CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO

CULMINATING EXPERIENCE IN FIRE PROTECTION ENGINEERING

ANALYSIS OF COSTCO, SAN FRANCISCO

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EXECUTIVE SUMMARY

This report provides an in-depth analysis of the fire safety systems and design considerations of the Costco store located at 450 10th Street in San Francisco, California, satisfying the requirements for completion of the FPE 596 – Culminating Experience in Fire Protection Engineering academic series. The building is introduced, followed by an analysis of the building structure, alarm and detection, egress, and sprinkler systems are designed based on prescriptive code. These systems are then analyzed from a performance based perspective to gain understanding of how the systems will respond to a challenging design fire. Their response is used to determine if the building is compliant with requirements of performance based design.

The Costco store is a large warehouse style building of mixed occupancy. The fully sprinklered 122,000 sq. ft. building is of noncombustible construction and is used for multiple occupancies. The primary occupancy of the large, warehouse-style building is for mercantile purposes. As seen in Figure 1, the store features an open floor plan with goods such consumer electronics, clothing, home, office, and work supplies, fresh and packaged foods and beverage are stored throughout the store in floor display and high piled rack storage orientations. Office, kitchen, and dining occupancies constitute a portion of the building, along with some areas designated service occupancies as shown in Figure 2.

The study begins with an introduction to the structure of the building. Occupancy classification is determined, which combined with height and area data is used to determine allowable types of construction and the materials used. An array of prescriptive codes is examined and the structure of the building is found to be acceptable. After the structure of the building is fully explored, the life safety systems that impact occupant safety during a fire are discussed.

An alarm and detection system is designed for compliance with prescriptive code. The alarm and detection section first identifies components used in the system, such as heat detectors, horn-strobes, and the fire alarm control panel. The locations of the system components are presented, and the expected response of the system to a fire is calculated. Adequate backup power is provided and maintenance of the system is established. Application of a Voice Alarm Communication Systems (EVACS) is considered but deemed unnecessary.

After the alarm and detection design, the Costco is analyzed for its ability to allow for safe egress of occupants. The maximum occupancy of the building is determined, and the number, size, and location of exits are evaluated with consideration to the expected demographics of the store. Expected evacuation time is calculated, and tenability of occupants in a fire environment is discussed.

Once egress is investigated, a sprinkler system is designed with the goals of reducing the risk of harm to life and property. The sprinkler system components are discussed and the systems are laid out based on the occupancy and materials found the building. The hydraulic demands of the systems are calculated using hand calculations and sprinkler system modeling software, followed by a discussion of inspection, testing, and maintenance protocol. Recommendations are made to improve the sprinkler system performance.

With these life safety systems designed and analyzed from a prescriptive approach, their effectiveness is put the test using performance based design. In the fire scenario, an ultra-fast growth rate fire with high heat release rate and output of toxic gases, based on full-scale testing of electrical equipment similar to that found in the Costco, is located in front of the main exit from the building, blocking its use. The Costco is filled to maximum occupancy. The required safe egress time of 5.5 minutes is demonstrated to be less than the available safe egress time, based on the height of the smoke layer filling the store.

Recommendations are then made for furthering the research of this report and exploring other design fires and performance criteria.

Figure 1– Inside a typical Costco store

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STRUCTURAL ANALYSIS

The report begins with an analysis of the structural composition of the building. Occupancy and Construction classifications are established before determining the type of construction allowed and fire resistance ratings of structural components based on International Building Code, 2012 [1].

OCCUPANCY CLASSIFICATION

The Costco building has areas serving a variety of purposes with different occupancies per IBC 2012 Section 303. There is a small food court inside the store that has an associated kitchen area, designated occupancy A-2: “Restaurant seating and associated kitchen.” The office rooms, locker room, storage closet, and employee break room would be occupancy B, “office space.” The central region of the sales floor is mercantile – occupancy M. It has tables and shelves displaying merchandise such as clothing, books, videos, and outdoor equipment, along with refrigerators for food. Around the inside perimeter of the Costco is rack storage of all other merchandise, along with some large food freezers and a walk-in refrigerator. Many of the items are combustible, earning an S-1 occupancy.

To summarize:

- Restaurant and kitchen: A-2

- Office space: B

- Sales floor: M

- Rack storage: S-1

Note that the restaurant seating, kitchens, and office areas are considered accessory occupancies.

CONSTRUCTION CLASSIFICATION

The construction classification is based on the occupancy, size, and height of the building. Because the building is utilized for multiple occupancies without separation, the most restrictive occupancy shall be used to determine building construction per IBC 2012, 508.3.2.

Since the Costco is just a single story, the floor area of the building and occupancy group play the largest role in determining allowable construction types. The International Building Code allows for modifications to be made to the maximum allowable size for a given construction type if the

building has an automatic sprinkler system and ample frontage space for emergency vehicles and escape of occupants. The increases are shown below.

IBC 2012, 506.2 – Frontage increase: 48%

$$I_f = [F/P - 0.25] * W/30$$

I_f = Area increase due to frontage: 48%

F = building perimeter that fronts on a public way: 1,182 ft

P = perimeter of entire building: 1,616 ft

W = width of public way: 30 ft

IBC 2012, 506.3 – Automatic sprinkler system increase: 300%

Total increase: 348%

IBC 2012, Table 503 lists the size limitations of each construction type for occupancy groups (table 1). With the area of the Costco totaling 122,000 sq.ft., the maximum size permitted for a given construction type is 35,000 sq.ft. (122,000 sq.ft. / 3.48 area increase). For both group M and S-1 occupancies, allowable construction types are limited to Type I-A and I-B, in which the primary structural frame, bearing and nonbearing walls on the exterior and interior, and floor and roof construction are of noncombustible materials (with some exceptions – see next section).

Note that all other construction types are prohibited because the size of the Costco building exceeds their stated maximum square footage. If the storage was considered noncombustible, it would fall into the S-2 category, thereby complying with the requirements for type II-A as well.

Table 1 – IBC 2012 Table 503: Allowable Building Heights and Areas

TABLE 503 ALLOWABLE BUILDING HEIGHTS AND AREAS ^{a, b}										
Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane. Building area limitations shown in square feet, as determined by the definition of "Area, building," per story										
GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT (feet)	UL	160	65	55	65	55	65	50	40
		STORIES(S) AREA (A)								
M	S	UL	11	4	2	4	2	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
S-1	S	UL	11	4	2	3	2	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000

Next, the fire resistance ratings for individual structural components are addressed.

FIRE RESISTANCE

The building elements in each different construction type have minimum fire resistance requirements outlined in Table 601 of the IBC (table 2).

Table 2 – IBC 2012 Table 601: Fire-Resistance Rating Requirements for Building Elements

TABLE 601 FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)									
BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A ^d	B	A ^d	B	HT	A ^d	B
Primary structural frame ^g (see Section 202)	3 ^a	2 ^a	1	0	1	0	HT	1	0
Bearing walls									
Exterior ^{f, g}	3	2	1	0	2	2	2	1	0
Interior	3 ^a	2 ^a	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions									
Exterior			See Table 602						
Nonbearing walls and partitions									
Interior ^e	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1½ ^b	1 ^{b, c}	1 ^{b, c}	0 ^c	1 ^{b, c}	0	HT	1 ^{b, c}	0

The primary structural frame includes all columns, structural members have direct connections to columns (such as beams, girders, and trusses), members of the floor and roof construction that have direct connection to the columns, and all bracing members. For type I-A and I-B construction, the fire resistance ratings are 3 hours and 2 hours, respectively.

Load bearing walls on the interior and exterior are required to have 3 and 2 hour fire resistances, respectively. If the three load bearing exterior walls adjacent to the road were non-load bearing, they would require a fire resistance rating of 0 hours based on a fire separation distance of 30 feet measured from the wall to the center of the roads. For the side of the building next to the parking garage, a fire separation distance of 10 feet is used. For I-A and I-B construction of type S-1 and M occupancies, 1 hour fire resistance rating would be needed if the wall was non-load bearing. Table 2 tabulates the requirements for nonbearing exterior walls. Nonbearing interior walls and partitions also require a 0 hour fire resistance rating.

The floor construction and all associated secondary members require 2 hours of fire protection for both type I-A and I-B construction. Roof construction and all associated secondary members require 1½ hours for type I-A construction and 1 hour for type I-B construction. Some modifications can be made to the data provided above to allow for some combustible materials to

be used in type I construction based on IBC 2012 – 603.1. For example, fire retardant treated wood is permitted for the nonbearing partitions because their fire resistance rating is less than 2 hours. If the exterior walls were nonbearing, they could be constructed of fire retardant treated wood because they would have 0 hour fire resistance requirement. The roof construction can also use fire retardant treated wood.

STRUCTURAL COMPONENTS

All structural elements are required to be noncombustible in type I construction, except for those described in the previous section. The IBC prescribes fire resistance ratings for each structural component in Chapter 7.

PRIMARY STRUCTURAL COMPONENTS

The primary structural components are steel: columns, beams, and joists. Columns and beams are wide flange and joists are open web. To achieve the required fire ratings these components may need additional protection. This can be accomplished using a variety of materials: SFRM, an insulating coating that is sprayed onto structural components at a specified thickness to provide fire protection; applying protective membranes to the surface of the member; or enclosing the member in fire resistant paneling. It is crucial that the entire surface of the structural component and all joints are protected with no gaps. Fire has a tendency to “find a way” through any cracks, holes, or openings. Table 721.1(1) of IBC 2012 provides a very thorough list of the required insulating material thickness for different structural components, insulating materials, and fire resistance times.

Walls

The exterior walls are made of concrete bricks. Table 721.1(2) specifies the required face to face thickness of a large variety of concrete constructions to achieve fire resistance ratings of 1, 2, 3, and 4 hours. If the thickness is not sufficient to achieve the rating, additional protection can be achieved through plaster or gypsum wallboard. Per 705.5, the exterior walls adjacent to roadways can be rated for exposure from the inside, while the exterior wall near the parking garage must be rated on both sides due to its smaller fire separation distance. It is important to note that if additional protection is added to the concrete, it cannot provide more than half of the total fire resistance time (IBC 2012, 722.2.1.4.4).

To achieve the minimum required fire resistance rating of 2 hours for exterior bearing walls, concrete masonry units are required to be between 3.2 inches thick for expanded slag or pumice, up to 4.2 inches thick for calcareous or siliceous gravel. The concrete brick used for walls of the Costco are 8 inches thick, satisfying the required minimum thickness for 2 hour fire resistance ratings.

Nonbearing interior walls and partitions are of light-frame fire retardant treated wood construction, per IBC 2012 – 603.1. The fire resistance for these components is calculated by adding up the fire resistance time of the membrane on the fire exposed side, the time assigned to framing members, and time assigned for additional contributions per 722.6.2.1. If necessary, fire resistance rating of the wall assembly can be increased by adding gypsum wallboard, structural panels, or other membranes. In both 1A and 1B construction, non-loadbearing interior walls have a required fire resistance rating of 0 hours, which they meet.

Floor And Roof

The floor is a concrete slab on grade. To determine the required floor slab thickness table 722.2.2.1 should be used. For carbonate type concrete, 4.6" thick concrete is required to achieve 2 hour protection. For siliceous concrete, 5" thickness is required. If the floor is reinforced or prestressed, the depth of the thickness over reinforcements based on concrete type and restraint is tabulated in tables 722.2.3(2) and 722.2.3(3). The concrete slab of 12" thickness satisfies the IBC requirement of 2 hour fire resistance ratings in type 1A and 1B construction.

The roof assembly is a steel deck attached to the roof joists. Various membranes and spray applied formulas are available to increase the fire resistance rating if necessary. The roof has a required fire resistance rating of 1½ hours for type 1A construction and 1 hour for type 1B construction. To meet these requirements, I recommend constructing the roof of steel joists with a poured reinforced concrete slab on metal lath forms. With 2½ inch thick gypsum plaster over the metal lath attached to the bottom cord with wire ties 16" on center, 2 hour fire rating is achieved. To meet the 1 hour requirement for type 1B construction, 2¼ inch thick gypsum can be used.

Joints

The joints between walls, the floor, the roof, and columns must have a fire resistance rating equal to that of the components they are connecting (715.1). For the exterior walls, the required rating is therefore 2 hours. Any interior load bearing walls would require 3 hours. For type I-A construction, the joints between the columns and floor would need to be rated for 3 hours. For I-

B, joints would require a 2 hour rating. Since the roof has a lower required fire resistance rating than the walls and joists it is attached to, the joints at the roof would take on the fire resistance rating of the component it is connected to.

Penetrations

Penetrations through the walls and membranes must be installed in such a way that the fire resistance rating of the structural component is not compromised. For the concrete floor and roof, penetrations can be made using the Hilti CP-680 series of firestops (Appendix), which are approved for penetrations through concrete and steel with fire resistance ratings of up to 4 hours. These firestops can be used with plumbing and fire sprinkler piping and are available in a large range of sizes. For mechanical ductwork and electrical and data conduit, Hilti produces FS-ONE MAX firestop sealant (Appendix), that is also compatible with a wide variety of materials and provides up to 4 hours of fire resistance rating.

Doors

The Costco has 11 doors around its perimeter, along with a large garage door style entrance and exit in one corner. Per table 716.5, doors through exterior walls with a 2 hour rating require a fire resistance rating of 1½ hours. Interior doors through 2 hour rated exit passageways must have ratings of 1½ hours.

Prefabricated doors listed with 1½ fire resistance ratings are readily available from a variety of manufacturers, with sources as common as Home Depot or Lowe's. For this application, the Republic Doors and Frames models DE 820 and DE 420 (Appendix) are suitable for use in single-door and double-door 1½ fire rating applications.

SUMMARY

Overall, the Costco meets the structural requirements prescribed by International Building Code. The floor and roof are made of concrete with a thickness adequate to provide the required 2 hour and 1½ hour fire resistance ratings. The concrete brick walls are also of satisfactory thickness, exceeding the most stringent depth requirement of 4.2 inches by a factor of two. Joints, penetrations, and doors meet their respective fire resistance ratings requirements with readily available proprietary products.

With the Costco demonstrably compliant with International Building Code requirements for structural fire protection, the building is deemed structurally safe in the event of a fire. Next, we examine the alarm and detection system of the Costco, the purpose of which is to alert occupants and emergency personnel to the presence of a fire, leading to building evacuation.

ALARM AND DETECTION

The alarm and detection system constantly monitors the environment inside the Costco building for signs of fire, ready to alert occupants to danger or emergency with fast response times and reliability. In this section, components of the alarm and detection are identified and located in the room as required by NFPA 72, 2013 [2] and the manufacturer specifications. Expected response times are calculated using the DETACT model, and the employment of Emergency Voice Alarm Communications Systems is considered. Computations are conducted of the required backup power source in case the alarm and detection system loses power from San Francisco's grid. The signals monitored by the fire alarm control panel are discussed, as well as the emergency warning characteristics of the notification appliances. Lastly, the inspection, testing, and maintenance required for the alarm and detection system is described.

ALARM AND DETECTION OVERVIEW

The Costco building will be well served by a central station type fire alarm system. The central service system will constantly transmit signals to the independent, UL or FM listed central station staffed by trained, qualified operators who are responsible for managing the system, record keeping, and taking action in the event of an emergency signal based on the mandates of NFPA 72, 2013. The central station is also to be responsible for installation, testing, maintenance, and runner service to the Costco building.

The benefits of a central station include rapid response times, professional handling of emergency signals, and reliable upkeep and maintenance. Staff of the Costco building would not be responsible for the management of emergency scenarios, which requires specialized training. The building would be monitored 24 hours a day, which includes times when the building would otherwise be unoccupied.

The fire alarm control panel to be used is the Fire-Lite MS-9200UDLS (see Appendix), capable of monitoring the entire Costco system while communicating to the central station via telephone line or internet connection.

FIRE DETECTION DEVICES

The Costco will be fully protected by heat and smoke detectors. Heat detection will be provided by fire protection sprinklers, which automatically activate if they reach a given temperature, often

155° F or 165° F. Activation of the fire sprinkler system triggers an alarm signal at the fire alarm control panel, which activates the building alarm system as well as sends an emergency signal to the central station. The sprinkler system section of this report details the design, implementation, components, materials, and maintenance of the sprinkler system.

Spot type heat detection will be provided by the Potter PSHA combination photoelectric smoke/heat sensor (see Appendix) located at the ceiling, which is activated if it reaches a fixed temperature of 135° F or smoke obscuration of as low as 1.05%/foot. Heat detection satisfies the demands of UL 521. The photoelectric smoke detection responds better to smoldering fires than flaming fires, as the smoke interferes with a light sensor in the detector to actuate the alarm signal. In the event of a fire, convected heat increases the temperature of the highly sensitive detectors which send a signal should the activation temperature be reached.

Spacing is based on the design requirements of NFPA 72 and manufacturer's recommendations for smooth ceilings, with a base distance of 30 ft. Modifications are made as needed to account for the high ceilings of 30 ft:

NFPA 72, 2013 - 17.6.3.1.1: Distance between detectors shall not exceed their listed spacing.

NFPA 72, 2013 – Table 17.6.3.5.1: 30 ft ceilings – multiply spacing by 0.34.

Spacing is reduced to 10 feet for the majority of the floor area of the building.

For the auxiliary areas in the northwest side of the building, such as restrooms, offices, vault, and kitchen, assume a ceiling height of 10 feet. Assume the same for the accessible cooler in the southeast corner of the shopping floor, dairy cooler on the east side of the building, and bakery and meat handling areas on the right side of the south leg of the building. The recommended spacing of 30 ft is used.

See Figure 3 for detector layout on the floor plan.

Note that light detecting devices, which respond to the radiant energy of a fire, are inappropriate as the floor plan of the building contains too many obstructions to reasonably provide full line of sight coverage. Beam type detectors are inappropriate as the ceiling has exposed beam construction, with electrical, mechanical, and plumbing equipment exposed, which would obstruct the beam.

DETECTION DEVICE LOCATIONS

The following codes come from NFPA 72, 2013 and apply to the location, spacing, and placement of fire detection devices in the Costco building. Each code is presented with rationale for its satisfaction of code demands.

17.4.4 – “Initiating devices shall be installed in a manner that provides accessibility for periodic inspection, testing, and maintenance.”

The sensors are placed at the ceiling, which is accessible from below via a scissor lift, and the floor of the building has large aisles that provide adequate room for travel of the scissor lift.

17.5.3.1 – “Where required by other governing laws, codes, or standards, and unless otherwise modified by 17.5.3.1.1 through 17.5.3.1.5, total coverage shall include all rooms, halls, storage areas, basements, attics, lofts, spaces above suspended ceilings, and other subdivisions and accessible spaces, as well as the inside of all closets, elevator shafts, enclosed stairways, dumbwaiter shafts, and chutes.”

Heat detectors have been placed throughout the building as mandated by this code.

17.5.3.1.5 – “Detectors shall not be required underneath open loading docks or platforms and their covers and for accessible underfloor spaces if all of the following conditions exist:

- 1) Space is not accessible for storage purposes or entrance of unauthorized persons and is protected against the accumulation of windborne debris.*
- 2) Space contains no equipment such as electric wiring, shafting, or conveyors.*
- 3) Floor over the space is tight.*
- 4) No flammable liquids are processed, handled, or stored on the floor above.”*

The loading dock does not satisfy the requirements listed above, as mechanical garbage equipment is located there, which is assumed to require the use of electrical wiring. Flammable liquids such as gasoline for forklifts or scissor lifts, as well as alcohols, may also be stored there during shipping operations. Therefore, the loading dock is equipped with detectors.

17.6.3.6 – “A heat-sensing detector integrally mounted on a smoke detector shall be listed for not less than 50 ft spacing.”

Required spacing is 10 ft, satisfying the 50 ft. minimum.

17.6.3.5 .1 – “On ceilings 10 ft to 30 ft high, heat detector spacing shall be reduced in accordance with Table 17.6.3.5.1 prior to any additional reductions for beams, joists, or slope where applicable.”

Spacing was adjusted based on the specified provisions, as explained in the previous section.

17.7.3.2.1 – “Spot-type smoke detectors shall be located on the ceiling or, if on a sidewall, between the ceiling and 12 in. down from the ceiling to the top of the detector.”

The combination detectors are located on the ceiling throughout the building as shown in Figure 3. With the heat and smoke detector types identified and their locations arranged, we can examine how they will respond to a realistic fire.

FIRE SCENARIOS AND ALARM ACTIVATION TIME

The Costco store sells wares of a variety of flammable materials, including but not limited to clothing, electronics, fresh and dry foods, alcoholic beverages, industrial kitchen equipment, tools, batteries, tobacco, pharmaceuticals, furniture and homewares. Table 3 compiles available heat release rates for some materials found in the store. Heat release rate data comes from the Society of Fire Protection Engineers Handbook of Fire Protection Engineering, 4th ed. [3] as well as document AIAA 2000-0722, published by the American Institute of Aeronautics and Astronautics, titled *Heat Release Rates of Burning Items in Fires* [4]. The data comes from tables that list peak heat release rates for a wide array of constituent materials. If many values are listed, a representative value is chosen. Data also comes from graphs of heat release rate over the course of a test burn, in which case the peak HRR is used.

To determine the response characteristics of the detection devices the DETACT model is used. DETACT uses the Alpert correlation for unconfined ceiling jets to estimate the temperature at a location in the fire plume based on the heat release rate, fire growth coefficient, height of the detector, and radial distance from the heat source to the detector.

The most intense fire from the materials tested came from a plywood wardrobe. The parameters used for the DETACT model are shown in the table 4. Worst-case values are utilized where applicable to produce the most conservative results. The plywood wardrobe produced the maximum heat release rate in the table above. According to fig. 3-1.105 in the SFPE handbook

(test 41, Figure 4), it reached its 6400 kW HRR after about 160 seconds of burning. Arriving at the maximum heat release rate in this time period corresponds to an ultra-fast growth fire.

Figure 3 – Alarm and detection system layout

Table 3 - Heat Release Rates of various fuels in the Costco store

MATERIAL	PEAK HEAT RELEASE RATE (kW)	NOTES	SOURCE
Computer monitor	239.2	High-impact polystyrene, worst case	SFPE, Table 3-1.3
Computer monitors	4700	Boxed monitors, 1 pallet of 12	SFPE, Table 3-1.11
Bedding	200		SFPE, Fig 3-1.14
Wooden dresser	1700		SFPE, Fig 3-1.38
Potato and cheese snack foods	6000		SFPE, Fig 3-1.41
Pillows	115	Feathers	SFPE, Fig 3-1.66
Upholstered furniture	3000		SFPE, Fig 3-1.102
Wardrobe	6400	Plywood, unpainted, filled with clothing and paper	SFPE, Table 3-1.31
Cooking Oil	111		AIAA, Table B
Small dresser	1766		AIAA, Table C
Cotton fabric	71		AIAA, Table D
Wool fabric	167		AIAA, Table D
Stackable chairs	2000	Polypropylene, steel	SFPE, 3.1-18

Figure 4 – Heat release rate curves for plywood wardrobes

Table 4 - DETACT input variables for heat detector activation

VARIABLE	VALUE	NOTE
Ceiling height	30 ft	
Room width	407 ft	Building is approximately square
Radial distance	7 ft	Maximum possible dimension
Ambient temperature	20 °C	Room temperature
Actuation temperature	58 °C	Heat detector rated for 135 °F
	69 °C	Sprinkler activation temperature of 155 °F
Response time index	2	Heat detector: low value chosen to capture rapid response
	80	Sprinkler: standard response
Fire growth power	2	t-squared fire
Fire growth coefficient	0.4 kW/s ⁿ	Ultra-fast fire growth.

Results of the DETACT model calculations for heat detector and sprinkler activation are shown in Figures 5 and 6, respectively. As expected, the heat detector activates before the sprinklers because it has a lower activation temperature and higher RTI, resulting in faster response. This can be visually confirmed in Figure 5: the detector temperature and gas temperature are nearly the same, so the data points corresponding to these temperatures overlap. When the heat detector reaches its activation temperature of 58 °C, the heat release rate of the fire is about 1250 kW. It takes about 53 seconds for the fire to be detected.

After about 95 seconds the sprinkler reaches its activation temperature of 69 °C, at which time the heat release rate of the fire is 4500 kW. This is an intense and rapidly growing fire following a t-squared growth curve. Though the store is protected with a sprinkler system, in the event that the fire overcomes the impacts of the sprinklers evacuation of the store would be required. The evacuation process is analyzed in the egress section of this report.

FIRE ALARM CONTROL PANEL AND SIGNAL TYPES

All signals from the alarm and detection system will be sent to the Fire-Lite MS-9200UDLS fire alarm control panel, which will be located near the main entrance of the building in the southwest corner. The flow sensor on the fire pump will be connected to the control panel, signaling that water is flowing through the sprinkler system and a sprinkler has been activated. The Potter PSHA heat and smoke detectors are to be connected to the control panel as well. Also connected to the control panel are the notification appliances, power sources, and EVACS system components. The control panel is connected to the central station via either telephone or internet connection.

Figure 5 - Calculated temperature of heat detector using DETACT model

Figure 6 - Calculated temperature of sprinkler using DETACT model

Signal priority is outlined in NFPA 72, 2013 Section 10.7. Fire alarm signals have the highest priority, followed by EVACS notification signals and messages under circumstances outlined in NFPA 72 Chapter 24. Alarm signals warn of the possibility of immediate danger. Supervisory signals, which indicate if part of the alarm and detection system is off normal, take precedence over trouble signals, which alert control station to any broken components.

Alarm signals must be distinguishable from pre-alarm, supervisory and trouble signals (NFPA 72, 2013 - 10.10.4 through 10.10.8) to allow the central station to identify the type of system component producing the signal. Notification actuation must occur within 10 seconds of receiving the alarm (NFPA 72, 2013 - 10.12.1) to ensure immediate response by occupants to the alarm signal. Where voice communication signals are used, visual signaling must also simultaneously activate (NFPA 72, 2013 - 10.13.2.1) which alerts individuals whose hearing is impaired to the presence of danger. In this case, visual signaling is accomplished using strobe lights.

Unacknowledged alarm signals must continue to be transmitted in the event of a fault on an initiating device circuit (NFPA 72, 2013 - 10.12.5) and the audible and visible alarms must remain active until they are manually silenced or acknowledged (NFPA 72, 2013 - 10.12.6.2). These requirements ensure that alarm signals are distinct and responded to in an appropriate and timely manner. In the event of alarm activation, it is never permitted to be automatically deactivated (as if responding to a false alarm) to ensure that occupants are alerted to danger in the event of an actual fire.

Supervisory signals must be acknowledged within 90 seconds at the fire alarm control panel and central station (NFPA 72, 2013 - 10.14.1). The supervisory signals appliances are to be located in an area where they will be immediately noticed (NFPA 72, 2013 - 10.14.5) and are to operate until they are restored (NFPA 72, 2013 - 10.14.7.5). These requirements ensure abnormalities in the alarm and detection system are addressed immediately and the system is not deactivated for a prolonged period of time.

Trouble signals must be indicated and restored within 200 seconds. The notification appliances must operate until they are manually shut off (NFPA 72, 2013 - 10.15.6), and must send signals to the fire alarm control panel and central station (NFPA 72, 2013 - 10.15.7). Again, these provisions are included to keep the system actively monitoring the environment to ensure legitimate detection of a fire through heat or smoke is not compromised.

The location of all operating signal devices must be conveyed (NFPA 72, 2013 - 10.18.1.1-2), and the location must continue to be identified after the alarm is deactivated (NFPA 72, 2013 - 10.18.1.1.3), which allows staff to identify the system component causing the signal in the event of malfunction or actual fire response.

FIRE ALARM NOTIFICATION DEVICES

The Costco building is to be fully covered by the Wheelock Exceder combination alarm and strobe model HSC (see Appendix), which will provide both auditory and visual alarm signaling. The system is designed to be fully compliant with NFPA 72, 2013 and matches all requirements therein.

