34.1 -7.4	

Node Data

Node# Elev	Type Hgroup	K-Fact. Open/Closed	Discharge Overdischarge	Coverage Density	Tot. Pres. Elev. Pres.	Req. Pres. Req. Discharge
ft		gpm/psi ^{1/2}	gpm gpm	ft ² gpm/ft ²	psi psi	psi gpm
0782-O 3	Node NODE				39 -4	
0782-I 3	Node NODE				41.5 -4	
W1 -6.17	Supply SUPPLY		-352.4		54 0	

PIPE INFORMATION

Node 1 Node 2	Elev 1 Elev 2	K-Factor 1 K-Factor 2	Flow added (q) Total flow (Q)	Nominal ID Actual ID	Fittings quantity x (name) = length	L F T	C Factor Pf per ft	total (Pt) elev (Pe) frict (Pf)	NOTES
	(ft)	(gpm/psi ^{1/2})	(gpm)	(in)	(ft)	(ft)	(psi)	(psi)	

Path No: 1

N200	11	5.6	19.5	1		10	100	12.1	
N201	11	5.6	19.5	1.049		0	0.1734	0	
						10		1.7	
N201	11	5.6	20.8	1	1x(us.Tee-Br)=3.56	5	100	13.9	
0064	11		40.3	1.049		3.56	0.6667	0	
						8.56		5.7	
0064	11		40.3	3		12.25	100	19.6	
0065	11		80.7	3.26		0	0.0096	0	
						12.25		0.1	
0065	11		80.9	3		12.25	100	19.7	
0069	11		161.6	3.26		0	0.0348	0	
						12.25		0.4	
0069	11		81.8	3		12.25	100	20.1	
0070	11		243.5	3.26		0	0.0744	0	
						12.25		0.9	
0070	11		83.7	3		12.25	100	21	
0002	11		327.2	3.26		0	0.1286	0	
						12.25		1.6	
0002	11		25.2	3	1x(coupling)=0.96	60.06	100	22.6	
0006	11		352.4	3.26	2x(us.90)=13.42	14.37	0.1475	0	
						74.43		11	
0006	11		0	4	1x(coupling)=0.94	0.45	100	33.6	
0075-O	11		352.4	4.26		0.94	0.0401	0	
						1.39		0.1	
0075-O	11		0	4		1.14	0	33.6	DPV-1
0075-I	11		352.4	0		0	0.381	0	***
						1.14		0.4	
0075-I	11		0	4	1x(coupling)=1.32	9.11	120	34.1	
0782-O	3		352.4	4.26	1x(us.Tee-Br)=26.33	40.82	0.0286	3.5	
					1x(us.90)=13.17	49.93		1.4	
0782-O	3		0	4		3.33	0	39	Ames2000SS
0782-I	3		352.4	0		0	0.7549	0	***
						3.33		2.5	
0782-I	3		0	4	4x(us.90)=52.67	247.84	120	41.5	
W1	-6.17		352.4	4.26		52.67	0.0286	4	
						300.51		8.6	
W1								54	

Path No: 2

N203	11	5.6	19.5	1		10	100	12.1	
N202	11	5.6	19.5	1.049		0	0.1734	0	
						10		1.7	
N202	11	5.6	20.8	1	1x(us.Tee-Br)=3.56	5	100	13.9	
0064	11		40.3	1.049		3.56	0.6667	0	
						8.56		5.7	
0064								19.6	

PIPE INFORMATION**Path No: 3**

N207	11	5.6	19.6	1		10	100	12.2	
N206	11	5.6	19.6	1.049		0	0.1744	0	
						10		1.7	
N206	11	5.6	20.9	1	1x(us.Tee-Br)=3.56	5	100	13.9	
0065	11		40.5	1.049		3.56	0.6705	0	
						8.56		5.7	
0065									19.7

Path No: 4

N204	11	5.6	19.6	1		10	100	12.2	
N205	11	5.6	19.6	1.049		0	0.1744	0	
						10		1.7	
N205	11	5.6	20.9	1	1x(us.Tee-Br)=3.56	5	100	13.9	
0065	11		40.5	1.049		3.56	0.6705	0	
						8.56		5.7	
0065									19.7

Path No: 5

N211	11	5.6	19.8	1		10	100	12.5	
N210	11	5.6	19.8	1.049		0	0.178	0	
						10		1.8	
N210	11	5.6	21.1	1	1x(us.Tee-Br)=3.56	5	100	14.3	
0069	11		40.9	1.049		3.56	0.6843	0	
						8.56		5.9	
0069									20.1

Path No: 6

N208	11	5.6	19.8	1		10	100	12.5	
N209	11	5.6	19.8	1.049		0	0.178	0	
						10		1.8	
N209	11	5.6	21.1	1	1x(us.Tee-Br)=3.56	5	100	14.3	
0069	11		40.9	1.049		3.56	0.6843	0	
						8.56		5.9	
0069									20.1

Path No: 7

N212	11	5.6	20.2	1		10	100	13.1	
N213	11	5.6	20.2	1.049		0	0.1857	0	
						10		1.9	
N213	11	5.6	21.6	1	1x(us.Tee-Br)=3.56	5	100	14.9	
0070	11		41.9	1.049		3.56	0.7137	0	
						8.56		6.1	
0070									21

Path No: 8

N215	11	5.6	20.2	1		10	100	13.1	
N214	11	5.6	20.2	1.049		0	0.1857	0	
						10		1.9	
N214	11	5.6	21.6	1	1x(us.Tee-Br)=3.56	5	100	14.9	
0070	11		41.9	1.049		3.56	0.7137	0	
						8.56		6.1	
0070									21

PIPE INFORMATION

Node 1 Node 2	Elev 1 Elev 2	K-Factor 1 K-Factor 2	Flow added (q) Total flow (Q)	Nominal ID Actual ID	Fittings quantity x (name) = length	L F T	C Factor Pf per ft	total (Pt) elev (Pe) frict (Pf)	NOTES
	(ft)	(gpm/psi ^{1/2})	(gpm)	(in)	(ft)	(ft)	(psi)	(psi)	

Path No: 9

N216	11	5.6	25.2	1	1x(us.Tee-Br)=3.56	5	100	20.2	
0002	11		25.2	1.049		3.56	0.2784	0	
						8.56		2.4	
0002								22.6	

* Pressures are balanced to a high degree of accuracy. Values may vary by 0.1 psi due to display rounding.

* Maximum Velocity of 15.54 ft/s occurs in the following pipe(s): (0070-N213), (0070-N214)

*** Device pressure loss (gain in the case of pumps) is calculated from the device's curve. If the device curve is printed with this report, it will appear below. The length of the device as shown in the table above comes from the CAD drawing. The friction loss per unit of length is calculated based upon the length and the curve-based loss/gain value. Internal ID and C Factor values are irrelevant as the device is not represented as an addition to any pipe, but is an individual item whose loss/gain is based solely on the curve data.

Pressure vs. Flow Function
Design Area: 2; Supply Ref.: W1; Supply Name:W1

Pressure Loss Function
Design Area: 2; BFP Ref.: 1853 (Ames2000SS, Size = 4); Inlet Node: 0782-I; Outlet Node: 0782-O

Pressure Loss Function
Design Area: 2; DPV Ref.: 1852 (DPV-1, Size = 4); Inlet Node: 0075-I; Outlet Node: 0075-O

CALCULATION SUMMARY

Project Name : Centennial Station

Project Location: 12154 East Easter Ave

Drawing No. : 15-001

City: Centennial, CO 80112

Design Areas

Design Area Name	Calc. Mode (Model)	Occupancy	Area of Application	Total Water	Pressure @ Source	Min. Density	Min. Pressure	Min. Flow	Calculated Heads	Hose Streams	Margin To Source
			(ft ²)	(gpm)	(psi)	(gpm/ft ²)	(psi)	(gpm)	#	(gpm)	(psi)
1	Demand (HW)	Light Hazard	1035	282	Required 51.4	0.1	16.1	22.5	8	100	18.7

HYDRAULIC CALCULATIONS for

Job Information

Project Name : Centennial Station

Contract No. : 15-001

City: Centennial, CO 80112

Project Location: 12154 East Easter Ave

Date: 3/12/2015

Contractor Information

Name of Contractor: Cal Poly

Address: 123 Margaret Street

City: Neptune Beach, FL 32266

Phone Number: 303-905-2196

E-mail: brhuffma@calpoly.edu

Name of Designer: BAH

Authority Having Jurisdiction: CPFPE

Design

Remote Area Name	1
Remote Area Location	1
Occupancy Classification	Light Hazard
Density (gpm/ft ²)	0.1
Area of Application (ft ²)	1035
Coverage per Sprinkler (ft ²)	225
Number of Calculated Sprinklers	8
In-Rack Demand (gpm)	0
Special Heads	
Hose Streams (gpm)	100
Total Water Required (incl. Hose Streams) (gpm)	282
Required Pressure at Source (psi)	51.4
Type of System	Wet
Volume - Entire System (gal)	533 gal

Water Supply Information

Date	05/06/2008
Location	Easter and Quentin
Source	W1

Notes

**Diagram for Design Area : 1
(Optimized Hvdraulic Simplified)**

Hydraulic Analysis for : 1**Calculation Info**

Calculation Mode
 Hydraulic Model
 Fluid Name
 Fluid Weight, (lb/ft³)
 Fluid Dynamic Viscosity, (lb·s/ft²)

Demand
 Hazen-Williams
 Water @ 60F (15.6C)
 N/A for Hazen-Williams calculation.
 N/A for Hazen-Williams calculation.

