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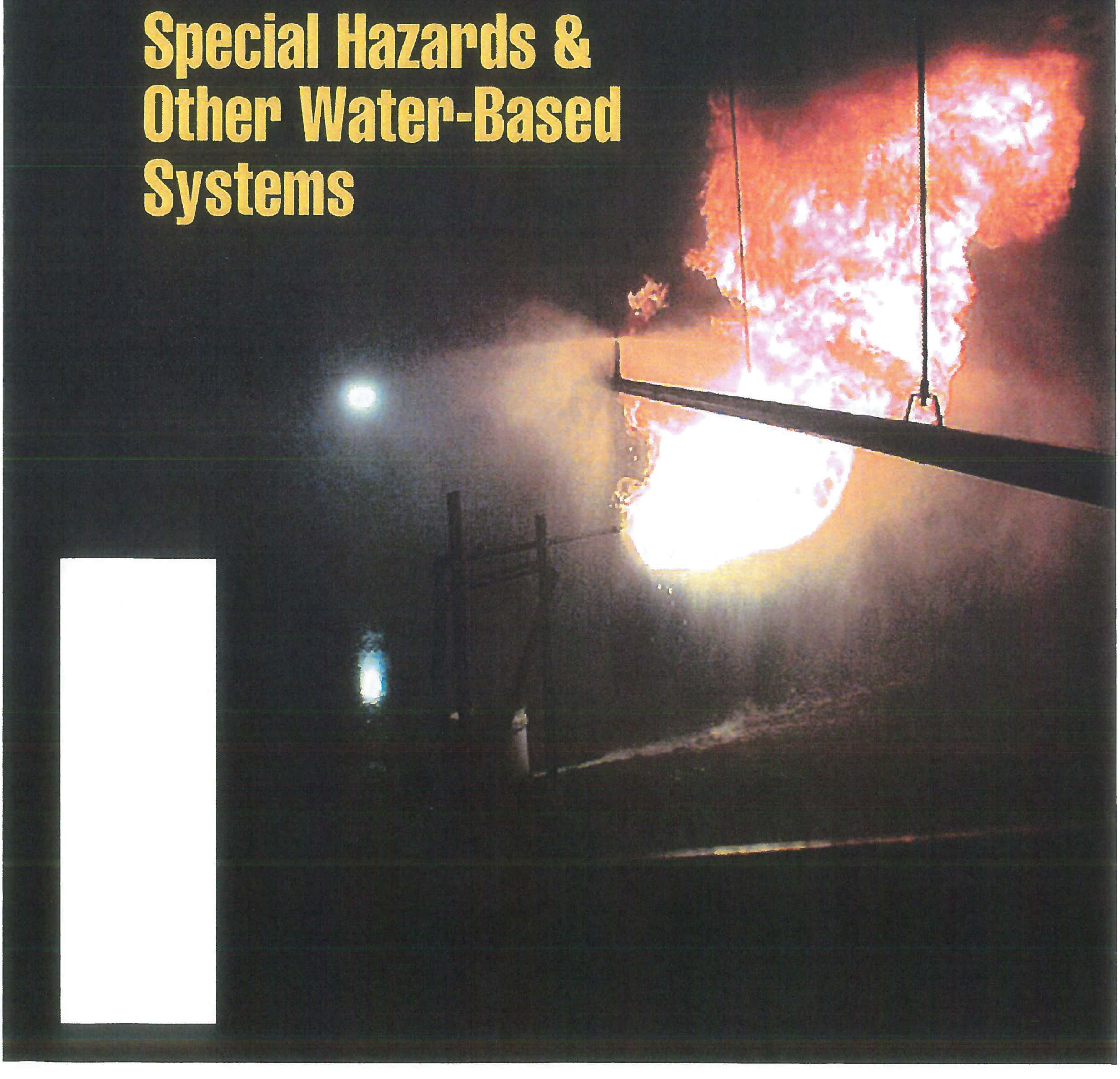
Special Hazards & Other Water-Based Systems