Alarms are to be 15 dBa louder than ambient throughout the building, which according to NFPA 72, 2013 Table A.18.4.3 for mercantile occupations, has an ambient sound level of 40 dBa, without exceeding a safe maximum of 110 dBa per NFPA 72, 2013 Section 18.4.1.2. Thus, the minimum sound level throughout the store must be 55 dBa.

The alarms have an output rating of 99 dBa measured at a distance of 10 ft. Spacing of alarms is determined using the principle that sound levels decrease by 6dBa every time the distance to the alarm is doubled [5]. Using this method, at a distance 20 ft from the alarm, the signal is 93 dBa; at 40 feet, 87 dBa, and so on, until the spacing reaches a maximum of 1280 feet maintaining a signal of 55 dBa. This spacing is implausible given the dimensions of the room, but can be compared to the spacing requirements of the strobes to determine if the audibility or visibility limitations are more stringent.

Strobes must be visible from all locations within the building. To satisfy these requirements, the notification appliances are to be placed at the ceiling level, where merchandise and shelving will not obstruct the view.

Per NFPA 72, 2013 – 18.4.8.3, combination audio/visual notification appliances are to be located based on the requirements of Section 18.5.5. Ceiling mounted appliances are permissible and required to be spaced based on table 18.5.5.4.1(b), which outlines required light output based on area of coverage and ceiling height. Due to the size of the building and large distance from the floor to the ceiling, appliances with high sound and light outputs were selected.

Based on the aforementioned table, many devices that provide coverage for a 68 ft sided square area are used, each requiring 177 cd of light output. The main floor area will be covered by ceiling mounted devices. The rooms surrounding the main shopping area, including freezers, locker rooms, offices, maintenance rooms, and other auxiliary rooms, will be covered by ceiling mounted appliances spaced based on the provisions of table 18.5.5.4.1(b). Most satellite rooms are covered using 28 ft spacing (30 cd strobe output), except for the offices on the north side of

the building and the bakery freezer to the south east, which will use 40 ft spacing (60 cd strobe output). Some 55 ft. spaced devices (115 cd) are used to provide necessary coverage in specific locations. At the end of the northwest corridor, a single 15 cd strobe is required.

The strobe spacing is required to be shorter than the alarm spacing. Because the notification appliances are combination alarm strobes, the strobe spacing is used to determine their locations. The layout of notification appliances is shown on Figure 3.

EMERGENCY VOICE ALARM COMMUNICATION SYSTEMS

Emergency Voice Alarm Communication Systems (EVACS) are alarm systems that use speakers or various other means of communication to broadcast emergency messages to the occupants of a building. In some special circumstances they are able to supersede alarm systems, if they match the capability to reach all occupants and transmit the necessary information with intelligibility. The necessary intelligibility is established in NFPA 72, and can involve design considerations and equipment entirely different from those of a conventional alarm system.

Requirements of emergency communications are addressed in Chapter 24 of NFPA 72, 2013. Section 24.3.3 establishes that emergency communications systems are to be installed based on local authority. San Francisco Fire Code Section 907.2.8.2 only establishes mandatory EVACS for high rise buildings, which does not include the Costco store analyzed in this report. Supplementary material found in Section A.24.3.3 further explains that EVACS should be utilized in vital infrastructural facilities, such as buildings that if destroyed would disrupt national security, the economy, or public health and safety. Because the Costco does not meet these requirements, an EVACS system is not required.

If an EVACS system were installed in the building, it would be subject to the strict standards outlined in NFPA 72, 2013 Section 24.4.2. It would likely be a one-way communication system integrated into the fire alarm control panel and would require using an amplifier, speaker, and recorded voices or a microphone to broadcast live messages in real time.

Intelligibility and audibility of the voice messages is required throughout the whole building per NFPA 72, 2013 - 24.4.2.2.2.1. The clarity of the speaker broadcast tends to decrease with high ceilings, requiring increased speaker density that would create prohibitively high costs. Furthermore, the floor and much of the contents of the store are of hard materials that tend to reflect sounds, creating reverberations that impact intelligibility. Because intelligibility would be difficult and extremely expensive to achieve, it is not appropriate for the Costco store.

SECONDARY POWER SUPPLY

Per NFPA 72, 2013 – 10.6.7.2, alarm and detection systems are required to operate in standby mode for 24 hours, followed by 5 minutes of system activity with a 20% additional factor of safety. The sensing and notification devices require a steady, small amount of power to continue to function. The fire alarm control panel also requires some power in standby mode. The notification appliances have no standby power but upon actuation require a large power draw. Table 5 shows the calculation for the total system alarm current. Table 6 shows the calculation for the needed battery capacity for all components of the system. Power requirements are provided by the manufacturer's material data sheets located in the Appendix.

Table 5 - Calculation of standby power required for alarm and detection components

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER UNIT (AMPS)	TOTAL ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL SYSTEM ALARM CURRENT (AMPS)
A	FACU	0.145	X	1	=	0.145	3	X	1	=	3
B	Combination Detector	0.000325	X	1562	=	.50765	0.0065	X	72	=	0.468
C	Horn/Strobe	0	X	35	=	0	0.282	X	35	=	9.87
	99 dBA/177 cd										
D	Horn/Strobe	0	X	2	=		0.197	X	2	=	0.394
	99 dBA/115 cd										
E	Horn/Strobe	0	X	5	=	0	0.141	X	5	=	0.705
	99 dBA/60 cd										
F	Horn/Strobe	0	X	9	=	0	0.102	X	9	=	0.918
	99 dBA/30 cd										
G	Horn/Strobe	0	X	1	=	0	0.082	X	1	=	0.082
	99 dBA/15 cd	TOTAL SYSTEM STANDBY CURRENT (AMPS)				0.65265	TOTAL SYSTEM ALARM CURRENT (AMPS)				15.437

The total backup power required by the system is 20.34 amp-hours. Various battery options are available for the fire alarm control panel that satisfy this demand. BAT-12260 has a capacity of 26 amp-hours (Appendix). For higher storage demands, batteries of 55 and 100 amp-hours are available. It is also possible to employ battery boxes that can hold 2 25 amp-hour or 2 55 amp-hour batteries.

Table 6 - Calculation of required battery capacity for standby power

REQUIRED OPERATING TIME OF SECONDARY POWER SOURCE PER NFPA 72 10.5.6.3:		
STANDBY	24 hours	
ALARM	5 min	0.0833 hr
REQUIRED STANDBY TIME (HOURS)	24.00	
TOTAL SYSTEM STANDBY CURRENT	0.653	
REQUIRED STANDBY CAPACITY (AMP-	15.66	
REQUIRED ALARM TIME (HOURS)	0.0833	
TOTAL SYSTEM ALARM CURRENT (AMPS)	15.44	
REQUIRED ALARM CURRENT (AMP-	1.29	
REQUIRED STANDBY CAPACITY (AMP-HOURS)	15.66	
REQUIRED ALARM CAPACITY (AMP-HOURS)	1.29	
TOTAL REQUIRED CAPACITY (AMP-HOURS)	16.95	
FACTOR OF SAFETY	1.20	
REQUIRED BATTERY CAPACITY (AMP-HOURS)	20.34	

VOLTAGE DROP

Voltage drop calculations have been conducted to analyze the ability of the FACP to satisfy the requirements of the proposed system. Table 7 shows the calculation of voltage drop for the system. Current required for each notification appliance is based on manufacturer's specifications (Appendix). The calculations use 2,599 ft of #12 copper wire with a resistance of 1.588 ohm/1000 ft. With all appliances served by a single circuit, the voltage drop is calculated to be 204%, far below the permissible value of 15% per section 10.3.5 of NFPA 72, 2013.

To overcome the severe voltage drop associated with a single circuit, the notification system is broken into 4 subsystems, utilizing all 4 of the available NAC on the Fire Alarm Control Panel. Tables 8 through 11 present the voltage drop calculations with the redistributed power. System demand is decreased twofold: fewer appliances draw less current, while simultaneously requiring less wire per circuit to reduce the resistance in the circuit. An acceptable level of voltage drop results from redistributing power to four circuits.

Table 7 – Calculation of voltage drop with all notification appliances on single circuit

ALL DEVICES ON ONE CIRCUIT						
Device	Horn/Strobe	Horn/Strobe	Horn/Strobe	Horn/Strobe		
Specifications	99 dBA/177 cd	99 dBA/115 cd	99 dBA/60 cd	99 dBA/30 cd		Wire
Current (A)	0.282	0.197	0.141	0.102		#12 AWG
Quantity	36	2	3	9		
Resistance (ohms/1000 ft)	-	-	-	-		1.588
Feet	-	-	-	-		2599
Total Current (A)	10.152	0.394	0.423	0.918	11.887	
Voltage Drop	= [Length of wire (ft) * Conductor resistance (ohm/1000 ft) * Load current (A)]					
	= 2599*(1.588/1000)*11.89					
	= 49.07255068					
% Voltage Drop	=49/24*100					
	204.1666667		Percent voltage drop not to exceed 15% per NFPA 72, 2013 10.3.5.			

Table 8 – Calculation of voltage drops from notification appliances on circuit 1 of 4

CIRCUIT 1						
Device	Horn/Strobe	Horn/Strobe	Horn/Strobe	Horn/Strobe		
Specifications	99 dBA/177 cd	99 dBA/115 cd	99 dBA/60 cd	99 dBA/30 cd		Wire
Current (A)	0.282	0.197	0.141	0.102		#12 AWG
Quantity	7	0	2	5		
Resistance (ohms/1000 ft)	-	-	-	-		1.588
Feet	-	-	-	-		811
Total Current (A)	1.974	0	0.282	0.51	2.766	
Voltage Drop	3.56					
% Voltage Drop	14.84					

Table 9 – Calculation of voltage drops from notification appliances on circuit 2 of 4

CIRCUIT 2						
Device	Horn/Strobe	Horn/Strobe	Horn/Strobe	Horn/Strobe		
Specifications	99 dBA/177 cd	99 dBA/115 cd	99 dBA/60 cd	99 dBA/30 cd		Wire
Current (A)	0.282	0.197	0.141	0.102		#12 AWG
Quantity	10	0	0	4		
Resistance (ohms/1000 ft)	-	-	-	-		1.588
Feet	-	-	-	-		649
Total Current (A)	2.82	0	0	0.408	3.228	
Voltage Drop	3.33					
% Voltage Drop	13.86					

Table 10 – Calculation of voltage drops from notification appliances on circuit 3 of 4

CIRCUIT 3						
Device	Horn/Strobe	Horn/Strobe	Horn/Strobe	Horn/Strobe		
Specifications	99 dBA/177 cd	99 dBA/115 cd	99 dBA/60 cd	99 dBA/30 cd		Wire
Current (A)	0.282	0.197	0.141	0.102		#12 AWG
Quantity	9	2	1	0		
Resistance (ohms/1000 ft)	-	-	-	-		1.588
Feet	-	-	-	-		730
Total Current (A)	2.538	0.394	0.141	0	3.073	
Voltage Drop	3.56					
% Voltage Drop	14.84					

Table 11 – Calculation of voltage drops from notification appliances on circuit 4 of 4

CIRCUIT 4						
Device	Horn/Strobe	Horn/Strobe	Horn/Strobe	Horn/Strobe		
Specifications	99 dBA/177 cd	99 dBA/115 cd	99 dBA/60 cd	99 dBA/30 cd		Wire
Current (A)	0.282	0.197	0.141	0.102		#12 AWG
Quantity	10	0	0	0		
Resistance (ohms/1000 ft)	-	-	-	-		1.588
Feet	-	-	-	-		800
Total Current (A)	2.82	0	0	0	2.82	
Voltage Drop	3.58					
% Voltage Drop	14.93					

INSPECTION, TESTING, AND MAINTENANCE

As expected, alarm and detection systems have a wide range of inspection, testing, and maintenance requirements to ensure the systems operate correctly for the entirety of their lifespan.

Complete logs of the components of the system need to be created that provide a wealth of information about the installed system. Contact information for the installing, testing, and service parties must be provided. Data for all system components is to be included, including, but not limited to, the control unit, power, circuits, initiating devices, notification appliances, and system controls. Documentation for the code compliance of the system and thorough testing is also required. Power system information must include electrical specifications of the components and batteries. Any deviation from required code is documented.

For inspection and testing, contact information of the responsible parties is tabulated. The software, power, detection, and alarm test sheets must be provided. The supervising station is tested for alarm, trouble, and supervisory signals and their respective restorations. Visual inspections and functional tests must be conducted and documented for the control unit, fuses, trouble signals, switches, annunciators, batteries, and chargers.

An extremely detailed list of all components to be tested, the required frequency, and method for conducting and accepting the test is found in NFPA 72, 2013 Table 14.4.3.2.

SUMMARY

This section examined the alarm and detection system of the Costco building. The types of devices were identified and their locations were established based on manufacturer specifications and code requirements. The response of alarms to a realistic fire scenario was explored, followed by an analysis of the notification appliances and their layout. The application of an EVACS system was considered. The secondary power supply requirements of the system were determined in case primary power became unavailable, and inspection, testing, and maintenance requirements were addressed.

It has been determined that the devices and components used in the alarm and detection system satisfy the demands of NFPA 72, 2013 and San Francisco City Code. Using DETACT, the heat detectors were shown to activate in 53 seconds and sprinklers in 93 seconds. The acceptability of these results is considered in the Performance Based Design Chapter of this report.

The fire alarm control panel is assessed. Various signal types it is required to monitor and respond to are described, each with their own code requirements that are to be met. The potential for an EVACS system to be incorporated into the alarm and detection system is discussed, and is determined to be inappropriate for use in this building based on design criteria and prescriptive code.

Once the system is fully defined, the secondary power requirements are calculated to ensure the system can remain active for 24 hours of passive monitoring followed by 5 minutes of activation time. Backup power sources are identified that are compatible with the system and meet the power demands. A calculation of the voltage drop is presented to ensure adequate power reaches all the devices and serves the fire alarm system.

To ensure the system remains functional and continues to meet the requirements of NFPA 72 and San Francisco City Code, the inspection, testing, and maintenance needs are briefly discussed.

The primary purpose of the alarm and detection system is to alert occupants of the presence of danger due to fire. The response of occupants is examined in the next section: Egress.

EGRESS ANALYSIS

Egress of the building designed for compliance with NFPA 101, 2012: Life Safety Code [6]. The fundamental principle of egress design is to ensure occupants can escape the building safely and efficiently in the event of a fire.

First, maximum occupancy of the building is determined. The egress capacity is shown to be satisfactory based on available exit routes from the building. The exits and occupant paths of travel are examined, along with signage and interior separation requirements. The psychology of evacuation is discussed, addressing decision making during emergency escape scenarios. Pre-movement and movement times are calculated and considered in the calculation of the total time required to evacuate the building. Finally, the concept of tenability is discussed, in which the impacts of toxic smoke inhalation are examined.

OCCUPANCY RATINGS AND OCCUPANCY LOAD

NFPA 101, 2012 – 7.3.1.2: “The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use as specified in Table 7.3.1.2.”

Table 7 shows the area, occupant load factor, and occupant load for each occupancy of the Costco. Service areas have a negligible occupant load factor. A large portion of Costco’s floor area is for mercantile purposes, the majority of which is open to the public and a small allocation for a shipping area occupied by employees. For these calculations, egress paths are not considered occupied spaces even though in practice they often will be occupied. This reduction in mercantile area is offset by a large, changing amount of floor area occupied by tables, shelves, and displays containing merchandise.

The high-stacked arrangement of goods in Costco may make some areas storage occupancies. The Life Safety Code accounts for this combination of occupancies:

NFPA 101, 2012 – 42.1.2.2: “Incidental storage in another occupancy shall not be the basis for overall occupancy classification.”

NFPA 101, 2012 – 6.1.14.1.3: “Where incidental to another occupancy, areas used as follows shall be permitted to be considered part of the predominant occupancy

and shall be subject to the provisions of the Code that apply to the predominant occupancy:

(1) Mercantile, business, industrial, or storage use..."

The Life Safety Code further specifies the mercantile occupancy to be Class A:

NFPA 101, 2012 – 36.1.2.2.1: *"Mercantile occupancies shall be subclassified as follows:*

(1) Class A, all mercantile occupancies having an aggregate gross area of more than 30,000 ft² or occupying more than three stories for sales purposes"

Table 12 - Occupancy areas and occupant loads

OCCUPANCY	AREA (FT ²)	OCCUPANT LOAD FACTOR (FT ² PERSON)	OCCUPANT LOAD
Service	1,036	-	-
Office	9,408	100	95
Kitchen	9,224	100	93
Dining – Assembly, less concentrated	2,468 gross 1,234 net	15 net	83
Mercantile - Sales area on street floor	87,606	30	2921
Mercantile - Shipping area	4,755	300	16
TOTAL			3,208

Note: The dining area's net area is calculated as one-half of its total area.

EGRESS CAPACITY

NFPA 101, 2012 – 7.3.3.1: *"Egress capacity for approved components of means of egress shall be based on the capacity factors shown in Table 7.3.3.1."*

According to the Table 7.3.3.1, egress capacity is calculated by requiring 0.2 inches of horizontal exit length per occupant. This value is calculated by dividing the length of the opening by 0.2 in/person.

Table 8 shows the quantity and size of each exit of the Costco. Exits are located on all walls. The main entrance and exit are on the south east corner of the building, with single door exits in the storeroom area and adjacent to the restrooms and main exit. Eight double door exits surround the entirety of the Costco's floor space.

Table 13 - Exit quantities, dimensions, and capacities

EXITS	QUANTITY	SIZE OF OPENING	TOTAL LENGTH (INCHES)	CAPACITY FACTOR (IN/PERSON)	EGRESS CAPACITY (PERSONS)
Main entrance	1	92	92	0.2	460
Main exit	1	92	92	0.2	460
Single door	3	36	108	0.2	540
Double door	8	72	576	0.2	2,880
CUMULATIVE	13	-	868	0.2	4,340

Since the required egress capacity of 4,340 persons exceeds the occupancy load of 3,208, the Costco meets the egress capacity required by the Life Safety Code.

NUMBER AND ARRANGEMENT OF EXITS

The Costco building has 13 exits which exceeds the minimum number of exits requirement:

NFPA 101, 2012 – 7.4.1.2: *“The number of means of egress from any story or portion thereof, other than for existing buildings as permitted in Chapters 11 through 43, shall be as follows:*

Occupant load more than 500 but not more than 1000 – not less than 3

Occupant load more than 1000 – not less than 4”

Exit through the south east storeroom is allowed based on the following provision:

NFPA 101, 2012 – 36.2.5.11: *“Exit access in Class A and Class B mercantile occupancies that are protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1(1), and exit access in all Class C mercantile occupancies, shall be permitted to pass through storerooms, provided that all of the following conditions are met:*

Not more than 50 percent of exit access shall be provided through the storeroom.

The storeroom shall not be subject to locking.

The main aisle through the storeroom shall be not less than 44 in. wide.

The path of travel through the storeroom shall be defined, direct, and continuously maintained in an unobstructed manner.”

To ensure exit access in the event that some become blocked, as in the event of a large fire or one located around the perimeter of the building, 2 exits must be spaced at least one-third the maximum diagonal distance of the floor area:

NFPA 101, 2012 – 7.5.1.3.3: “In buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 9.7, the minimum separation distance between two exits, exit accesses, or exit discharges, measured in accordance with 7.5.1.3.2, shall be not less than one-third the length of the maximum overall diagonal dimension of the building or area to be served.”

The Costco’s maximum diagonal dimension is 520 feet, resulting in a minimum door separation distance of 174 feet. Since exits are located throughout the building surrounding the sales area and near opposite corners of the building, the minimum separation distance is satisfied.

In mercantile occupancies rows of checkout stands may block some exits from being accessed quickly in the case of emergency. For this reason, the Life Safety Code has the following provision:

NFPA 101, 2012 – 36.2.5.8: “Not less than one-half of the required exits shall be located so as to be reached without passing through the checkout stands.”

According to this code, Costco must have at least 7 exits accessible from the mercantile area without passing through the checkout stands. It satisfies this requirement with 10 exit doors connected to the mercantile area.

PATHS OF TRAVEL

The majority of occupants are expected to be well-dispersed throughout the dining and mercantile areas while inside the building. Although travel between aisles is common while shopping for goods, shoppers often use exit access paths shown in orange on Figure 7 for travel between different areas of the store. Some areas of the building require travel starting in kitchen or office occupancies and moving through mercantile zones.

To achieve efficient building evacuation in time of emergency, the Life Safety Code has requirements for the maximum travel distance to exit, as well as lengths of common paths and dead ends:

NFPA 101, 2012 – 36.2.6.2: “In mercantile occupancies classified as ordinary hazard in buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1(1), travel distance shall not exceed 250 ft.”

Figure 7 – Exit plan showing exits, exit signage, longest path of travel, and dead ends.

The most remote point in the Costco is marked with the diamond symbol located in the center of the mercantile area. Travel route is shown with a red arrow traveling to an exit along the south wall in Figure 7. The distance of travel shown is measured along the center of the path of travel, curving around corners and obstructions with at least 12" of space, and ends at the center of the doorway as specified in NFPA 101, 2012 - 7.6.1. The measured travel distance is 225 ft., which complies with the maximum of 250 ft.

NFPA 101, 2012 – 36.2.5.3: *“Common paths of travel shall be limited by any of the following:*

Common paths of travel shall not exceed 75 ft in mercantile occupancies classified as low or ordinary hazard.

Common paths of travel shall not exceed 100 ft in mercantile occupancies classified as low or ordinary hazard where the building is protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1 (1).

NFPA 101, 2012 – 36.2.5.2.1: *“In buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1(1), dead-end corridors shall not exceed 50 ft.”*

In Table A.7.6, Life Safety Code also allows for kitchens, classified as areas of general industry, to have common paths and dead ends of 100 and 50 feet, respectively. NFPA 101 has the following definitions for common paths and dead ends:

NFPA 101, 2012 – A.7.5.1.5: *“A common path of travel exists where a space is arranged so that occupants within that space are able to travel in only one direction to reach any of the exits or to reach the point at which the occupants have the choice of two paths of travel to remote exits. A dead end can exist where there is no path of travel from an occupied space but can also exist where an occupant enters a corridor thinking there is an exit at the end and, finding none, is forced to retrace his or her path to reach a choice of exits.”*

The open nature of the mercantile and dining areas provide exits in many directions, so no common paths or dead ends exist. However, the kitchen area in the southeast corner of the store has only one exit. While the area is not large enough to require more than one exit, the length of the common path of travel and dead end should be addressed. The common path of travel is shown in Figure 7 as a red line with arrows starting at the southeast corner of the room and

traveling northward to the door. It measures 98 feet – just below the requirement in the Life Safety Code.

Although the kitchen area is not defined as a corridor, an individual unfamiliar with the building may flee into the kitchen area to seek an exit from the building. The dead end travel route is shown as a red line with arrows ending at an X mark in Figure 7. The distance from the kitchen entrance to the southeast corner of the room measures 98 feet, which exceeds the 50 foot maximum dead end length for corridors. Even though the Life Safety Code does not require exits through kitchens to be accessible to the public (NFPA 101, 2012 – 7.5.2.1), from a practical perspective an additional exit in the kitchen is recommended.

EXIT SIGNAGE

The Life Safety Code requires signage labeling exits and paths of egress to ensure timely, organized egress in case of an emergency:

NFPA 101, 2012 – 7.10.1.2.1: “Exits, other than main exterior doors that obviously and clearly are identifiable as exits, shall be marked by an approved sign that is readily visible from any direction of exit access.”

NFPA 101, 2012 – 7.10.1.2.2: “Horizontal components of the egress path within an exit enclosure shall be marked by approved exit or directional exit signs where the continuation of the egress path is not obvious.”

NFPA 101, 2012 – 7.10.1.5.2: “New sign placement shall be such that no point in an exit access corridor is in excess of the rated viewing distance or 100 ft, whichever is less, from the nearest sign.”

NFPA 101, 2012 – 7.10.2.1: “A sign with a directional indicator showing the direction of travel shall be placed in every location where the direction of travel to reach the nearest exit is not apparent.”

In Figure 7, exits are labeled with green and white exit signs. Signs point toward the nearest exit in areas where the direction is not immediately obvious. These signs are laid out to comply with visibility distance required above. In times of emergency, individuals often attempt to use exit the building the same way they came in, even though there may be other exits nearby. For this reason, directional signage is emphasized in areas that are far from the main entrance/exit area to show where emergency exits are located.

INTERIOR FINISH AND SEPARATIONS

Interior finishes are subject to the requirements of Section 10.2 of the Life Safety Code. Many of the requirements are tested by ASTM, UL, or similar agencies. The fundamental requirement pertaining to the Costco building is written as follows:

NFPA 101, 2012 – 10.2.3.4: “Product required to be tested in accordance with ASTM E 84... shall be classified... in accordance with their flame spread index and smoke developed index...”

Table 14 - Interior finish requirements from NFPA 101, 2012 – Table A.10.2.2

Interior finish	Component	Construction
Mercantile	Exits	A or B
	Exit Access Corridor	A or B
	Other	A or B
Business	Exits	A or B
	Exit Access Corridor	A or B
	Other	A, B, or C
Kitchen (Industrial)	Exits	A or B
	Exit Access Corridor	A, B, or C
	Other	A, B, or C
Dining	Treat as mercantile per 6.1.14.1.3	

Table 9 requires exits, exit access corridors, and other spaces in mercantile occupancies to be Class A or B construction, corresponding to a flame spread index of 0-25 or 26 to 75 and smoke developed index of 0-450. Class C construction has a flame spread index of 76-100 and smoke developed index of 0-450.

Firewall separations are required between different occupancies and exit corridors in an attempt to contain the fire and prevent it from developing too rapidly.

NFPA 101, 2012 – 7.1.3.1: “Corridors used as exit access and serving an area having an occupant load exceeding 30 shall be separated from other parts of the building by walls having not less than a 1-hour fire resistance rating...”

NFPA 101, 2012 – 6.1.14.4.1: “Where separated occupancies are provided, each part of the building comprising a distinct occupancy, as described in this chapter, shall be completely separated from other occupancies by fire-resistive assemblies.”

NFPA 101, 2012 – 6.1.14.4.3: *“The minimum fire resistance rating... shall be permitted to be reduced by 1 hour, but in no case shall it be reduced to less than 1 hour, where the building is protected throughout by an approved automatic sprinkler system....”*

Separations are shown with a green line in Figure 7. The requirements are tabulated in Table 6.1.14.4.1 of the Life Safety Code. The separations between mercantile and office zones, mercantile and kitchen zones, and office and kitchen zones are said to be 2 hours. With the reduction of code 6.1.14.4.3 applied, each separation is required to have a fire resistance rating of at least 1 hour.

TIME TO EVACUATION

Figure 8 comes from the NFPA Handbook and illustrates the decision processes of individuals in a fire. Each step of the decision process should be included in the assessment of time to evacuate in the event of a fire.

Fig. 8– Decision Processes of the Individual in a Fire (NFPA Handbook)

OVERVIEW

The individual first recognizes that a threat exists, but does not yet know if she is vulnerable or if action is required. In a Costco building, this is likely to be an auditory alarm. For individuals in close proximity to the fire, the first sign of fire may be visually seeing flames or smelling smoke. Due to the size of the store, many shoppers may not be immediately alerted to the threat, especially those with disabilities such as blindness or deafness.

Next is the validation phase, during which the individual seeks additional information to better understand the nature of the threat. Shoppers at a large store like Costco would likely seek out visual or auditory signs to confirm that a threat exists. They may gather to verbally share information. Some may believe that the alarm is simply a drill and continue shopping. Others may misinterpret the alarm and take no action.