Water Supply Parameters

Supply 1 : W1

Flow (gpm)	Pressure (psi)
0	72
872	57

Supply Analysis

Node at Source	Static Pressure (psi)	Residual Pressure (psi)	Flow (gpm)	Available Pressure (psi)	Total Demand (gpm)	Required Pressure (psi)
W1	72	57	872	71.2	282	51.4

Hoses

Inside Hose Flow / Standpipe Demand (gpm)

Outside Hose Flow (gpm)

Additional Outside Hose Flow (gpm) 100

Other (custom defined) Hose Flow (gpm)

Total Hose Flow (gpm) 100**Sprinklers**

Ovehead Sprinkler Flow (gpm) 182

InRack Sprinkler Flow (gpm) 0

Other (custom defined) Sprinkler Flow (gpm) 0

Total Sprinkler Flow (gpm) 182**Other**

Required Margin of Safety (psi) 0

W1 - Pressure (psi) 51.4

W1 - Flow (gpm) 182

Demand w/o System Pump(s) N/A

Hydraulic Analysis for : 1

Hydraulic Analysis for : 1

Graph Labels

Label	Description	Values	
		Flow (gpm)	Pressure (psi)
S1	Supply point #1 - Static	0	72
S2	Supply point #2 - Residual	872	57
D1	Elevation Pressure	0	22.2
D2	System Demand	182	51.4
D3	System Demand + Add.Out.Hose	282	51.4

Curve Intersections & Safety Margins

Curve Name	Intersection		Safety Margin	
	Pressure (psi)	Flow (gpm)	Pressure (psi)	@ Flow (gpm)
Supply	70.6	239.1	18.7	282

Open Heads

Head Ref.	Head Type	Coverage	K-Factor	Required			Calculated		
				Density	Flow	Pressure	Density	Flow	Pressure
		(ft ²)	(gpm/psi ^{1/2})	(gpm/ft ²)	(gpm)	(psi)	(gpm/ft ²)	(gpm)	(psi)
N100	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.1	22.6	16.2
N101	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.1	22.5	16.1
N102	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.1	22.5	16.2
N103	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.1	22.6	16.3
N104	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.1	22.5	16.2
N105	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.1	22.6	16.2
N106	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.104	23.3	17.4
N107	Overhead Sprinkler	225	5.6	0.1	22.5	16.1	0.104	23.3	17.4

Node Data

Node# Elev	Type Hgroup	K-Fact. Open/Closed	Discharge Overdischarge	Coverage Density	Tot. Pres. Elev. Pres.	Req. Pres. Req. Discharge
ft		gpm/psi ^{1/2}	gpm gpm	ft ² gpm/ft ²	psi psi	psi gpm
N101 45	Overhead Sprinkler HEAD	5.6 Open	22.5 0	225 0.1	16.1 -22.2	16.1 22.5
N104 45	Overhead Sprinkler HEAD	5.6 Open	22.5 0.0	225 0.1	16.2 -22.2	16.1 22.5
N102 45	Overhead Sprinkler HEAD	5.6 Open	22.5 0.0	225 0.1	16.2 -22.2	16.1 22.5
N100 45	Overhead Sprinkler HEAD	5.6 Open	22.6 0.1	225 0.1	16.2 -22.2	16.1 22.5
N105 45	Overhead Sprinkler HEAD	5.6 Open	22.6 0.1	225 0.1	16.2 -22.2	16.1 22.5
N103 45	Overhead Sprinkler HEAD	5.6 Open	22.6 0.1	225 0.1	16.3 -22.2	16.1 22.5
N106 45	Overhead Sprinkler HEAD	5.6 Open	23.3 0.8	225 0.104	17.4 -22.2	16.1 22.5
N107 45	Overhead Sprinkler HEAD	5.6 Open	23.3 0.8	225 0.104	17.4 -22.2	16.1 22.5
0061 46	Node NODE				16.7 -22.6	
0067 46	Node NODE				16.7 -22.6	
0001 46	Node NODE				16.7 -22.6	
0060 46	Node NODE				16.8 -22.6	
0068 46	Node NODE				16.8 -22.6	
0066 46	Node NODE				16.8 -22.6	
0089 46	Node NODE				18 -22.6	
0090 46	Node NODE				18 -22.6	
0058 46	Node NODE				18.1 -22.6	
0057 46	Node NODE				18.2 -22.6	
0056 46	Node NODE				18.7 -22.6	
0055 46	Node NODE				19.3 -22.6	
0054 46	Node NODE				19.5 -22.6	
0051 46	Node NODE				20.2 -22.6	
0175 46	Node NODE				20.2 -22.6	
0050 46	Node NODE				20.2 -22.6	
0048 46	Node NODE				20.3 -22.6	

Node Data

Node# Elev	Type Hgroup	K-Fact. Open/Closed	Discharge Overdischarge	Coverage Density	Tot. Pres. Elev. Pres.	Req. Pres. Req. Discharge
ft		gpm/psi ^{1/2}	gpm gpm	ft ² gpm/ft ²	psi psi	psi gpm
0044 46	Node NODE				20.4 -22.6	
0013 46	Node NODE				21.8 -22.6	
0015 46	Node NODE				21.8 -22.6	
0017 46	Node NODE				21.8 -22.6	
0018 46	Node NODE				21.8 -22.6	
0019 46	Node NODE				21.8 -22.6	
0020 46	Node NODE				21.9 -22.6	
0025 46	Node NODE				22 -22.6	
0023 46	Node NODE				22 -22.6	
0022 46	Node NODE				22 -22.6	
0021 46	Node NODE				22 -22.6	
0782-O 3	Node NODE				42.8 -4	
0782-I 3	Node NODE				44.9 -4	
W1 -6.17	Supply SUPPLY		-182		51.4 0	

PIPE INFORMATION

Node 1 Node 2	Elev 1 Elev 2	K-Factor 1 K-Factor 2	Flow added (q) Total flow (Q)	Nominal ID Actual ID	Fittings quantity x (name) = length	L F T	C Factor Pf per ft	total (Pt) elev (Pe) frict (Pf)	NOTES
	(ft)	(gpm/psi ^{1/2})	(gpm)	(in)	(ft)	(ft)	(psi)	(psi)	

Path No: 1

N101 0061	45 46	5.6	22.5 22.5	1 1.049	1x(us.Tee-Br)=5	1 5 6	120 0.1613	16.1 -0.4 1	
0061 0060	46 46		-9.9 12.6	1.5 1.61		14 0 14	120 0.0068	16.7 0 0.1	
0060 0058	46 46		22.6 35.2	1.5 1.61	1x(us.Tee-Br)=8	20.44 8 28.44	120 0.0458	16.8 0 1.3	
0058 0057	46 46		0 35.2	2 2.157		12 0 12	120 0.011	18.1 0 0.1	
0057 0056	46 46		36 71.2	2 2.157		12 0 12	120 0.0407	18.2 0 0.5	
0056 0055	46 46		20.5 91.7	2 2.157		9.35 0 9.35	120 0.065	18.7 0 0.6	
0055 0054	46 46		-18 73.7	2 2.157		3.41 0 3.41	120 0.0433	19.3 0 0.1	
0054 0051	46 46		-16.1 57.6	2 2.157		26.24 0 26.24	120 0.0274	19.5 0 0.7	
0051 0050	46 46		-13.9 43.7	2 2.157		4.06 0 4.06	120 0.0164	20.2 0 0.1	
0050 0048	46 46		-15 28.7	2 2.157		14 0 14	120 0.0076	20.2 0 0.1	
0048 0044	46 46		-14.1 14.6	2 2.157	1x(us.Tee-Br)=12.31	13.72 12.31 26.02	120 0.0022	20.3 0 0.1	
0044 0025	46 46		0 14.6	1.5 1.61	1x(us.Tee-Br)=8 2x(us.90)=8	165.29 16 181.29	120 0.0089	20.4 0 1.6	
0025 0023	46 46		0 14.6	4 4.26		24 0 24	120 0.0001	22 0 0	
0023 0022	46 46		14.1 28.7	4 4.26		9.31 0 9.31	120 0.0003	22 0 0	
0022 0021	46 46		15 43.7	4 4.26	1x(us.Tee-Br)=26.33	2.07 26.33 28.4	120 0.0006	22 0 0.0	
0021 0782-O	46 3		138.4 182	4 4.26	1x(coupling)=1.32 7x(us.90)=92.17 1x(us.Tee-Br)=26.33	131.25 119.82 251.07	120 0.0084	22 18.6 2.1	

