To Wally and To Gloria
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Glossary
Introduction

Be it on the job or in the classroom, this text is directed towards the individual beginning vocational training in the engineering discipline of automatic fire sprinkler system design. National building and fire codes are revised and updated almost annually. By comparison, there has been very little published to aid sprinkler system designers, particularly in the area of design basics. This book was written largely because I could not find one that comprehensively dealt with this subject matter.

Although designed as a text, this book’s target audience is not limited to students. Its purpose is to see that the information discussed can be applied by those already employed as consulting engineers and architects as well as those engineers specializing in related areas of fire protection engineering. It is also directed towards the needs of insurance underwriters, fire protection researchers, building inspectors, and municipal officials. If ongoing education is pivotal to the focus of the attitude of the professional, then exposure to works such as this will provide a solid benefit to his or her abilities as a competent engineer.

This text will not only outline the role of the fire sprinkler designer, but will shed light on the broad expanse of responsibilities this role encompasses. As many fire protection publications do a thorough job of keeping professionals abreast of changing code requirements, the goal of this work is to furnish an overview of the basics necessary to initiate sprinkler system design and layout. Apart from some fire sprinkler associations, the burden of engineering training today has fallen on independent sprinkler contractors, most of whom are much too small and without the financial resources to pay someone to devote a significant portion of his time to teach new engineers. Hopefully, this text will serve to more efficiently put this training process in motion.

It typically takes two or more years of on-the-job training for a sprinkler designer to feel confident and comfortable in his responsibilities. This book is organized with the intention of speeding that process.

The chapter sequences allow for new knowledge to be acquired at a gradual pace. The beginning chapters of the book take the reader through all of the steps involved with the design engineering process using an easy, basic example building. This has been authored to familiarize the reader with the entire process, and to provide a broad foundation on which to build a deeper understanding of the basics of the fire protection engineering.

This book is formatted for a semester-length curriculum. The contents are structured for easy learning, and as a guide in acquiring a foundation of knowledge that will accentuate the subsequent understanding of various detailed fire codes and pamphlets. It also serves as a preparation for the NICET examination, and a vocational reference tool.

The 175+ study questions are included for two reasons. Since they are “open-book” questions, they introduce the reader to the unending activity of referencing codes to locate the answers to questions of application. Second, as the questions are prepared in the same fashion as those encountered in many NICET examinations, they will aid in preparation for this test.

The creations of a mechanical engineer involve motion, or specifically: by customizing a system in such a way to convert energy into a useful mechanical form. If designing a sprinkler system were as simple as that statement makes it sound, then of course the existence of this text would be completely unnecessary. There is a lot to learn about the regimen of fire sprinkler system design. Not that any of that information is very hard to learn, there simply is a lot of it to digest.

One of the reasons for the many different fire sprinkler rules and regulations is that some things are more apt to spread fire more quickly than others. When these are known stored products, the occupancy (or classification) of the building changes, necessitating a separate set of requirements.
Another way to look at this relates to the objects used to build the building itself. Larger or thicker objects will take longer to burn or to breach by burning, and are therefore more fire resistive, because mass is directly related to fire resistance. However, building code requirements that call for parapet walls, non-combustible building materials, or additional fire separation walls, are not a complete solution or remedy from the danger and destruction of fire. Rather, these are viewed more as passive protection, while automatic fire suppression systems are viewed as active protection; and this protection must be compatible with the potential lurking danger.

Just as the invention of the ox-drawn plow marked the beginning of agricultural civilization, the development of the fire sprinkler system in conjunction with the invention of the fusible sprinkler nozzle marked the beginning of set-in-place fire suppression security. The automatic fire sprinkler system is the conduit that connects the water supply to the place of fire origin.