During the definition phase, the individual assesses the threat and becomes aware of its magnitude and seriousness. After definition comes evaluation: the phase when the individual

decides how to respond to the threat. Factors evaluated include the proximity to egress routes, physical effects of the fire, or the behaviors of surrounding individuals. Shoppers would likely hesitate to leave their groceries behind and delay immediate exit. Adults in groups or individuals with children or disabled may need to gather their party before making a decision.

After evaluation is complete, commitment begins. During this time, the individual takes physical action and attempts to find safety. Individual movement speeds and the sizes and locations of egress routes play a major role in the timeliness for a building to evacuate. Reassessment occurs if the previous commitment does not succeed. Throughout the decision process, stress levels increase, reducing the individual's ability to make reasonable decisions. A panicking individual may make decisions that increase the likelihood of injury or death.

PRE-MOVEMENT TIME

The pre-movement time is the first four steps in the process, starting with recognition of the threat and ending with commitment to take action. In theory, the pre-movement time can be very hard to predict. Fortunately, there are some real-world data that may be applicable. Table 4.2.1 of the NFPA Fire Protection Handbook, ed. 20, shows that in 3 unannounced evacuation drills of one-story department stores, the mean delay times were 0.4, 0.5, and 0.6 minutes. The maximum delay times were 0.9, 1.0 and 1.7 minutes.

MOVEMENT TIME

The Costco building is expected to have occupants with a wide range of physical capabilities and limitations. Occupants are expected to be fully awake, but may suffer from physical handicaps: a study conducted in N. Ireland found that 58.5% of adult individuals with disabilities go shopping (NFPA Handbook ed. 20, table 4.1). Occupants can be expected to have a wide range of physical abilities. Therefore, the emergency egress design of the Costco building should account for individuals who may take longer to escape. For these occupants, extra time should be granted for safe egress:

NFPA 101, 2012 – 5.4.5.1: “The selection of occupant characteristics to be used in the design calculations shall be approved by the authority having jurisdiction and shall provide an accurate reflection of the expected population of building users. Occupant characteristics shall represent the normal occupant profile, unless design specifications are used to modify the expected occupant features.

Occupant characteristics shall not vary across fire scenarios, except as authorized by the authority having jurisdiction.”

NFPA 101, 2012 – 5.4.5.2: “The basic response characteristics of sensibility, reactivity, mobility, and susceptibility shall be evaluated. Such evaluation shall include the expected distribution of characteristics of a population appropriate to the use of the building. The source of data for these characteristics shall be documented.”

Following are calculations for the total time it takes for occupants to move through the exits once movement begins.

Table 15 - Average walking speeds for users of two shopping centers. See NFPA Handbook, 20th edition, Table 4.2.2

Measured Travel Speed	Type of Situation	ft/s	Maximum Travel Distance (feet)	Maximum Travel Time (s)
Minimum	Adult with walking disability	2.5	225	90
Average	Average of all Shoppers	3.38	225	66.6
Maximum	Adult walking alone	3.74	225	60.2

Based on this data, movement from the most remote point in the Costco to an exit is not likely to take longer than 90 seconds.

Table 16 - Effective exit widths. The effective width of the doorways accounts for the natural formation of a boundary layer as people pass through the door without bumping into the frame. See NFPA Handbook, 20th edition, Table 4.2.4.

Exits	Quantity	Actual Width per door (in)	Boundary Layer per door (in)	Total Effective Width (in)	Total Effective Width (ft)
Main entrance	1	92.0	12	80	6.67
Main exit	1	92.0	12	80	6.67
Single door	3	36	12	72	6
Double door	8	72	12	480	40
Total	13	-	-	712	59.4

Based on the number of occupants and amount of doorway space available for exit, it is calculated to take 2.25 minutes for all occupants to pass through the exits of the Costco. Combined with the 1.7 minute pre-movement time of the slowest-responding adult, evacuation can be expected to take 4 minutes. Because it takes less time for the slowest moving individual to reach the door than the time required for individuals to pass through the doors, travel time does

not impact the overall evacuation time. This result is based on the assumption that occupants use all available exits and travel through the doorways at the optimal density.

Table 17 - Evacuation time based on maximum specific flow. Calculated flow is the product of total effective width and maximum specific flow rate for doors. Evacuation time is the quotient of the maximum occupancy and calculated flow rate. See NFPA Handbook, 20th edition, Table 4.2.8

Maximum Specific Flow Rate (person/ft)	Calculated Flow (person/min)	Maximum Occupancy (persons)	Exit Flow Time (minutes)	Pre-Movement Time (minutes)	Evacuation Time (minutes)
24	1424	3208	2.25	1.7	3.95

Accounting for additional delays with a factor of safety of 20%, the evacuation time of the Costco building could take up to 5 minutes.

TENABILITY ANALYSIS

PERFORMANCE CRITERIA

In enclosure fires, exposure to smoke and toxic gas is often more dangerous than the threat posed by flames. For this reason it is important to consider the magnitude of the effects of smoke and toxic gases on the human body. One method for calculating the amount of toxic gas a human can withstand is presented by David Purser in The SFPE Handbook, 4th edition, Section 2, Chapter 6.

The method begins by providing equations for calculating the amount of a particular toxin the body absorbs based on concentration and amount of air breathed. The example equation is for carbon monoxide:

$$F_{ICO} = 3.317 * 10^{-5} * [CO] * V * \frac{t}{D}$$

Similar equations are used to predict the time of incapacitation due to hydrogen cyanide, lack of oxygen, and overexposure to carbon dioxide. Once the impact of each compound is known, the impact of their mixture can be found by using the following equation:

$$F_{IN} = \left[\left(F_{ICO} + F_{ICN} + F_{INO_x} + FLD_{irr} \right) * VCO_2 + FED_{I_0} \right]$$

The equation combines all the fractional incapacitating doses into a single fractional effective dose *FED* that can be used to find if the summation of effects will incapacitate the individual. Incapacitation is likely to occur when $F = 1$. Lethality is predicted at F values greater than 2. The survival of virtually all occupants is likely when F is less than 0.8.

SUMMARY

Based on the areas and occupant load factors of each occupancy classifications of the Costco store, the maximum occupancy was calculated to be 3,208 people. It was then shown that the egress capacity of the building is able to satisfy this quantity of occupants by adding up the total length of exit openings of the store and dividing by the capacity factor, resulting in a total egress capacity of 4,340 people.

The number of exits and their arrangement was next examined for compliance with Life Safety Code. The Costco store met all of the requirements addressed, including quantity of exits, the minimum separation distance of two exits, and code for occupancies with checkout stands and store rooms.

The maximum travel distance from any point in the store to an exit was calculated to be 225 ft, complying with Life Safety Code's required 250 ft. A potential dead end exceeding the maximum travel distance of 50 ft was discovered in a kitchen area, which while technically acceptable by code, may present a risk to occupants during egress.

To guide occupants to emergency exits, directional signage and exit labels were laid out throughout the store. Next, allowable interior finishes and separations are tabulated and discussed, with required separations shown on Figure 7.

The psychology and decision making of evacuation was next discussed, which introduced a wide array of complexities that could impact the time required for occupants to respond to and escape from a fire. Using real world data, the time required for occupants to respond to an emergency signal, move to an exit, and pass through the exit was calculated to be 4 minutes.

The egress section ends with a tenability analysis, which looks at the impacts of breathing toxic products of combustion in the event that an occupant is unable to escape the smoke without inhaling smoke and toxins.

The next section explores the application of a water based fire protection system, which plays a role in all three of the major topics considered thus far: protection of structural components; additional heat detection, and improving tenability in the event of a fire by reducing the rate of fuel burning or extinguishing the fire altogether.

WATER BASED FIRE PROTECTION

The Costco store is to be fully sprinklered in conformance with NFPA 13, 2013 [7]. The sprinkler system provides structural, life, and property protection to the by automatically spraying water onto the contents of the building if a sprinkler head reaches its activation temperature. Water is an extremely effective extinguishing agent for 3 main reasons. First, it has a high specific heat, which means it can absorb a lot of energy from the heat of a fire, reducing its intensity. Second, when applied directly to burning flames, it prevents oxygen from reaching the fuel and can slow or even extinguish a fire. Third, it can often permeate into fuel loads nearby, slowing or preventing their ignition.

In this section, the general design of the sprinkler system is addressed. The design requirements are determined from occupancy classifications that are defined based on the type and orientation of materials being protected. The type of heads used in the system is discussed.

Hand calculations of hydraulic testing are presented in the Appendix and summarized in the calculation results. Computer hydraulic test calculations are also presented in the Appendix. Their results are presented alongside hand calculations for comparison and analysis. Lastly, inspection, testing, and maintenance of the sprinkler system is addressed.

SYSTEM DESIGN

First, water flow information was gathered at a fire hydrant at ground level located at 450 11th St, approximately 70 feet southwest of the riser (see Appendix for water flow results). When conducting the flow test, the static pressure of the water supply at an established point near the Costco was measured. Then, a nearby fire hydrant was fully opened to flow at maximum capacity. The pressure was measured at the same location as the static pressure, this time with the water flowing, establishing the residual pressure for a given flow rate. The static pressure and residual pressure are plotted along a curve that can be used to determine the available pressure at a given flow rate as seen in the Appendix.

The system is tied into the underground water supply and enters the building at the riser room, located in the northeast corner of the building. In the event that a sprinkler is activated, the water is sent to individual sprinkler risers for each system. Each riser connects to a steel overhead feed main that delivers the water to the area of the building the system is serving.

Coming off the feed main are smaller steel cross mains that distribute the water across the system area. The water sprayed by sprinklers comes from steel branch lines that split off of each cross main.

TYCO TY-B 4151 standard spray uprights are used in the light hazard and ordinary hazard occupancies. For the storage areas, special applications TYCO ELO-231 upright sprinklers were chosen. Manufacturer cut sheets for these sprinklers are located in the Appendix. Storage areas require a large density of water to be applied, so if the orifice is too small, a great deal of pressure is required to force the water out, adding pressure demand to the system. With a larger orifice, the same flow can be achieved with less pressure. Furthermore, lower pressure produced larger droplets, which are desirable in applications with high ceilings because the large droplets are able to permeate down into the fire, absorbing heat and permeating fuels, reducing its spread.

Additionally, if the water flows out of the sprinkler at too high of a pressure, a process called atomization can occur in which the water droplets come out of the sprinkler as a fine mist. Instead of falling down on the fire and nearby fuel loads, they can be swept away by the heat of the fire and land on other sprinkler heads, which can slow or even prevent their activation.

The type of sprinkler heads used for a given system is important because each system must be able to provide a specific amount of water flow at a given pressure based on the occupancy classification of the area.

OCCUPANCIES

The Costco is broken into 6 zones that characterize the entire floor area, each with a separate occupancy or commodity classification as shown in Figure 9. Some of the zones in Figure 9 have been lumped together where occupancy classifications are similar. Since the store requires 4 risers, some of the risers cover multiple zones, in which case the most demanding design criteria will be used for the whole system. Where two different hazards are adjacent, the area with the higher demand extends 15 ft beyond its perimeter per NFPA 13, 2013 - 12.3(1).

Tables 13 through 18 include descriptions for each zone of the Costco including contents occupancy or commodity classification, storage orientation, and design criteria. Commodity classification data comes from NFPA 13, 2013 Table A.5.6.3. Each zone is sprinklered to conform to the specifications of the highest demand design criteria.

CHECKOUT, DINING, AND ADMINISTRATION

Area: 17,481 ft²

Highest demand design criteria: Light Hazard

Density: 0.10 gpm/ft²

Design Area: 1500 ft²

Table 18 – Checkout, Dining, and Administration area occupancy classification

Contents	Occupancy	Design Criteria	Notes
Restaurant Seating	Light Hazard	Light curve, fig 11.2.3.1.1	NFPA 13 5.2: “quantity and combustibility of contents is low and fires with relatively low rates of heat release are expected”
Offices			
Checkout Tables			

ELECTRONICS

Area: 6,515 ft²

Highest demand design criteria: Ordinary Hazard Group II

Density: 0.20 gpm/ft²

Design Area: 1500 ft²

Table 19 – Electronics area occupancy classification

Commodity	Commodity Class	Storage Orientation	Design Criteria	Notes
Televisions	Group A Plastic	Solid pile, storage height ≤5 ft. Cartoned.	Table 13.2.1: Design Curve OH2, fig 13.2.1	Treat as miscellaneous storage per 15.2.1.
Computer Hardware				
Home Entertainment				

NORTHEAST CORNER FLOOR

Area: 18,434 ft²

Highest demand design criteria: Ordinary Hazard II

Density: 0.20 gpm/ft²

Design Area: 1500 ft²

Table 20 – Northeast corner floor area occupancy classification

Commodity	Commodity Class	Storage Orientation	Design Criteria	Notes
Milk	Class I	Treat refrigerators as back to back shelf storage up to 12 ft in height	Table 13.2.1: Design Curve OH1, fig 13.2.1	Treat as miscellaneous storage per 14.2.3.1
Eggs	Class I		Table 13.2.1: Design Curve OH2, fig 13.2.1	
Dairy	Class III			
Frozen Meats	Class II			
Beer	Class I	Palletized under 12 ft	Table 13.2.1: Design Curve OH1, fig. 13.2.1	
Soda & Fruit Juice	Class I			
Fresh produce	Class I			
Paper Towel	Class III	Rack storage up to 12 ft	Table 13.2.1: Design Curve OH2, fig 13.2.1	Treat as miscellaneous storage per 16.2.1.2.1
Toilet Paper	Class III			

CENTRAL FLOOR AREA

Area: 27,492 ft²

Highest demand design criteria: Ordinary Hazard Group II

Density: 0.15 gpm/ft²

Design Area: 1500 ft²

Table 21 – Central floor area occupancy classification

Commodity	Commodity Class	Storage Orientation	Design Criteria	Notes
Garden Supplies	Class I	Palletized under 12 ft	Table 13.2.1: Design Curve OH1, fig. 13.2.1	Treat as miscellaneous storage per 14.2.3.1.
Apparel	Class III	Solid pile under 12 ft	Table 13.2.1: Design Curve OH2, fig 13.2.1	
Fresh meat	Class I	Solid pile under 12 ft	Table 13.2.1: Design Curve OH1, fig 13.2.1	Stored in horizontal floor coolers: treat as solid pile storage. Treat as miscellaneous storage per 14.2.3.1.
Fresh cheese	Class I			
Baked goods	Class II	Shelf storage under 12 ft	Table 13.2.1: Design Curve OH2, fig 13.2.1	Treat as miscellaneous storage per 14.2.3.1
Bread	Class III			

SOUTH RACK STORAGE

Area: 22,291 ft²

Highest demand design criteria: Class III Rack Storage

Density: 0.42 gpm/ft²

Design Area: 2000 ft²

Table 22 – South rack storage area occupancy classification

Commodity	Commodity Class	Storage Orientation	Design Criteria	Notes
Batteries	Class I	Rack storage up to 20 ft in height with 10 ft clearance to ceiling.	Table 16.2.1.3.2: Design curve G, fig. 16.2.1.3.2(a). Apply fig. 16.2.1.3.4.1	Unencapsulated storage. 8 ft aisles. No in-rack sprinklers needed.
Kitchen Supplies	Class I			
Light Fixtures	Class II		Table 16.2.1.3.2: Design curve F, fig. 16.2.1.3.2(b). Apply fig. 16.2.1.3.4.1	
Office supplies	Class II			
Books	Class III		Table 16.2.1.3.2: Design curve F, fig. 16.2.1.3.2(c). Apply fig. 16.2.1.3.4.1	
Food containers	-			Table A.5.6: Storage containers not addressed by classification outline. Treat as equal to most demanding criteria in design area.

NORTH RACK STORAGE

Area: 29,555 ft²

Highest demand design criteria: Class III Rack Storage

Density: 0.42 gpm/ft²

Design Area: 2000 ft²

Table 23 – North rack storage area occupancy classification

Commodity	Commodity Class	Storage Orientation	Design Criteria	Notes
Canned Produce	Class I	Rack storage up to 20 ft in height with 10 ft clearance to ceiling.	Table 16.2.1.3.2: Design curve G, fig. 16.2.1.3.2(a). Apply fig. 16.2.1.3.4.1	Unencapsulated storage. 8 ft aisles. No in-rack sprinklers needed.
Wine	Class I			
Dry Cereals	Class III		Table 16.2.1.3.2: Design curve F, fig. 16.2.1.3.2(c). Apply fig. 16.2.1.3.4.1	
Candy	Class III			
Cereals	Class III			
Pharmaceuticals	Class IV	Palletized under 10 ft	Table 13.2.1: Design Curve OH2, fig. 13.2.1	Treat as miscellaneous storage per 16.2.1.2.1
Alcohol (over 20% alcohol)	Class IV	Palletized under 10 ft		

Figure 10 shows the organization of the sprinkler systems, with each area identified by its occupancy classification and design criteria. The feed mains are represented by blue lines starting in the riser rooms. Cross mains, represented with pink lines, tee off the feed mains and spread out over the system area. Branch lines are shown in red, with sprinklers represented by hollow circles on the branch lines. The remote areas for each system are outlined with a dashed line.

Next, hand and computer generated calculation results are summarized and compared – refer to the Appendix for full calculations.

Figure 9 – Occupancy map of Costco store

Figure 10 – System map and layout of Costco store

CALCULATION RESULTS

RISER 1

Occupancy: Light Hazard

Actual Area: 17,246 ft²

Design Area: 1,500 ft²

Design Density: 0.10 gpm/ft²

Total hose stream allowance: 100 gpm

Duration: 30 min

Total sprinkler demand:

$$Q = 0.10 \text{ gpm/ft}^2 * 1,500 \text{ ft}^2$$

$$Q = 150 \text{ gpm}$$

Sprinkler: Tyco TY-B 4151

Upright

Standard Spray

Temperature Rating: 155 °F

K-factor: 8.0

Maximum protection area: 225 ft²

Maximum spacing: 15 ft

NFPA 13 Table 8.6.2.2.1(a)

Number of sprinklers in design area:

$$N_s = \text{Design Area} / \text{Area per sprinkler}$$

$$N_s = 1500 \text{ ft}^2 / 225 \text{ ft}^2$$

$$N_s = 7 \text{ sprinklers}$$

Sprinkler demand at base of riser:

Computer: 179.79 gpm @ 53.765 psi

Hand Calculation: 129.1 gpm @ 69.5 psi

Total demand at base of riser:

Computer: 279.79 gpm @ 53.765 psi

Hand Calculation: 229.1 gpm @ 69.5 psi

According to AutoSPRINK's calculations, the city water supply can provide adequate pressure and flow for Area 1's sprinkler system. This is to be expected as the light hazard occupancy has comparatively low water demand compared to the other systems. Hand calculations resulted in a higher pressure required to satisfy system demand.

RISER 2

Occupancy: Storage – Class III

Actual Area: 38,607ft²

Density: 0.42 gpm/ft²

Design Area: 2000 ft²

Total hose stream allowance: 500 gpm

Duration: 120 min

Total sprinkler demand:

$$Q = 0.42 \text{ gpm/ft}^2 * 2,000\text{ft}^2$$

$$Q = 840 \text{ gpm}$$

Sprinkler: Tyco ELO-231

Upright

Standard Spray

Temperature Rating: 155 °F

K-factor: 11.2

Maximum protection area: 100 ft²

Maximum spacing: 12 ft

NFPA 13 Table 8.6.2.2.1(d)

Number of sprinklers in design area:

$$N_s = \text{Design Area} / \text{Area per sprinkler}$$

$$N_s = 2000 \text{ ft}^2 / 100 \text{ ft}^2$$

$$N_s = 20 \text{ sprinklers}$$

Sprinkler demand at base of riser:

Computer: 1028.37 gpm @ 100.278 psi

Hand Calculation: 961.0 gpm @ 81.1 psi

Total demand at base of riser:

Computer: 1528.37 gpm @ 100.278 psi

Hand Calculation: 1461.0 gpm @ 81.1 psi

AutoSPRINK and the hand calculations both returned extremely high water demand for area 2. This is to be expected due to the large size and density of the area of protection, resulting from higher fire hazard. The city water supply cannot provide adequate volume nor pressure of water.

RISER 3

Occupancy: Ordinary Hazard II

Actual Area: 29,464ft²

Density: 0.20 gpm/ft²

Design Area: 1500 ft²

Total Hose Allowance: 250 gpm

Duration: 60 min

Total sprinkler demand:

$$Q = 0.20 \text{ gpm/ft}^2 * 1,500\text{ft}^2$$

$$Q = 300 \text{ gpm}$$

Sprinkler: Tyco TY-B 4151

Upright

Standard Spray

Temperature Rating: 155 °F

K-factor: 8.0

Maximum protection area: 130 ft²

Maximum spacing: 15 ft

NFPA 13 Table 8.6.2.2.1(b)

Number of sprinklers in design area:

$$N_s = \text{Design Area} / \text{Area per sprinkler}$$

$$N_s = 1500 \text{ ft}^2 / 130 \text{ ft}^2$$

$N_s = 12$ sprinklers

Sprinkler demand at base of riser:

Computer: 290.64 gpm @ 40.147 psi

Hand Calculation: 291.2 gpm @ 35.0 psi

Total Demand at base of riser:

Computer: 540.64 gpm @ 40.147 psi

Hand: 541.2 gpm @ 35.0 psi

The results of the computer and hand calculations for area 3 were almost identical. Both methods agree that the system as designed will meet system demands.

RISER 4

Occupancy: Storage – Class III

Area: 39,635ft²

Density: 0.42 gpm/ft²

Design Area: 2000 ft²

Total hose stream allowance: 500 gpm

Duration: 120 min

Total sprinkler demand:

$$Q = 0.42 \text{ gpm/ft}^2 * 2,000\text{ft}^2$$

$$Q = 840 \text{ gpm}$$

Sprinkler: Tyco ELO-231

Upright

Standard Spray

Temperature Rating: 155 °F

K-factor: 11.2

Design Density: 0.42 gpm/ft²

Maximum protection area: 100 ft²

Maximum spacing: 12 ft

NFPA 13 Table 8.6.2.2.1(d)

Number of sprinklers in design area:

$$N_s = \text{Design Area} / \text{Area per sprinkler}$$

$$N_s = 2000 \text{ ft}^2 / 100 \text{ ft}^2$$

$$N_s = 20 \text{ sprinklers}$$

Sprinkler Demand at base of riser:

Computer: 819.42 gpm @ 66.432 psi

Hand: 936.1 gpm @ 69.4 psi

Total Demand at base of riser:

Computer: 1319.42 gpm @ 66.432 psi

Hand: 1436.1 gpm @ 69.4 psi

Similar to Area 4, Area 2 has high water and pressure demand. This can be attributed to the high piled storage requiring large amounts of water to be controlled in the event of a fire. Furthermore, the location of the remote area is on the opposite corner of the Costco from the pump room, so the water loses a lot of pressure due to friction by the time it has traveled from the riser to the remote area.

ANALYSIS

Risers 1 and 3 are able to meet the hydraulic demands at the most remote points of the systems, so the design of these systems is considered a success. Risers 2 and 4, however, are not able to meet the pressure or flow demands. Modifications or redesign of the systems is required.

There are myriad ways to reduce the pressure required to satisfy hydraulic demands. The design used in this report is based on a tree system, in which branch lines split off each side of a cross main to feed multiple sprinklers. Tree systems are inefficient in their design because they force some heads to spray at a higher pressure than is required. For example, if a single branch line is feeding four activated sprinklers, the last sprinkler on the branch line will be the most demanding because the water must travel the longest distance. Because pressure is lost due to friction as water flows through the pipes, the pressure at the sprinklers closer to the cross main will have higher pressure than is required, increasing the pressure demand. Furthermore, because the pressure is higher at those heads, they tend to flow more water, increasing the volume demand of the system.

A more efficient design is the grid system, in which branch lines are connected to cross mains on both sides. For our 4-head branch line example, the water would tend to flow from each cross main to only 2 sprinklers, so there would be less pressure wasted at sprinkler upstream of the most demanding head. Furthermore, the water flowing to the sprinklers is spread over multiple pipes, which reduces the volumetric flow rate for a given pipe, decreasing the velocity of the water and thereby reducing the pressure loss due to friction.

There are also many smaller changes that can be made to the system to help with the hydraulic calculations. Increasing the sizes of pipes flowing large volumes of water can drastically reduce pressure loss in the system. Using pipe with a smaller wall thickness increases cross sectional size of the pipe, allowing for more efficient water flow. Increasing the number of sprinklers by decreasing their spacing can allow the same density of water to reach the design area without forcing all of the sprinklers to spray at high pressures. Additionally, a large variety of fittings are available that have less pressure loss associated with their use.

If the above methods are not able to satisfy the pressure demands, a pump may be required. Pumps are able to provide significant increase in the pressure of the water, but are not able to increase the amount of water available. They are expensive, complex, and take up space in the building. For these reasons, improving the efficiency of the system should always be done first, utilizing a pump as a last resort.

INSPECTION, TESTING, AND MAINTENANCE PROTOCOL

Table 24 – Inspection, testing, and maintenance protocol of automatic sprinkler system.

COMPONENT	INSPECTION, TESTING, AND MAINTENANCE
Sprinkler Heads	<p>Deflectors should be positioned properly. Do not obstruct flow or activation. Make sure occupancy classification has not changed.</p> <p>Routinely check for loading: any buildup on the sprinkler that could insulate it and delay/prevent activation. Loading includes paint or corrosion that can delay response or impact spray development.</p> <p>Test the system every 10 years. Must test at least 1% of heads in system or 4 sprinkler heads total, whichever is greater.</p> <p>Extra sprinklers are to be kept on hand in case of discharge or damage.</p>
Pipe	<p>Check for leaks, warping, and corrosion on fittings and pipes. Use of coatings or noncorrosive materials can prevent corrosion.</p> <p>Look for piping being used for anything besides its purpose.</p>
Control Valves and Meters	<p>Employ lockout/tag out procedures to make sure accidental discharge doesn't occur and valves don't get left shut by accident. Use electronic systems to regularly ensure valves are open and signal systems are operating correctly.</p> <p>Keep meters in controlled and protected areas to avoid tampering.</p> <p>Periodically make sure check valves are tight and installed to NFPA standards to avoid contamination. Check valves should be labeled and must be accessible in dry, unobstructed areas – no plants or fences or garbage cans surrounding them.</p>
Hanging and Bracing	Installed properly. Hanging and bracing is adequate to support the load with a factor of safety and meets code. Nuts are sufficiently tightened.
Waterflow	Make sure the water can adequately drain from the sprinkler system without causing damage. When draining, monitor pressure and look for any drops in pressure that could indicate blockages or defects. A flow test should be made for each water supply and connection.
Pressure Gauges	Functioning and accurate.
Alarms	Respond when necessary. Occupants and fire departments are notified immediately.
Fire Department Connection	Is accessible, caps are in place, threads are in good condition, ball drip or drain is in order and the check valve is not leaking.

SUMMARY

The Costco is equipped with an automatic fire sprinkler system to provide protection of occupants, property, and the structure of the building. Water flow information is first discussed, followed by an outline of the design of the system. The types of sprinkler heads used are identified, and an explanation of why they are appropriate for this application is presented.

Next, the contents of the Costco are analyzed based on their location in the store. Areas are grouped together based on their location and contents to establish the occupancy rating for system serving that area. Where the contents result in storage-type occupancy, the storage classification is determined. These occupancy classifications are then used to set the requirements for water flow density and pressure in the most remote area of each system. The pressure and flow demands of each system are calculated using hand calculations and computer modeling. The results of these calculations are then compared.

Risers 1 and 3 are shown to meet the requirements of the area protected by demonstrating that an adequate density of water can be protected over the entire remote area without any alteration to the system as currently designed.