PIPE INFORMATION

Node 1 Node 2	Elev 1 Elev 2	K-Factor 1 K-Factor 2	Flow added (q) Total flow (Q)	Nominal ID Actual ID	Fittings quantity x (name) = length	L F T	C Factor Pf per ft	total (Pt) elev (Pe) frict (Pf)	NOTES
	(ft)	(gpm/psi ^{1/2})	(gpm)	(in)	(ft)	(ft)	(psi)	(psi)	

Path No: 1

0782-O	3		0	4		3.33	0	42.8	Ames2000SS ***
0782-I	3		182	0		0	0.6432	0	
						3.33		2.1	
0782-I W1	3 -6.17		0 182	4 4.26	4x(us.90)=52.67	247.84 52.67 300.51	120 0.0084	44.9 4 2.5	
W1								51.4	

Path No: 2

N104	45	5.6	22.5	1	1x(us.Tee-Br)=5	1	120	16.2	
0067	46		22.5	1.049		5	0.1618	-0.4	
						6		1	
0067	46		-9.1	1.5		14	120	16.7	
0066	46		13.4	1.61		0	0.0077	0	
						14		0.1	
0066	46		22.6	1.5	1x(us.Tee-Br)=8	20.44	120	16.8	
0057	46		36	1.61		8	0.0479	0	
						28.44		1.4	
0057								18.2	

Path No: 3

N102	45	5.6	22.5	1	1x(us.Tee-Br)=5	1	120	16.2	
0001	46		22.5	1.049		5	0.1618	-0.4	
						6		1	
0001	46		9.9	1.5	3x(us.90)=12	115.19	120	16.7	
0013	46		32.4	1.61		12	0.0394	0	
						127.19		5	
0013	46		0	4		10	120	21.8	
0015	46		32.4	4.26		0	0.0003	0	
						10		0	
0015	46		31.7	4		9.1	120	21.8	
0017	46		64.1	4.26		0	0.0012	0	
						9.1		0.0	
0017	46		26.2	4		14	120	21.8	
0018	46		90.3	4.26		0	0.0023	0	
						14		0.0	
0018	46		18	4		10.78	120	21.8	
0019	46		108.4	4.26		0	0.0032	0	
						10.78		0.0	
0019	46		16.1	4		10	120	21.8	
0020	46		124.5	4.26		0	0.0042	0	
						10		0.0	
0020	46		13.9	4	1x(us.Tee-Br)=26.33	7.12	120	21.9	
0021	46		138.4	4.26		26.33	0.0051	0	
						33.46		0.2	
0021								22	

PIPE INFORMATION**Path No: 4**

N100 0060	45 46	5.6	22.6 22.6	1 1.049	1x(us.Tee-Br)=5	1 5 6	120 0.1621	16.2 -0.4 1	
0060								16.8	

Path No: 5

N105 0068	45 46	5.6	22.6 22.6	1 1.049	1x(us.Tee-Br)=5	1 5 6	120 0.1623	16.2 -0.4 1	
0068 0015	46 46		9.1 31.7	1.5 1.61	1x(us.Tee-Br)=8 2x(us.90)=8	115.54 16 131.54	120 0.0377	16.8 0 5	
0015								21.8	

Path No: 6

N103 0066	45 46	5.6	22.6 22.6	1 1.049	1x(us.Tee-Br)=5	1 5 6	120 0.1627	16.3 -0.4 1	
0066								16.8	

Path No: 7

N106 0089	45 46	5.6	23.3 23.3	1 1.049	1x(us.Tee-Br)=5	1 5 6	120 0.1727	17.4 -0.4 1	
0089 0056	46 46		-2.8 20.5	1.5 1.61	1x(us.Tee-Br)=8	34.44 8 42.44	120 0.0169	18 0 0.7	
0056								18.7	

Path No: 8

N107 0090	45 46	5.6	23.3 23.3	1 1.049	1x(us.Tee-Br)=5	1 5 6	120 0.1727	17.4 -0.4 1	
0090 0017	46 46		2.8 26.2	1.5 1.61	1x(us.Tee-Br)=8 4x(us.90)=16	118.44 24 142.44	120 0.0265	18 0 3.8	
0017								21.8	

Path No: 9

0061 0001	46 46		0 9.9	1.5 1.61		14 0 14	120 0.0044	16.7 0 0.1	
0001								16.7	

Path No: 10

0055 0018	46 46		0 18	1.5 1.61	2x(us.Tee-Br)=16 2x(us.90)=8	163.32 24 187.32	120 0.0133	19.3 0 2.5	
0018								21.8	

PIPE INFORMATION**Path No: 11**

0054	46		0	1.5	2x(us.Tee-Br)=16	180.86	120	19.5	
0019	46		16.1	1.61	6x(us.90)=24	40	0.0108	0	
						220.86		2.4	
0019									21.8

Path No: 12

0051	46		0	2.5	1x(us.Tee-Br)=12	10.32	120	20.2	
0175	46		13.9	2.469		12	0.001	0	
						22.32		0.0	
0175	46		0	1.5	1x(us.Tee-Br)=8	172.67	120	20.2	
0020	46		13.9	1.61	6x(us.90)=24	32	0.0082	0	
						204.67		1.7	
0020									21.9

Path No: 13

0050	46		0	1.5	2x(us.Tee-Br)=16	165.98	120	20.2	
0022	46		15	1.61	2x(us.90)=8	24	0.0094	0	
						189.98		1.8	
0022									22

Path No: 14

0048	46		0	1.5	3x(us.Tee-Br)=24	170.66	120	20.3	
0023	46		14.1	1.61	1x(us.90)=4	28	0.0085	0	
						198.66		1.7	
0023									22

Path No: 15

0067	46		0	1.5		14	120	16.7	
0068	46		9.1	1.61		0	0.0038	0	
						14		0.1	
0068									16.8

Path No: 16

0089	46		0	1.5		14	120	18	
0090	46		2.8	1.61		0	0.0004	0	
						14		0	
0090									18

* Pressures are balanced to a high degree of accuracy. Values may vary by 0.1 psi due to display rounding.

* Maximum Velocity of 8.67 ft/s occurs in the following pipe(s): (0090-N107)

*** Device pressure loss (gain in the case of pumps) is calculated from the device's curve. If the device curve is printed with this report, it will appear below. The length of the device as shown in the table above comes from the CAD drawing. The friction loss per unit of length is calculated based upon the length and the curve-based loss/gain value. Internal ID and C Factor values are irrelevant as the device is not represented as an addition to any pipe, but is an individual item whose loss/gain is based solely on the curve data.