High Expansion Foam: A Design Option

A Case Study for Mausoleums

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In September of 2001 I received a call from a general contractor asking if I would look at designing and installing a system to protect a mausoleum. My first thought was: "Who is this and how are they intending to make a fool of me?" I resisted the urge to hang up as they stroked my ego by stating that someone in the city had suggested that Jackson Associates was adept at coming up with unique solutions to unusual and weird protection problems. Finally, I asked, "Is this for real?" The response: "Yes, meet me in Rochester Hills and we will look at it." Still leery, I met the contractor at the site. Sure enough, there were two approximately 100 ft by 100 ft by 30 ft burial vaults with an existing light hazard sprinkler system. The problem was that the crypts were a fiber reinforced polypropylene plastic, and the owner wanted them stacked 28 ft high. The previous two fire protection contractors had informed them that standard spray sprinklers only allowed exposed Group A plastic storage to 25 ft, and ESFR sprinklers could not be used in precast concrete tee construction since the stems are greater than 12 in. deep. It appeared to be an interesting (and serious) challenge, so I said that I would be back with them in a week.

Outside photograph of mausoleum.

Over the next few days we thought of many scenarios and decided to consider the following:

- Control mode sprinklers
- Suppression mode sprinklers
- Carbon dioxide – low and high pressure
- Halon replacement gasses
- High expansion foam

Control Mode Sprinklers

NFPA 13 allows control mode sprinklers to protect exposed Group A plastic to a maximum of 25 ft. The required density (Table 7-3. 3. 2.2 NFPA 13 1999 addition) of .7/2500 would require replacing the existing system, adding a fire pump and possibly increasing the size of the underground. It was suggested that we look at attempting a performance-based design but we ignored this suggestion since this can not be done for suppression criteria.

HAZARD
Two mausoleum vaults separated by 100 ft of concrete construction service basement.
Each vault approximately 9,000 ft^2 and 30 ft high – approximately 270,000 ft^3.
Construction is concrete tee fire resistive construction.
Vaults are unoccupied (by live people) except for occasional installation of casket or maintenance.
Storage is 28 ft high and consists of bodies in caskets stored in polypropylene (group A plastic) crypts. The crypts are stacked to 28 ft high with a solid flat top and a honey comb front side with solid end caps on the exposed ends.

Table 1. Hazard description.

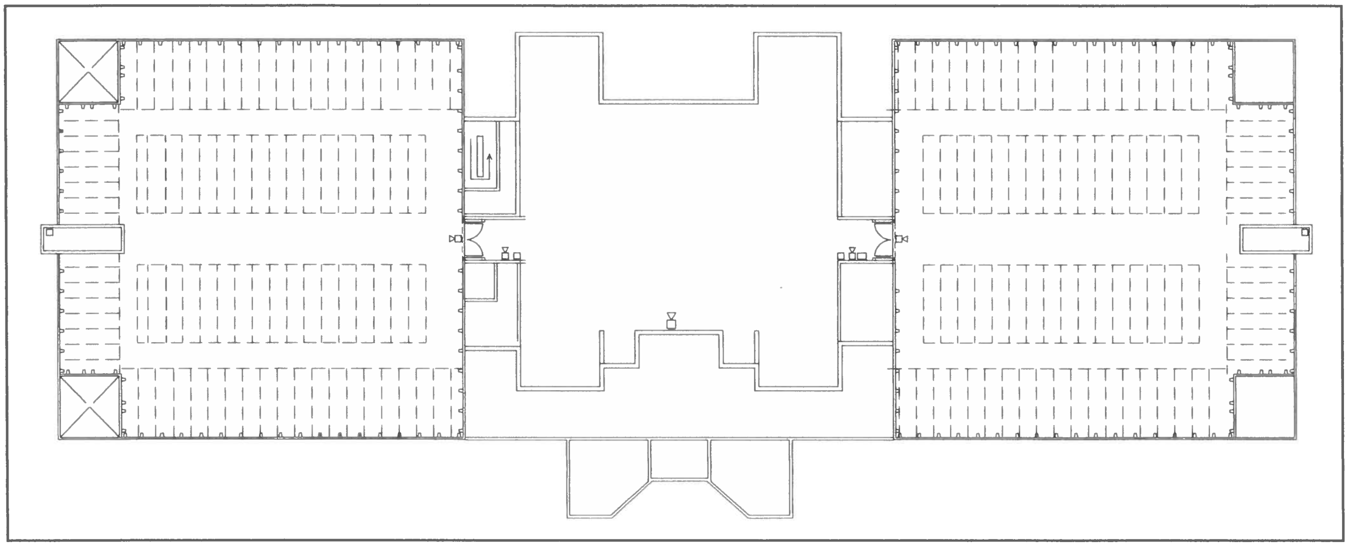


Figure 1. Plan showing crypt locations.