As the nature of the demand for engineering of diverse functional mechanisms becomes more specialized over time, it appears that the future of fire protection engineering will also become more fractioned. This is all the more reason for cross-training within the professional engineering subfields. While each individual in the field of engineering has a role to play, it is paramount that all the players be in sync with regard to fire safety. Whatever part your endeavors play in the overall picture, I hope you do invest the time to read and assimilate the information contained herein. To avoid lengthy interruptions within the text, all figures and photographs have been placed at the end of the book. Your interest in fire protection and life safety is appreciated.
At or around 1813, the portable fire extinguisher was invented by a Virginian named George Manby. In stating his purpose for the invention, he remarked that “a small quantity of water, well directed and early applied, will accomplish what, probably, no quantity would effect at a later period” [1]. This idea embracing early extinguishment, carrying with it the inherent curtailing of the extent of water damage, fostered the idea for the invention of the automatic fire sprinkler. Another American, Henry S. Parmalee, wished to protect his own piano factory. To accomplish this to his satisfaction, he successfully created the automatic fire sprinkler, prior to the existence of automobiles, in 1864.1

The operation of that sprinkler was heat-actuated, as are fire sprinklers today. The sprinkler, tied into a system of piping that holds water under pressure, contains an operating element that will melt or burst when its temperature is raised to a specific point (usually around 160°F). Water from that sprinkler is then released directly over the heat source. Today, in step with the original theory, “depending on the intensity of the fire, a sprinkler head will activate in one minute or less, containing the fire...” [2].

What has always been known is the devastating damage and toll on human life for which fire is responsible. Through documentation and analysis, the public has become more aware of these effects. In the late 1800s, the National Fire Protection Association (NFPA) was formed, and insurance companies very wisely became involved with the business of protecting buildings from fire. The development of the very first code for fire protection was made by insurance underwriters, notably the Factory Improvement Committee of the New England Insurance Exchange. While much slimmer than the ever-expanding current codes, they were specific [4]:

87. Under a pitch roof sloping more steeply than 1 foot in 4—One line of sprinklers to be located in peak of roof, and sprinklers on either side to be spaced according to above requirements. Distance between sprinklers to be measured on a line parallel with roof.

Along with sketches and tables, the first codes also included numerous footnotes, such as: “no practicable set of rules can be framed to cover all conditions of construction. The experienced sprinkler piper will know when to consult with the underwriters relative to exceptional cases” [5]. Today’s codes promulgated by the NFPA, however, do endeavor to cover all conditions of construction. The current
Corrective safety measures have historically been put into motion following awful tragedies. The original co-operative for the National Fire Sprinkler Association was founded in 1905, just two years after the Iroquois Theatre fire in Chicago which left 602 dead. In 1911, the Triangle Shirtwaist Factory fire killed 150 in New York City, and two years after that today’s Life Safety Code was first published.

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The fire sprinkler system originally was designed as a means of holding a fire in check until help arrived from the nearest available fire company. The safety of all systems was augmented in the 1920s by the motorized fire engine. New York City, in an effort of “modernization,” retired its last horse-drawn fire equipment vehicles in 1922.

The Cocoanut Grove Nightclub Fire of November 28, 1942, in Boston, left 490 dead and many injured. Two 1946 hotel fires (in Chicago and Atlanta) accounted for 180 more deaths. It then became all the more apparent to those familiar with the alarming fire-related death rate in the United States and elsewhere, that the means for in-place life safety systems to protect building occupants was a necessity.

After the 1946 fires, with research confirming the marvelous record for sprinkler systems, building codes increasingly called for the installation of fire sprinklers in buildings with obvious life safety needs. These included structures in which rapid evacuation of occupants was difficult, high-rises, and buildings containing a high hazardous material content. The Society of Fire Protection Engineers began in 1953, and avenues of change towards more all-encompassing fire prevention measures began to develop which still carry on in the 2000s. These include the improvements to manufactured fire protection products, the streamlining of hydraulic calculation techniques, refinement of existing fire codes, and efforts for stronger code adoption. The decades following World War II saw tougher building code legislation take place gradually. When that national legislation did not go far enough to satisfy certain parties, individual states and cities enacted their own sprinkler ordinances. Although unpopular, the mandating of fire sprinklers in numerous existing facilities became a reality for the property owners in those areas.

The amenability of sprinkler system acceptance was improved by cost-saving changes made to the installed systems. The introduction of welding and thinwall pipe, in 1973, was a big step forward in reducing installation costs. The largest cost-savings was realized, of course, when the sprinkler system was installed as a part of new construction, and not as an afterthought.