Pressure vs. Flow Function
Design Area: 1; Supply Ref.: W1; Supply Name:W1

Pressure Loss Function
Design Area: 1; BFP Ref.: 1852 (Ames2000SS, Size = 4); Inlet Node: 0782-I; Outlet Node: 0782-O

APPENDIX B – FIRE ALARM CALCULATIONS

FACP Battery Calculation

PART NUMBER	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL ALARM CURRENT PER ITEM (AMPS)
SK-5820XL	Panel	0.215000	X	1	=	0.215000	0.385000	X	1	=	0.385000
SK-Beam	Beam Smoke Detector	0.002000	X	1	=	0.002000	0.008500	X	1	=	0.008500
SK-Photo	Smoke Detector	0.000300	X	14	=	0.004200	0.006500	X	14	=	0.091000
SK-Heat	Heat Detector	0.000300	X	1	=	0.000300	0.006500	X	1	=	0.006500
SK-Duct	Duct Detector	0.000300	X	9	=	0.002700	0.006500	X	9	=	0.058500
RTS-151	Remote Test Switch	0.000000	X	1	=	0.000000	0.012000	X	1	=	0.012000
SK-Pull-DA	Pull Station	0.000300	X	1	=	0.000300	0.000300	X	1	=	0.000300
SK-Monitor	Monitor Module	0.000375	X	1	=	0.000375	0.005000	X	1	=	0.005000
SK-Relay	Relay Module	0.000255	X	5	=	0.001275	0.006500	X	5	=	0.032500
SK-Monitor-2	Dual Monitor Module	0.000750	X	5	=	0.003750	0.006400	X	5	=	0.032000
SR/SCR	15cd Strobe	0.000000	X	9	=	0.000000	0.066000	X	9	=	0.594000
SR/SCR	30cd Strobe	0.000000	X	0	=	0.000000	0.094000	X	0	=	0.000000
SR/SCR	75cd Strobe	0.000000	X	2	=	0.000000	0.158000	X	2	=	0.316000
P2R/PC2R	15cd Horn/Strobe	0.000000	X	8	=	0.000000	0.079000	X	8	=	0.632000
P2R/PC2R	30cd Horn/Strobe	0.000000	X	0	=	0.000000	0.100000	X	0	=	0.000000
P2R/PC2R	75cd Horn/Strobe	0.000000	X	7	=	0.000000	0.176000	X	7	=	1.232000
P2R/PC2R	115cd Horn/Strobe	0.000000	X	1	=	0.000000	0.218000	X	1	=	0.218000
P2RK	75cd WP Horn/Strobe	0.000000	X	1	=	0.000000	0.176000	X	1	=	0.176000
TOTAL SYSTEM STANDBY CURRENT (AMPS)						0.229900	TOTAL SYSTEM ALARM CURRENT (AMPS)				3.799300
Project Name: Centennial Station		REQUIRED STANDBY TIME (HRS) PER NFPA 72 - 4.4.1.5.2.1		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) PER NFPA 72 - 4.4.1.5.3.1		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
		4	X	0.229900	=	0.919600	0.083333	X	3.799300	=	0.316608
Prepared by: Brandon Huffman		TOTAL CAPACITY (AMP-HOURS)				SAFETY FACTOR 20% PER NFPA 72 - 10.5.6.3.1(1)			REQUIRED MINIMUM BATTERY CAPACITY (AMP-HOURS)		
		1.236208			X	120%		=	1.48		
ACTUAL BATTERY SIZE (AMP-HOURS) SPECIFIED:										=	7
IS ACTUAL BATTERY CAPACITY GREATER THAN OR EQUAL TO REQUIRED?							YES				

FAPS 1 Battery Calculation

PART NUMBER	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL ALARM CURRENT PER ITEM
5496	Power Supply	0.040000	X	1	=	0.040000	0.160000	X	1	=	0.160000
SR/SCR	15cd Strobe	0.000000	X	8	=	0.000000	0.066000	X	8	=	0.528000
SR/SCR	30cd Strobe	0.000000	X	2	=	0.000000	0.094000	X	2	=	0.188000
SR/SCR	75cd Strobe	0.000000	X	0	=	0.000000	0.158000	X	0	=	0.000000
P2R/PC2R	15cd Horn/Strobe	0.000000	X	9	=	0.000000	0.079000	X	9	=	0.711000
P2R/PC2R	30cd Horn/Strobe	0.000000	X	2	=	0.000000	0.107000	X	2	=	0.214000
P2R/PC2R	75cd Horn/Strobe	0.000000	X	10	=	0.000000	0.176000	X	10	=	1.760000
TOTAL SYSTEM STANDBY CURRENT (AMPS)						0.040000	TOTAL SYSTEM ALARM CURRENT (AMPS)				3.561000
Project Name: Centennial Station		REQUIRED STANDBY TIME (HRS) PER NFPA 72 - 4.4.1.5.2.1		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) PER NFPA 72 - 4.4.1.5.3.1		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
		4	X	0.040000	=	0.160000	0.083333	X	3.561000	=	0.296750
Prepared by: Brandon Huffman		TOTAL CAPACITY (AMP-HOURS)				SAFETY FACTOR 20% PER NFPA 72 - 10.5.6.3.1(1)			REQUIRED MINIMUM BATTERY CAPACITY (AMP-HOURS)		
		0.456750			X	120%		=	0.55		
ACTUAL BATTERY SIZE (AMP-HOURS) SPECIFIED:										=	7
IS ACTUAL BATTERY CAPACITY GREATER THAN OR EQUAL TO REQUIRED?							YES				

FAPS 2 Battery Calculation

PART NUMBER	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL ALARM CURRENT PER ITEM
5496	Power Supply	0.040000	X	1	=	0.040000	0.160000	X	1	=	0.160000
SR/SCR	15cd Strobe	0.000000	X	7	=	0.000000	0.066000	X	7	=	0.462000
SR/SCR	30cd Strobe	0.000000	X	4	=	0.000000	0.094000	X	4	=	0.376000
SR/SCR	75cd Strobe	0.000000	X	0	=	0.000000	0.158000	X	0	=	0.000000
P2R/PC2R	15cd Horn/Strobe	0.000000	X	6	=	0.000000	0.079000	X	6	=	0.474000
P2R/PC2R	30cd Horn/Strobe	0.000000	X	0	=	0.000000	0.107000	X	0	=	0.000000
P2R/PC2R	75cd Horn/Strobe	0.000000	X	10	=	0.000000	0.176000	X	10	=	1.760000
TOTAL SYSTEM STANDBY CURRENT (AMPS)						0.040000	TOTAL SYSTEM ALARM CURRENT (AMPS)				3.232000
Project Name: Centennial Station		REQUIRED STANDBY TIME (HRS) PER NFPA 72 - 4.4.1.5.2.1		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) PER NFPA 72 - 4.4.1.5.3.1		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
		4	X	0.040000	=	0.160000	0.083333	X	3.232000	=	0.269333
Prepared by: Brandon Huffman		TOTAL CAPACITY (AMP-HOURS)				SAFETY FACTOR 20% PER NFPA 72 - 10.5.6.3.1(1)			REQUIRED MINIMUM BATTERY CAPACITY (AMP-HOURS)		
		0.429333			X	120%		=	0.52		
ACTUAL BATTERY SIZE (AMP-HOURS) SPECIFIED:										=	7
IS ACTUAL BATTERY CAPACITY GREATER THAN OR EQUAL TO REQUIRED?							YES				

FAPS 3 Battery Calculation

PART NUMBER	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QUANTITY		TOTAL ALARM CURRENT PER ITEM
5496	Power Supply	0.040000	X	1	=	0.040000	0.160000	X	1	=	0.160000
SR/SCR	15cd Strobe	0.000000	X	2	=	0.000000	0.066000	X	2	=	0.132000
SR/SCR	30cd Strobe	0.000000	X	6	=	0.000000	0.094000	X	6	=	0.564000
SR/SCR	75cd Strobe	0.000000	X	3	=	0.000000	0.158000	X	3	=	0.474000
P2R/PC2R	15cd Horn/Strobe	0.000000	X	4	=	0.000000	0.079000	X	4	=	0.316000
P2R/PC2R	30cd Horn/Strobe	0.000000	X	3	=	0.000000	0.107000	X	3	=	0.321000
P2R/PC2R	75cd Horn/Strobe	0.000000	X	6	=	0.000000	0.176000	X	6	=	1.056000
TOTAL SYSTEM STANDBY CURRENT (AMPS)						0.040000	TOTAL SYSTEM ALARM CURRENT (AMPS)				3.023000
Project Name: Centennial Station		REQUIRED STANDBY TIME (HRS) PER NFPA 72 - 4.4.1.5.2.1		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) PER NFPA 72 - 4.4.1.5.3.1		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
		4	X	0.040000	=	0.160000	0.083333	X	3.023000	=	0.251917
Prepared by: Brandon Huffman		TOTAL CAPACITY (AMP-HOURS)				SAFETY FACTOR 20% PER NFPA 72 - 10.5.6.3.1(1)			REQUIRED MINIMUM BATTERY CAPACITY (AMP-HOURS)		
		0.411917			X	120%		=	0.49		
ACTUAL BATTERY SIZE (AMP-HOURS) SPECIFIED:										=	7
IS ACTUAL BATTERY CAPACITY GREATER THAN OR EQUAL TO REQUIRED?							YES				