Suppression Mode Sprinklers

ESFR sprinklers were a natural choice except for two problems. First, there were 18 in. deep pockets 54 in. wide formed by the concrete tee construction. Code requires sprinkler spacing between 8 and 12 ft. The system did not work with the construction. Secondly, the required 36-in. commodity clearance requirements further restricted storage height.

Since the pockets were 54 in. wide, the maximum distance we could get from the beams was 27 in. This would allow the deflector to be a maximum of 5 1/2 in. above this obstruction. (See Figure 2.) This would require us to install a drop ceiling above the pipe to maintain proper ceiling to deflector distance. By doing all of this, we could get the deflector to 29 ft 2 in. at the eaves of the building. This would allow 26 ft 2 in. storage at the eaves and just over 27 ft at the peak. While this was not the 28 ft the customer desired, it would allow an additional layer of crypts.

Carbon Dioxide

With a quick look at NFPA 12, each pound of carbon dioxide would protect 22 cubic ft of space. This requires: 270,000/ft^3 divided by 22 pounds/ft^3 = 12,273 pounds of CO_2. Using selector valves, we could size the tank for one discharge into either vault. It was apparent that a low pressure storage tank outside would be preferable to over 120 cylinders inside, which require periodic weighing. The carbon dioxide systems would allow the entire vault to be used full height. Carbon dioxide's main drawback is that it displaces the oxygen and people cannot breathe in the space when it discharges.

Halon Replacement Gasses

It did not take long to realize that this was not the likely winner. Since a large FM-200 system typically runs in the range of five dollars per cubic ft, it was obvious that a two zone system would be well over a million dollars.

High Expansion Foam

Many are familiar with AFFF which is considered a low expansion foam (expansion ratio less than 20). High expansion foam is similar but has a ratio between 200 and 1000. Both types require a foam solution, a means to combine it with the water, and a means to aerate (though AFFF can use standard spray sprinklers). AFFF only covers the surface whereas high expansion foam fills the entire space.

Thus, the first task in design of a high expansion foam system is to determine the time required to fill the vault with foam. NFPA 11A: Table 2-3.4 provides guidance on recommended fill time. We felt that the closest example in the table for burn characteristics and heat release would be rubber tires. We recognize tires present a more demanding threat but nothing was listed that adequately resembled this commodity and felt it was appropriate to be conservative. With heavy or fire resistive construction, the table requires a maximum fill time of eight minutes for a sprinklered facility, and six minutes for an unsprinklered facility. The vaults were already sprinklered with a light hazard system. Although it was totally inadequate, it would provide some cooling of the structure and possibly some delay in initial fire growth. Due to the conservative fill time having been based on tires, we elected to use a seven minute fill time.

To determine the required rate of foam discharge, you must use the following formula from NFPA 11A: Paragraph 2-3.5.2:

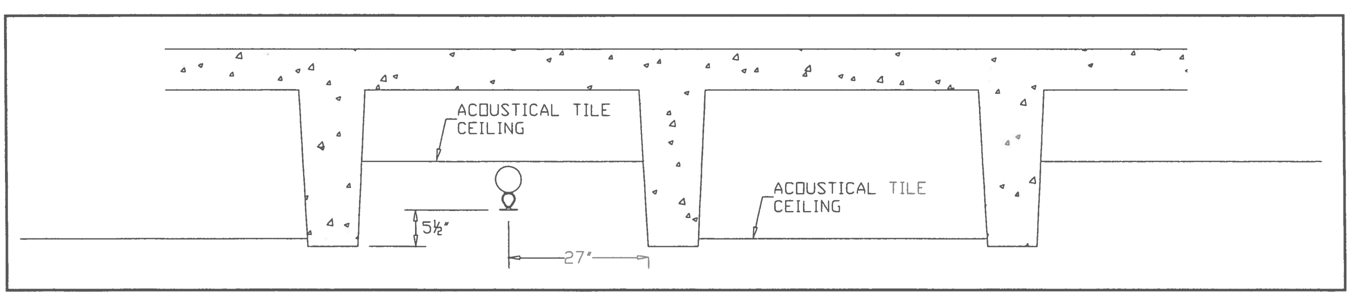


Figure 2. Tee construction with ceiling and ESFR sprinklers.