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Thus, the reliable means of building protection and life safety, like most everything else, has evolved to what it is today. While Parmalee’s invention has without a doubt been responsible for saving countless lives and sparing countless others from the horrible injuries caused by fire and smoke, history has his name etched alongside others of his day in relative anonymity, although they are responsible for the creation of devices that we use in our everyday lives. Parmalee, indeed, is truly an unsung hero because his invention is a particularly efficient one. The probability of a sprinkler head malfunction is virtually nonexistent. The most recent ten-year study by a major insurance company noted that 83% of all fires were controlled by ten or fewer sprinklers. Fifty-six percent of fires in protected commercial properties were halted by the operation of three or fewer sprinkler heads, and 37% of all fires are controlled by the operation of one sprinkler. “The fact remains that there has never been a multiple loss of life in a building equipped with fire sprinkler systems” [6]. It is the presence of automatic fire sprinkler systems that have prevented the rapidly developing fires of blinding smoke and intense heat that are capable of trapping and killing many at a time.

The most reliable fire protection system known for any structure is a wet-pipe automatic fire sprinkler system installed throughout all building areas, equipped with electrical alarms and some type of valve supervision. This is the only system combining the elements of prompt detection, alarm, and suppression. The proper design and installation code for these systems has been standardized nationally by the National Fire Protection Association, in their consensus pamphlet No. 13. In 1980, efforts to certify fire sprinkler designers was taken on by the National Institute for Certification in Engineering Technologies (NICET), and to certify these engineers at four different levels of competency and experience. Today, there are over 3000 such engineers certified in the subfield of automatic sprinkler system layout, for fire protection engineering technology, by this relatively new organization nationwide.

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This chapter would be incomplete without some notes on the costs of fire sprinkler installations. “Whenever a fire official makes a policy decision regarding built-in fire protection systems, that decision has an economic impact on the community” [7]. These costs have always depended on numerous factors, such as building type, water supply availability and pressure, degree of occupancy hazard, and the size and height of the structure in question. Usually the systems cost less than the cost for carpeting that building. Of the many published cost guidelines I have read, the following table reflects most closely the price breakdown:

<table>
<thead>
<tr>
<th>New Construction exposed</th>
<th>10–20,000 sq. ft.</th>
<th>$1–$1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20–50,000 sq. ft.</td>
<td>$0.80–$1.35</td>
</tr>
<tr>
<td></td>
<td>50–100,000 sq. ft.</td>
<td>$0.75–$1.10</td>
</tr>
<tr>
<td></td>
<td>100,000+ sq. ft.</td>
<td>$0.70–$1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>New Construction concealed</th>
<th>10–20,000 sq. ft.</th>
<th>$1–$1.75</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20–50,000 sq. ft.</td>
<td>$0.95–$1.50</td>
</tr>
</tbody>
</table>

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This cost is eventually offset completely by insurance savings. “In practically every instance, much higher fire insurance premiums are charged to businesses that are not sprinkler equipped. Once a system is installed, however, the cost of insurance premiums are charged to businesses that are not sprinkler equipped.” [6]. Additionally, most building codes regard the superiority of sprinkler protection so highly that specific building design alternatives (reduced fire-resistive requirements) are permitted, which further validate sprinkler system expense. Then try to add this up: the water, fire department house expense, and man-hours expended to extinguish a fire in a non-sprinklered facility. Also, as the NFPA reports, “43% of businesses which experience a fire do not resume business” [10].

Fires simply happen. Just in waste containers alone, over 300,000 fires occur annually. “There is no way to fill in the blank in this sentence so that it is both true and useful: Most fires are caused by ______. No specific cause, such as smoking, heating, cooking, or arson, can accurately be placed in the blank” [11]. Attempts to decrease the number of fires have always been a futile uphill battle. “At this moment a building somewhere is burning. Somebody, somewhere, will be killed by fire today, tomorrow, and the day after tomorrow” [12]. The fire-related death toll was 5195 people in the United States for 1990, meaning that about one in every 48,000 perished in a fire. In 1991, “4465 civilians died in the United States as the result of fire” [13]. Two years later this yearly figure was 4635, and “there were 30,475 civilian fire injuries in 1993” [14]. In addition, “half a million American homes catch on fire (yearly). Property loss from fires totals about $8 billion annually” [15]. Overseas, “large fires lost Britain an estimated 304 million pounds in 1986” [16]. Societies, throughout history, are often judged by how effectively they protect their more helpless, weak, and vulnerable members. Another grim statistic found that of the annual fire-related death rate, half of those killed were either elderly, handicapped, intoxicated, or children. “Children under age 5 are at serious risk of being killed in a fire—more than double the average population” [17].