Voltage Drop Calculations - FACP

NAC Label	Qty	Horn/Strobe, Strobe Model#	Description	Current Per Device (AMPS)	Total Circuit Load (AMPS)	Approx Length (FEET)	Voltage Drop (VOLTS)	Maximum Wire Run (FEET)	Voltage at Last Device* (VOLTS)	Voltage Drop %**
NAC1-1	3	SR/SCR	15cd Strobe	0.066	0.198					
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	4	P2R/PC2R	75cd Horn/Strobe	0.176	0.704					
	9	Total Load (AMPS)				1.060	250	1.63	676	18.77
NAC1-2	3	SR/SCR	15cd Strobe	0.066	0.198					
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
	4	P2R/PC2R	15cd Horn/Strobe	0.079	0.316					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	2	P2R/PC2R	75cd Horn/Strobe	0.176	0.352					
	9	Total Load (AMPS)				0.866	350	1.86	827	18.54
NAC1-3	3	SR/SCR	15cd Strobe	0.066	0.198					
		SR/SCR	30cd Strobe	0.094	0.000					
	2	SR/SCR	75cd Strobe	0.158	0.316					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
	1	P2R/PC2R	75cd Horn/Strobe	0.176	0.176					
	1	P2R/PC2R	115cd Horn/Strobe	0.218	0.218					
	9	Total Load (AMPS)				1.066	245	1.60	672	18.80
NAC1-4	1	P2RK	75cd Horn/Strobe WP	0.176	0.176					
	1	Total Load (AMPS)				0.176	70	0.08	4072	20.32
Nominal Resistance per "Ugly's Electrical Reference" 2008 Edition For 14 AWG*** =							3.07	Ω/1000FT		
Wire Resistance per 1000 ft: 18AWG=7.77 16AWG=4.89 14AWG=3.07 12AWG=1.98										
18-14 Awg = Solid Conductors 12 Awg = Stranded Conductors										
Notes:										
*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.										
**The voltage drop percentage has been calculated using 24 volts.										
***Only one size of conductor has been used for the entire circuit length.										

Voltage Drop Calculations - FAPS 1										
NAC Label	Qty	Horn/Strobe, Strobe Model#	Description	Current Per Device (AMPS)	Total Circuit Load (AMPS)	Approx Length (FEET)	Voltage Drop (VOLTS)	Maximum Wire Run (FEET)	Voltage at Last Device* (VOLTS)	Voltage Drop %**
NAC2-1		SR/SCR	15cd Strobe	0.066	0.000	200	0.87	1012	19.53	3.62%
	2	SR/SCR	30cd Strobe	0.094	0.188					
		SR/SCR	75cd Strobe	0.158	0.000					
	3	P2R/PC2R	15cd Horn/Strobe	0.079	0.237					
	1	P2R/PC2R	30cd Horn/Strobe	0.107	0.107					
	1	P2R/PC2R	75cd Horn/Strobe	0.176	0.176					
	7	Total Load (AMPS)			0.708					
NAC2-2	2	SR/SCR	15cd Strobe	0.066	0.132	280	1.42	865	18.98	5.93%
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
	3	P2R/PC2R	15cd Horn/Strobe	0.079	0.237					
	1	P2R/PC2R	30cd Horn/Strobe	0.107	0.107					
	2	P2R/PC2R	75cd Horn/Strobe	0.176	0.352					
	8	Total Load (AMPS)			0.828					
NAC2-3	3	SR/SCR	15cd Strobe	0.066	0.198	245	1.33	811	19.07	5.54%
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	3	P2R/PC2R	75cd Horn/Strobe	0.176	0.528					
	8	Total Load (AMPS)			0.884					
NAC2-4	3	SR/SCR	15cd Strobe	0.066	0.198	280	1.69	730	18.71	7.03%
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
	1	P2R/PC2R	15cd Horn/Strobe	0.079	0.079					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	4	P2R/PC2R	75cd Horn/Strobe	0.176	0.704					
	8	Total Load (AMPS)			0.981					
Nominal Resistance per "Ugly's Electrical Reference" 2008 Edition For 14 AWG*** =							3.07	Ω/1000FT		
Wire Resistance per 1000 ft: 18AWG=7.77 16AWG=4.89 14AWG=3.07 12AWG=1.98										
18-14 Awg = Solid Conductors 12 Awg = Stranded Conductors										
Notes:										
*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.										
**The voltage drop percentage has been calculated using 24 volts.										
***Only one size of conductor has been used for the entire circuit length.										

*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.

***Only one size of conductor has been used for the entire circuit length.

Voltage Drop Calculations - FAPS 2										
NAC Label	Qty	Horn/Strobe, Strobe Model#	Description	Current Per Device (AMPS)	Total Circuit Load (AMPS)	Approx Length (FEET)	Voltage Drop (VOLTS)	Maximum Wire Run (FEET)	Voltage at Last Device* (VOLTS)	Voltage Drop %**
NAC3-1		SR/SCR	15cd Strobe	0.066	0.000	205	0.88	1027	19.52	3.66%
	2	SR/SCR	30cd Strobe	0.094	0.188					
		SR/SCR	75cd Strobe	0.158	0.000					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	2	P2R/PC2R	75cd Horn/Strobe	0.176	0.352					
	6	Total Load (AMPS)			0.698					
NAC3-2	3	SR/SCR	15cd Strobe	0.066	0.198	295	2.27	571	18.13	9.46%
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
		P2R/PC2R	15cd Horn/Strobe	0.079	0.000					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	6	P2R/PC2R	75cd Horn/Strobe	0.176	1.056					
	9	Total Load (AMPS)			1.254					
NAC3-3	2	SR/SCR	15cd Strobe	0.066	0.132	250	0.99	1116	19.41	4.11%
		SR/SCR	30cd Strobe	0.094	0.000					
		SR/SCR	75cd Strobe	0.158	0.000					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	2	P2R/PC2R	75cd Horn/Strobe	0.176	0.352					
	6	Total Load (AMPS)			0.642					
NAC3-4	2	SR/SCR	15cd Strobe	0.066	0.132	230	0.68	1499	19.72	2.81%
	2	SR/SCR	30cd Strobe	0.094	0.188					
		SR/SCR	75cd Strobe	0.158	0.000					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
		P2R/PC2R	75cd Horn/Strobe	0.176	0.000					
	6	Total Load (AMPS)			0.478					
Nominal Resistance per "Ugly's Electrical Reference" 2008 Edition For 14 AWG*** =							3.07	Q/1000FT		
Wire Resistance per 1000 ft: 18AWG=7.77 16AWG=4.89 14AWG=3.07 12AWG=1.98										
18-14 Awg = Solid Conductors 12 Awg = Stranded Conductors										
Notes:										
*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.										
**The voltage drop percentage has been calculated using 24 volts.										
***Only one size of conductor has been used for the entire circuit length.										

*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.

***Only one size of conductor has been used for the entire circuit length.

Voltage Drop Calculations - FAPS 3										
NAC Label	Qty	Horn/Strobe, Strobe Model#	Description	Current Per Device (AMPS)	Total Circuit Load (AMPS)	Approx Length (FEET)	Voltage Drop (VOLTS)	Maximum Wire Run (FEET)	Voltage at Last Device* (VOLTS)	Voltage Drop %**
NAC4-1		SR/SCR	15cd Strobe	0.066	0.000					
	2	SR/SCR	30cd Strobe	0.094	0.188					
		SR/SCR	75cd Strobe	0.158	0.000					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	2	P2R/PC2R	75cd Horn/Strobe	0.176	0.352					
	6	Total Load (AMPS)			0.698					
NAC4-2	1	SR/SCR	15cd Strobe	0.066	0.066					
		SR/SCR	30cd Strobe	0.094	0.000					
	1	SR/SCR	75cd Strobe	0.158	0.158					
		P2R/PC2R	15cd Horn/Strobe	0.079	0.000					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
	4	P2R/PC2R	75cd Horn/Strobe	0.176	0.704					
	6	Total Load (AMPS)			0.928					
NAC4-3	1	SR/SCR	15cd Strobe	0.066	0.066					
		SR/SCR	30cd Strobe	0.094	0.000					
	1	SR/SCR	75cd Strobe	0.158	0.158					
		P2R/PC2R	15cd Horn/Strobe	0.079	0.000					
	3	P2R/PC2R	30cd Horn/Strobe	0.107	0.321					
		P2R/PC2R	75cd Horn/Strobe	0.176	0.000					
	5	Total Load (AMPS)			0.545					
NAC4-4		SR/SCR	15cd Strobe	0.066	0.000					
	4	SR/SCR	30cd Strobe	0.094	0.376					
	1	SR/SCR	75cd Strobe	0.158	0.158					
	2	P2R/PC2R	15cd Horn/Strobe	0.079	0.158					
		P2R/PC2R	30cd Horn/Strobe	0.107	0.000					
		P2R/PC2R	75cd Horn/Strobe	0.176	0.000					
	7	Total Load (AMPS)			0.692					
Nominal Resistance per "Ugly's Electrical Reference" 2008 Edition For 14 AWG*** =							3.07	Q/1000FT		
Wire Resistance per 1000 ft: 18AWG=7.77 16AWG=4.89 14AWG=3.07 12AWG=1.98										
18-14 Awg = Solid Conductors 12 Awg = Stranded Conductors										
Notes:										
*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.										
**The voltage drop percentage has been calculated using 24 volts.										
***Only one size of conductor has been used for the entire circuit length.										