Interior photograph of mausoleum showing the new crypts.

Testing the high expansion foam system.

R = (V/T + Rs) x Cn x Cl

R= Rate of discharge require in ft^3/minute
V= Volume of hazard = 270,000 ft^3
T= Submergence time = 7 minutes
Rs = Rate of foam breakdown = 10 CFM/GPM of sprinkler discharge = .1GPM/ft^2 x 1500 ft^2 = 150 GPM x 10 CFM/GPM = 1500 CFM
Cn= Compensation for normal foam shrinkage = 1.15
Cl= Compensation for leakage = in a very tight vault = 1.0

Therefore, our required rate of discharge would be:

R = (270,000/7 + 1500) x 1.15 x 1.0 = 46080 CFM of foam discharge required.

Notes: This assumes providing fresh air (not from the fire area) to the foam generators. We elected not to take a reduction in volume for the crypts despite their substantial portion of the vault's volume.

We had determined that there were three scenarios to present to the owner, with three different prices. The first two were for the two types of sprinklers, and the third was for carbon dioxide. The high expansion foam was essentially comparatively priced to the CO_2.

There were two other sprinkler contractors involved, and I was dealing with an out-of-state owner whom I had never met. I had a dilemma. How do I provide a proposal without allowing the owner to take my homework and put it out for bids with my competition? I decided instead to tell the owner what the end resulting storage heights would be.

My bid was very simple:

1) For $80,000 I would install a sprinkler system that would allow 25 ft storage.
2) For $150,000 I would install a system to allow 26 ft 2 in. storage at the eaves, and over 27 ft storage at the peak.
3) For no more than $250,000 they could store as high as they wanted to go.

The owner asked what I was providing them. I explained that I was not telling and why. Although he wanted information, he was very understanding of my concerns. Over the next few days we had a few conversations and developed a level of mutual trust. By the end of the week, the owner called and said, "Okay, you have the job, we just don't know which job. Before we know whether we are spending 80, 150, or 250 thousand dollars, you have to tell us what you are providing!" I responded: "That seems reasonable," and proceeded to explain the various systems that I considered, and how I proposed to make a standard density, ESFR or carbon dioxide system work.

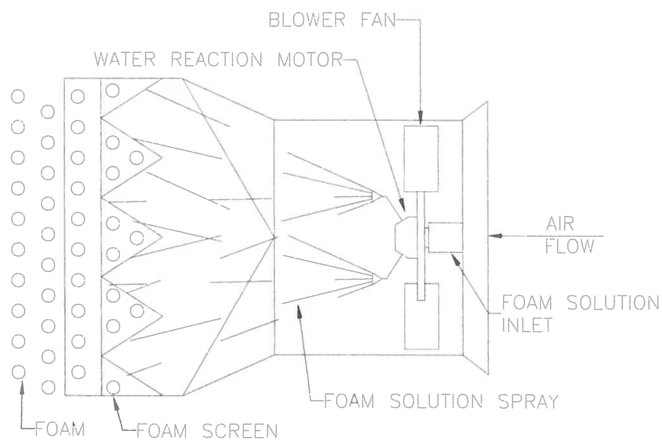
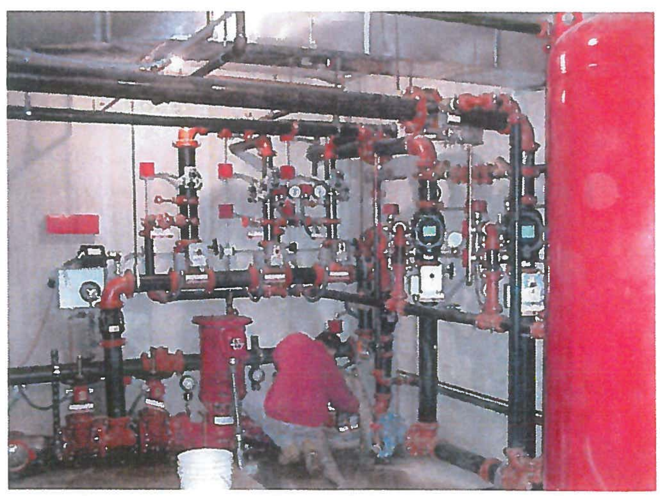


Figure 3. Diagram of high expansion foam generator.