It is concluded that risers 2 and 4, which serve the more demanding Class III Storage areas, are not adequately protected with the systems designed as shown, but it is possible that the system be redesigned to meet the system demands with some minor alterations. Where the water pressure and volume available is not satisfactory, ways to improve the systems are discussed, from making changes to the fittings and pipe used to fully redesigning the layout of the system. Often, simple changes to the sizing of a given section of pipe or reducing the number of fittings required can have a large impact on the amount of pressure required at the base of the riser. Increasing pipe size or focusing on a more efficient design is often the most cost effective way to improve the performance of the sprinkler system.

If the system simply cannot meet the pressure demand requirements, a pump is required. The pros and cons of using a fire pump to increase water pressure are addressed, with an emphasis away from relying on the use of a pump to meet the system demands. Lastly, an outline of inspection, testing, and maintenance methods is presented.

Having examined the sprinkler system, egress, alarm and detection, and structure of the Costco building from a prescriptive approach, a performance based analysis can be conducted, in which the fire protection systems design of the building are put to the test in a simulation of a realistic design fire.

PERFORMANCE BASED ANALYSIS

INTRODUCTION

While the application of pre-established building code is crucial in ensuring a building is safe for occupancy, a prescriptive approach can be limited in its ability to take into account unique intricacies that vary from building to building. The foundational code upon which a prescriptive approach is taken is often based on actual fire events that revealed shortcomings in the construction or safety features of a building. As such, code is periodically rewritten to take into account lessons learned over time. New developments in fire safety technology and breakthroughs in material and fire dynamics also lead to updates to building code.

A performance based approach can overcome the limitations of code based on the past by forecasting potential hazards that could theoretically arise given plausible scenarios for a particular building based on its location, structure, occupancy, use, and life safety systems. Through modern computing, detailed simulations and calculations capturing the flow of heat, smoke, and toxins can be performed to replicate actual fires with striking levels of detail. The ever-increasing amount of data on the burning characteristics of materials enables these

simulations to provide high levels of accuracy in their modeling of the growth and decay of a fire.

Figure 11 - Performance-Based Life Safety Code Compliance Process (NFPA 101: Figure A.5.1.1)

THE LIFE SAFETY CODE APPROACH

NFPA 101 - Life Safety Code, Chapter 5 provides a framework for conducting a performance based analysis. The performance based design must be conducted by a registered professional engineer and is subject to review by the authority having jurisdiction. Data used is to be identified and catalogued from a reliable source. The authority having jurisdiction is authorized to make the final determination as to whether the goals of the performance based design have been met.

As seen in Figure 11, the Life Safety Code stipulates that the performance based design must meet the prescriptive goals and objectives stated in Chapter 4:

4.1.1 Fire. A goal of this code is to provide an environment for the occupants that is reasonably safe from fire by the following means:

- 1) Protection of occupants not intimate with the initial fire development*
- 2) Improvement of the survivability of occupants intimate with the initial fire development*

4.1.2 Comparable Emergencies. An additional goal is to provide life safety during emergencies that can be mitigated using methods comparable to those used in case of fire.

4.1.3 Crowd Movement. An additional goal is to provide for reasonably safe emergency crowd movement and, where required, reasonably safe nonemergency crowd movement.

4.2.1 Occupant Protection. A structure shall be designed, constructed, and maintained to protect occupants who are not intimate with the initial fire development for the time needed to evacuate, relocate, or defend in place.

4.2.2 Structural Integrity. Structural integrity shall be maintained for the time needed to evacuate, relocate, or defend in place occupants who are not intimate with the initial fire development.

4.2.3 Systems Effectiveness. Systems utilized to achieve the goals of Section 4.1 shall be effective in mitigating the hazard or condition for which they are being used, shall be reliable, shall be maintained to the level at which they were designed to operate, and shall remain operational

Next, the code sets forth the performance criterion that any occupant not in direct contact with ignition must not be exposed to “instantaneous or cumulative untenable conditions.” Compliance with this requirement can be shown using one of 4 methods:

1. The first method aims to ensure occupants are not incapacitated by fire effects by demonstrating that tenability limits are not reached as described in the Tenability Analysis discussion in the egress chapter of this report. The fractional effective dose (FED) of the most common toxins released in fires are calculated, including carbon monoxide, hydrogen cyanide, carbon dioxide, hydrogen chloride, and hydrogen bromide, as well as the effects of anoxia. The FED used is to be representative of the expected vulnerability of the building occupants.
2. The second method calls for the performance based analysis to demonstrate that each room or area will be fully evacuated before the smoke and toxic gas layer descends to a level lower than 6 feet above the floor. By doing so, it can be shown that all occupants are able to escape the building before being exposed to products of combustion. With the layer at 6 feet, it is ensured that occupants are able to walk or run upright to safety without the smoke and gas being inhaled.
3. Method 3 is essentially a simplified version of method 2. It allows for a demonstration that in any realistic design fire the smoke and toxic gas layer will not descend to a level lower than 6 feet above the floor in any occupied room, again for the purpose of ensuring safe breathing and movement of occupants.
4. Finally, method 4 calls for the design team to show that no fire effects will reach any occupied rooms for a given design fire.

Once the method is established, design specifications, inputs, and assumptions should be added to the model and documented. The contents and operations of the building that may impact the behavior of occupants and hazard development should also be documented. Building safety features are to be included in the analysis, and any modifications thereof must be included in the report.

Occupant characteristics are factored into the analysis by accurately representing the expected occupants of the building. This includes the varying ages of building occupants, levels of awareness of egress routes, physical condition and movement ability, and decision making as it is impacted by mental condition and situational response. Ability to notice signs of emergency and act accordingly is considered. The speed at which occupants can travel should be taken into account.

It is further assumed that occupants are spread throughout the building and are to be located in the most remote location from a point of exit. The design is based on the maximum permissible number of occupants based on the occupancy, use, and size of the building. If employees are trained in egress assistance, the impact of that training should be considered in

the analysis as well. Where appropriate, the effect of emergency response personnel should be analyzed. The conditions of the environment around the exterior of the building should also be acknowledged and included.

After these factors have been identified and required data is collected, a design fire can be decided upon. The design fires must be realistic and represent the worst-case scenario for potential to cause damage or harm. Life Safety Code specifies three important factors in determining the safety of the building in a performance based analysis: 1) the initial fire location; 2) early rate of growth in fire severity; and 3) smoke generation.

A total of 8 hypothetical scenarios are presented to analyze the response to a fire from the 3 aforementioned design factors:

- 1) A typical fire given the occupancy of the building that accounts for the number, location, and activities of the occupants. It considers the size of the room, contents and furnishing present, fuel sources, ventilation, and the location and item where the fire starts.
- 2) An ultra-fast developing fire that develops in the primary means of egress. Interior doors are open at the onset of fire. This scenario focuses on the impact of limiting the availability of egress routes.
- 3) A fire starts in an unoccupied room and spreads to a room where the most people are located. This accounts for a sudden onset of well-developed fire into a densely populated compartment.
- 4) Similar to scenario 3, in this case a fire starts in a concealed space without detection or suppression and spreads to the most highly or densely populated compartment.
- 5) A slow developing fire that is shielded from fire protection systems develops in close proximity to a highly occupied area.
- 6) The worst-case fire from the largest possible fuel load that can be expected to be located in the building.
- 7) An exposure fire, in which an exterior fire blocks escape or spreads to the interior of a building.
- 8) A typical fire develops in an area in which a fire protection system is provided but is deactivated or somehow rendered unavailable.

Data used in these scenarios must be identified, and assumptions or data not available must be made known. Factors of safety must be included. The results of the fire scenarios are then compared with the objectives of occupant protection, structural integrity, and systems effectiveness established in Chapter 4 of the Life Safety Code and presented to stakeholders

and the Authority Having Jurisdiction for approval. If performance based design is used to assess the safety of a building, owners and management of the building must be notified that approval is based on a performance-based analysis using known design criteria and assumptions. If the occupancy, structure, or use of the building is modified, the performance based approach used for initial approval of building safety may be rendered obsolete, requiring re-assessment of the building's ability to satisfy stated goals.

PERFORMANCE BASED ANALYSIS – OBJECTIVES

The performance based approach conducted for this report is an analysis of the most potentially harmful fire from a life safety based perspective, following the guided methodology in the Life Safety Code. The goal, therefore, is for the egress system and building design to allow for all occupants not directly incident to the fire to escape without being subject to untenable conditions. In order to demonstrate that all occupants can safely escape the building before conditions become dangerous, method 2 from Appendix A.5.2.2 of the Life Safety Code is utilized. This method requires that the entire room or compartment can be fully evacuated before the hot gas layer reaches a point lower than 6 feet above the floor.

In this case, Life Safety Code Design Fire Scenario 2 (NFPA 101, 2012: 5.5.3.2) is applied to demonstrate that available safe egress time (ASET), the time it takes for the smoke layer to descend to 6 feet, is greater than the required safe egress time (RSET), the time it takes for the building to be fully evacuated. The fire scenario is an ultrafast-developing fire in the primary means of egress with interior doors open at the start of the fire.

The Costco has only one primary route of entry and exit, which is the 2 large garage doors in the southwest corner of the store. Additional smaller single and double exit doors line the perimeter of the store but are only used in case of emergency. For the purpose of this analysis, the main entry and exit ways are to be blocked by a fire, limiting egress to the fire escape doors.

For this analysis, the design fire will first be introduced. To determine compliance with the Life Safety Code's performance based objectives, the egress time is then calculated using the methodology of Rita F. Fahy as presented in Section 4, Chapter 2 of the NFPA Fire Protection Handbook [8], using the same approach used in the egress section of this report and modified for the given design fire.

Next, an evacuation simulation is conducted using Thunderhead Engineering's Pathfinder software to provide additional estimation of egress time. Once egress time is estimated, CFAST is used to simulate the design fire and examine the height of the smoke layer during the fire. The egress time is then compared to the smoke layer height: if the smoke layer is higher than 6 feet above the floor after the total time expected for full evacuation of the Costco, the fire safety of the building can be deemed acceptable given the life safety parameters of our analysis.

DESIGN FIRE OVERVIEW

Adjacent to the main exit is the electronics display section, in which pallets of computers, monitors, printers, and cell phones are stored on the ground. The materials located here conveniently provide a challenging scenario. Electronics contain large amounts of plastics which tend to be highly flammable, with large heat release rates and high growth rates, while also producing relatively high concentrations of soot and carbon monoxide.

Series P6 in Figure 12 shows the heat release rates for palletized plastic computer monitors gathered from full-scale testing of boxed computer items. The test was conducted with 2 pallets of boxed monitors, oriented side by side, each with dimensions approximately 1m x 1m x 1m in height. The monitors were ignited with line burners of 50-200 kW. Note that the impact of the line burners on the heat release rate is negligible as it is several orders of magnitude lower than the heat release rate of the burning material.

The peak heat release rate is reached extremely quickly – after only 25 seconds. This exceeds the growth rate of an ultrafast-developing fire as required by Life Safety Code's Scenario 2, and is therefore appropriate for the use in this model as the faster growth rate fire would produce smoke and gas faster than the prescribed ultrafast-growth fire, reducing the ASET. Once the peak heat release rate is reached, the fire is sustained for roughly 10 additional seconds before decaying to extinguishment.

According to the American Chemistry Council, polystyrene accounts for half of the plastics contained in electronics products [9]. This analysis utilizes the carbon monoxide and smoke yields of polystyrene for calculating the smoke and gas produced. Carbon monoxide yield is taken to be 0.050 g released/g polystyrene burned and smoke yield is set to 0.135 g smoke produced/g polystyrene burned per Table 3-4.22 of the SFPE Handbook.

The design fire can be assumed to be large and hot enough to completely block escape using the main exit, with a high output of smoke and CO released. The impact of the main exit being blocked is examined in the following egress analyses.

Figure 12 - Heat release rate of packaged, larger arrays of computer monitors (SFPE Handbook, Figure 3-1.51). The design fire used follows curve P6.

EGRESS TIME – NFPA APPROACH

The egress time for this scenario is calculated from data presented in the egress chapter of this report, with some modification. The maximum travel distance, used to estimate maximum travel time (Table 25) has been increased by 100 feet to account for confusion in reaching the nearest exit. Because occupants tend to seek escape from the same location they entered, it is likely that some occupants will be alerted to the fire and move toward the main exit, but need to adjust their travel path to a different emergency exit.

Table 25 - Average walking speeds for users of two shopping centers. See NFPA Handbook, 20th edition, Table 4.2.2

Measured Travel Speed	Occupant Description	Speed (ft/s)	Maximum Travel Distance (feet)	Maximum Travel Time (s)
Minimum	Adult with walking disability	2.5	325	130
Average	Average of all Shoppers	3.38	325	96.2
Maximum	Adult walking alone	3.74	325	86.9

With the main entrance and exit blocked, their total effective widths are reduced to zero. The calculation of the total effective exit width is shown in Table 26 below.

Table 26 - Effective exit widths. The effective width of the doorways accounts for the natural formation of a boundary layer as people pass through the door without bumping into the frame. See NFPA Handbook, 20th edition, Table 4.2.4.

Exits	Quantity	Actual Width per door (in)	Boundary Layer per door (in)	Total Effective Width (in)	Total Effective Width (ft)
Main entrance	1	92.0	12	0	0
Main exit	1	92.0	12	0	0
Single door	3	36	12	72	6
Double door	8	72	12	480	40
Total	13	-	-	552	46

Table 27- Evacuation time based on maximum specific flow. Calculated flow is the product of total effective width and maximum specific flow rate for doors. Evacuation time is the quotient of the maximum occupancy and calculated flow rate. See NFPA Handbook, 20th edition, Table 4.2.8

Maximum Specific Flow Rate (person/ft)	Calculated Flow (person/min)	Maximum Occupancy (persons)	Exit Flow Time (min)	Pre-Movement Time (min)	Evacuation Time (min)	Factor of Safety	Total Evacuation Time (min)
24	1104	3208	2.9	1.7	4.6	1.2	5.5

The total evacuation time is again calculated using the maximum specific flow rate, with adjusted total exit length, presented in Table 27. Using a factor of safety of 20%, the total evacuation time is estimated to be 5.5 minutes.

The benefit of this methodology is that it is based on real-world data that accurately represents the occupants expected to be inside the Costco store. By using the worst-case scenario pre-movement time, the results become more conservative. Coupled with the factor of safety, it is unlikely that egress would actually require the calculated value of 5.5 minutes; that being said, if it can be shown that after 5.5 minutes the smoke layer is not less than 6 feet above the floor, we can deem the simulation a success.

EGRESS TIME – PATHFINDER

Pathfinder is a simulation tool created by Thunderhead Engineering that allows for simulation of egress of a building. For the simulation conducted here, the Costco store is modeled as one large room with auxiliary rooms around the perimeter, accurately representing the actual layout of the Costco store. Doors between the auxiliary spaces and main floor are represented as gaps in the walls. Emergency exits are located around the perimeter to reflect their actual location and size, represented in the simulation environment at the locations exit signs seen in Figure 13. Obstacles such as tables and racks of merchandise are modeled into the program to realistically capture the paths of travel occupants are expected to take in exiting the building. Because the design scenario calls for the main exit to be blocked, an obstacle is placed around the garage doors in the southwest corner of the building.

The maximum number of occupants is evenly spread around the store. Average rate of travel is set to 3.38 ft/s per Table 20. The motion of the occupants is modeled using the steering behavior mode, in which occupants first identify the nearest exit and begin to move toward it. As they do so, they avoid collisions with walls, obstacles, and nearby occupants while maintaining a boundary layer of at least 1 inch. Updates to the direction of movement for each occupant occur at a frequency of 10 steering updates per second.

PATHFINDER RESULTS AND ANALYSIS

Figure 13: Visualization of the initial conditions of the Pathfinder egress simulation at $t=0s$

Figure 13 shows the initial setup of the simulation at $t = 0$ seconds. Occupants are represented by small green cylinders. In the simulation, evacuation begins at $t = 0s$. It is assumed that there is no pre-movement time and that all occupants become alerted and respond to the need to evacuate immediately.

Figure 14: Pathfinder egress simulation results after 30 seconds have elapsed

Figure 14 shows the progress of evacuation after 30 seconds. Note that many of the occupants have reached an exit, with other still traveling from the floor area to an exit. Jamming is visibly occurring at the doors, where occupants are waiting to exit. Most auxiliary spaces have been completely cleared, except for some jamming occurring in the kitchen areas which has only one exit.

Figure 15: Pathfinder egress simulation results after 60 seconds have elapsed

As seen in Figure 15, after 60 seconds nearly all occupants have reached an exit door. Jamming continues to occur. Auxiliary spaces are completely clear. Many occupants have safely exited the building at this time.

Figure 16: Pathfinder egress simulation results after 120 seconds have elapsed

Figure 16 shows the results of the simulation after 120 seconds have passed. At this time, all occupants have reached an exit door and are waiting their turn to pass through the exit. The floor is completely clear of occupants. In the southeast corner of the room, some occupants can be seen moving from the door experiencing significant jamming to the nearby door that is clear of jams.

Figure 17: Pathfinder egress simulation results after 180 seconds have elapsed

After 180 seconds, the building is nearly entirely clear of occupants, with some minor jamming in the northwest and southwest corners as the final occupants exit the building.

The last occupant exited the building after 190.8 seconds. A summary of the test results is shown in Tables 23, 24, and 25. The average travel distance was 116.1 feet with a maximum of 374 feet, exceeding the estimated maximum of 325 feet using the NFPA approach by 49 feet. Average exit time was 73.6 seconds, with the last occupant escaping after 190.8 seconds. Once occupants reached an exit, they were required to wait an average of 32.4 seconds before exiting the building. The longest jam any occupant experienced was 147.5 seconds.

Table 28: Summary of occupant travel distances during Pathfinder simulation

TRAVEL DISTANCE			
Min (ft)	Mean (ft)	Max (ft)	SD (ft)
0.99	116.1	374	68.6

Table 29: Summary of occupant travel exit times during Pathfinder simulation

EXIT TIME				
Min (s)	Mean (s)	Median (s)	Max (s)	SD (s)
0.6	73.6	69.6	190.8	45.5

Table 30: Summary of occupant jam times during Pathfinder simulation

JAM TIME				
Min (s)	Mean (s)	Median (s)	Max (s)	SD (s)
0.1	32.4	22.9	147.5	31.3

While the average number of occupants passing through all doors was 291.6 individuals, the double door located in the northwest corner of the room to the right of the blue office areas has the highest usage, with 461 occupants using it for escape. This exit was the last one used by the final escapee. The next most used door was the double door located on the west side of the south face of the building, with 401 occupants passing through. The two least used doors were the single door located in the northwest corner of the store and the single door on the southern east face of the store, used by 172 and 128 occupants, respectively.

In an actual fire, there would be some delay in the occupants responding to the fire alarms. Utilizing the 1.7 minute worst-case pre-movement time from the NFPA method of egress and adding a factor of safety of 20% to the total evacuation time, complete egress of the Costco can be expected to occur within 5.3 minutes.

PATHFINDER CONCLUSIONS AND RECOMMENDATIONS

The simulation reveals that evacuation time given incapacitation of the main exit can be improved by enhancing the exit capacity of the portions of the building served by the two most highly used doors. The service areas along the western face of the building prevent exit access for shoppers. As a result, additional exit capacity should be added to the west side of the building: the single exit door in the northwest corner of the store could be expanded to a double door, allowing for faster exit in that quadrant of the building. This door was used by the

second smallest number of occupants during escape. Improving its exit capacity would allow faster escape in the northwest side of the building, as well as reducing the number of occupants at other doors, decreasing jamming.

The single door in the southwest corner of the store could also be enlarged, which would allow for more balanced egress through doors to the south. Additionally, the middle double exit door on the south face of the building could be moved inward, encouraging its use by occupants waiting to escape using the door to the west.

These recommendations serve to decrease the actual evacuation time given a real fire event. For the purpose of this analysis, these values are useful in providing a conservative estimate for the worst case evacuation time.

The Pathfinder simulation resulted in an expected evacuation time of 5.3 minutes, a disagreement of 3.6% with the NFPA method. As a result, the worst case scenario of 5.5 minutes will be used in the fire modeling analysis. The smoke height in the building during the design fire will be estimated using CFAST fire modeling software. If the results of the CFAST simulation can demonstrate realistically that the hot gas layer will not drop below 6 feet above floor level after 5.5 minutes have elapsed, the performance based analysis will be successful.

CFAST FIRE SIMULATION

INTRODUCTION

CFAST (Consolidated model of Fire growth And Smoke Transport), developed by the National Institute of Standards and Technology, is a two-zone fire model that can predict conditions in multiple compartments in the event of a fire, including temperature of lower and upper layers, smoke spread, gas velocities, and heat and smoke detection. It takes into account user-defined thermophysical properties of the structure of the room along with the effects of passive or active ventilation, and can simulate a wide range of t-squared fires or fires following heat release rate curves defined by the user. Coupled with Smokeview, visualizations of temperature gradients, gas velocity gradients, and more can be generated. CFAST version 7 was used for the following analysis.

SIMULATION ENVIRONMENT

The large compartment shown in Figure 18 is a visual representation of the simulation environment used in the CFAST model, showing vents, detection devices, and the location of the design fire. The compartment is set to the maximum value of 100 meters in length and width and 9 meters in height. Tables 26, 27, and 28 summarize the input parameters for the thermal properties of the surfaces of the compartment, the wall vents, and the locations and activation characteristics of the heat and smoke detectors. The design fire inputs are summarized in Table 29.

Figure 18: visual representation of the CFAST simulation environment

The floor of the Costco is modeled as 12 inch thick concrete slab. Walls are 8 inch thick concrete blocks. The ceiling is made of steel panels with a thickness of 0.2 inches. Thermal properties come from a variety of sources, including the SFPE Handbook, Wikipedia [10], and Engineering Toolbox [11].

Table 31: Thermal properties of the CFAST simulation environment

Thermal Properties of Simulation Environment						
Structural Component	Material	Conductivity (kW/m ²)	Specific Heat (kJ/kg-K)	Density (kg/m ³)	Thickness (m)	Emissivity
Floor	Concrete	0.0016	0.88	2400	0.3	0.85
Walls	Concrete Block	0.00051	0.88	1400	0.2	0.85
Ceiling	Steel Panels	0.052	0.5	790	0.005	0.88

The exit doors around the Costco are represented as wall vents open to the environment. Air flows into the Costco during the fire, providing ample oxygen to fuel the reaction.

Table 32: Ventilation in the CFAST simulation environment

Wall Vents				
Vent	Wall	Width (m)	Height (m)	Location (m)
Single Doors	Left	1	2	10
	Rear	1	2	10
	Right	1	2	40
Double Doors	Front	2	2	25
		2	2	50
		2	2	60
	Rear	2	2	20
		2	2	40
		2	2	60
		2	2	80
	Right	2	2	70
Main Entry	Front	2.4	2.4	2
	Left	2.4	2.4	2

Detection devices are located above the fire at the maximum possible distance allowed while complying with NFPA 72 spacing and location requirements as discussed in the alarm and detection chapter of this report. Heat detectors have a response time index (RTI) of $2 \text{ m-s}^{1/2}$, rapidly responding to the change in temperature of their environment. Sprinklers are treated as heat detectors with an RTI of $80 \text{ m-s}^{1/2}$, corresponding to standard response sprinklers as discussed in the sprinkler chapter of this report. Smoke detectors measure smoke obscuration at a level of $12\%/m$, their maximum activation obscuration level.

Table 33: Heat and smoke detectors in the simulation environment

Heat and Smoke Detection				
Type	Location X (m)	Location Y (m)	Activation	RTI ((m-s) ^{0.5})
Heat	8.5	8.5	57.2 °C	2
	8.5	11.5	57.2 °C	2
	11.5	8.5	57.2 °C	2
	11.5	11.5	57.2 °C	2
Smoke	8.5	8.5	12 %/m	-
	8.5	11.5	12 %/m	-
	11.5	8.5	12 %/m	-
	11.5	11.5	12 %/m	-

Sprinkler	Location X (m)	Location Y (m)	Activation	RTI ((m-s) ^{0.5})
	8.5	8.5	68 °C	80
	8.5	11.5	68 °C	80
	11.5	8.5	68 °C	80
	11.5	11.5	68 °C	80

DESIGN FIRE

The design fire used in the simulation is based on the fire heat release rate curve in Figure 12 and is located 10 meters from the south and west corners of the building. The design fire curve input into the CFAST model is shown in Figure 19, with Table 29 summarizing the fire specifications. The fire starts at $t = 0$ s and rises to its peak heat release rate (HRR) of 17,400 kW after 25 seconds following a t -squared curve. Rather than sustain steady burning for approximately 10 seconds before extinguishing like in the actual full-scale fire test curve, the fire is modeled to remain at its peak HRR for at least the amount of time needed to fully evacuate the building, which in this case is 5.5 minutes. This is based on the assumption that there is ample fuel source located in the vicinity of the fire to allow for sustained burning for a prolonged period of time, which in this case is likely given the large amounts of good stored on display in Costco stores. After the evacuation time has passed, the smoke level in the room no longer plays a role in the performance based analysis and the fire is modeled to extinguish.

Table 34: input parameters for the CFAST design fire

Design Fire	
Location	10m from front wall and left wall
Height	0.5m above ground
Area of Fuel	2m (2 adjacent pallets of 1m x 1m x 1m)
Peak HRR	17,400 kW
Steady Burn Time	5 min
Soot Yield	0.135 g/g
CO Yield	0.050 g/g

Figure 19: heat release rate of design fire used in CFAST simulation

CFAST RESULTS AND ANALYSIS

Figure 20 shows the temperature response of the heat detectors and hot gas layer to the design fire. The temperature of the heat detectors increases in close conformance with the temperature of the hot gas layer due to the low RTI of the heat detectors, which are at approximately the same temperature throughout the simulation. Within 5 seconds of fire ignition, the heat detectors reach their activation temperatures, signaling to the FACP to activate the alarms and strobes. After steady state burning is reached at 25 seconds, the heat detectors quickly reach equilibrium temperature with the hot gas, where they remain for the duration of the fire.

Figure 20: Temperature of heat detectors and upper gas layer in CFAST design fire simulation

The Smokeview visual output file seen in Figure 21 has a temperature slice file through the location of the fire at $x = 10\text{m}$ showing the initial conditions. Temperatures in the room are homogenous at room temperature of 22°C . After 10 seconds (Figure 22) the fire can be seen rapidly growing. The hot plume is already extending toward the ceiling, and the hot gas layer is already forming along the ceiling where previously there had been no smoke obscuration. By this time, the heat detectors have activated.

Figure 21: Smokeview slice file (x=10m) of design fire CFAST simulation at t=0s

Figure 22: Smokeview slice file (x=10m) of design fire CFAST simulation at t=10s

Figure 23: Smokeview slice file ($x=10\text{m}$) of design fire CFAST simulation at $t=20\text{s}$

Figure 24: Smokeview slice file ($x=10\text{m}$) of design fire CFAST simulation at $t=30\text{s}$

After 20 seconds (Figure 23), the plume has grown nearly to the ceiling and the hot gas layer has started spreading radially outward along the ceiling. Dark smoke is visible at the upper layer. Figure 24 shows the simulation at $t = 30$ seconds. At this time the peak heat release rate has been reached. The flames extend all the way to the ceiling and the temperature of the hot gas layer has increased significantly. The gas layer interface is at a height of 8.87m.

Figure 25: Smokeview slice file (x=10m) of design fire CFAST simulation at t=60s

Figure 26: Smokeview slice file (x=10m) of design fire CFAST simulation at t=120s

When 60 seconds have passed (Figure 25) the temperature of the upper layer continues to rise and the smoke layer grows larger and visibly denser. The interface height is 8.67m. Between 60 and 120 seconds (Figure 26) after the fire begins, the upper layer continues to increase in temperature. The interface height has descended to 8.30m. By this time, the pre-movement time has passed. Everyone has begun moving toward an exit, and many occupants have already exited the building.