Statistics, however, have historically backed up another steadfast actuality and that is “that automatic fire sprinkler systems were, unquestionably, the most effective fire protection for structures” [18]. Through effective design work in his daily regimen, the engineer’s job can be seen as a safeguard in the overall equation of public protection from fire.

**ENDNOTES**

Overview of a Basic Sprinkler System Design (Getting Started)

This chapter will take you through one fire sprinkler system design project. This will be done as briefly as possible and will cover simple basics. The layout and design for this project is detailed on page 141, labeled Figure A-2. The depiction of this hypothetical office/warehouse facility is naturally drawn on something that can be mailed or carried around and is by necessity two-dimensional. However, you must remember to think of the layout and design in realistic three-dimensional terms. The rate at which your job gets easier directly corresponds to how well you can visualize the system layout as a three-dimensional picture, and how that picture relates to the finished structure and the structure’s other mechanical systems. Every component of the fire sprinkler system drawn on the two-dimensional plan needs to be visualized effectively, so that the engineer is assured that these components can, in fact, be installed where shown.

As a fire sprinkler system designer for a particular job, the job description could be chronologically listed as follows:

1. Review building plans, and collect facts.
2. “Block out” the building plan.
3. Lay out the system.
4. Calculate system piping for pipe sizing.
5. “Cut” the pipe.
6. Complete system details and add notes.
7. Field check the job construction.
8. Stocklist the job.

For our example, we will assume that this building is of non-combustible construction: consisting of steel bar-joist and I-beam structural materials. The best way to begin any such new construction job is by patiently leafing through all the architectural and mechanical plans that you have at your disposal, to get a good feel for the job. This is done to familiarize yourself with the project, and to help you visualize what the building is actually going to look like. Of utmost importance is understanding how this building will be structurally supported, for you will need to know where the bar joists and solid beams are to be located. This information, as we will see, is critical, and you cannot proceed without it. You will also need to know where the air handling system ductwork is going to be routed. Ideally, this information will be obtained from the shop drawing made by the HVAC contractor. However, the HVAC contractor often uses the architect’s engineer’s preliminary HVAC plan as his own shop drawing.

PLANS AND SPECIFICATIONS

The architect’s job specifications must also be reviewed. These should include a section (normally numbered anywhere from 15,300 to 15,700) reserved for the fire sprinkler system installation. The specifications are often “canned,” or just copied from an old job, and hence may not relate exactly to or in entirety to the project that you will be working on. But since the intent of the specifications must be adhered to in your system design, any obvious divergences referred to are typical discrepancies that the engineer will have to clarify with the architect before proceeding, or as soon as possible.

The source of the building’s water supply is noted, usually from the civil or plumbing drawings. The HVAC drawings will let you know the whereabouts of the larger air handling units and if any unit heaters are to be installed. On all drawings, any noted elevations will give you the best information possible for deciding on the optimum fire sprinkler pipe elevations. But for the most part, the detailed information necessary for the ideal situation, derived from the architectural plan package, is limited and generally imperfect. “Mechanical/electrical engineers do design drawings, which are not the
Installation drawings we work with daily. Plumbers and electricians do not do shop drawings as a rule, they use the design drawings for installation. So these are the contract documents we are expected to use to create our drawings. Preliminary fire sprinkler plans, if available, are a recurring enigma. More often than not, they are either incomplete, or have been prepared by someone inexperienced in fire protection engineering to the extent that the plans contain numerous errors and contradictions with regard to the specifications and/or the hazard level of the building occupancy. Usually, these plans should be ignored altogether [1]. The point of this discussion should be clear: the first phase of your work, the gathering of information, is of top priority and cannot be bypassed. This brings us to the first important rule for engineers:

**IF YOU DON’T KNOW, PLEASE ASK!**

A sprinkler contractor or his salesman has already contracted to install this fire protection work for a specific dollar amount. In doing so, he became a professional gambler: he decided that if paid “X” thousand dollars, he could have this job designed and installed completely, and make money besides. He is the first person to ask, when you need to know what type of materials should be used for the job, what the building will be used for, if the specifications are pertinent to the job, if expensive hanger materials have been figured in the cost estimate, if sprinklers are to be located in the geometric centers of drop-ceiling tiles, where the fire department connection should be placed, what the available water pressure is, and so on. The secondary source of inquiry to obtain the answers that you need is traditionally the architect’s office.