*The starting voltage has been reduced to 20.4 volts DC from 24 in accordance with NFPA 72 - 4.4.4.1 requiring the system to operate at 85% of the nameplate voltage. The voltage drop must remain above 16 volts DC. The end of line method has been used to calculate the voltage drop, the voltage drop is calculated with the total load at the end of the wire length providing the most conservative calculation.

***Only one size of conductor has been used for the entire circuit length.

APPENDIX C – DRAWINGS

LEGEND

BUSINESS

ELECTRICAL

INSTITUTIONAL

MECHANICAL

PARKING GARAGE

STORAGE

2-HOUR EGRESS CORRIDOR

CORRIDOR/LOBBY

EXIT STAIR/ELEVATOR

ACCESSORY/RESTROOM

FIRST FLOOR OCCUPANCY DESCRIPTION

0 8' 16'
SCALE: 1/8"=1'-0"

CAL POLY
SAN LUIS OBISPO

Number	Revisions	Date	Approved
1	EGRESS ANALYSIS AND DESIGN PROJECT	12/11/2014	BAH

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

FIRST FLOOR OCCUPANCY TYPE

Drawn By:	BAH
AHJ:	SMFR
Date:	12/11/2014
Paper Size:	24 x 36
Class Number:	FPE S521

LS-1

LEGEND

BUSINESS

ELECTRICAL

INSTITUTIONAL

MECHANICAL

PARKING GARAGE

STORAGE

2-HOUR EGRESS CORRIDOR

CORRIDOR/LOBBY

EXIT STAIR/ELEVATOR

ACCESSORY/RESTROOM

SECOND FLOOR OCCUPANCY DESCRIPTION

0 8' 16'
SCALE: 1/8"=1'-0"

Number	Revisions	Date	Approved
1	EGRESS ANALYSIS AND DESIGN PROJECT	12/11/2014	BAH

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

SECOND FLOOR OCCUPANCY TYPE

Drawn By:	BAH
AHJ:	SMFR
Date:	12/11/2014
Paper Size:	24 x 36
Class Number:	FPE S521

LS-2

LEGEND

BUSINESS

ELECTRICAL

INSTITUTIONAL

MECHANICAL

PARKING GARAGE

STORAGE

2-HOUR EGRESS CORRIDOR

CORRIDOR/LOBBY

EXIT STAIR/ELEVATOR

ACCESSORY/RESTROOM

THIRD FLOOR OCCUPANCY DESCRIPTION

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Descriptions	Date	Approved
Number	1	12/11/2014	BAH
EGRESS ANALYSIS AND DESIGN PROJECT			

Centennial Station

12154 East Easter Avenue

Englewood, CO 80112

THIRD FLOOR OCCUPANCY TYPE

Drawn By:	BAH
AHJ:	SMFR
Date:	12/11/2014
Paper Size:	24 x 36
Class Number:	FPE S521

LEGEND

BUSINESS

ELECTRICAL

INSTITUTIONAL

MECHANICAL

PARKING GARAGE

STORAGE

2-HOUR EGRESS CORRIDOR

CORRIDOR/LOBBY

EXIT STAIR/ELEVATOR

ACCESSORY/RESTROOM

FOURTH FLOOR OCCUPANCY DESCRIPTION

0 8' 16'
SCALE: 1/8"=1'-0"

Number	Revisions	Date	Approved
1	EGRESS ANALYSIS AND DESIGN PROJECT	12/11/2014	BAH

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112
FOURTH FLOOR OCCUPANCY TYPE

Drawn By:	BAH
AHJ:	SMFR
Date:	12/11/2014
Paper Size:	24 x 36
Class Number:	FPE S521

LEGEND

ROOM USE
AREA
QLF
OCCUPANCY

ROOM IDENTIFICATION TAG

ACTUAL WIDTH
REQUIRED WIDTH
ACTUAL CAPACITY
MAXIMUM CAPACITY

EXIT IDENTIFICATION TAG

1-HOUR FIRE RESISTANCE RATED WALL

2-HOUR FIRE RESISTANCE RATED WALL

SINGLE SIDED ILLUMINATED EGRESS SIGN

DOUBLE SIDED DIRECTIONAL ILLUMINATED EGRESS SIGN

(X) SHEET NOTES

- DOORS TO BE AUTOMATICALLY CLOSED UPON SMOKE DETECTION OR WATER FLOW.

FIRST FLOOR LIFE SAFETY PLAN

0 8' 16'
SCALE: 1/8"=1'-0"

CAL POLY
SAN LUIS OBISPO

Revisions	Date	Approved
Number	1	BAH
Descriptions	EGRESS ANALYSIS AND DESIGN PROJECT	

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

FIRST FLOOR LIFE SAFETY PLAN

Drawn By:	BAH
AHJ:	SMFR
Date:	12/11/2014
Paper Size:	24 x 36
Class Number:	FPE S521

LS-5

LEGEND

<table><tr><td>ROOM USE</td></tr><tr><td>AREA QLF</td></tr><tr><td>OCCUPANCY</td></tr></table>	ROOM USE	AREA QLF	OCCUPANCY	ROOM IDENTIFICATION TAG	
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AREA QLF					
OCCUPANCY					
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ACTUAL WIDTH					
REQUIRED WIDTH					
ACTUAL CAPACITY					
MAXIMUM CAPACITY
1-HOUR FIRE RESISTANCE RATED WALL
2-HOUR FIRE RESISTANCE RATED WALL
SINGLE SIDED ILLUMINATED EGRESS SIGN
DOUBLE SIDED DIRECTIONAL ILLUMINATED EGRESS SIGN

0 8' 16'

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

LEGEND

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AREA QLF					
OCCUPANCY					
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ACTUAL WIDTH					
REQUIRED WIDTH					
ACTUAL CAPACITY					
MAXIMUM CAPACITY
1-HOUR FIRE RESISTANCE RATED WALL
2-HOUR FIRE RESISTANCE RATED WALL
SINGLE SIDED ILLUMINATED EGRESS SIGN
DOUBLE SIDED DIRECTIONAL ILLUMINATED EGRESS SIGN

LEGEND

<table><tr><td>ROOM USE</td></tr><tr><td>AREA</td></tr><tr><td>OLF</td></tr><tr><td>OCCUPANCY</td></tr></table>	ROOM USE	AREA	OLF	OCCUPANCY	ROOM IDENTIFICATION TAG
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AREA					
OLF					
OCCUPANCY					
<table><tr><td>ACTUAL WIDTH</td></tr><tr><td>REQUIRED WIDTH</td></tr><tr><td>ACTUAL CAPACITY</td></tr><tr><td>MAXIMUM CAPACITY</td></tr></table>	ACTUAL WIDTH	REQUIRED WIDTH	ACTUAL CAPACITY	MAXIMUM CAPACITY	EXIT IDENTIFICATION TAG
ACTUAL WIDTH					
REQUIRED WIDTH					
ACTUAL CAPACITY					
MAXIMUM CAPACITY
1-HOUR FIRE RESISTANCE RATED WALL
2-HOUR FIRE RESISTANCE RATED WALL
SINGLE SIDED ILLUMINATED EGRESS SIGN
DOUBLE SIDED DIRECTIONAL ILLUMINATED EGRESS SIGN

LEGEND

- LIGHT HAZARD
- ORDINARY HAZARD GROUP 1
- ORDINARY HAZARD GROUP 2

FIRST FLOOR HAZARD CLASSIFICATION

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Date	Approved
Number	1	BAH
Descriptions	WATER BASED SUPPRESSION DESIGN PROJECT	