Figure 27: Smokeview slice file (x=10m) of design fire CFAST simulation at t=240s

Figure 28: Smokeview slice file (x=10m) of design fire CFAST simulation at t=300s

After 240 seconds, the average lower layer temperature has increased to 29 °C (Figure 27). The hot gas layer is at a height of 7.63m. Figure 28 shows that the interface height is 7.32m above the floor 300 seconds after the fire begins. Now, all occupants have reached an exit. Most have evacuated the building, while others wait at the doors to pass to the outside.

Figure 29: Smokeview slice file (x=10m) of design fire CFAST simulation at t=330s

Lastly, Figure 29 shows the fire burning at 330 seconds, the time at which all occupants have escaped the building. The final layer height is 7.18m. The lower layer temperature has increased to 32.2 °C.

Figure 30 shows the changing temperatures resulting from the fire and the height of the smoke layer during the simulation. The graph captures the slow, steady decrease in height of the smoke layer, and the relatively small rise of the average lower layer temperature due to the massive volume of the room.

Hot Gas Layer Height and Layer Temperatures in Design Fire - CFAST Simulation

Figure 30: Hot gas layer height and upper and lower layer temperatures in design fire (CFAST)

PERFORMANCE BASED DESIGN CONCLUSIONS

The CFAST simulation demonstrates that even during an extreme fire event, the Costco will not fill with smoke to a level hazardous to tenability in the amount of time required for all occupants to escape the building. At the end of the simulation, the smoke layer is at a height of roughly 7m, 5m beyond the required minimum upper layer height for safe egress.

The simulation is truly a worst case scenario, using an intense fire curve with massive output of heat, smoke, and carbon monoxide. The intensity of the fire followed the most severe curve available for real-world test data of materials contained in the Costco.

The fire protection services provided by the sprinkler system were not included in the analysis to make for conservative results: if the entire building can be evacuated without using the fire protection services, those means of control stand to increase the likelihood of safe escape in the event of the emergency. The sprinkler system can be expected to reduce the heat release rate of the fire, prevent it from spreading to nearby fuels that become permeated with water, or extinguish the flame altogether; the simulation fire foregoes these safeguards and allows the fire to burn without intervention, producing increased volumes of smoke and heat in less time than with a functioning sprinkler system.

The analysis assumes full blocking of the primary means of egress, which is significantly larger than other exit and forces occupants to use smaller exits without access through wide aisles and located in less obvious locations. The egress time used was also assumed to be the worst case scenario, using the longest pre-movement time available for real data of department stores such as Costco. In practice, pre-movement time data is often higher than would be expected in a real fire scenario. Although most people have experienced fire alarm testing and drills training them to evacuate safely and without panic, in many instances alarms are misinterpreted as drills which increases the response time. A fire such as this, in which smoke is visibly spreading across the ceiling and a massive fire is blazing from the floor to the ceiling would likely elicit an immediate response in most occupants of the building, effectively lowering the pre-movement time and drastically reducing the time to evacuation of the building.

PERFORMANCE BASED DESIGN RECOMMENDATIONS

There is room for improvement in the simulation and egress calculations that could more realistically capture the sequence of events of the design fire.

Pathfinder has the ability to delay the response of occupants during evacuation. By programming the model to have some occupants respond more quickly or slowly, occupants could be expected to approach different points of exit, which would impact the number of occupants using each door. In this way, improvements to the layout of egress points could potentially allow for more efficient use of doors, even though the time to respond is increased.

Additionally, Pathfinder is capable of representing series of events that occupants may undergo in the event of a fire. For example, some occupants of the store may be with a party of children or other individuals with whom they would congregate prior to evacuation and move toward safety as a party. Individuals may try to find a place for safekeeping for the contents of their

shopping carts. Others may try to extinguish the fire manually, which would involve moving toward the fire, finding extinguishing equipment such as hoses or fire extinguishers, and attempting to put out the fire. The benefits of staff trained for evacuation could help occupants move toward exits more efficiently and spread to available exits to reduce jamming time, with the added impact of personnel remaining in the store to help others. These responses could be programmed into the simulation using a series of events that represents the diverse results of decision making in the emergency scenario. All of these factors would likely impact the results of the simulation, and using real-world data, may more accurately simulate the expected response of occupants to the design fire.

Modifications can also be made to the CFAST simulation that would impact the smoke filling rate and gas layer interface height due to the fire. Obstacles placed around the fuel source representing the actual layout of goods in the store could provide more realistic air entrainment, potentially reducing the heat release rate of the fire. While the cost would be high, full-scale testing of actual goods located in the store, oriented the way they are displayed, would improve the accuracy of the test results.

CFAST is also capable of modeling the opening and closing times and percent-open factors of vents. Using the results of the Pathfinder simulation, the time at which doors are first opened could be added to the CFAST simulation, making for more representative ventilation conditions further impacting the rate of growth and heat release rate of the fire.

In CFAST, sprinklers are modeled to reduce the heat release rate of the fire once activated, but are not capable of extinguishing it. It is also limited to modeling the impact of a single sprinkler activating. In the simulation conducted in this report, the impact of sprinklers was not included to provide more intense fire growth and heat release to produce more conservative results; while this makes the comparison of smoke filling rate and egress time more challenging, it reduces the accuracy of the simulation.

Additional design scenarios involving high piled storage of less combustible and smoke-producing materials could be studied. Given the lack of sprinkler activation, the heat release rate may continue growing to a level higher than that used in this study, in which case more fuel may be burned during the simulation and increasing the production of smoke and carbon monoxide in the design environment.

CONCLUSIONS

In this report, the structure, alarm and detection, egress systems, and sprinkler system design of the Costco store located in San Francisco have been examined from a code-based perspective. The structural and alarm and detection systems are found to be fully code compliant. The egress design is good but a problematic dead end was found in one of the kitchen areas. The sprinkler system failed to satisfy the hydraulic calculation demands; recommendations for improving pressure throughout the system are made.

With these systems fully designed and evaluated, a performance based analysis demonstrated that available safe egress time was greater than the required safe egress time ($ASET > RSET$) for a highly challenging design fire scenario. The performance criteria was established using Method 2 of the Life Safety Code, ensuring all occupants could be evacuated from the building before smoke from a design fire reached a height of 6 feet above the floor. The fire scenario was a large, ultra-fast growth fire blocking the primary means of exit. The design fire was used for palletized electronic equipment with extremely high heat release rate, smoke yield, and carbon monoxide yield, located near the main exit of the store; full-scale test data was used to establish fire growth curves and heat release rates.

The RSET with the main exit blocked was calculated using the NFPA method and Pathfinder simulation software. A simulation using CFAST was then conducted, showing that the smoke layer height after the time required for full evacuation did not reach the limit of 6 feet above the floor. Using these methods demonstrated that $ASET > RSET$, and the Costco was deemed to meet the success criteria of the performance based analysis.

RECOMMENDATIONS

The largest issue in the prescriptive analysis was the failure of the sprinkler systems to meet the pressure and flow demands in the hydraulic calculations. It is recommended that a redesign of the systems is analyzed using recommendations from the Water Based Fire Protection section to determine if the available water can be used to adequately protect all areas of the building without the use of a pump. If required, a pump should be specified with a suitable pump curve and power requirements compatible with those available in the building.

The performance based analysis utilized assumptions for steady state heat release and application of sprinklers that produced a highly challenging fire scenario, but may not be realistic in an actual fire. The results of the simulations demonstrated that the height of the smoke layer is unlikely to put occupants at risk even when compared to the conservative results of the egress calculations. This suggests that life safety may not be the most challenging performance based goals. The CFAST results could be compared to a detailed FDS simulation utilizing fewer assumptions that could provide more realistic results.

Because the life safety criteria were satisfied by a large margin, it is recommended that performance criteria be developed for property protection. The Costco store contains a great deal of products, many of which are expensive and valuable. Pass/fail criteria could be established related to the value of product lost in a realistic design fire scenario that tests the water based suppression systems or orientation of products in the store. For example, an ultra-fast growth rate fire in high piled storage of expensive goods could result in severe financial losses to the company. A simulation could be conducted using Fire Dynamics Simulator to examine the ability of sprinklers designed to prescriptive code to reduce or prevent financial loss. The simulation could be repeated with a variety of suppression systems to compare their abilities to protect valuable products. The cost of implementing different suppression systems could be compared with the projected savings in the event of a fire to determine if expensive suppression systems would be worth the cost.

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APPENDIX

9/1/13

SAN FRANCISCO FIRE DEPARTMENT
BUREAU OF FIRE PREVENTION
PLAN CHECK DIVISION/WATER FLOW
1660 MISSION STREET, 4TH FLOOR
SAN FRANCISCO, CA. 94103
FAX # 415-575-6933

REQUEST FOR WATER FLOW INFORMATION

DATE: 9 / 16 / 13

REQUEST IS FOR:

☐ FIRE FLOW
☒ SPRINKLER DESIGN

CONTACT PERSON: [REDACTED]

ADDRESS: [REDACTED]

PHONE NO. [REDACTED]

FAX NO. [REDACTED]

EMAIL: [REDACTED]

OWNER'S NAME: Costco Wholesale Inc. PHONE # (425) 313 / 8100

ADDRESS FOR WATER FLOW INFORMATION:

450 Tenth Street, San Francisco, CA 94103

CROSS STREETS (BOTH ARE REQUIRED):

Harrison Street / Bryant Street

SPECIFY STREET FOR POINT OF CONNECTION: 11th street

PROVIDE SKETCH HERE:

OCCUPANCY (CIRCLE ONE): R3 R2 LIVE/WORK COMMERCIAL OTHER

HAZARD CLASSIFICATION: LIGHT ORD 1 ORD 2 EXT 1 EXT 2 OTHER

CAR-STACKER: YES NO

NUMBER OF STORIES: 2 HEIGHT OF BLDG.: 30 FT.

- SUBMIT FORM WITH A \$115.00 CHECK MADE PAYABLE TO 'S.F.F.D.'
- REQUESTS REQUIRING A FIELD FLOW TEST WILL BE NOTIFIED BY FAX OR EMAIL, AND AN ADDITIONAL FEE OF \$230.00 WILL BE NECESSARY.
- WATER FLOW INFORMATION WILL BE RETURNED BY FAX, MAIL, OR EMAIL.
- INCOMPLETE FORMS WILL NOT BE PROCESSED.
- PLEASE ALLOW 7-14 WORKING DAYS FOR PROCESSING.

*****Official use only*****

Flow data provided by: R. Brown

Date Forwarded 9-30-13

Flow data: FIELD FLOW TEST
RECORDS ANALYSIS X

STATIC 61 PSI

RESIDUAL 58 PSI

FLOW 1050 GPM

Gate Page 117

8" MAIN on 11th St.

IF YOU HAVE ANY QUESTIONS PLEASE CONTACT INSPECTOR BROWN @ 415-558-6114

Riser 1

AutoSPRINK Hydraulic Analysis - Costco floorplan areas and zones and sprink with riser jank

Remote Area Summary Data – Riser 1

Remote Area Data | System Demand Graph | Pipes Listed By Velocity | Node Analysis | Pipe Analysis |

Item to graph: Supply at Node 34 (61.000 58.000 1050.00)

Density: 0.100gpm/ft² for 1500.00ft² (Actual 587.94ft²)

7 Flowing sprinklers

System Demand Graph – Riser 1

Riser 2

Remote Area Summary Data – Riser 2

Remote Area Data | System Demand Graph | Pipes Listed By Velocity | Node Analysis | Pipe Analysis

Item to graph: Supply at Node 34 (61.000 58.000 1050.00)

Density: 0.420gpm/ft² for 2000.00ft² (Actual 1449.24ft²)

20 Flowing sprinklers

System Demand Graph – Riser 2

Riser 3

Remote Area Summary Data – Riser 3

System Demand Graph – Riser 3

Riser 4

Remote Area Summary Data – Riser 4

Remote Area Data | System Demand Graph | Pipes Listed By Velocity | Node Analysis | Pipe Analysis

Item to graph: Supply at Node 34 (61.000 58.000 1050.00)

Density: 0.420gpm/ft² for 2000.00ft² (Actual 1483.44ft²)

20 Flowing sprinklers

System Demand Graph – Riser 4

Project name:		Area 1 Riser		Owner:		Ian Levine		Notes	
Step No.	Nozzle Ident and Location	Flow in gpm	Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length	Fri cti	Pressure Summary	Normal Pressure	
1	1 BL-1	q 22.5	Nominal 1.25	Actual 1.38	L	13 C=	Pt 7.9	Pt	k=8.0 q=D'A
2	2 BL-1	Q 22.5			F	13 pf	Pe	Pv	q = 0.10'225 = 22.5
3	3 BL-1	Q 23.3			L	13 C=	Pt 8.5	Pt	P = (Q/k)^2 = (22.5/8)^2 = 7.91
4	4 BL-1	Q 45.8			F	13 pf	Pe	Pv	# Sprinklers = 7
5	5 BL-1	Q 24.6			L	13 C=	Pt 1.0	Pn	Coverage per sprinkler: 225 ft^2
6	6 BL-1	Q 70.3			F	13 pf	Pe	Pv	Schedule 40 Steel: C=120
7	7 BL-1	Q 27.2			L	13 C=	Pt 2.1	Pn	Pf calculated with Darcy Weisbach
8	8 BL-1	Q 97.5			F	13 C=	Pt 11.6	Pt	
9	9 BL-1	Q 31.5			L	13 pf	Pe	Pv	
10	10 BL-1	Q 129.0			F	13 C=	Pt 3.9	Pn	
11	11 BL-1	Q 129.0			L	1.5 C=	Pt 15.5	Pt	
12	12 BL-1	Q 129.0			F	4.5	Pe	Pv	
13	13 BL-1	Q 129.0			L	6 pf	Pt 3.1	Pn	
14	14 BL-1	Q 129.0			F	1.5 C=	Pt 18.6	Pt	
15	15 BL-1	Q 129.0			L	10	Pe	Pv	
16	16 BL-1	Q 129.0			F	11.5 pf	Pt 1.7	Pn	
17	17 BL-1	Q 129.0			L	14.33 C=	Pt 20.9	Pt	
18	18 BL-1	Q 129.0			F	14.33 pf	Pe	Pv	
19	19 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
20	20 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
21	21 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
22	22 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
23	23 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
24	24 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
25	25 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
26	26 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
27	27 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
28	28 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
29	29 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
30	30 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
31	31 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
32	32 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
33	33 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
34	34 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
35	35 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
36	36 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
37	37 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
38	38 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
39	39 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
40	40 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
41	41 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
42	42 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
43	43 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
44	44 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
45	45 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
46	46 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
47	47 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
48	48 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
49	49 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
50	50 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
51	51 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
52	52 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
53	53 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
54	54 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
55	55 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
56	56 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
57	57 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
58	58 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
59	59 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
60	60 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
61	61 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
62	62 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
63	63 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
64	64 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
65	65 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
66	66 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
67	67 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
68	68 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
69	69 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
70	70 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
71	71 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
72	72 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
73	73 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
74	74 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
75	75 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
76	76 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
77	77 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
78	78 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
79	79 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
80	80 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
81	81 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
82	82 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
83	83 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
84	84 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
85	85 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
86	86 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
87	87 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
88	88 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
89	89 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
90	90 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
91	91 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
92	92 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
93	93 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
94	94 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
95	95 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
96	96 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
97	97 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
98	98 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
99	99 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
100	100 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
101	101 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
102	102 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
103	103 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
104	104 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
105	105 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
106	106 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
107	107 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
108	108 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
109	109 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
110	110 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
111	111 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
112	112 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
113	113 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
114	114 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
115	115 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
116	116 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
117	117 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
118	118 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
119	119 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
120	120 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
121	121 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
122	122 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
123	123 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
124	124 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
125	125 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
126	126 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
127	127 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
128	128 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
129	129 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
130	130 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
131	131 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
132	132 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
133	133 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
134	134 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
135	135 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
136	136 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
137	137 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
138	138 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
139	139 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
140	140 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
141	141 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
142	142 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
143	143 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
144	144 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
145	145 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
146	146 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
147	147 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
148	148 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
149	149 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
150	150 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
151	151 BL-1	Q 129.0			L	14.33 pf	Pt 0.3	Pn	
152	152 BL-1	Q 129.0			F	14.33 pf	Pt 0.3	Pn	
153									

CONTRACT NAME: COSTCO - 10th & BRYANT, ST. : AREA 1

FLOW—GPM

Project name: Area 2 Riser									
Step No.	Nozzle Ident and Location	Flow in gpm	Pipe Fittings and Devices		Equivalent Pipe Length	Friction loss (psi/ft)		Pressure Summary	Notes
			Nominal	Actual		8/C=	120		
1	1 BL-1	Q 42.0	1.50	1.61	L	8/C=	120	Pt 14.1	Occupancy: Storage Design area =2000 ft ² D = 0.42 gpm/ft ² # Sprinklers = 20 Coverage per sprinkler: 100 ft ² Schedule 40 Steel: C=120 Pf calculated with Darcy Weisbach
		Q 42.8	1.50	1.61	T	8/pf	0.064	Pf 0.5	
2	2 BL-1	Q 42.8	1.50	1.61	L	8/C=	120	Pt 14.6	
		Q 42.8	1.50	1.61	T	8/pf	0.064	Pf 0.5	
3	3 BL-1	Q 42.8	1.50	1.61	L	8/C=	120	Pt 14.6	
		Q 42.8	1.50	1.61	T	8/pf	0.064	Pf 0.5	
4	4 BL-1	Q 42.8	1.50	1.61	L	8/C=	120	Pt 14.6	q = 0.42*100 = 42 P = (Q/k) ² = (42/11.2) ² = 14.1 q = 11.2 * (15.2) ^{1/2} q = 11.2 * (19.2) ^{1/2} q = 11.2 * (20.5) ^{1/2} q = 11.2 * (21.5) ^{1/2}
		Q 42.8	1.50	1.61	T	8/pf	0.064	Pf 0.5	
5	5 BL-1 to T1	Q 42.8	1.50	1.61	L	8/C=	120	Pt 14.6	
		Q 42.8	1.50	1.61	T	8/pf	0.064	Pf 0.5	
6	6 BL-2 to T1	Q 42.8	1.50	1.61	L	8/C=	120	Pt 14.6	
		Q 42.8	1.50	1.61	T	8/pf	0.064	Pf 0.5	
7	T1 DN to CM	Q 277.7	3.00	3.068	L	3/C=	120	Pt 18.8	Guess q = 48 gpm P = (Q/k) ² = (48/11.2) ² = 18.4 Pressures at T match to 0.5 psi
		Q 277.7	3.00	3.068	T	3/pf	0.095	Pf 0.4	
8	BL-2 TO BL-3	Q 277.7	4.00	4.026	L	12/C=	120	Pt 20.8	
		Q 277.7	4.00	4.026	T	12/pf	0.024	Pf 0.3	
		Q 277.7	4.00	4.026	T	12/pf	0.024	Pf 0.3	
9	BL-3 to T2	Q 234.0	3.00	3.068	L	3.67/C=	120	Pt 21.2	guess q = 234 gpm P = (Q/k) ² = (234/50.8) ² = 21.2 Pressures at T match to 0.5 psi
		Q 234.0	3.00	3.068	T	3.67/pf	0.066	Pf 0.2	
		Q 234.0	3.00	3.068	T	3.67/pf	0.066	Pf 0.2	
10	7 to 8	Q 51.0	2.50	2.469	L	8/C=	120	Pt 21.6	
		Q 51.0	2.50	2.469	T	8/pf	0.011	Pf 0.1	
11	8 to T2	Q 52.1	3.00	3.068	L	4.25/C=	120	Pt 21.6	guess 52 P = (Q/k) ² = (52/11.2) ² = 21.6 q = 11.2 * (21.6) ^{1/2} Pressures at T match to 0.5 psi
		Q 52.1	3.00	3.068	T	4.25/pf	0.015	Pf 0.1	
		Q 52.1	3.00	3.068	T	4.25/pf	0.015	Pf 0.1	
		Q 103.1	3.00	3.068	T	4.25/pf	0.015	Pf 0.1	
		Q 103.1	3.00	3.068	T	4.25/pf	0.015	Pf 0.1	
12	T2 DN to CM	Q 337.1	3.00	3.068	L	3/C=	120	Pt 21.7	Pressure at base of riser nipple
		Q 337.1	3.00	3.068	T	3/pf	0.095	Pf 0.4	
		Q 337.1	3.00	3.068	T	3/pf	0.095	Pf 0.4	
13	BL-3 TO BL-5	Q 614.8	4.00	4.026	L	12/C=	120	Pt 24.5	
		Q 614.8	4.00	4.026	T	12/pf	0.105	Pf 1.3	

CONTRACT NAME: **COSTCO - 10th & BRYANT ST. AREA 2**

FLOW TEST SUMMARY SHEET

FLOW—GPM

Project name:				Area 3 Riser				Owner: Ian Levine				Notes			
Step No.	Nozzle Ident and Location	Flow in	Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length	Friction loss (psi/ft)	Pressure Summary	Normal Pressure							
1	1 BL-1	q	26.0		L	8.25 C=	Pt	10.6	Pt	k=8	Ordinary Hazard II Design area =1500 ft² D = 0.20 gpm/ft² # Sprinklers = 12 Coverage per sprinkler: 130 ft² Schedule 40 Steel: C=120 Pf calculated with Darcy Weisbach				
		Q	26.0				Pf	0.2				Pv			
		Q	26.3				Pf	0.2				Pn			
2	2 BL-1	q	52.3		T	8.25 pf	Pf	0.2	Pf	k=8					
		Q	26.6				Pf	0.2				Pn			
		Q	78.9				Pf	0.5				Pn			
3	3 BL-1	q	27.2		F	1 C=	Pf	11.1	Pf	k=8					
		Q	27.2				Pf	11.6				Pv			
		Q	106.1				Pf	0.1				Pn			
4	4 BL-1	q	27.0		T	8.25 pf	Pf	0.2	Pf	k=8					
		Q	27.0				Pf	0.1			Pn				
		Q	27.1				Pf	0.2			Pn				
5	5 BL-2	q	27.0		T	8.25 pf	Pf	0.2	Pf	k=8					
		Q	27.0				Pf	0.1			Pn				
		Q	27.1				Pf	0.2			Pn				
6	6 BL-2	q	27.0		L	8.25 C=	Pt	11.4	Pt	k=8					
		Q	27.0				Pf	0.1			Pn				
		Q	27.1				Pf	0.2			Pn				
7	7 T1 DN TO CM	q	160.2	T: 2"	L	1 C=	Pt	11.7	Pt	k=8					
		Q	160.2				Pf	0.4			Pv				
		Q	160.2				Pf	2.5			Pn				
8	8 BL-1 TO BL-3 + CM	q	4.00		L	14.25 C=	Pt	14.6	Pt	k=8					
		Q	4.026				Pf	0.1			Pv				
		Q	160.2				Pf	0.1			Pn				
9	9 BL-3 to T2	q	86.0		L	3.67 C=	Pt	7.7	Pt	k=31.0					
		Q	86.0				Pf	0.3			Pn				
		Q	86.0				Pf	8.0			Pn				
9	9 BL-4 to T2	q	45.0		L	3.67 C=	Pt	8.1	Pt	k=37.2					
		Q	45.0				Pf	0.0			Pv				
		Q	45.0				Pf	8.1			Pn				
7	7 T2 DN TO CM	q	131.0	T: 2"	L	1 C=	Pt	12.6	Pt	k=8					
		Q	131.0				Pf	0.4			Pv				
		Q	131.0				Pf	1.7			Pn				

18	CM to Tee	q		4.00	4.026	4" Tee	L	270.5	C=	120	Pt	14.7	Pt	k=8	
		Q	291.2				F	14			Pe		Pv		
	CM to Top of Riser	q		4.00	4.026	4" Tee	L	42	C=	120	Pt	22.2	Pt	k=8	
		Q	291.2				F	14			Pe		Pv		
21	Top of riser to base of riser	q		4.00	4.026	Check Valve Gate Valve	L	56	pf	0.026	Pf	1.5	Pn	k=8	Pe=0.433*26
		Q					L	26	C=	120	Pt	23.7	Pt		
		q				F	24			Pe	11.3	Pv			
		Q	291.2			T	50	pf	0.026	Pt	1.3	Pn			
												Pt	35.0		

CONTRACT NAME: COSTCO, 10th & BRYANT, SF : NO: AREA 3

Project name:			Area 4 Riser			Owner:			Ian Levine			Notes		
Step No.	Nozzle Ident and Location	Flow in gpm	Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length	Friction loss (psi/ft)	Pressure Summary	Normal Pressure						
1	1 BL-1	q	Nominal 1.50		L	7.75 C= 120	Pt 14.1	Pt	k=11.2	Q=D^A	Occupancy Storage Class III Design area =2000 ft^2 D = 0.42 gpm/ft^2 # Sprinklers = 20 Coverage per sprinkler: 100 ft^2 Schedule 40 Steel: C=120 Pf calculated with Darcy Weisbach			
		Q	Actual 1.61		F	7.75 Pf 0.064	Pe	Pv		q = 0.42^100 = 42				
		q	42.8		T	7.75 C= 120	Pt 0.5	Pn	k=11.2	P = (Q/k)^2 = (42/11.2)^2 = 14.1				
2	2 BL-1	Q	2.00	2.067		7.75 Pf 0.069	Pf 0.5	Pv		q = 11.2 * (14.6)^1/2				
		q	43.6		L	7.75 C= 120	Pt 15.1	Pt	k=11.2					
		Q	2.00	2.067		F	7.75 Pf 0.149	Pe	Pn					
4	4 BL-1	q	2.50	2.469		7.75 C= 120	Pt 16.3	Pv	k=11.2	q = 11.2 * (16.3)^1/2				
		Q	173.6		T	7.75 Pf 0.110	Pf 0.8	Pn						
		q	46.4		L	1 C= 120	Pt 17.1	Pt	k=11.2	q = 11.2 * (17.1)^1/2				
5	5 BL-1 to T1	Q	2.50	2.469		1 Pf 0.170	Pf 0.2	Pn						
		Pressures at T match to 0.5 psi												
		k of entire branch = Q/(P^1/2)												
									K=52.9					
5	7 BL-2	q	2.00	2.067		7.75 C= 120	Pt 16.9	Pt	k=11.2	Guess q = 46 gpm				
		Q			F	7.75 Pf 0.022	Pe	Pv		P = (Q/k)^2 = (46/11.2)^2 = 16.9				
		q	46.2		L	6.75 C= 120	Pt 17.0	Pt	k=11.2					
3	6 BL-2	Q	2.50	2.469		6.75 Pf 0.034	Pf 0.2	Pn		q = 11.2 * (11.5)^1/2				
		Pressures at T match within 0.5 psi												
		k of entire branch = Q/(P^1/2)												
									K=22.2					
7	T1 DN TO CM	q	3.00	3.068	T: 2.5"	1 C= 120	Pt 17.3	Pt	k=11.2	q = 11.2 * (8.5)^1/2				
		Q			F	12	Pe	Pv						
		q			T	13 Pf 0.113	Pf 1.5	Pn						
8	BL-2 TO BL-3	Q	4.00	4.026		11.75 C= 120	Pt 19.2	Pt	k=11.2	q = 11.2 * (8.5)^1/2				
		q			F		Pe	Pv						
		Q	312.1		T	11.75 Pf 0.030	Pf 0.4	Pn						
									Pressures at CM match within 0.5 psi					
6	6 BL-3 to T2	q	1.50	1.61		1 C= 120	Pt 16.7	Pt	k=52.9	Guess q = 216 gpm				
		Q			F		Pe	Pv		P = (Q/k)^2 = (216/52.9)^2 = 16.7				
		Q	216.0		T	1 Pf 1.319	Pf 1.3	Pn						
									Pressures at T match to 0.5 psi					
6	BL-4 to T2	q	1.50	1.61		1 C= 120	Pt 17.5	Pt	k=22.2	Guess q = 93 gpm				
		Q			F	1 Pf 0.277	Pe	Pv		P = (Q/k)^2 = (93/22.2)^2 = 17.5				
		Q	93.0		T		Pf 0.3	Pn						
									Pressures at T match to 0.5 psi					
7	T2 DN TO CM	q	3.00	3.068	T: 2.5"	1 C= 120	Pt 17.8	Pt						
		Q			F	12	Pe	Pv						
		Q	309.0		T	13 Pf 0.111	Pf 1.4	Pn						
									Pressures at CM match within 0.5 psi					