**STARTING THE WORK ON YOUR PLAN**

Tracing, or “blocking out” the building plan, is a vital step in the engineering process if this hasn’t already been done for you. Sometimes a mylar or vellum copy of the building background can be obtained from the architect. If an uncluttered print is not available, then blocking out is necessary. Many engineers, who have access to a tracing table, will block out the building on the reverse side of the sprinkler plan, so that the subsequent drawing and erasing and re-drawing of the system components is a less messy task. Nevertheless, tracing the building plan on either side of your mylar or vellum sheet is quite common and acceptable. Choosing which of the architect’s plans to trace, and what size sheet you should use for this work, is dependent on the recognition of this principle:

**DO NOT SCALE THE PLAN TOO SMALL!**

An architect’s plan has its own syllogistics, but your blueprints will be read in the field. Sometimes when you are physically at a field installation, take a good look at the blueprint that a fitter is using. It is typically covered with thread-cutting oil fingerprint smudges, grease, and other lovely dirt. And it is being read by a fitter in poor light who doesn’t want to bother to put on his own prescription reading glasses. This experience will help to make you aware of the importance of not only keeping everything that you draw as legible as possible, but also scaling the drawing large enough so that there is room for all your notes and dimensions to be readable [2]. On a typical retail office project involving piping concealed above a ceiling for example, a 1/8″ = 1′0″ scaled print is usually too small. The minimum scale for a fire pump and bypass layout is generally considered to be 3/4″ = 1′0″. A good scale to use for details and elevation sections is 3/8″ = 1′0″. As a rule-of-thumb, a 1/8″ = 1′0″ scaled print is typical, if the majority of piping shown is to be exposed pipe.

A fire sprinkler plan by definition is what you see when you look up. What goes on every blocked-out plan is the fire sprinkler piping and sprinkler-heads, structural steel, and/or ceiling grid layout. If time allows and if the designer can help himself out by their inclusion, the drawing then must also include possible obstructions such as lights, duct diffusers, speakers located in ceilings, smoke detectors, medium and large runs of ductwork, and track lighting. Obviously, we always need to show the locations of all walls, stairs, columns, elevators, and the like, as well as all components of the sprinkler system itself. Potential sprinkler spray obstructions such as baffles, soffits, crane rails, and overhead garage door tracks need to be included as well.

An inked or CADD-generated drawing is generally required in instances where the plan must be on permanent record. Government projects are notorious for this requirement. For various reasons that involve marketing and company image, there has been increased use of CADD-based sprinkler system design products. But this trend has been growing slowly, mainly because the CADD programs utilized for the sprinkler industry have yet to show (with the exception of the chore of stocklisting) any proven engineer labor time-savings. Users of CADD software maintain that “with the shortage of good designers, sprinkler contractors must consider any alternative that holds the promise of allowing the contractor to improve engineering efficiency. CADD holds that promise, and properly implemented can fulfill it. Improperly implemented, it may be both frustrating and actually decrease design efficiency” [2]. Since this can be debated elsewhere, this text will concern itself with designs of typical, traditional projects drafted on paper, vellum, or mylar. Since inks are commonly used, those who like to use them will be able to understand how the following paragraphs discuss the same principles, despite the redundant usage of the “language” of various ink pen products.

Leads of differing hardness will make their image appear lighter or darker on the print. For your purposes, it is best to keep three mechanical pencils handy and loaded for use.
These would be used when drawing or tracing the different plan elements. For instance, a 4H (harder) lead which will appear lighter on the blueprint, would be used for: ceiling grid lines, ductwork, diffusers, structural components, unit heaters, or other items of lesser significance to the sprinkler plan. Lighter lines are to be used at your discretion for elements of the actual building that you need to reference during your phases of system design.

A 2H (medium grade) lead will be used extensively. Anything drawn with the 2H lead, of course, will stand out a little more on the print than the items used with the 4H lead. These items should include pipe dimensions off of walls, details, columns, point of compass, and so on; and definitely all of the full-height building walls. An excellent article written by Edwin Kotak discussing the day-to-day rigors of a fire sprinkler designer, elicits his own personal technique [3]:

Shop drawings are done manually on 4 mil mylar. Piping, partitions, and lettering are done with graphite leads. Ceiling tile grid lines, ceiling mounted fixtures, structural members, and the like are drawn in different colored pencils. This helps to differentiate between bar joists and ceiling grid lines. When the drawings are printed the colors come out as different shades of blue making it easy to distinguish different items.