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

FIRST FLOOR HAZARD CLASSIFICATION

Drawn By:	BAH
AHJ:	SMFR
Date:	03/11/2015
Paper Size:	24 x 36
Class Number:	FPE S521

FS-1

LEGEND

LIGHT HAZARD

ORDINARY HAZARD GROUP 1

ORDINARY HAZARD GROUP 2

SECOND FLOOR HAZARD CLASSIFICATION

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Date	Approved
Number	Date	BAH
1	03/11/2015	
WATER BASED SUPPRESSION DESIGN PROJECT		

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

SECOND FLOOR HAZARD CLASSIFICATION

Drawn By:	BAH
AHJ:	SMFR
Date:	03/11/2015
Paper Size:	24 x 36
Class Number:	FPE S521

LEGEND

LIGHT HAZARD

ORDINARY HAZARD GROUP 1

ORDINARY HAZARD GROUP 2

THIRD FLOOR HAZARD CLASSIFICATION

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Descriptions	Date	Approved
Number	1	03/11/2015	BAH
WATER BASED SUPPRESSION DESIGN PROJECT			

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

THIRD FLOOR HAZARD CLASSIFICATION

Drawn By:	BAH
AHJ:	SMFR
Date:	03/11/2015
Paper Size:	24 x 36
Class Number:	FPE S521

LEGEND

- LIGHT HAZARD
- ORDINARY HAZARD GROUP 1
- ORDINARY HAZARD GROUP 2

FOURTH FLOOR HAZARD CLASSIFICATION

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Date	Approved
Number	03/11/2015	BAH
1		
Descriptions		
WATER BASED SUPPRESSION DESIGN PROJECT		

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

FOURTH FLOOR HAZARD CLASSIFICATION

Drawn By:	BAH
AHJ:	SMFR
Date:	03/11/2015
Paper Size:	24 x 36
Class Number:	FPE S521

LEGEND

- 2-1/2" PIPE INDICATING 2-1/2" DIAMETER AND 10'-0" CUT LENGTH
- PIPE ELEVATION TAG
- PIPE RISE
- PIPE DROP
- STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY313
- STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY3531
- STANDARD SPRAY SIDEWALL, QR, K-5.6, 155°F SPRINKLER, 3331

(X) SHEET NOTES

1. PROVIDE 200°F INTERMEDIATE TEMPERATURE SPRINKLERS.

UNDERGROUND TO CONTINUE
220 FEET TO THE CITY MAIN

CAL POLY
SAN LUIS OBISPO

Revisions	Descriptions	Date	Approved
Number			BAH
1	WATER BASED SUPPRESSION DESIGN PROJECT	03/11/2015	

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

FIRST FLOOR SPRINKLER LAYOUT

Drawn By:	BAH
AHJ:	SMFR
Date:	03/11/2015
Paper Size:	24 x 36
Class Number:	FPE S521

FS-5

FIRST FLOOR LIFE SPRINKLER LAYOUT

0 8' 16'
SCALE: 1/8"=1'-0"

LEGEND

- PIPE INDICATING 2-1/2" DIAMETER AND 10'-0" CUT LENGTH
- PIPE ELEVATION TAG
- PIPE RISE
- PIPE DROP
- STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY313
- STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY3531
- STANDARD SPRAY SIDEWALL, QR, K-5.6, 155°F SPRINKLER, 3331

SECOND FLOOR LIFE SAFETY PLAN

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Date	Approved
Number	03/11/2015	BAH
Descriptions		
1		
WATER BASED SUPPRESSION DESIGN PROJECT		

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

SECOND FLOOR SPRINKLER LAYOUT

Drawn By:	BAH
AHJ:	SMFR
Date:	03/11/2015
Paper Size:	24 x 36
Class Number:	FPE S521

LEGEND	
$\frac{21}{10-0}$	PIPE INDICATING 2-1/2" DIAMETER AND 10'-0" CUT LENGTH
-(44')	PIPE ELEVATION TAG
○	PIPE RISE
●	PIPE DROP
○	STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY313
●	STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY3531
▽	STANDARD SPRAY SIDEWALL, QR, K-5.6, 155°F SPRINKLER, 3331

Architectural floor plan of the second floor, showing various rooms and corridors. The plan includes a grid system with letters A-D and numbers 1-9.

Rooms and areas labeled include:

- OFFICE 302, OFFICE 303, COPY/SHRED 307, OFFICE 309
- OPEN OFFICE 301, DIVERSION DRUG STORAGE 305, COPY/SHRED 304, STORAGE 308
- CORRIDOR 328, MENS TOILET 302, WOMENS TOILET 303, ELECTRICAL 204
- ELEV. LOBBY 300, SERVER ROOM 323, CONFERENCE 324, CORRIDOR 325
- CONFERENCE 326, COPY 327, STANDPIPE FREIGHT ELEV. XXX, STAIR 2
- OFFICE 311, BREAK ROOM 310, CORRIDOR 322
- OPEN OFFICE 319, COPY 320, COPY/SHRED 317, COPY/SHRED 315
- OFFICE 321, OFFICE 318, OFFICE 314, OFFICE 329
- OPEN OFFICE 316, INTEL STORAGE 313, OPEN OFFICE 312

Dimensions are provided for many rooms and corridors. A note on the left indicates "SUPPLY FROM FIRST FLOOR" and "OPEN TO BELOW".

0 8' 16'

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

LEGEND

- PIPE INDICATING 2-1/2" DIAMETER AND 10'-0" CUT LENGTH
- PIPE ELEVATION TAG
- PIPE RISE
- PIPE DROP
- STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY313
- STANDARD SPRAY PENDENT, QR, K-5.6, 155°F SPRINKLER, TY3531
- STANDARD SPRAY SIDEWALL, QR, K-5.6, 155°F SPRINKLER, 3331

FOURTH FLOOR SPRINKLER LAYOUT

0 8' 16'
SCALE: 1/8"=1'-0"

Revisions	Date	Approved
Number	03/11/2015	BAH
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Centennial Station
12154 East Easter Avenue
Englewood, CO 80112
FOURTH FLOOR SPRINKLER LAYOUT

Drawn By:	BAH
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Date:	03/11/2015
Paper Size:	24 x 36
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LINE TYPE	DESCRIPTION	CLASS	TYPE
A	— SLC — SLC — SLC —	SIGNALING LINE CIRCUITS	B 2 #16 AWG FPLP
B	— STR — STR — STR —	NOTIFICATION APPLIANCE CIRCUITS	B 2 #14 AWG FPLP
C	— IDC — IDC — IDC —	INITIATING DEVICE CIRCUITS	B 2 #18 AWG FPL
D	— RS — RS — RS —	DATA	2 #16 AWG FPLP, SHIELDED
E		24VDC	2 #14 AWG FPLP

WIRE CHART

TYPICAL DEVICE MOUNTING HEIGHTS

SCALE: NOT TO SCALE

Input Signals		Output Signals															
		Fire Alarm Panel Indication				Notification				Safety Control / Interlocks							
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	<i>Ancillary Control Functions</i>	
General Fire Detection Initiating Devices																	
1	Manual pull station	•	•					•	•							•	•
2	Smoke detector	•	•	•				•	•					•		•	•
3	Spot heat detector	•	•	•				•	•					•		•	•
4	Beam smoke detector	•	•	•				•	•					•		•	•
5	Waterflow	•	•		•	•		•	•					•			
6	Waterflow pressure switch	•						•	•		•			•			
7	Low/High air pressure switch							•			•			•			
8	Tamper switch			•	•										•		
9	Duct smoke detector			•	•									•			
Elevator Control Initiating Devices																	
10	Primary floor elevator lobby smoke detector	•	•											•		•	•
11	Alternate floor elevator lobby smoke detector	•	•											•		•	•
12	Smoke detector in elevator equipment room	•												•		•	•
13	Heat detector in elevator equipment room	•	•											•		•	•
Trouble Conditions																	
14	Ground fault					•	•									•	•
15	Notification appliance short circuit					•	•									•	•
16	Open circuit					•	•									•	•
17	Low battery					•	•									•	•
18	AC power failure					•	•									•	•
19	Telephone line fault					•	•									•	•
20	Remote power supply trouble condition					•	•									•	•
Notification Functions																	
21	Silence feature on fire alarm panel								•								