8	BL-4 TO BL-5	q	621.1	4.00	4.026		L	11.75 C=		120	Pt	19.3	Pt	k=11.2	q = 11.2 * (8.5) ^{1/2}
		Q	621.1				F				Pe		Pv		
							T	11.75 pf		0.107	Pf	1.3	Pn		
											Pt	20.5	Pressures at CM match within 0.5 psi		
6	BL-5 to T3	q	220.0	1.50	1.61		L	1 C=		120	Pt	17.3	Pt	k=52.9	Guess q = 216 gpm P = (Q/k) ^{1/2} = (216/52.9) ^{1/2} = 17.3
		Q	220.0				F				Pe		Pv		
							T	1 pf		1.364	Pf	1.4	Pn		
											Pt	18.7	Pressures at T match to 0.5 psi		
6	BL-6 to T3	q	95.0	1.50	1.61		L	1 C=		120	Pt	18.3	Pt	k=11.2	Guess q = 93 gpm P = (Q/k) ^{1/2} = (93/11.2) ^{1/2} = 18.3
		Q	95.0				F				Pe		Pv		
							T	1 pf		0.289	Pf	0.3	Pn		
											Pt	18.6	Pressures at T match to 0.5 psi		
7	T2 DN TO CM	q	315.0	3.00	3.068	T: 2.5"	L	1 C=		120	Pt	18.6	Pt		
		Q	315.0				F	12			Pe	0.4	Pv		
							T	13 pf		0.115	Pf	1.5	Pn		
											Pt	20.5	Pressures at CM match within 0.5 psi		
18	CM to Elbow	q		4.00	4.026	6" Elbow	L	61.33 C=		120	Pt	20.5	Pt		
		Q	936.1				F	14			Pe		Pv		
		q					T	75.33 pf		0.229	Pf	17.3	Pn		
							L	535 C=		120	Pt	37.8	Pt		
19	CM to Top of Riser	q		6.00	6.065	6" Elbow (4)	F	56			Pe		Pv		
		Q	936.1				T	591 pf		0.031	Pf	18.4	Pn		
		q					L	27 C=		120	Pt	56.2	Pt		
							F	35			Pe	11.3	Pv		
21	Top of riser to base of riser	q		6.00	6.065	Check Valve Gate Valve	L	62 pf		0.031	Pf	1.9	Pn		Pe=0.433*27
		Q	936.1				F				Pe		Pv		
							T				Pt	69.4	Pn		
											Pt	69.4			

CONTRACT NAME: COSTCO, 10th & BRYANT, SF NO: AREA 4

Flow-CPM

Cast-In Firestop Devices (CP 680-P and CP 680-M)

For use in

- Dust and fiber free environments such as hospitals, computer centers and laboratories
- Concrete floor assemblies rated up to 4 hours

Product description

- A one-step cast-in firestop device for a variety of pipe materials and diameters
- Helps reduce labor costs and increase productivity
- Ready-to-use out of the package
- Internationally tested and approved by UL and FM
- Reduces the chance of project delays due to failed inspections

Product features

- Quick and simple installation
- SpeedLine Alignment system promotes faster layout
- QuickTurn System creates fast, simple vertical connections
- Integrated moisture and smoke seal
- Innovative adapter for metal deck applications

Installation and applications

- Concrete floors from 2.5" (63 mm) thickness for either flat concrete or concrete over metal deck

CP 680-M:

- Insulated and non-insulated metal pipes
- EMT and electrical conduits
- Cable bundles
- Multiple pipes

CP 680-P:

Addresses all applications for CP 680-M as well as the following:

- Plastic pipes such as PVC, CPVC, ABS, ENT and FRPP
- Fresh and waste water pipes

Not suited for

- Areas with high condensation
- Outdoor areas
- Wall applications

CP 680-P in concrete over wood forms

CP 680-M in concrete over wood forms

CP 680-P over metal deck

CP 680-M over metal deck

Technical Data		CP 680-P and CP 680-M
ID	Footprint	Opening required thru metal deck
2"	3-3/4" x 4-1/2"	3-1/2" diameter
3"	4-3/4" x 5-5/8"	4-1/2" diameter
4"	6-3/8" x 6-3/4"	5-1/2" diameter
6"	9" x 9-1/2"	7-1/4" diameter
Expansion temperature		392°F (200°C)
Expansion rate		1:50 (unrestrained) 1:30 (Load expansion, Load = 20g/cm³)
Standard height		8"
Temperature resistance		Maximum 212°F (100°C)
Color		CP 680-P: red CP 680-M: black

Tested in accordance with

- UL 1479 • ASTM E 814 • ASTM G21

Internationally tested and approved

Installation instructions

Notice

- Before handling, read Material Safety Data Sheet and product label for safe usage and health information.
- Instructions below are general guidelines — always refer to the applicable drawing in the UL Fire Resistance Directory or Hilti Firestop Systems Guide for complete installation information

Instructions for use

- Before pouring concrete, secure the cover cap in place, thereby preventing the flow of concrete into the cast-in device
- Do not use for wall applications

Concrete floor with metal decking

For concrete floor with metal decking applications use the correct size CP 680 Metal Deck Adapter for installed cast-in device and follow the illustrations.

Concrete floor

Installation option

Follow the illustrations if CP 680 has to be cut to slab thickness before installation, or when riser clamps are used.

Hilti. Outperform. Outlast.

LABELED DOOR SIZES AND TYPES

TECHNICAL DATA SHEET No. 405

Single Doors

- Doors may be fabricated from cold rolled or galvanized steel.
- 20 gage, 18 gage or 16 gage "Unifit" Doors can be labeled after the appropriate preparations are added by an authorized U.L. or W.H. warehouse or distributor. Maximum size 20 gage Unifit door is 3072.
- DE 418 and 420 Doors may be full flush or (6) panel embossed design. Six panel doors are available as insulated only.

Door Type	Maximum Size	Rating Available
DE 820	3072 (914 x 2184)	1 1/2 Hr., 3/4 Hr., 20 Min.
DE 818	3072 (914 x 2184)	1 1/2 Hr., 3/4 Hr., 20 Min.
DM 820	3072 (914 x 2184)	1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 420	4080 (1219 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 418	40100 (1219 x 3048)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 416	40100 (1219 x 3048)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE 414	40100 (1219 x 3048)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE 420 (Insulated)	3072 (914 x 2184)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 418 (Insulated)	4080 (1219 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 416 (Insulated)	4080 (1219 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 420 (Temp. Rise)	3072 (914 x 2184)	3 Hr., 1 1/2 Hr., 3/4 Hr.
DE & DL 418 (Temp. Rise)	4080 (1219 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr.
DS 418	4080 (1219 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DS 416	50100 (1524 x 3048)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DS 414	50100 (1224 x 3048)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DM 420	4070 (1219 x 2134)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DM 418	4070 (1219 x 2134)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
UNIFIT™	4080 (1219 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.

Dutch Doors

Door Type	Maximum Size	Rating Available
DL 420	3072 (914 x 2184)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DL 418	4072 (1219 x 2184)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE 420	3072 (914 x 2184)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE 418	4072 (1219 x 2184)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.

- Dutch Doors must have an astragal attached to the top leaf.
- A half shelf is optional.
- Lock provision may be for either cylindrical or mortise lock sets.
- Louvers are not permitted.
- Glass lights are permitted in 1-1/2 hr., 3/4 hr. and 20 min. rated doors.

Double Egress Doors

- Surface mounted or concealed vertical rod device hardware is required on each leaf.
- All series doors exceeding 1 1/2 hr. rating require an astragal.
- Glass lights are permitted up to 100 sq. in. of exposed glass per leaf in 1 1/2 hr. rated doors and 1296 sq. in. of exposed glass per light in 3/4 hr. rated doors.

Door Type	Maximum Size	Rating Available
DM 418	8080 (2438 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 420	8080 (2438 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 418	8080 (2438 x 2438)	1 1/2 Hr., 3/4 Hr., 20 Min.
DE & DL 416	8080 (2438 x 2438)	1 1/2 Hr., 3/4 Hr., 20 Min.
DE 418 (Insulated)	8080 (2438 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.
DE 420 (Insulated)	8080 (2438 x 2438)	3 Hr., 1 1/2 Hr., 3/4 Hr., 20 Min.

Doors with Fusible Link Louvers

Door Type	Maximum Size	Label Available
DM 420	3072 (914 x 2184)	1 1/2 Hr., 3/4 Hr.
DL 418	3672 (914 x 2184)	1 1/2 Hr., 3/4 Hr.
DE & DL 420	3072 (1067 x 2184)	1 1/2 Hr., 3/4 Hr.
DE & DL 418	3672 (1067 x 2184)	1 1/2 Hr., 3/4 Hr.
DE 416	3672 (1067 x 2184)	1 1/2 Hr., 3/4 Hr.

- Maximum louver size: one 24" (610) x 24" (610) per door leaf. Not available with glass lites or fire exit hardware.

Revised 9/14

High performance intumescent firestop sealant FS-ONE MAX

Product description

- Intumescent (expands when exposed to fire) firestop sealant that helps protect combustible and non-combustible penetrations for up to 4 hours fire rating

Applications

- Effectively seals most common through penetrations in a variety of base materials
- For use on concrete, masonry and drywall
- Mixed and multiple penetrations
- Metal pipe penetrations
- Insulated metal pipe penetrations
- Plastic pipe penetrations
- Cable bundles and trays
- HVAC penetrations

Advantages

- One product for a variety of common through penetrations
- Cost-effective and easy-to-use solution
- Water-based and paintable
- W-rated systems available
- Ethylene glycol-free
- Industry leading VOC results
- Convenient multi application firestop solution for penetrations

Technical Data*

Chemical basis	Water-based acrylic dispersion
Color	Red
Application temperature	41°F to 104°F
Storage and transportation range	41°F to 77°F
Approx. cure time *	4 mm / 3 days
Shelf life	12 months **
Temperature resistance range	-4°F to 212°F
Mold and mildew performance	Class 0 (ASTM G21-13)
Mold and mildew resistant	Yes
Surface burning characteristics (ASTM E 84-14)	Flame Spread: 0 Smoke Development: 10
Approvals	California State Fire Marshal - in progress
Tested in accordance with	ASTM G21 ASTM E 90 CAN/ULC-S115 UL 1479 ASTM E 814 ASTM E84

* At 75°F (24°C) and 50% relative humidity

** from date of manufacture

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MS-9200UDLS(E) Rev 3

Intelligent Addressable FACP with Built-In Communicator

Addressable Fire Alarm Control Panel

General

The Fire•Lite MS-9200UDLS Rev 3 with Version 5.0 firmware is a combination FACP (Fire Alarm Control Panel) and DACT (Digital Alarm Communicator/Transmitter) all on one circuit board. This compact intelligent addressable control panel has an extensive list of powerful features.

While the MS-9200UDLS Rev 3 may be used with an SLC configured in the CLIP (Classic Loop Interface Protocol) mode, it can also operate in LiteSpeed™ mode—Fire•Lite's latest polling technology—for a quicker device response time. LiteSpeed's patented technology polls 10 devices at a time. This improvement allows a fully-loaded panel with up to 198 devices to report an incident and activate the notification circuits in under 10 seconds. With Litespeed polling, devices can be wired on standard twisted, unshielded wire up to a distance of 10,000 feet.

The MS-9200UDLS Rev 3's quick-remove chassis protects the electronics during construction. The backbox can be installed allowing field wiring to be pulled. When construction is completed, the electronics can be quickly installed with just two bolts.

New features for Rev 3 with Version 5.0 firmware include removable terminal blocks, improved transient protection, additional secondary ANN-BUS, and increased power for the resettable and remote sync outputs.

Available accessories include ANN-BUS devices as well as ACS LED, graphic and LCD annunciators, and reverse polarity/city box transmitter.

The integral DACT transmits system status (alarms, supervisory, troubles, AC loss, etc.) to a Central Station via the public switched telephone network. It also allows remote and local programming of the control panel using the PS-Tools Upload/Download utility. In addition, the control panel may be programmed or interrogated off-site via the public switched telephone network. Any personal computer with Windows® XP or greater, a compatible modem, and PS-Tools—the Fire•Lite Upload/Download software kit—may serve as a Service Terminal. This allows download of the entire program or upload of the entire program, history file, walktest data, current status and system voltages. The panel can also be programmed through the FACP's keypad or via a standard PS-2 computer keyboard, which can be plugged directly into the printed circuit board. This permits easy typing of address labels and other programming information.

Version 5.0 firmware supports the following: Primary and Secondary ANN-bus devices, AD355 (LiteSpeed), USB port, NAC circuit diagnostics, a new report has been added to the walktest that lists untested devices, new device types added: audio telephone type code for ACC 25/50ZST, Photo Supervisory and auto-resettable Drill (non-latching).

The FireWatch Series internet monitoring modules IPDACT-2 and IPDACT-2UD permit monitoring of alarm signals over the Internet saving the monthly cost of two dedicated business telephone lines. Although not required, the secondary telephone line may be retained providing backup communication over the public switched telephone line.

NOTE: Unless otherwise specified, the term MS-9200UDLS is used in this document to refer to both the MS-9200UDLS and the MS-9200UDLS(E) FACP's (Fire Alarm Control Panels).

Features

- Listed to UL standard 864, 9th edition.
- On-board DACT.
- Remote site or local USB port upload/download, using PS-Tools.
- Four (4) Style Y (Class B) NAC circuits, which can be converted to four (4) Style Z (Class A) circuits with optional ZNAC-92 converter module. (Up to 6.0 amps total NAC power when using optional XRM-24B.)
- Selectable strobe synchronization for System Sensor, Wheelock, and Gentex devices.
- Remote Acknowledge, Silence, Reset and Drill via addressable monitor modules or LCD-80F, ANN-80 or Legacy ACS Annunciators.
- ANN-BUS for connection to following optional modules (cannot be used if ACS annunciators are used):
 - ANN-80(-W) Remote LCD Annunciator
 - ANN-I/O LED Driver
 - ANN-S/PG Printer Module
 - ANN-RLY Relay Module
 - ANN-LED Annunciator Module
 - ANN-RLED Annunciator Module alarms only
 - ROME Relay Option Module Enclosure
- ACS/TERM:
 - ACS Annunciators: Up to 32 Legacy ACM Series annunciators (ACM-16AT or ACM-32 series). Cannot be used if ANN-BUS devices are used.
 - Terminal-mode Annunciators: Up to 32 Legacy LCD-80F remote annunciators.

- EIA-232 printer/PC interface (variable baud rate) on main circuit board, for use with optional UL-listed printer PRN-6F.
- Integral 80-character LCD display with backlighting.
- Real-time clock/calendar with automatic daylight savings control.
- Detector sensitivity test capability (NFPA 72 compliant).
- History file with 1,000-event capacity.
- Maintenance alert warns when smoke detector dust accumulation is excessive.
- Automatic device type-code verification.
- One person audible or silent walk test with walk-test log and printout.
- Point trouble identification.
- Waterflow (nonsilenceable) selection per monitor point.
- System alarm verification selection per detector point.
- PAS (Positive Alarm Sequence) and presignal delay per point (NFPA 72 compliant).

NOTE: Only detectors may participate in PAS.

SLC LOOP:

- SLC can be configured for NFPA Style 4, 6, or 7 operation.
- SLC supports up to 198 addressable devices per loop (99 detectors and 99 monitor, control, or relay modules).
- SLC loop maximum length 10,000 ft. (3,000 m.).
See *installation manual for wire tables*.

NOTIFICATION APPLIANCE CIRCUITS (NACS):

- Four onboard NACs with additional NAC capability using output control modules (CMF-300 or CMF-300-6). The four Class B NACs can be converted to four Class A NACs with optional ZNAC-92 converter module.
- Silence Inhibit and Auto Silence timer options.
- Continuous, March Time, Temporal or California code for main circuit board NACs with two-stage capability.
- Selectable strobe synchronization per NAC.
- 2.5 amps maximum per each NAC circuit.

NOTE: Maximum 24VDC system power output is shared among all NAC circuits and 24VDC special-application auxiliary power outputs. Total available output is 3.0 amps. Using the optional XRM-24B transformer increases 24VDC output to 6.0 amps.

PROGRAMMING AND SOFTWARE:

- Autoprogram (learn mode) reduces installation time.
- Custom English labels (per point) may be manually entered or selected from an internal library file.
- Three Form-C relay outputs (two programmable).
- 99 software zones.
- Continuous fire protection during online programming at the front panel.
- Program Check automatically catches common errors not linked to any zone or input point.
- **OFFLINE PROGRAMMING:** Create the entire program in your office using a Windows®-based software package (order programming kit PS-Tools, separately). Upload/download system programming locally to the MS-9200UDLS Rev 3 in less than one minute.
- USB upload/download programming with standard Male-A to Male-B cable.

User Interface

LED INDICATORS

- AC Power (green)
- Fire Alarm (red)

- Supervisory (yellow)
- Alarm Silenced (yellow)
- System Trouble (yellow)
- Maintenance/Presignal (yellow)
- Disabled (yellow)
- Battery Fault (yellow)
- Ground Fault (yellow)

KEYPAD CONTROLS

- Acknowledge/Step
- Alarm Silence
- Drill
- System Reset (lamp test)
- 16-key alpha-numeric pad (similar to telephone keypad)
- 4 cursor keys
- Enter

Product Line Information

MS-9200UDLS: 198-point addressable Fire Alarm Control Panel, one SLC loop. Includes 80-character LCD display, single printed circuit board mounted on chassis, and cabinet. 120 VAC operation.

MS-9200UDLSE: Same as **MS-9200UDLS**, except with 240 VAC operation.

4XTMF Reverse Polarity Transmitter Module: Provides supervised output for local energy municipal box transmitter, alarm, and trouble.

ZNAC-92: Optional converter module which converts four (4) Style Y (Class B) NAC circuits to four (4) Style Z (Class A) circuits.

PK-CD Programming software for Windows®-based PC computer (cable not included), available on www.firelite.com.

DP-9692: Optional dress panel for MS-9200UDLS Rev 3.

TR-CE: Optional trim Ring for semi-flush mounting.

BB-26: Battery backbox, holds up to two 25 AH batteries and CHG-75.

BB-55F: Battery box, houses two 55 AH batteries.

CHG-75: Battery charger for lead-acid batteries with a rating of 25 to 75 AH.

CHG-120F: Remote battery charging system for lead-acid batteries with a rating of 55 to 120 AH. Requires additional BB-55F for mounting.

BAT Series: Batteries, see data sheet DF-52397.

XRM-24B(E): Optional transformer. Increases system power output to 6.0 amps. Use XRM-24BE with MS-9200UDLS Rev 3(E).

PRT/PK-CABLE: Cable printer/personal computer interface cable; required for printer or for local upload/download programming and updating panel firmware.

PRN-6F: UL listed compatible event printer. Uses tractor-fed paper.

IPDACT-2/2UD, IPDACT Internet Monitoring Module: Mounts in bottom of enclosure with optional mounting kit (PN IPBRKT). Connects to primary and secondary DACT telephone output ports for internet communications over customer provided ethernet internet connection. Requires compatible Teldat VisorALARM Central Station Receiver. Can use DHCP or static IP. (See data sheet DF-60407 or DF-52424 for more information.)

IPBRKT: Mounting kit for IPDACT-2/2UD in common enclosure.

IPSPLT: Y-adaptor option allows connection of both panel dialer outputs to one IPDACT-2/2UD cable input.

COMPATIBLE ANNUNCIATORS

ANN-80(-W): LCD Annunciator is a remote LCD annunciator that mimics the information displayed on the FACP LCD display. Recommended wire type is un-shielded. (Basic model is red; order -W version for white; see DF-52417.)

ANN-LED: Annunciator Module provides three LEDs for each zone: Alarm, Trouble and Supervisory. Ships with red enclosure (see DF-60241).

ANN-RLED: Provides alarm (red) indicators for up to 30 input zones or addressable points. (See DF-60241).

ANN-RLY: Relay Module, which can be mounted inside the cabinet, provides 10 programmable Form-C relays. (See DF-52431.)

ROME: Relay Option Module Enclosure. Provides one **ANN-RLY** Relay Module already installed. The ROME Series provides mounting space for one additional Relay Module or one addressable Multi-module. (See *Installation Sheet PN 53530*.)

ANN-S/PG: Serial/Parallel Printer Gateway module provides a connection for a serial or parallel printer. (See DF-52429.)

ANN-I/O: LED Driver Module provides connections to a user supplied graphic annunciator. (See DF-52430.)

ACM-8RF: Relay module provides 8 Form-C 5.0 amp relays.

ACS-LED Zone Series: LED-type fire annunciators capable of providing up to 99 software zones of annunciation. Available in increments of 16 or 32 points to meet a variety of applications.

LDM Graphic Series: Lamp Driver Module series for use with custom graphic annunciators.

LCD-80F (Liquid Crystal Display) point annunciator: 80-character, backlit LCD-type fire annunciators capable of displaying English-language text.

NOTE: For more information on Compatible Annunciators for use with the MS-9200UDLS Rev 3, see the following data sheets (document numbers) *ACM-8RF (DF-51555)*, *ACS/ACMSeries (DF-52378)*, *LDM Series (DF-51384)*, *LCD-80F (DF-52185)*.

LITESPEED COMPATIBLE ADDRESSABLE DEVICES

All feature a polling LED and rotary switches for addressing.

CP355: Addressable low-profile ionization smoke detector.

SD355: Addressable low-profile photoelectric smoke detector.

SD355T: Addressable low-profile photoelectric smoke detector with thermal sensor.

SD355R: Addressable remote test capable detector for use with D355PL or DNR(W) duct smoke detector housings.

H355: Fast-response, low-profile heat detector.

H355R: Fast-response, low-profile heat detector with rate-of-rise option.

H355HT: Fixed high-temperature detector that activates at 190F/88C.

AD355(A): Low-profile, intelligent, "Adapt" multi-sensor detector (B350LP base included).

BEAM355: Intelligent beam smoke detector.

BEAM355S: Intelligent beam smoke detector with integral sensitivity test.

D355PL: Innovair Flex low-flow non-relay duct-detector housing. SD355R included.

DNRW: Innovair Flex low-flow non-relay duct-detector housing, with NEMA-4 rating. Watertight. (Order SD355R separately.)

MMF-300: Addressable Monitor Module for one zone of normally-open dry-contact initiating devices. Mounts in standard 4.0" (10.16 cm.) box. Includes plastic cover plate and end-of-line resistor. Module may be configured for either a Style B (Class B) or Style D (Class A) IDC.

MDF-300: Dual Monitor Module. Same as MMF-300 except it provides two Style B (Class B) only IDCs.

MMF-301: Miniature version of MMF-300. Excludes LED and Style D option. Connects with wire pigtails. May mount in device backbox.

MMF-302: Similar to MMF-300, but may monitor up to 20 conventional two-wire detectors. Requires resettable 24 VDC power. Consult factory for compatible smoke detectors.

CMF-300: Addressable Control Module for one Style Y/Z (Class B/A) zone of supervised polarized Notification Appliances. Mounts directly to a 4.0" (10.16 cm.) electrical box. Notification Appliance Circuit option requires external 24 VDC to power notification appliances.

CRF-300: Addressable relay module containing two isolated sets of Form-C contacts, which operate as a DPDT switch. Mounts directly to a 4.0" (10.16 cm.) box, surface mount using the SMB500.

BG-12LX: Addressable manual pull station with interface module mounted inside.

I300: Fault Isolator Module. This module isolates the SLC loop from short circuit conditions (required for Style 6 or 7 operation).

SMB500: Used to mount all modules except the MMF-301 and M301.

MMF-300-10: Ten-input monitor module. Mount one or two modules in a BB-2F cabinet (optional). Mount up to six modules on a CHS-6 chassis in a BB-6F.

MMF-302-6: Six-zone interface module for compatible conventional two-wire detectors. Mount one or two modules in a BB-2F cabinet (optional). Mount up to six modules on a CHS-6 chassis in a BB-6F.

CMF-300-6: Six-circuit supervised control module. Mount one or two modules in a BB-2F cabinet (optional). Mount up to six modules on a CHS-6 chassis in a BB-6F.

CRF-300-6: Six Form-C relay control module. Mount one or two modules in a BB-2F cabinet (optional). Mount up to six modules on a CHS-6 chassis in a BB-6F.

NOTE: 1) For more information on Compatible Addressable Devices for use with the MS-9200UDLS Rev 3, see the following data sheets (document numbers): AD355 (DF-52324), BG-12LX (DF-52013), CMF-300-6 (DF-52365), CRF-300-6 (DF-60379), CMF/CRF Series (DF-52130), CP355 (DF-52383), D355PL (DF-52398), H355 Series (DF-52385), I300 (DF-52389), MMF-300 Series/MDF-300 (DF-52121), MMF-300-10 (DF-52347), MMF-302-6 (DF-52356), SD355/SD355T (DF-52384). 2) Legacy 300 Series detection devices such as the CP300/CP350, SD300(T)/SD350(T) and older modules such as the M300, M301, M302, C304, and BG-10LX are **not compatible** with LiteSpeed polling. If the SLC contains one of these devices, polling must be set for standard LiteSpeed protocol. Please consult factory for further information on previous 300 Series devices.

Wiring Requirements

While shielded wire is not required, it is recommended that all SLC wiring be twisted-pair to minimize the effects of electrical interference. Wire size should be no smaller than 18 AWG (0.78 mm²) and no larger than 12 AWG (3.1 mm²). The wire size depends on the length of the SLC circuit. Refer to the panel manual for wiring details.

SYSTEM SPECIFICATIONS

System Capacity

- Intelligent Signalling Line Circuits..... 1
- Addressable device capacity 198
- Programmable software zones 99
- ACS Annunciators 32
- ANN-bus devices..... 16

Electrical Specifications

AC Power: MS-9200UDLS Rev 3: 120 VAC, 60 Hz, 3.0 amps. MS-9200UDLS Rev 3E: 240 VAC, 50 Hz, 1.5 amps. Wire size: minimum 14 AWG (2.00 mm²) with 600 V insulation.

Battery charger capacity: 7 AH - 18 AH batteries. Up to two 18 Ah batteries can be housed in the FACP cabinet. Larger batteries require an external battery charger such as the CHG-75 or CHG-120, and a separate battery cabinet such as the BB-26 or NFS-LBB.

Communication Loop: Supervised and power-limited.

Notification Appliance Circuits: Each terminal block provides connections for two Style Y (Class B) for a total of four Style Y (Class B) or with an optional ZNAC-92 module converts to four Style Z (Class A) NACs. Maximum signaling current per circuit: 2.5 amps. End-of-Line Resistor: 4.7K ohm, 1/2 watt (P/N 71252 UL listed) for Style Y (Class B) NAC. Refer to panel documentation and *Fire•Lite Device Compatibility Document* for listed compatible devices.

Two Programmable Relays and One Fixed Trouble Relay: Contact rating: 2.0 amps @ 30 VDC (resistive), 0.5 amps @ 30 VAC (resistive). Form-C relays.

Special Application Non-resettable Power (24 VDC Nominal): Jumper selectable (JP4) for conversion to resettable power output. Up to 1.0 amp total DC current available from each output. Power-limited.