Foam system riser room.

The next day the owner asked more questions and said that, even though the tenants would not care, the owners were concerned about the carbon dioxide for their maintenance personnel. He asked for more information regarding the foam system. I explained how it worked and that, although it is very disorienting to be in, you can pull your shirt over your mouth and breathe normally.

Jet-X High Expansion Foam Generators Performance Characteristics

Model No.	Generator Inlet Pressure (psi)	(kPa)	Foam Outlet (cfm)	(cmm)	Solution Flow (gpm)	(Lpm)	Expansion
JET-X-2	50	345	1,140	32	30	114	275:1
	75	517	1,770	50	38	144	340:1
	100	690	2,170	61	44	166	360:1
JET-X-2A	50	345	2,240	63	35	132	465:1
	75	517	3,200	91	42	159	555:1
	100	690	3,735	106	50	189	545:1
JET-X-5	50	345	5,350	151	36	136	1105:1
	75	517	6,720	190	45	170	1115:1
	100	690	7,225	204	50	189	1080:1
JET-X-5A	50	345	5,700	161	61	230	700:1
	75	517	7,500	212	75	283	750:1
	100	690	8,000	226	87	329	685:1
JET-X-15A (UL)	50	345	13,880	393	119	450	870:1
	75	517	17,410	493	145	548	900:1
	100	690	19,545	553	169	639	865:1
JET-X-15A (FM)	50	345	12,985	368	105	397	925:1
	75	517	17,985	509	128	484	1050:1
	100	690	17,100	484	150	567	855:1
JET-X-15a (LNG)	50	345	12,625	357	180	681	525:1
	75	517	14,495	410	220	832	495:1
	100	690	18,240	516	260	984	525:1

Table 2. Example of the wide range of performance characteristics for foam generators.

The following day, we were directed to complete the design of the foam system, obtain city approval, provide a final price and install the system. We later learned that the two additional layers of crypts are worth a couple million dollars in revenue.

Foam System Design

We then began the final design process. The first problem that surfaced was that it was going to be difficult to provide fresh air to the foam generators. The only wall that was practical to mount the generators to was already filled with HVAC equipment. The others were covered with granite. The roof was not a good option either because of the concrete tee construction. The only alternative was to take a 20 percent penalty in fill rate and use the air in the hazard. A fire can degrade the output volume of the generators; therefore, we had to take the rate previously determined and multiply by 1.2 for inside air. The rate is:

$$R = 46{,}080 \times 1.2 = 55{,}398 \text{ CFM}$$

The next step was to determine what generators to use. There are basically two types: electric driven and water motor driven. My personal preference is water motor driven since they require no electricity. This eliminates wiring to the generators and, if no fire pump is required, greatly increases reliability. You must look at various manufacturers and specific generators.

The various manufacturers have numerous sizes of generators. Because of the size of the vaults, the economics pushed us toward large generators. However, there are several factors to consider in selecting generators, such as: 1) Cost, 2) Pressure available, 3) Foam output, 4) Expansion ratio (efficiency), and 5) Required listings.

While some factors are simple, other factors are intermingled and must be looked at carefully. The most complex is expansion ratio, which is the volume of foam discharged/volume of the foam water solution. The expansion ratio directly affects the amount of foam concentrate and thereby the tank size and cost. With water driven generators, the thrust of solution exiting the internal nozzles spin an air fan that, in turn, blows the air and foam/water solution through a screen, which creates the foam. (See Figure 3 on page 10.)

Because of the mechanical efficiencies, each model of generator has its own peak expansion ratio that varies with water pressure at the inlet of the generator. Finding the generator that best fits the pressure available to provide a high expansion ratio and still be economical to install requires some analysis. From Table 2 above, you can see that expansion ratios can vary from under 300 to over 1100. That is, one generator could use four times the concentrate of another to fill the same space.