SEQUENCE OF OPERATIONS

NOT TO SCALE

LEGEND			
FACP	FIRE ALARM CONTROL PANEL	DM	DUAL MONITOR MODULE (TWO POINTS)
FAPS	FIRE ALARM POWER SUPPLY	CM	CONTROL/RELAY MODULE
SD	SMOKE DETECTOR (PHOTOELECTRIC)	TS	TAMPER SWITCH
BSM	BEAM SMOKE DETECTOR (T-BT/BR TRANSMITTER, R-REFLECTOR)	FS	FLOW SWITCH
DSM	DUCT SMOKE DETECTOR (PHOTOELECTRIC)	LHAPS	LOW/HIGH AIR PRESSURE SWITCH
RTS	REMOTE TEST STATION WITH RESET SWITCH	WPS	WATERFLOW PRESSURE SWITCH
HSTD	HEAT DETECTOR FIXED TEMP.	H75	HORN WITH STROBE (NUMBER INDICATES CANDELA)
P	MANUAL PULL STATION	S15	STROBE (NUMBER INDICATES CANDELA)
M	MONITOR MODULE	EOL	END OF LINE RESISTOR
		DH	DOOR HOLDER (24VDC)
		SCF	SMOKE CONTROL FAN

SCHEMATIC RISER DIAGRAM

NOT TO SCALE

Number	Revisions		Date	Approved
	Descriptions			
1	DETECTION, ALARM, AND COMMUNICATION SYSTEMS DESIGN PROJECT		06/08/2015	BAH

Drawn By:	BAH
AHJ:	SMFR
Date:	06/08/2015
Paper Size:	24 x 36
Class Number:	FPE S522

Number	Revisions	Date	Approved
1	DETECTION, ALARM, AND COMMUNICATION SYSTEMS DESIGN PROJECT	06/08/2015	BAH

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

FIRST FLOOR FIRE ALARM PLAN

Drawn By: BAH
AHJ: SMFR
Date: 06/08/2015
Paper Size: 24 x 36
Class Number: FPE S522

FA-2

LEGEND

FACP	FIRE ALARM CONTROL PANEL	DM	DUAL MONITOR MODULE (TWO POINTS)
FAPS	FIRE ALARM POWER SUPPLY	CM	CONTROL/RELAY MODULE
2P	SMOKE DETECTOR (PHOTOELECTRIC)	TS	TAMPER SWITCH
2BT/BR	BEAM SMOKE DETECTOR (T-BEAM TRANSMITTER, R-REFLECTOR)	FS	FLOW SWITCH
1D	DUCT SMOKE DETECTOR (PHOTOELECTRIC)	LH	LOW/HIGH AIR PRESSURE SWITCH
RTS	REMOTE TEST STATION WITH RESET SWITCH	WPS	WATERFLOW PRESSURE SWITCH
135	HEAT DETECTOR FIXED TEMP.	H75	HORN WITH STROBE (NUMBER INDICATES CANDELA)
P	MANUAL PULL STATION	15	STROBE (NUMBER INDICATES CANDELA)
M	MONITOR MODULE	EOL RE	END OF LINE RESISTOR
		DOOR	DOOR HOLDER (24VDC)
		SCF	SMOKE CONTROL FAN

FIRST FLOOR FIRE ALARM PLAN

0 8' 16'
SCALE: 1/8"=1'-0"

Number	Revisions	Date	Approved
1	DETECTION, ALARM, AND COMMUNICATION SYSTEMS DESIGN PROJECT	06/08/2015	BAH

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

SECOND FLOOR FIRE ALARM PLAN

Drawn By:	BAH
AHJ:	SMFR
Date:	06/08/2015
Paper Size:	24 x 36
Class Number:	FPE S522

FA-3

LEGEND

FACP	FIRE ALARM CONTROL PANEL	DM	DUAL MONITOR MODULE (TWO POINTS)
FAPS	FIRE ALARM POWER SUPPLY	CM	CONTROL/RELAY MODULE
SD	SMOKE DETECTOR (PHOTOELECTRIC)	TS	TAMPER SWITCH
BS	BEAM SMOKE DETECTOR (T-BT/BR TRANSMITTER, R-REFLECTOR)	FS	FLOW SWITCH
DS	DUCT SMOKE DETECTOR (PHOTOELECTRIC)	LHPS	LOW/HIGH AIR PRESSURE SWITCH
RTS	REMOTE TEST STATION WITH RESET SWITCH	WPS	WATERFLOW PRESSURE SWITCH
HDT	HEAT DETECTOR FIXED TEMP.	HWS	HORN WITH STROBE (NUMBER INDICATES CANDELA)
MPS	MANUAL PULL STATION	SWS	STROBE (NUMBER INDICATES CANDELA)
MM	MONITOR MODULE	EOL	END OF LINE RESISTOR
		DH	DOOR HOLDER (24VDC)
		SCF	SMOKE CONTROL FAN

SECOND FLOOR FIRE ALARM PLAN

0 8' 16'
SCALE: 1/8"=1'-0"

Number	Revisions	Date	Approved
1	DETECTION, ALARM, AND COMMUNICATION SYSTEMS DESIGN PROJECT	06/08/2015	BAH

Centennial Station
12154 East Easter Avenue
Englewood, CO 80112

THIRD FLOOR FIRE ALARM PLAN

Drawn By:	BAH
AHJ:	SMFR
Date:	06/08/2015
Paper Size:	24 x 36
Class Number:	FPE S522

FA-4

LEGEND

FACP	FIRE ALARM CONTROL PANEL	DM	DUAL MONITOR MODULE (TWO POINTS)
FAPS	FIRE ALARM POWER SUPPLY	CM	CONTROL/RELAY MODULE
SD	SMOKE DETECTOR (PHOTOELECTRIC)	TS	TAMPER SWITCH
BTD	BEAM SMOKE DETECTOR (T-BT/BR TRANSMITTER, R-REFLECTOR)	FS	FLOW SWITCH
DSD	DUCT SMOKE DETECTOR (PHOTOELECTRIC)	LHAPS	LOW/HIGH AIR PRESSURE SWITCH
RTS	REMOTE TEST STATION WITH RESET SWITCH	WPS	WATERFLOW PRESSURE SWITCH
HDT	135° HEAT DETECTOR FIXED TEMP.	H75	HORN WITH STROBE (NUMBER INDICATES CANDELA)
MPS	MANUAL PULL STATION	S15	STROBE (NUMBER INDICATES CANDELA)
MM	MONITOR MODULE	EOL	END OF LINE RESISTOR
		DH	DOOR HOLDER (24VDC)
		SCF	SMOKE CONTROL FAN

SHEET NOTES

- CONTROL MODULE TO ACTIVATE THE SMOKE EXHAUST FAN IN THE ATRIUM. FIELD LOCATE THE EXACT LOCATION OF THE EXHAUST FAN.
- MONITOR MODULE TO BE MOUNTED ABOVE THE CEILING ADJACENT TO THE REMOTE TEST SWITCH.

THIRD FLOOR FIRE ALARM PLAN

0 8' 16'
SCALE: 1/8"=1'-0"

LEGEND			
	FIRE ALARM CONTROL PANEL		DUAL MONITOR MODULE (TWO POINTS)
	FIRE ALARM POWER SUPPLY		CONTROL/RELAY MODULE
	SMOKE DETECTOR (PHOTOELECTRIC)		TAMPER SWITCH
	BEAM SMOKE DETECTOR (T-BT/BR TRANSMITTER, R-REFLECTOR)		FLOW SWITCH
	DUCT SMOKE DETECTOR (PHOTOELECTRIC)		LOW/HIGH AIR PRESSURE SWITCH
	REMOTE TEST STATION WITH RESET SWITCH		WATERFLOW PRESSURE SWITCH
	HEAT DETECTOR FIXED TEMP.		HORN WITH STROBE (NUMBER INDICATES CANDELA)
	MANUAL PULL STATION		STROBE (NUMBER INDICATES CANDELA)
	MONITOR MODULE		END OF LINE RESISTOR
			DOOR HOLDER (24VDC)
			SMOKE CONTROL FAN

<div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; padding: 2px 5px; margin-right: 5px;">X</div> <div>SHEET NOTES</div> </div>	
1.	CONTROL MODULES TO BE PROVIDED TO SHUTDOWN THE AIR HANDLING UNITS LOCATED ON THE ROOF. FIELD LOCATE THE AIR HANDLING UNITS.
2.	DUCT SMOKE DETECTOR IS LOCATED ON RETURN PLENUM.

0 8' 16'

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

Centennial Station
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FOURTH FLOOR FIRE ALARM PLAN

$$= A - 5)$$