Special Application Resettable Power (24 VDC nominal): Jumper selectable (JP6) for conversion to non-resettable power. Up to 1.0 amp total DC current available. Refer to the *Fire•Lite Device Compatibility Document* for listed compatible devices.

Remote Sync Output: Remote power supply synchronization output. Nominal special application power: 24 VDC. Maximum current: 300 mA. End-of-Line Resistor: 4.7K ohm. Output linked to NAC 1 control. Supervised and power-limited.

Telephone Interface: Unless used with Teldat VISORALARM, requires dedicated business telephone number with a minimum of 5 volts DC (off-hook voltage). Obtain dedicated phone line directly from your local phone company. Do not use shared phone lines or PBX (digital) type phone line extensions.

Cabinet Specifications

Door: 19.26" (48.92 cm.) high x 16.82" (42.73 cm.) wide x 0.12" (.30 cm.) deep. **Backbox:** 19.00" (48.26 cm.) high x

16.65" (42.29 cm.) wide x 5.20" (13.34 cm.) deep. **Trim Ring (TR-CE):** 22.00" (55.88 cm.) high x 19.65" (49.91 cm.) wide.

Shipping Specifications

Weight: 26.9 lbs. (12.20 kg.) **Dimensions:** 20.00" (50.80 cm.) high x 22.5" (57.15 cm.) wide x 8.5" (21.59 cm.) deep.

Temperature and Humidity Ranges

This system meets NFPA requirements for operation at 0 – 49°C/32 – 120°F and at a relative humidity 93% ± 2% RH (noncondensing) at 32°C ± 2°C (90°F ± 3°F). However, the useful life of the system's standby batteries and the electronic components may be adversely affected by extreme temperature ranges and humidity. Therefore, it is recommended that this system and its peripherals be installed in an environment with a normal room temperature of 15 – 27°C/60 – 80°F.

NFPA Standards

The MS-9200UDLS Rev 3 complies with the following NFPA 72 Fire Alarm Systems requirements:

- **LOCAL** (Automatic, Manual, Waterflow and Sprinkler Supervisory).
- **AUXILIARY** (Automatic, Manual and Waterflow) (requires 4XTMF).
- **REMOTE STATION** (Automatic, Manual, Waterflow and Sprinkler Supervisory) (Where a DACT is not accepted, the alarm, trouble and supervisory relays may be connected to UL 864 listed transmitters. For reverse polarity signaling of alarm and trouble, 4XTMF is required.)
- **PROPRIETARY** (Automatic, Manual, Waterflow and Sprinkler Supervisory).
- **CENTRAL STATION** (Automatic, Manual, Waterflow and Sprinkler Supervisory).
- **OT, PSDN** (Other Technologies, Packet-switched Data Network)

Agency Listings and Approvals

The listings and approvals below apply to the basic MS-9200UDLS Rev 3 control panel. In some cases, certain modules may not be listed by certain approval agencies, or listing may be in process. Consult factory for latest listing status.

- **UL Listed:** S624
- **FM approved**
- **CSFM:** 7165-0075:0208
- **MEA:** 120-06-E

For ULC-listed version, see DF-60599.

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For more information, contact Fire•Lite Alarms. Phone: (800) 627-3473, FAX: (877) 699-4105.
www.firelite.com

Made in the U.S.A.

Features

- Photoelectric smoke and fixed temperature heat sensor
- Wide sensitivity range of 1.05 to 3.82%/foot
- 135° Fahrenheit restorable heat detector
- Sensor communicates sensitivity to control panel
- UL listed smoke calibration and sensitivity
- Optional locking tab to prevent unwanted removal
- Simple and accurate address setting without mechanical switches
- LED for 360° viewing

Product includes a 5 year warranty

Description

The combination Photoelectric Smoke/Heat Sensor is a listed Analog/Addressable smoke sensor and fixed temperature heat sensor compatible with any fire alarm control panel that has the Potter/Nohmi protocol. The PSHA is a low profile combination smoke/heat sensor with a wide sensitivity range. The heat sensing portion utilizes a proven thermistor for accurate and reliable heat detection. The sensor and base (not included) are made of a durable plastic in an eggshell white (off white) to blend in with the ceiling.

The PSHA has a sensitivity range of 1.05 to 3.82% per foot and is UL and cUL listed. The PSHA is also a 135° Fahrenheit restorable heat sensor. The PSHA can be configured for drift compensation and has built in dirty detector warning as well as. The PSHA and the control panel communicate over a proven and robust digital communication path and the system analyzes the level of alarm at the particular device. The total polling speed is less than five (5) seconds, well under the UL requirements. The PSHA is listed to both UL 268 Smoke Detection Standard and UL 521 Heat Detection Standard.

The PSHA has a single LED that allows for 360° viewing. The sensor is compatible with any of the Potter/Nohmi bases and simply twists on. The PSHA is addressed using the hand held programmer or the control panel addressing function.

Air Velocity Ratings

The PSHA has an Open Area of Protection air velocity rating of 0 to 300 feet per minute.

The system has a maximum of 13 LEDs that can be turned on simultaneously. If the system already has 13 LEDs on, the PSHA will operate even though the LED will not illuminate.

Setting the Address

Each addressable module, smoke sensor, heat detector and combination sensor/detector must have the address set before connecting the device to the SLC loop. The address is set using the hand held device programmer or the addressing feature on the control panel.

Before connecting a device to the SLC loop, take the following precautions to prevent potential damage to SLC or device. Verify the following:

1. Power to the device is removed
2. Field wiring is correctly installed.
3. Field wiring has no open or short circuits.

Document discrepancies and notify appropriate personnel.

Specifications

Item	PSHA
Working voltage range	22.0 to 24.0 V
Standby current	325 μ A
Alarm indicator	1 LED
Alarm indicator current	1.2 mA D.C.
Alarm set-point range	1.05 to 3.82 %/ft / 3.4 to 12.0 %/m
Installation temperature range	32 to 115 ° F / 0 to 46 ° C
Heat Alarm Point	135 ° F
Operating relative humidity range	0% to 93% (Non-condensing)
Start-up time	Max. 1 sec.
Maximum number of addresses per loop	127
Maximum number of lighted indicators in alarm per zone.	13
Color	Eggshell White
Weight (without base)	85g (2.99 oz)
Dimensions (without base)	Height: 1.69 in (43 mm) Diameter: 4.0 inches (99 mm)
Approvals / Listings	UL, cUL, CSFM

Operation

The PSHA is an analog/addressable combination sensor that uses one address on the Signaling Line Circuit (SLC) of a compatible fire alarm control panel. The unit communicates with the control panel as it is polled. The LED flashes every time the unit is polled and they will latch steady if the unit is in an active status.

The PSHA is a proven design being in service throughout the world. The PSHA with the AB-4 or AB-6 base has a low profile of about two (2) inches to blend into the surrounding environment. The sensor includes an insect screen to prevent foreign objects from reaching the chamber and the entire unit can be cleaned with a simple vacuum. The thermistor provides reliable heat detection at a fixed temperature. The unit is reusable

Sensor Sensitivity

The PSHA and the compatible control panel work in tandem to keep the sensitivity consistent. As the sensor is installed over time, the sensor compensates for the dirt in the unit until it is out of range. At that time, the panel will indicate a dirty sensor. The sensor will then have to be cleaned or replaced.

Anytime the PSHA is being polled, the sensitivity may be viewed or printed from the control panel.

Note: As required by NFPA, do not install the sensors until all construction is complete and the work area has been thoroughly cleaned. If the sensors have been installed in a construction environment, they should be cleaned or replaced before the system is placed into service.

Spacing

The PSHA is UL/ULC listed with a recommended maximum spacing of 30 feet. Refer to NFPA 72 for specific information regarding detector spacing, placement and special applications.

Compatible Bases

All bases will mount on a single gang, double gang, octagon, 4" square or mud ring electrical box.

Device	Description
AB-4	4" Standard Base
AB-6	6" Standard Base
AIB	6" base with an isolator module included. The base is pre-wired with a pluggable jumper to the module.
ARB	6" base with a dual relay module included. One relay is rated for 8 amps at 240 VAC/30 VDC and the second is rated for 2 amps at 240 VAC/30 VDC. The base is pre-wired with a pluggable jumper to the module.
ASB	6" base with sounder module included. Sound pattern is provided from external source. The base is pre-wired with a pluggable jumper into the module.

Exceder Strobe, Horn Strobe, and Horn Notification Appliances

Description

The Wheelock Exceder Series of notification appliances feature a sleek modern design that will please building owners with reduced total cost of ownership. Installers will benefit from its comprehensive feature list, including the most candela options in one appliance, low current draw, no tools needed for setting changes, voltage test points, 12/24 VDC operation, universal mounting base and multiple mounting options for both new and retrofit construction.

The Wheelock Exceder Series incorporates high reliability and high efficiency optics to minimize current draw allowing for a greater number of appliances on the notification appliance circuit. All strobe models feature an industry first of 8 candela settings on a single appliance. Models with an audible feature 3 sound settings (90, 95, 99 dB). All switches to change settings, can be set without the use of a tool and are located behind the appliance to prevent tampering. Wall models feature voltage test points to take readings with a voltage meter for troubleshooting and AHJ inspection.

The Wheelock Exceder Series of wall and ceiling notification appliances feature a Universal Mounting Base (UMB) designed to simplify the installation and testing of horns, strobes, and combination horn strobes. The separate universal mounting base can be pre-wired to allow full testing of circuit wiring before the appliance is installed and the surface is finished. It comes complete with a Contact Cover for protection against dirt, dust, paint and damage to the contacts. The Contact Cover also acts as a shunting device to allow pre-wire testing for common wiring issues. The Contact Cover is polarized to prevent it from being installed incorrectly and prevents the appliance from being installed while it is on the UMB. When the Contact Cover is removed the circuit will show an open until the appliance is installed. The UMB allows for consistent installation and easy replacement of appliances if required. Wall models provide an optional locking screw for extra secure installation, while the ceiling models provide a captivated screw to prevent the screw from falling during installation.

EAT•N

Powering Business Worldwide

Features

- Sleek modern aesthetics
- Finger slide switches
- Voltage test points
- Multiple voltages
- **3 Audible settings**
 - **90, 95, 99 dB**
- Industry leading—8 candela settings on 1 device
 - **Wall: 15/1575/30/75/95/110/135/185**
 - **Ceiling: 15/30/60/75/95/115/150/177**

- Universal mounting base
 - **Ceiling and wall**
- Mounts to 5 backbox types: 1 gang, 2 gang, 4" square, 3.5" octal. & 4" octal. (100mm for international customers)

Universal mounting base

Contact cover

Common base for wall and ceiling with 5 mounting options

- Voltage test points for quick troubleshooting and easy spot checking (wall models only)

- Environmentally friendly
 - Low current draw
- Up to 9 models now in 1 appliance draw^①
- 12/24VDC on a single appliance
- Easy to remember model numbers

^① Patented

Note: All CAUTIONS and WARNINGS are identified by the symbol ▲. All warnings are printed in bold capital letters.

▲ WARNING

PLEASE READ THESE SPECIFICATIONS AND ASSOCIATED INSTALLATION INSTRUCTIONS CAREFULLY BEFORE USING, SPECIFYING OR APPLYING THIS PRODUCT. VISIT WWW.COOPERNOTIFICATION.COM OR CONTACT COOPER NOTIFICATION FOR THE CURRENT INSTALLATION INSTRUCTIONS. FAILURE TO COMPLY WITH ANY OF THESE INSTRUCTIONS, CAUTIONS OR WARNINGS COULD RESULT IN IMPROPER APPLICATION, INSTALLATION AND/OR OPERATION OF THESE PRODUCTS IN AN EMERGENCY SITUATION, WHICH COULD RESULT IN PROPERTY DAMAGE, AND SERIOUS INJURY OR DEATH TO YOU AND/OR OTHERS.

General Notes

- Strobes are designed to flash at 1 flash per second minimum over their "Regulated Voltage Range".
- All candela ratings represent minimum effective strobe intensity based on UL Standard 1971.
- Series Exceder Strobe products are Listed under UL Standards 1971 and 464 for indoor use with a temperature range of 32°F to 120°F (0°C to 49°C) and maximum humidity of 93% (± 2%) UL 464 (85% UL 1971).
- Series Exceder horns are under UL Standard 464 for audible signal appliances (Indoor use only).

Compatibility and requirements

- Synchronize using the Wheelock® Sync Modules or panels with built-in Wheelock® Patented Sync Protocol
- Compatible with UL "Regulated Voltage" using filtered VDC or unfiltered VRMS input voltage
- Strobes produce 1 flash per second over the "Regulated Voltage" range

Compliance

- UL 1971, UL 464, ULC, CSFM, FM
- ADA/NFPA/ANSI/OSHA
- RoHS

Table 1. Strobe Ratings per UL Standard 1971

		UL Max Current ^①													
		24 VDC / 24 FWR												12 VDC	
Model	Regulated Voltage Range VDC	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
ST	8.0-33.0	0.057	0.070	0.085	—	0.135	0.163	0.182	—	0.205	—	—	0.253	0.110	0.140
STC	8.0-33.0	0.061	—	0.085	0.103	0.135	0.163	—	0.182	—	0.205	0.253	—	0.110	—

Table 2. Horn Strobe Ratings per UL 1971 & Anechoic at 24 VDC

		UL Max Current ^① at Anechoic 99 dBA													
		24 VDC												12 VDC	
Model	Regulated Voltage Range VDC	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
HS	8.0-33.0	0.082	0.095	0.102	—	0.148	0.176	0.197	—	0.242	—	—	0.282	0.125	0.159
HSC	8.0-33.0	0.082	—	0.102	0.141	0.148	0.176	—	0.197	—	0.242	0.282	—	0.125	—

		UL Max Current ^① at Anechoic 95 dBA													
		24 VDC												12 VDC	
Model	Regulated Voltage Range VDC	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
HS	8.0-33.0	0.073	0.083	0.087	—	0.139	0.163	0.186	—	0.230	—	—	0.282	0.122	0.153
HSC	8.0-33.0	0.073	—	0.087	0.128	0.139	0.163	—	0.186	—	0.230	0.272	—	0.122	—

		UL Max Current ^① at Anechoic 90 dBA													
		24 VDC												12 VDC	
Model	Regulated Voltage Range VDC	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
HS	8.0-33.0	0.065	0.075	0.084	—	0.136	0.157	0.184	—	0.226	—	—	0.267	0.120	0.148
HSC	8.0-33.0	0.065	—	0.084	0.120	0.136	0.157	—	0.184	—	0.226	0.267	—	0.120	—

① UL max current rating is the maximum RMS current within the listed voltage range (16-33 VDC for 24 VDC units). For strobes the UL max current is usually at the minimum listed voltage (16 VDC for 24 VDC units). For audibles the max current is usually at the maximum listed voltage (33 VDC for 24 VDC units). For unfiltered ratings, see installation instructions.

Table 3. Horn Ratings per UL Anechoic

Model	Regulated Voltage Range VDC	99 dB	95 dB	90 dB
HN	16-33.0	0.064	0.044	0.022
HNC	16-33.0	0.084	0.044	0.022
HN	8.0-17.5	0.047	0.026	0.017
HNC	8.0-17.5	0.047	0.026	0.017

Table 4. Specification & Ordering Information

Model	Strobe Candela	Sync w/ Wheelock Power Supplies	12/24 VDC ^①	Mounting Options
Horn Strobes				
HSR	15/1575/30/75/95/110/135/185	X	X	UMB ^②
HSW	15/1575/30/75/95/110/135/185	X	X	UMB ^②
HSRC	15/30/60/75/95/115/150/177	X	X	UMB ^②
HSWC	15/30/60/75/95/115/150/177	X	X	UMB ^②
Strobes				
STR	15/1575/30/75/95/110/135/185	X	X	UMB ^②
STW	15/1575/30/75/95/110/135/185	X	X	UMB ^②
STRC	15/30/60/75/95/115/150/177	X	X	UMB ^②
STWC	15/30/60/75/95/115/150/177	X	X	UMB ^②
Horn				
HNR		X	X	UMB ^②
HNW		X	X	UMB ^②
HNRC		X	X	UMB ^②
HNWC		X	X	UMB ^②

① 12 VDC models feature 15 & 15/75 settings

② UMB = Universal Mounting Base

Model Legend

HN	=	Horn	R	=	Red
ST	=	Strobe	A	=	Agent Lettering (strobes only)
HS	=	Horn Strobe	AL	=	Alert Lettering (strobes only)
C	=	Ceiling Mount	N	=	No Lettering (strobes only)
W	=	White			

Example 1: STRC = Strobe, Red, Ceiling Mount

Example 2: HSR = Horn Strobe, Red, Wall Mount

Example 3: HSW = Horn Strobe, White, Wall Mount

Example 4: STW-AL = Strobe, White, Wall Mount, Alert Lettering

Example: HSR

Example: HSWC

Architects and Engineers Specifications

The notification appliances shall be Wheelock Exceder Series HS Audible Strobe appliances, Series ST Visual Strobe appliances and Series HN Audible appliances or approved equals. The Series HS and ST Strobes shall be listed for UL Standard 1971 (Emergency Devices for the Hearing-Impaired) for Indoor Fire Protection Service. The Series HS and HN Audibles shall be UL Listed under Standard 464 (Fire Protective Signaling). All Series shall meet the requirements of FCC Part 15 Class B. All inputs shall be compatible with standard reverse polarity supervision of circuit wiring by a Fire Alarm Control Panel (FACP) with the ability to operate from 8 to 33 VDC. Indoor wall models shall incorporate voltage test points for easy voltage inspection.

The Series HS Audible Strobe and ST Strobe appliances shall produce a flash rate of one (1) flash per second over the Regulated Voltage Range and shall incorporate a Xenon flashtube enclosed in a rugged Lexan® lens. The Series shall be of low current design. Where multi-candela appliances are specified, the strobe intensity shall have 8 field selectable settings at 15, 15/75, 30, 75, 95, 110, 135, 185 candela for wall mount and 15, 30, 60, 75, 95, 115, 150, 177 candela for ceiling mount. The selector switch for selecting the candela shall be tamper resistant. The 15/75 candela strobe shall be specified when 15 candela UL Standard 1971 Listing with 75 candela on-axis is required (e.g., ADA compliance). Appliances with candela settings shall show the candela selection in a visible location at all times when installed.

The audible shall have a minimum of three (3) field selectable settings for dBA levels and shall have a choice of continuous or temporal (Code 3) audible outputs.

The Series HS Audible Strobe, ST Strobe and Series HN Audible shall incorporate a patented Universal Mounting Base that shall allow mounting to a single-gang, double-gang, 4-inch square, 3.5-inch octal, 4-inch octal or 100mm European type back boxes. Two wire appliance wiring shall be capable of directly connecting to the mounting base. Continuity checking of the entire NAC circuit prior to attaching any notification appliances shall be allowed. Product shall come with Contact Cover to protect contact springs. Removal of an appliance shall result in a supervision fault condition by the Fire Alarm Control Panel (FACP). The mounting base shall be the same base among all horn, strobe, horn strobe, wall and ceiling models. All notification appliances shall be backwards compatible.

The Series HS and ST wall models shall have a low profile measuring 5.24" H x 4.58" W x 2.19" D. Series HN wall shall measure 5.24" H x 4.58" W x 1.6" D. The Series HSC and STC shall be round and have a low profile with a diameter of 6.68" x 2.63" D. Series HNC ceiling shall have a diameter of 6.68" x 1.50" D.

When synchronization is required, the appliance shall be compatible with Wheelock's DSM Sync Modules, Wheelock Power Supplies or other manufacturer's panels with built-in Wheelock Patented Sync Protocol. The strobes shall not drift out of synchronization at any time during operation. If the sync protocol fails to operate, the strobe shall revert to a non-synchronized flash-rate and still maintain (1) flash per second over its Regulated Voltage Range. The appliance shall also be designed so that the audible signal may be silenced while maintaining strobe activation when used with Wheelock synchronization protocol.

Wall Appliances: UL Standard 1971, UL Standard 464, California State Fire Marshal (CSFM), ULC, FM, RoHS

Ceiling Appliances: UL Standard 1971, UL Standard 464, California State Fire Marshal (CSFM), ULC, FM, RoHS

Note: Due to continuous development of our products, specifications and offerings are subject to change without notice in accordance with Cooper Wheelock Inc., dba Cooper Notification standard terms and conditions.

WE ENCOURAGE AND SUPPORT NICET CERTIFICATION
3 YEAR WARRANTY

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BAT Series Batteries

Sealed Lead-Acid

Power Supplies/Accessories

General

BAT Series Batteries are Power Sonic brand batteries. BAT Series (or Power Sonic brand) batteries are recommended for secondary power or backup power for all Fire•Lite fire alarm control equipment.

Features

- Provide secondary power for control panels.
- Sealed and maintenance-free.
- Overcharge protected.
- Easy handling with leakproof construction.
- Ruggedly constructed, high-impact case (ABS, polystyrene, or polypropylene, depending on models).
- Long service life.
- Compact design.

Agency Listings and Approvals

The listings and approvals below apply to BAT Series Batteries. In some cases, certain modules may not be listed by certain approval agencies, or listing may be in process. Consult factory for latest listing status.

- **UL Recognized Components:** MH20845 (*Power-Sonic*)

6933cov.jpg

Ordering Information

BAT-1250-BP: 10-unit bulk pack of BAT-1250 (12 V 5 AH)

BAT-1270-BP: 5-unit bulk pack of BAT-1270 (12 V 7 AH)

BAT-12120-BP: 4-unit bulk pack of BAT-12120 (12V 12 AH)

BAT-12180-BP: 2-unit bulk pack of BAT-12180 (12 V 18 AH)

BAT-12260-BP: 2-unit bulk pack of BAT-12260 (12 V 26 AH)

BAT-12550: single battery (12 V 55 AH)

BAT-121000: single battery (12 V 100 AH)

Part Number Reference & Specifications

Part Number	Power Sonic Part Number	Battery Description			DIMENSIONS									
		Nominal Voltage V	Nominal Capacity @ 20 hr. rate A.H.		Width		Depth		Height		Height over terminal		Weight	
					in.	mm	in.	mm	in.	mm	in.	mm	lb.	kg.
BAT-1250	PS-1250	12	5	sealed	3.54	90	2.76	70	4.02	102	4.21	107	4.1	1.9
BAT-1270	PS-1270	12	7	sealed	5.95	151	2.56	65	3.7	94	3.86	98	4.8	2.18
BAT-12120	PS-12120	12	12	sealed	5.95	151	3.86	98	3.7	94	3.94	100	7.92	3.59
BAT-12180	PS-12180	12	18	sealed	7.13	181	2.99	76	6.57	167	6.57	167	12.6	5.8
BAT-12260	PS-12260	12	26	sealed	6.56	167	6.97	177	4.92	125	4.92	125	17	7.71
BAT-12550	PS-12250	12	55	sealed	9.04	230	6.54	138	8.2	208	8.98	228	36	16.33
BAT-121000	PS-121000	12	100	sealed	12	305	6.6	168	8.2	208	8.98	228	68	30.84

at left:
PS-121000
Shelf-Life
and Storage

at left:
PS-121000
Discharge
Characteristics

Fire•Lite® Alarms is a registered trademark of Honeywell International Inc. Batteries display trademarks of the manufacturer.
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This document is not intended to be used for installation purposes.
We try to keep our product information up-to-date and accurate.
We cannot cover all specific applications or anticipate all requirements.
All specifications are subject to change without notice.

For more information, contact Fire•Lite Alarms. Phone: (800) 627-3473, FAX: (877) 699-4105.
www.firelite.com

Series TY-B – 2.8, 5.6, and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers Standard Response, Standard Coverage

General Description

TYCO Series TY-B, 2.8, 5.6, and 8.0 K-factor, Upright and Pendent Sprinklers described in this technical data sheet are standard response, standard coverage decorative 5 mm glass bulb type spray sprinklers designed for use in light, ordinary, or extra hazard, commercial occupancies such as banks, hotels, shopping malls, factories, refineries, and chemical plants.

The recessed version of the Series TY-B Pendent Sprinkler, where applicable, is intended for use in areas with a finished ceiling. It uses a two-piece Style 10 (1/2 inch NPT) or Style 40 (3/4 inch NPT) Recessed Escutcheon. The Recessed Escutcheon provides 1/2 inch (12,7 mm) of recessed adjustment or up to 3/4 inch (19,1 mm) of total adjustment from the flush pendent position. The adjustment provided by the Recessed Escutcheon reduces the accuracy to which the fixed pipe drops to the sprinklers must be cut.

Corrosion resistant coatings, where applicable, are utilized to extend the life of copper alloy sprinklers beyond that which would otherwise be obtained when exposed to corrosive atmospheres. Although corrosion resistant coated sprinklers have passed the standard corrosion tests of the applicable approval agencies, the testing is not representative of all possible corrosive atmospheres. Consequently, it is recommended that the end user be consulted with respect to the suitability of these coatings for any given corrosive environment. The effects of

ambient temperature, concentration of chemicals, and gas/chemical velocity, should be considered, as a minimum, along with the corrosive nature of the chemical to which the sprinklers will be exposed.

An intermediate level version of the Series TY-B Pendent Sprinkler can be obtained by utilizing the Series TY-B Pendent Sprinkler in combination with the Model S2 Shield.