We chose to use three Ansul – Rockwood JET-X-15A (UL) generators at 82 psi, which, from the manufacturer's graph, will provide 18,433 CFM each for a total discharge rate of 55299. This matches the requirement calculated above. This requires a fire pump, and is not as efficient as using 10 jet-X-5 generators, but the total installed cost was substantially less.

Now that we had found the best generator, the foam concentrate requirement had to be determined. From the manufacturer's graph, each generator will use 152gpm of foam water solution. The foam concentrate will be mixed with water prior

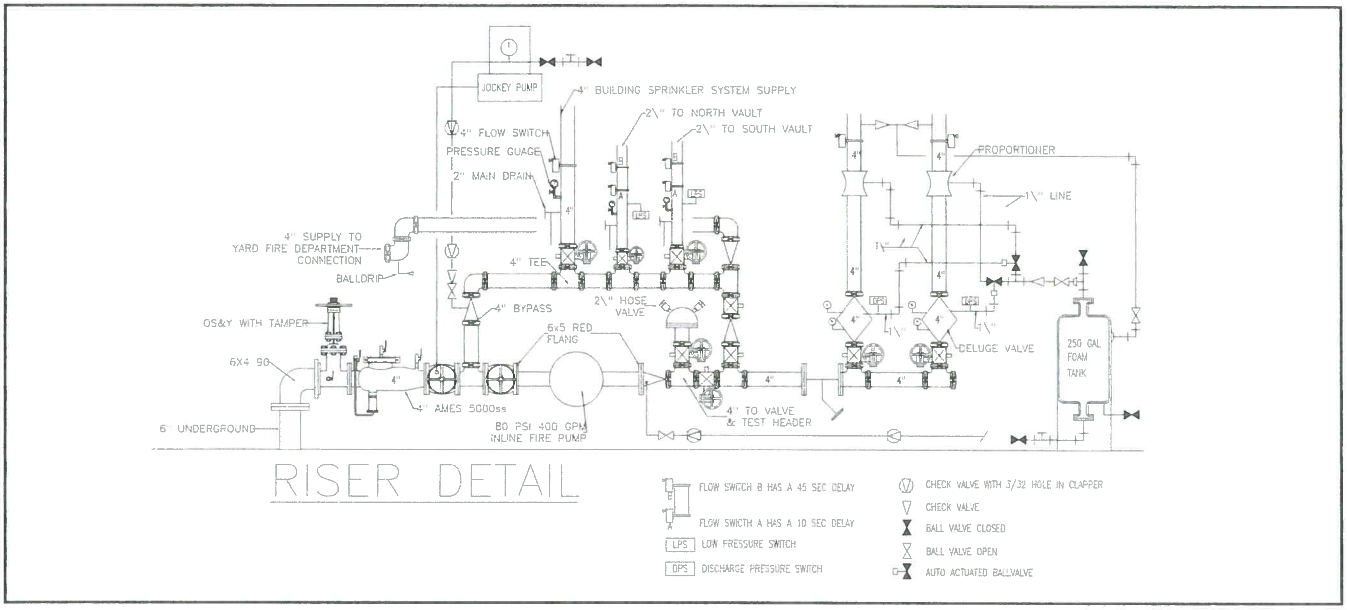


Figure 4. Riser detail.

to the generators at a rate of 2.75 percent foam concentrate to 97.25 percent water. Per paragraph 2-3.6.1, there must be enough concentrate for 25 minutes of discharge, or 4x fill volume, whichever is less (but not less than 15 minutes).

25 minutes x 3 generators @ 152gpm =
11,400 gallons of solution

$$4 \text{ fills} = \frac{70{,}000 \text{ ft}^3 \times 4 \text{ fills}}{3 \text{ GEN @ } 18{,}433 \text{ CFM}}$$

= 19.53 minute x 3 generators @ 152gpm

= 8,906 gallons of solution

Since four fills is less, the concentrate required by it is:

8,906 Gallons of solution
x 2.75% Concentrate
245 Gallon of concentrate is required