It is not necessary to include doors or doorway locations on the print. As has already been stated, the sprinkler plan is what you see when you look up and most doors do not extend upwards to the ceiling. Usually, an open door is the same as a wall for our purposes since the wall portion above a door (above the lintel) will prevent the sprinkler from reaching adjoining areas.

To achieve the greatest clarity and avoid reader confusion, wall lines should not be shown crossing over each other:

The softest (H or HB) lead that you are comfortable using should be reserved for what you want stand out prominently on your drawing; namely, sprinklers, sprinkler piping, and the pipe size and length numerics. Whoever reads your plan, be it the insurance company, fire department, or the field installer; the whereabouts of the sprinkler-heads and the routing of the sprinkler piping is always of the uppermost significance. This lead is also normally used for header details, site plans, and other building cross sections.

Every designer, over time, develops his own style and methods in his plan preparation. These should be “user-friendly.” The following example, again from Kotak, illustrates one time-saving procedure [4]:

Learning to use the copier for a lot more than just making standard copies has been a benefit. I like to call it “selective xeroxing.” The copier can reduce, enlarge, darken and lighten. This allows for many interesting possibilities. Depending on how much space is on the mylar and the scale of the drawing, I reduce or enlarge the material and then copy it onto an adhesive backed medium.

A reference table needs to be placed adjacent to the drafting table in your office set-up. It should be large enough so that architectural plans can rest on it wholly for reference. Since I happen to be right-handed, I like to keep this table immediately to the left of the drafting board. Any other means by which you can organize your office to increase the efficiency of your design operation, or to create a relaxed environment in which to concentrate, will be greatly beneficial.

As previously mentioned, plan legibility is absolutely vital. There is no great secret to achieving good legibility when writing plan notes, except to write at a slower than normal pace. The more time you take, the better your hand-scripted words will look. I’m sure that you will find this to be true if you try it out for yourself. While we are on the subject of legibility, it is most imperative that all numbers are written clearly. If your “4” looks like a “9,” the results could be disastrous.
To be fancy, or to delineate between different plan components on the original mylar or vellum, some engineers like to use different colored leads (or inks). But please take note that some of these colors will reproduce better than others. The lighter colors do not xerox very well at all. If you want to draw something in color, and wish to play it safe, then only use brown or red. Both brown and red blueprint and xerox very well.

The blocking out of the building plan will complete the “getting started” phase of your work. Immediately after completing this phase, it is necessary to jump right in to the task of spotting sprinkler-heads on the plan. The reason I say that it is necessary to jump right in to the next phase of the work, is to avoid slacking off or procrastinating between phases. All is well when you continue to proceed steadily.

CITATIONS


ENDNOTES

1 Recently, (September 1995), the Construction Specifications Institute has revised its master format. Under the new setup, the specifications for automatic fire suppression systems would be found in Section 13900.

2 The contractor’s salesperson responsible for selling the specific contract is the individual best informed to ask about the actual value of the prepared preliminary fire sprinkler plan, if there is one.

3 In the interests of keeping referenced drawings compact for the purposes of this book, please take note that some of the figures displayed in the “Figures and Photos” appendix of this text are not shown in actual scale, and have been “shrunk” to accommodate the physical book size.

4 While at the time of this writing the use of CADD is rapidly becoming widely utilized in the industry, it remains the designer’s option to choose drafting or the exclusive use of the computer to produce his work.
Basic Design Overview (Part 2)

This chapter begins with the assumption that you are by now somewhat familiar with the building plans for the project example, and that the initial drafting (blocking out) of the building layout is complete. Your sheet now looks something like the example on page 140 labeled Figure A-1. As is the typical procedure, what you have traced for areas of exposed construction is the architect’s “floor plan,” and what you have traced for areas with finished construction is a close copy of the architect’s “reflected ceiling plan.”

Once the building is blocked out in scale, it is time to draw the sprinklers and system piping on the plan. This is the most critical engineering portion of your work. It requires a complete knowledge of the applicable codes, mental visualization of the proposed building, and a recall of your own knowledge and instincts that you attained from all your past experience in this area.