NOTICE

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

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

Sprinkler Identification Numbers (SINs)

TY1151 – Upright 2.8K, 1/2" NPT
TY1251 – Pendent 2.8K, 1/2" NPT
TY3151 – Upright 5.6K, 1/2" NPT
TY3251 – Pendent 5.6K, 1/2" NPT
TY4151 – Upright 8.0K, 3/4" NPT
TY4251 – Pendent 8.0K, 3/4" NPT
TY4851 – Upright 8.0K, 1/2" NPT
TY4951 – Pendent 8.0K, 1/2" NPT

IMPORTANT

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

K	SPRINKLER TYPE	TEMPERATURE RATING	BULB LIQUID COLOR	SPRINKLER FINISH ⁽⁸⁾					
				NATURAL BRASS	CHROME PLATED	POLYESTER***	LEAD COATED	WAX COATED	WAX-OVER-LEAD COATED
2.8 1/2" NPT	UPRIGHT (TY1151) and PENDENT (TY1251) Figure 1	135°F (57°C)	Orange	1, 2, 3			N/A		
		155°F (68°C)	Red						
		175°F (79°C)	Yellow						
		200°F (93°C)	Green						
		286°F (141°C)	Blue						
		360°F (182°C)	Mauve	1, 2					
5.6 1/2" NPT	UPRIGHT (TY3151) and PENDENT (TY3251) Figure 2	135°F (57°C)	Orange	1, 2, 3, 4, 5, 6, 7			1, 2, 3, 5	1, 2, 3, 5	1, 2, 3, 5
		155°F (68°C)	Red						
		175°F (79°C)	Yellow						
		200°F (93°C)	Green						
		286°F (141°C)	Blue					1**, 2**, 3**, 5**	1**, 2**, 3**, 5**
		360°F (182°C)	Mauve					N/A	
	RECESSED PENDENT (TY3251)* Figure 5	135°F (57°C)	Orange	1, 2, 3, 4, 5			N/A		
		155°F (68°C)	Red						
		175°F (79°C)	Yellow						
		200°F (93°C)	Green						
		286°F (141°C)	Blue	1, 2					
8.0 3/4" NPT	UPRIGHT (TY4151) and PENDENT (TY4251) Figure 3	135°F (57°C)	Orange	1, 2, 3, 4, 5, 6, 7			1, 2, 5	1, 2, 3, 5	1, 2, 5
		155°F (68°C)	Red						
		175°F (79°C)	Yellow						
		200°F (93°C)	Green						
		286°F (141°C)	Blue					1**, 2**, 3**, 5**	1**, 2**, 5**
		360°F (182°C)	Mauve					N/A	
	RECESSED PENDENT (TY4251)* Figure 6	135°F (57°C)	Orange	1, 2, 3, 4, 5			N/A		
		155°F (68°C)	Red						
		175°F (79°C)	Yellow						
		200°F (93°C)	Green						
		286°F (141°C)	Blue	1, 2					
8.0 1/2" NPT	UPRIGHT (TY4851) and PENDENT (TY4951) Figure 4	135°F (57°C)	Orange	1, 2, 3, 4, 5, 6			N/A		
		155°F (68°C)	Red						
		175°F (79°C)	Yellow						
		200°F (93°C)	Green						
		286°F (141°C)	Blue						
		360°F (182°C)	Mauve						

Notes:

- Listed by Underwriters Laboratories, Inc. (UL)
 - Listed by Underwriters Laboratories, Inc. for use in Canada (C-UL)
 - Approved by FM Global (FM Approvals)
 - Approved by the Loss Prevention Certification Board (LPCB Ref. No. 007k/03)
 - Approved by the City of New York under MEA 354-01-E
 - VdS Approved (For details contact Tyco Fire Suppression & Building Products, Enschede, Netherlands, Tel. 31-53-428-4444 / Fax 31-53-428-3377)
 - Approved by the Loss Prevention Certification Board (LPCB Ref. No. 094a/05)
 - Where Polyester Coated, Lead Coated, Wax Coated, and Wax-over-Lead Coated Sprinklers are noted to be UL and C-UL Listed, the sprinklers are UL and C-UL Listed as Corrosion-Resistant Sprinklers. Where Lead Coated, Wax Coated, and Wax-over-Lead Coated Sprinklers are noted to be FM Approved, the sprinklers are FM Approved as Corrosion-Resistant Sprinklers.
- * Installed with Style 10 (1/2" NPT) or Style 40 (3/4" NPT) 3/4" Total Adjustment Recessed Escutcheon, as applicable
 ** 150°F (66°C) maximum ceiling temperature
 *** Frame and deflector only
 N/A – Not Applicable

TABLE A
SERIES TY-B UPRIGHT AND PENDENT SPRINKLERS
LABORATORY LISTINGS AND APPROVALS

K	TYPE	SPRINKLER FINISH					
		NATURAL BRASS	CHROME PLATED	POLYESTER*	LEAD COATED	WAX COATED	WAX-OVER-LEAD COATED
2.8 1/2" NPT	UPRIGHT (TY1151) and PENDENT (TY1251)	175 psi (12,1 bar)			N/A		
5.6 1/2" NPT	UPRIGHT (TY3151) and PENDENT (TY3251)	250 psi (17,2 bar) (a) OR 175 psi (12,1 bar)					
	RECESSED PENDENT (TY3251)						
8.0 3/4" NPT	UPRIGHT (TY4151) and PENDENT (TY4251)	175 psi (12,1 bar)					
	RECESSED PENDENT (TY4251)	175 psi (12,1 bar)			N/A		
8.0 1/2" NPT	UPRIGHT (TY4851) and PENDENT (TY4951)	175 psi (12,1 bar)					
Notes: a. The maximum working pressure of 250 psi (17,2 bar) only applies to the Listing by Underwriters Laboratories, Inc. (UL), the Listing by Underwriters Laboratories, Inc. for use in Canada (C-UL), and the Approval by the City of New York. * Frame and deflector only N/A – Not Applicable							
<div>TABLE B</div> <div>SERIES TY-B UPRIGHT AND PENDENT SPRINKLERS</div> <div>MAXIMUM WORKING PRESSURE</div>							

Technical Data

Approvals

UL and C-UL Listed
FM Approved
LPCB Approved
VdS Approved
NYC Approved

(Refer to Table A for complete approval information, including corrosion-resis-tant status.)

Maximum Working Pressure

Refer to Table B.

Discharge Coefficient

K=2.8 gpm/psi^{1/2} (40,3 lpm/bar^{1/2})
K=5.6 gpm/psi^{1/2} (80,6 lpm/bar^{1/2})
K=8.0 gpm/psi^{1/2} (115,2 lpm/bar^{1/2})

Temperature Ratings

Refer to Table A.

Finishes

Sprinkler: Refer to Table C.

Recessed Escutcheon: Signal or Pure White, Jet Black, Chrome Plated, or Natural Brass

Physical Characteristics

Frame Bronze
Button Brass/Copper
Sealing Assembly Beryllium Nickel w/TEFLON
Bulb Glass
Compression Screw Bronze
Deflector Copper
Bushing (K=2.8) Bronze

Operation

The glass bulb contains a fluid which expands when exposed to heat. When the rated temperature is reached, the fluid expands sufficiently to shatter the glass bulb, allowing the sprinkler to activate and water to flow.

Design Criteria

TYCO Series TY-B, 2.8, 5.6, and 8.0 K-factor, Upright and Pendent Sprinklers are intended for fire protection systems designed in accordance with the standard installation rules recognized by the applicable Listing or Approval agency (e.g., UL Listing is based on the requirements of NFPA 13, and FM Approval is based on the requirements of the FM Global Loss Prevention Data Sheets). Only the Style 10 or 40 Recessed Escutcheon, as applicable, is to be used for recessed pendent installations.

FIGURE 5
SERIES TY-B RECESSED PENDENT SPRINKLER ASSEMBLY
WITH TWO-PIECE 3/4 INCH TOTAL ADJUSTMENT
STYLE 10 RECESSED ESCUTCHEON 5.6 K-FACTOR, 1/2 INCH NPT

FIGURE 6
SERIES TY-B RECESSED PENDENT SPRINKLER ASSEMBLY
WITH TWO-PIECE 3/4 INCH TOTAL ADJUSTMENT
STYLE 40 RECESSED ESCUTCHEON 8.0 K-FACTOR, 3/4 INCH NPT

FIGURE 7
W-TYPE 6
SPRINKLER WRENCH

FIGURE 8
W-TYPE 7 RECESSED
SPRINKLER WRENCH

Installation

TYCO Series TY-B, 2.8, 5.6, and 8.0 K-factor, Upright and Pendent Sprinklers must be installed in accordance with this section.

General Instructions

Do not install any bulb type sprinkler if the bulb is cracked or there is a loss of liquid from the bulb. With the sprinkler held horizontally, a small air bubble should be present. The diameter of the air bubble is approximately 1/16 inch (1.6 mm) for the 135°F (57°C) to 3/32 inch (2.4 mm) for the 360°F (182°C) temperature ratings.

A leak-tight 1/2 inch NPT sprinkler joint should be obtained by applying a minimum-to-maximum torque of 7 to 14 ft.-lbs. (9.5 to 19.0 Nm). Obtain a leak-tight 3/4 inch NPT sprinkler joint by applying a minimum to maximum torque of 10 to 20 ft.-lbs. (13.4 to 26.8 Nm). Higher levels of torque may distort the sprinkler inlet and cause leakage or impairment of the sprinkler.

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

Upright and Pendent Sprinklers

The Series TY-B Upright and Pendent Sprinklers must be installed in accordance with the following instructions:

Note: *Install pendent sprinklers in the pendent position; install upright sprinklers in the upright position.*

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

Step 2. Tighten the sprinkler into the sprinkler fitting using only the W-Type 6 Sprinkler Wrench (Figure 7). For wax-coated sprinklers, use an 8 or 10 inch adjustable wrench. With reference to Figures 1 through 4, the W-Type 7 Recessed Sprinkler Wrench or an adjustable wrench, as applicable, is to be applied to the sprinkler wrench flats.

When installing wax-coated sprinklers with an adjustable wrench, exercise care to prevent damage to the wax coating on the sprinkler wrench flats or frame arms and, consequently, exposure of bare metal to the corrosive environment. Open the jaws of the wrench sufficiently wide to pass over the wrench flats without damaging the wax coating. Before wrench tightening the sprinkler, adjust the jaws of the wrench to contact only the sprinkler wrench flats. After wrench tightening the sprinkler, loosen the wrench jaws before removing the wrench.

After installation, inspect the sprinkler wrench flats and frame arms and retouch (repair) the wax coating whenever the coating has been damaged and bare metal is exposed. Retouch the wax coating on the wrench flats by gently applying a heated 1/8 inch diameter steel rod to the damaged areas of wax, to smooth it back over areas where bare metal is exposed.

NOTICE

Only retouching of the wax coating applied to the wrench flats and frame arms is permitted, and the retouching is to be performed only at the time of the initial sprinkler installation.

The steel rod should be heated only to the point at which it can begin to melt the wax, and appropriate precautions need to be taken when handling the heated rod in order to prevent the installer from being burned.

Recessed Pendent Sprinklers

The Series TY-B Recessed Pendent Sprinklers must be installed in accordance with the following instructions:

Step A. After installing the Style 10 or 40 Mounting Plate, as applicable, over the sprinkler threads and with pipe thread sealant applied to the pipe threads, hand-tighten the sprinkler into the sprinkler fitting.

Step B. Tighten the sprinkler into the sprinkler fitting using only the W-Type 7 Recessed Sprinkler Wrench (Figure 8). With reference to Figure 3 or 4, the W-Type 7 Recessed Sprinkler Wrench is to be applied to the sprinkler wrench flats.

Step C. After the ceiling is installed or the finish coat is applied, slide on the Style 10 or 40 Closure over the Series TY-B Sprinkler and push the Closure over the Mounting Plate until its flange contacts the ceiling.

Care and Maintenance

TYCO Series TY-B, 2.8, 5.6, and 8.0 K-factor, Upright and Pendent Sprinklers must be maintained and serviced in accordance with this section.

Before closing a fire protection system main control valve for maintenance work on the fire protection system that it controls, obtain permission to shut down the affected fire protection system from the proper authorities and notify all personnel who may be affected by this action.

The owner must assure that the sprinklers are not used for hanging any objects and that the sprinklers are only cleaned by means of gently dusting with a feather duster; otherwise, non-operation in the event of a fire or inadvertent operation may result.

Absence of an escutcheon, which is used to cover a clearance, may delay the time to sprinkler operation in a fire situation.

Sprinklers which are found to be leaking or exhibiting visible signs of corrosion must be replaced.

Automatic sprinklers must never be painted, plated, coated, or otherwise altered after leaving the factory. Modified sprinklers must be replaced. Sprinklers that have been exposed to corrosive products of combustion, but have not operated, should be replaced if they cannot be completely cleaned by wiping the sprinkler with a cloth or by brushing it with a soft bristle brush.

Care must be exercised to avoid damage to the sprinklers before, during, and after installation. Sprinklers damaged by dropping, striking, wrench twist/slippage, or the like, must be replaced. Also, replace any sprinkler that has a cracked bulb or that has lost liquid from its bulb. (Refer to Installation Section.)

The owner is responsible for the inspection, testing, and maintenance of their fire protection system and devices in compliance with this document, as well as with the applicable standards of the National Fire Protection Association (e.g., NFPA 25), in addition to the standards of any other authorities having jurisdiction. Contact the installing contractor or product manufacturer with any questions.

Automatic sprinklers are recommended to be inspected, tested, and maintained by a qualified Inspection Service in accordance with local requirements and/or national codes.

P/N 57 - XXX - X - XXX			SPRINKLER FINISH		TEMPERATURE RATING	
		SIN				
530	2.8K UPRIGHT (1/2" NPT)	TY1151	1	NATURAL BRASS	135	135°F (57°C)
531	2.8K PENDENT (1/2" NPT)	TY1251	3	PURE WHITE (RAL9010) * POLYESTER	155	155°F (68°C)
570	5.6K UPRIGHT (1/2" NPT)	TY3151	4	SIGNAL WHITE (RAL9003) POLYESTER	175	175°F (79°C)
571	5.6K PENDENT (1/2" NPT)	TY3251	5	JET BLACK (RAL9005) ** POLYESTER	200	200°F (93°C)
590	8.0K UPRIGHT (3/4" NPT)	TY4151	6	WAX COATED 286°F (141°C) MAX	286	286°F (141°C)
591	8.0K PENDENT (3/4" NPT)	TY4251	7	LEAD COATED	360	360°F (182°C)
560	8.0K UPRIGHT (1/2" NPT)	TY4851	8	WAX-OVER-LEAD 286°F (141°C) MAX	000	OPEN***
561	8.0K PENDENT (1/2" NPT)	TY4951	9	CHROME PLATED		

Notes:
 * Eastern Hemisphere sales only
 ** Available in only 8.0K, 155°F (68°C) or 200°F (93°C); requires lead time to manufacture
 *** Available only for 8.0 K-factor TY4151 and TY4251 for use in deluge systems ("OPEN" indicates sprinkler assembly without glass bulb, button, and sealing assembly)

TABLE C
SERIES TY-B UPRIGHT AND PENDENT SPRINKLERS
PART NUMBER SELECTION

Limited Warranty

For warranty terms and conditions, visit www.tyco-fire.com.

Ordering Procedure

Contact your local distributor for availability. When placing an order, indicate the full product name and Part Number (P/N).

Sprinkler Assemblies with NPT Thread Connections

Specify: Series TY-B (specify SIN), (specify K-factor), (specify Upright or Pendent) Sprinkler with (specify) temperature rating, (specify) finish or coating, P/N (Refer to Table C)

Recessed Escutcheon

Specify: Style (10 or 40) Recessed Escutcheon with (specify) finish, P/N*

* Refer to Technical Data Sheet TFP770

Sprinkler Wrenches

Specify: W-Type 6 Sprinkler Wrench, P/N 56-000-6-387

Specify: W-Type 7 Sprinkler Wrench, P/N 56-850-4-001

Wax Sticks

(for retouching wrench-damaged wax coating)

Specify: (specify color, below) Colored Coded Wax Stick for retouching (specify temperature rating) temperature-rated Series TY-B Sprinklers, P/N (specify)

Black for 135°F (57°C) P/N 56-065-1-135
 Red for 155°F (68°C) P/N 56-065-1-155
 Yellow for 175°F (79°C) P/N 56-065-1-175
 Blue for 200°F (93°C)
 and 286°F (141°C) P/N 56-065-1-286

Note: Each wax stick is suitable for retouching up to 25 sprinklers.

Note: The wax used for 286°F (141°C) sprinklers is the same as for 200°F (93°C) sprinklers, and, therefore, the 286°F (141°C) sprinkler is limited to the same maximum ceiling temperature as the 200°F (93°C) sprinkler (i.e., 150°F [66°C]).

Series ELO-231 Upright and Pendent Sprinklers Standard Response, Standard Coverage

General Description

The 11.2 K-factor, Series ELO-231, Standard Response, Standard Coverage, Upright and Pendent Sprinklers (Ref. Figure 1) are automatic sprinklers of the fusible solder type. They are "standard response - spray sprinklers" that produce a hemispherical water distribution pattern below the deflector.

The 11.2 K-factor, ELO-231 Sprinklers were subjected to full scale, high-piled storage, fire tests to qualify their use in lieu of 5.6 or 8.0 K-factor standard spray sprinklers for the protection of high-piled storage.

Higher flow rates can be achieved at much lower pressures with the 11.2 K-factor, ELO-231 Sprinklers — making their use highly advantageous in high density applications, such as the protection of high-piled storage.

Wax or lead coatings can be used to extend the life of the copper alloy components used in Series ELO-231 sprinklers beyond that which would otherwise be obtained when exposed to corrosive atmospheres. Although wax and lead coated sprinklers have passed the standard corrosion tests of the applicable approval agencies, the testing is not representative of all pos-

sible corrosive atmospheres. Consequently, it is recommended that the end user be consulted with respect to the suitability of these corrosion resistant coatings for any given corrosive environment. The effects of ambient temperature, concentration of chemicals, and gas/chemical velocity, should be considered, as a minimum, along with the corrosive nature of the chemical to which the sprinklers will be exposed.

An upright intermediate level version of the Series ELO-231 Sprinklers for in-rack applications can be obtained by utilizing the Series ELO-231 Upright Sprinkler with the WSG-2 Guard & Shield, and a pendent intermediate level version of the Series ELO-231 Sprinklers can be obtained by utilizing the Series ELO-231 Pendent Sprinkler with the WS-2 Shield. If there is a possibility of the pendent intermediate level version being exposed to mechanical damage, a G-2 Guard can be added.

WARNINGS

*The 11.2 K-factor, Series ELO-231 Upright and Pendent Sprinklers described herein must be installed and maintained in compliance with this document, as well as with the applicable standards of the National Fire Protection Association, in addition to the standards of any other authorities having jurisdiction. **Failure to do so may impair the performance of these devices.***

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

Installation of Series ELO-231 Pendent Sprinklers in recessed escutcheons will void all sprinkler warranties, as well as possibly void the sprinkler's Approvals and/or Listings.

IMPORTANT

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

			SPRINKLER FINISH				
TYPE	TEMPERATURE	FRAME COLOR	NATURAL BRASS	CHROME PLATED	LEAD COATED	WAX COATED	WAX OVER LEAD
UPRIGHT (TY5111 & TY5811)	165°F/74°C	Unpainted	1, 2, 3, 4		1, 2, 3, 4		
	212°F/100°C	White					
	286°F/141°C	Blue			1, 2, 3, 4	1 ^(a) , 2 ^(a) , 3 ^(a) , 4 ^(a)	
PENDENT (TY5211)	165°F/74°C	Unpainted	1, 2, 3, 4		1, 2, 4		
	212°F/100°C	White					
	286°F/141°C	Blue			1, 2, 4	1 ^(a) , 2 ^(a) , 4 ^(a)	

NOTES:

1. Listed by Underwriters Laboratories, Inc. (UL Listed).
2. Listed by Underwriters Laboratories, Inc. for use in Canada (C-UL Listed).
3. Approved by Factory Mutual Research Corporation (FM Approved).
4. Approved by the City of New York under MEA 291-04-E.

(a). Listed/Approved for a maximum ceiling temperature of 150°F/66°C.

TABLE A
LABORATORY LISTINGS AND APPROVALS
FOR 11.2 K-FACTOR SERIES ELO-231 UPRIGHT AND PENDENT SPRINKLERS
(Refer to the Design Criteria Section)

Model/Sprinkler Identification Numbers

TY5111 - Upright 11.2K, 3/4"NPT
TY5211 - Pendent 11.2K, 3/4"NPT
TY5811 - Upright 11.2K, 1/2"NPT

TY5111 is a redesignation for C5111.

TY5211 is a redesignation for C5211.

TY5811 is a redesignation for C5811.

Technical Data

Approvals

UL and C-UL Listed. FM and NYC Approved. (Refer to Table A for complete approval information including corrosion resistant status. The approvals apply to the service conditions indicated in the Design Criteria section.)

Maximum Working Pressure

175 psi (12,1 bar)

Discharge Coefficient

$K = 11.2 \text{ GPM/psi}^{1/2}$
(161,4 LPM/bar^{1/2})

Temperature Ratings

Refer to Table A

Finishes

Refer to Table A

Physical Characteristics

Frame	Bronze
Seal Disc	Copper
Cap	Bronze
Strut Assembly	Solder, Bronze, Stainless Steel
Compression Screw	Bronze
Deflector	Bronze
Helper Spring	Stainless Steel
Ejector Spring	Nickel
Strut Clip	Stainless Steel

Design Criteria

UL and C-UL Listing Requirements

The 11.2 K-factor, Model ELO-231 (TY5111, TY5211 & TY5811) Sprinklers are to be installed in accordance with NFPA 13 standard sprinkler position and area/density flow calculation requirements for light, ordinary, or extra hazard occupancies, as well as high piled storage occupancies (solid piled, palletized, rack storage, bin box, and shelf storage including but not limited to Class I-IV and Group A plastics) with a minimum residual (flowing) pressure of 7 psi (0,5 bar) for wet or dry pipe systems.

FM Approval Requirements

The 11.2 K-factor, Model ELO-231 (TY5111, TY5211 & TY5811) Sprinklers are to be installed in accordance with the applicable "control mode density/area" guidelines provided by Factory Mutual. (FM guidelines may differ from UL and C-UL Listing criteria.)

* Temperature rating is indicated on deflector.

** Pipe thread connections per ISO 7/1 can be provided on special request.

FIGURE 1

11.2 K-FACTOR SERIES ELO-231

UPRIGHT - 3/4" NPT (TY5111), UPRIGHT - 1/2" NPT (TY5811), AND PENDENT - 3/4" NPT (TY5211) SPRINKLERS

Operation

A fusible alloy is sealed into a bronze actuating rod (center strut) by a stainless steel ball. When the alloy melts at its rated temperature, the ball is forced upward into the center strut, releasing the two ejectors and operating the sprinkler.

Installation

The Series ELO-231 Sprinklers must be installed in accordance with the following instructions:

NOTES

A leak tight 3/4 inch NPT sprinkler joint should be obtained with a torque of 10 to 20 ft.lbs. (13,4 to 26,8 Nm). A maximum of 30 ft.lbs. (40,7 Nm) of torque is to be used to install sprinklers with 3/4 NPT connections. A leak tight 1/2 inch NPT sprinkler joint should be obtained with a torque of 7 to 14 ft.lbs. (9,5 to 19,0 Nm). A maximum of 21 ft. lbs. (28,5 Nm) of torque may be used to install sprinklers with 1/2 NPT connections. Higher levels of torque may distort the sprinkler inlet and cause leakage or impairment of the sprinkler.

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

The **Series ELO-231 Upright and Pendent Sprinklers** must be installed in accordance with the following instructions.

Step 1. Pendent sprinklers are to be installed in the pendent position, and upright sprinklers are to be installed in the upright position.

Step 2. With pipe thread sealant applied to the pipe threads, hand tighten the sprinkler into the sprinkler fitting.

Step 3. Tighten the sprinkler into the sprinkler fitting using only the W-Type

FIGURE 2
W-TYPE 3 SPRINKLER
WRENCH

3 Sprinkler Wrench (Ref. Figure 2), except that an 8 or 10 inch adjustable Crescent wrench is to be used for wax coated sprinklers. With reference to Figure 1, the W-Type 3 Sprinkler Wrench or the adjustable Crescent wrench, as applicable is to be applied to the wrench flats.

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

the wrench jaws before removing the wrench.

After installation, the sprinkler wrench flats and frame arms must be inspected and the wax coating retouched (repaired) whenever the coating has been damaged and bare metal is exposed. The wax coating on the wrench flats can be retouched by gently applying a heated 1/8 inch diameter steel rod to the areas of wax that have been damaged, to smooth it back over areas where bare metal is exposed.

NOTES

Only retouching of the wax coating applied to the wrench flats and frame arms is permitted, and the retouching is to be performed only at the time of the initial sprinkler installation.

The steel rod should be heated only to the point at which it can begin to melt the wax, and appropriate precautions need to be taken, when handling the heated rod, in order to prevent the installer from being burned.

If attempts to retouch the wax coating with complete coverage are unsuccessful, additional wax can be ordered in the form of a wax stick (the end of which is color coded). Only the correct color coded wax is to be used, and retouching of wrench flats and frame arms is only permitted at the time of initial sprinkler installation. With the steel rod heated as previously described, touch the rod to the area requiring additional wax with the rod angled downward, and then touch the wax stick to the rod approximately one-half inch away from the area requiring retouching. The wax will melt and run down onto the sprinkler.

Care and Maintenance

Series ELO-231 Sprinklers must be maintained and serviced in accordance with the following instructions:

NOTES

Before closing a fire protection system control valve for maintenance work on the fire protection system that it controls, permission to shut down the affected fire protection system must be obtained from the proper authorities and all personnel who may be affected by this action must be notified.

Sprinklers that are found to be leaking or exhibiting visible signs of corrosion must be replaced.

Automatic sprinklers must never be painted, plated, coated or otherwise altered after leaving the factory. Modified or over-heated sprinklers must be replaced.

Care must be exercised to avoid damage to the sprinklers — before, during, and after installation. Sprinklers damaged by dropping, striking, wrench twist/slippage, or the like, must be replaced.

Frequent visual inspections are recommended to be initially performed for corrosion resistant sprinklers, after the installation has been completed, to verify the long term potential integrity of the sprinkler coatings. Thereafter, annual inspections per NFPA 25 should suffice; however, instead of inspecting from the floor level, a random sampling of close-up visual inspections should be made, so as to better determine the exact sprinkler condition and the long term integrity of the corrosion resistant coating, as it may be affected by the corrosive conditions present.

The owner is responsible for the inspection, testing, and maintenance of their fire protection system and devices in compliance with this document, as well as with the applicable standards of the National Fire Protection Association (e.g., NFPA 25), in addition to the standards of any other authorities having jurisdiction. The installing contractor or sprinkler manufacturer should be contacted relative to any questions.

It is recommended that automatic sprinkler systems be inspected, tested, and maintained by a qualified Inspection Service in accordance with local requirements and/or national code.

Limited Warranty

Products manufactured by Tyco Fire & Building Products (TFBP) are warranted solely to the original Buyer for ten (10) years against defects in material and workmanship when paid for and properly installed and maintained under normal use and service. This warranty will expire ten (10) years from date of shipment by TFBP. No warranty is given for products or components manufactured by companies not affiliated by ownership with TFBP or for products and components which have been subject to misuse, improper installation, corrosion, or which have not been installed, maintained, modified or repaired in accordance with applicable Standards of the National Fire Protection Association, and/or the standards of any other Authorities Having Jurisdiction. Materials found by TFBP to be defective shall be either repaired or replaced, at TFBP's sole option. TFBP neither assumes, nor authorizes any person to assume for it, any other obligation in connection with the sale of products or parts of products. TFBP shall not be responsible for sprinkler system design errors or inaccurate or incomplete information supplied by Buyer or Buyer's representatives.

In no event shall TFBP be liable, in contract, tort, strict liability or under any other legal theory, for incidental, indirect, special or consequential damages, including but not limited to labor charges, regardless of whether TFBP was informed about the possibility of such damages, and in no event shall TFBP's liability exceed an amount equal to the sales price.

The foregoing warranty is made in lieu of any and all other warranties, express or implied, including warranties of merchantability and fitness for a particular purpose.

This limited warranty sets forth the exclusive remedy for claims based on failure of or defect in products, materials or components, whether the claim is made in contract, tort, strict liability or any other legal theory.

Ordering Procedure

A Part Number (P/N) is not specified when ordering sprinklers with thread connections per ISO 7/1.

Contact your local distributor for availability.

Sprinkler Assemblies

with NPT Thread Connection:

Specify: (specify SIN), 11.2 K-factor, (specify temperature rating), Series ELO-231 Standard Response (specify Pendent or Upright) Sprinkler with (specify finish), P/N (specify from Table B).

Sprinkler Wrench:

Specify: W-Type 3 Sprinkler Wrench, P/N 56-895-1-001.

Wax Sticks:

(for retouching wrench damaged wax coating)

Specify: (Specify color) color coded Wax Stick for retouching (specify temperature rating) temperature rated Series ELO-231 Sprinklers, P/N (specify).

Red for 165°F..... P/N 56-065-1-155
Blue for 212°F and
286°F..... P/N 56-065-1-286

NOTES

Each wax stick is suitable for retouching up to twenty-five sprinklers.

The wax used for 286°F sprinklers is the same as for 212°F sprinklers, and, therefore, the 286°F sprinkler is limited to the same maximum ceiling temperature as the 212°F sprinkler (i.e., 150°F).

P/N 50 — XXX — X — XXX

TYPE		SPRINKLER		TEMPERATURE RATING	
110	UPRIGHT 3/4" NPT (TY5111)	1	NATURAL BRASS	165	165°F/74°C
		9	CHROME PLATED	212	212°F/100°C
		6	WAX COATED	286	286°F/141°C
112	PENDENT 3/4" NPT (TY5211)	7	LEAD COATED		
		8	WAX OVER LEAD		
210	UPRIGHT 1/2" NPT (TY5811)				

TABLE B
PRODUCT SYMBOL NUMBER SELECTION
11.2 K-FACTOR SERIES ELO-231
STANDARD RESPONSE UPRIGHT AND PENDENT SPRINKLERS