SEQUENCE OF OPERATIONS

A. Sprinkler operates in a vault
   1. Pressure drops to 100 psi – control panel sends trouble to central station.
   2. After 10 seconds of water flow, flow switch A operates.
      a. Horn strobe in vault, in basement entrance to vault and at upstairs entrance to building energize.
      b. Control panel sends alarm to central station.
   3. After 45-60 seconds discharge flow switch B operates.
      a. Appropriate deluge valve opens.
      b. Fire pump starts
      c. Pressure trip releases, closing door to vault.
      d. Foam generator operates, filling vault in less than 7 minutes.
B. Operation of the hydraulic manual release at the outside emergency stairwell exit or the electric manual release at the basement entrance to the vault.
   1. After 10 seconds of water flow, flow switch A operates.
      a. Horn strobe in vault, in basement entrance to vault and at upstairs entrance to building energize.
      b. Control panel sends alarm to central station.
   2. After 45-60 seconds discharge flow switch B operates.
      a. Appropriate deluge valve opens.
      b. Fire pump starts
      c. Pressure trip releases, closing door to vault.
      d. Foam generator operates, filling vault in less than 7 minutes.
C. Operation of sprinkler flow switch for all areas other than vault.
   1. Control panel will send alarm to central station.
   2. Existing alarm bell outside building will operate.
D. Failure of jockey pump on vault sprinklers will cause control panel to send trouble signal to the central station when pressure gets below 100 psi, (jockey pump is to maintain vault sprinkler system pressure high enough that city surges will not cause foam discharge.)
E. Closing any sprinkler control valve will cause the control panel to send a trouble signal to the central station.

To summarize, we had determined that each of the two vaults would require three foam generators with a common foam concentrate supply containing 245 gallons. The system would be designed for a single fire in one vault. The city water pressure would be boosted with a 400gpm@40psi in line pump to operate three foam generators@82psi system operation.

Now that the foam equipment had been established, the next task was to determine what would trigger the system actuation. The initial thoughts were of the standard types of thermal detection and electric manual release. Then, an idea occurred to us. By separating the vault sprinklers from the sprinkler system protecting the remainder of the building and replacing the existing sprinklers with quick response sprinklers, the vault sprinklers could also serve as the detection for actuating the foam system. Although the sprinklers were not connected to the fire pump, we connected the vault sprinkler systems to the jockey pump to eliminate any chance of water surges causing nuisance alarms or causing an unwanted foam discharge.

The City of Rochester Hills utilizes an outside party for plan review and inspection of fire protection systems. The preliminary conceptual description, along with a sequence of operation, was forwarded to James Schifiliti of Fire Safety Consultants for any initial comments. Following an initial conversation with Mr. Schifiliti, the drawings were finalized, submitted, and approved. The owner was given a final proposal with a significant savings, and the system installed.

Testing – The Fun Part

Jackson Associates performed initial testing and operated all devices initiating all conceivable sequences, except for actual foam discharge. The final test was scheduled with the city.

The day of the test was a bit like the circus coming to town. There must have been over 50 people from Jackson Associates, the city, the fire department, the owners, Ansul and Fire Safety Consultants. After a short conference, we successfully executed a dry run of each sequence in vault 1. We then planned a foam discharge to five feet in vault 1, but cut it short when a generator started a banging noise. While we adjusted the generator supports which had bound up a fan, the observers got a chance to experiment with walking in foam.

We then inspected the foam riser room and moved on to vault 2 and performed a short discharge to verify that all three generators operated correctly.

It was time for the big show! We needed to confirm the seven-minute fill time. We put several observers on the roof to watch through the skylights. Several Jackson Associates employees, along with the owner's representative, (complete with a suit, tie and trench coat) said they wanted to watch and film from a scissors lift at the ceiling. A quick thinking fireman tied a rope from the lift to the door for the men to find their way out following the test. The test went perfectly. The fill was well within the seven minutes, the men all walked out safely after descending through the foam. All had great stories and some fascinating video was created. To see the video, go to JacksonAssociatesinc.com.

ABOUT THE AUTHOR:

Rick Jackson graduated from Wittenberg University with a degree in Physics/Engineering Science. Following college he moved to Michigan with the HPR Department of Kemper Insurance, and then spent seven years with a special hazards company.

Jackson Associates was incorporated 25 years ago and designs and installs sprinkler and special hazard systems. Jackson is a member AFAA, AFSA, NFPA, SFPE, and alternate on NFPA's 750 committee. To reach Jackson phone (248) 669-5155 or email rick@jacksonassociatesinc.com.