As was touched on in the last chapter, the architectural plans may include a preliminary sprinkler plan, complete with many legal disclaimers. It may be wise or unwise to use any part of this plan as your own. The preliminary plan may be an exact depiction of what the architect and building owner desire, or it may simply be a quick drawing made to satisfy some municipal requirement. Often, it has been prepared by an engineer (hired by the architect) whose real area of specialization is his accompanying drawings (i.e., the mechanical, electrical, civil, and/or plumbing plans). If the quality of the preliminary sprinkler plan does not make this possibility evident, a phone call to this engineer is always worthwhile: for only then will you find out if his design is “diagrammatic” in nature, or if you are expected to comply with his plan with limited latitude for deviation. In many of these cases however, the finer points in the engineer’s plan may be way off the mark of conforming to the fire sprinkler engineering code. If so, a good question to ask during this phone call would be about what, if any, requirements in excess of the NFPA Pamphlet No. 13 requirements are being asked for.

There are projects in which system design has already been thoroughly researched, prepared, and even reviewed. When a commercial insurance company is very involved, as with one of their H.P.R. clients, “a pre-construction meeting is held during the planning stages of a fire sprinkler system project to allow for recognition of the hazard, understanding of the project requirements, and providing bid specifications” [1]. This will take care of all the major engineering issues after the local fire prevention bureau has their say, although “the level of preconstruction document review may vary substantially depending on location” [2]. Most fire prevention bureaus are only interested in reviewing the final shop drawings which you will prepare.

***

For our purpose in this chapter, we are assuming that none of the above preplanning activities have taken place. We will now move on to the task of laying out the system after first determining the occupancy and hazard level of the building tenant, and whether or not any chance of pipe freezing will exist. The answer we get is that this tenant is in the business of manufacturing thermopane glass and aluminum patio doors, and that the facility will be heated year-round.

Since we have established that there is no reasonable chance of future pipe rupture caused by freezing temperatures, we will immediately decide to install the most reliable system available, which is the wet-pipe automatic sprinkler system. “Speed of operation, low installation cost, and ease of maintenance account for the fact that 75% of all sprinkler systems in use are of the wet-pipe type. There is no size limitation on wet pipe systems, except that the maximum area protected by any one system on any one floor of a single fire section cannot exceed 52,000 square feet” [3]. Our example building in Figure A-1 is well below this maximum limit in size, and can be protected by a single system.
We are not concerned in this chapter with gridded or looped systems, and so will utilize the only alternative left, which is called a “tree” system. In this layout configuration, the water flows from the system riser in a direction down feed-main and cross-main piping, and finally down smaller sized branch-line piping to the operating sprinkler. Water discharged from that sprinkler always comes from a single direction.

Bear in mind this golden rule:

DO NOT MAKE A MISTAKE ON THE CROSS-MAIN!

Why? Because if branch-line (normally 1”–2”) piping cannot be routed where you show it, an installer can correct that without much fanfare. But rerouting the big cross-main pipe is a different matter altogether. Not only is it expensive and time-consuming, and not only does it affect all other downstream piping, but it can halt the installation completely while the installers scratch their heads and attempt to achieve an engineering solution on the job. This wastes time and time is money.

Again, the cross-main location and elevation is the first thing that you lay out. The elevation must be low enough to cross below structural beams, which usually means: lower than the branch-lines. Naturally, the cross-main should be hung high enough so as not to interfere with future building operations. The system pipe elevations should be designed so that all or most of the system can be drained when necessary at the base of the system riser.

When steel bar-joists support the roof of the structure, the direction of the branch-line runs are always perpendicular to the joists, for ease of pipe hanging. Hence, to feed the branch-lines, the cross-main must run parallel to the joists.1

ALWAYS KNOW WHAT YOU’RE HANGING THE PIPE TO!

Specifically, for optimum cost efficiency, the main should be routed beneath a single joist, hung from one side of that joist or the other.2 Look at the HVAC (Mechanical) drawings to make absolutely certain that the joist location that you select has the least chance of obstructional interference. And don’t select a joist (obviously) that rests directly above a column, or the pipe will run smack into a structural column or I-beam. In order to avoid ductwork, it may be necessary to offset the main once, or several times, or even change elevation. Offsets, though, shall be minimized to reduce labor and material installation cost. Varying depths of I-beams must be checked (on the steel drawings),3 but the highest priority consideration must be that there is reasonable space available for the piping to fit where it is shown. This space includes space above the pipe as well: for example, there may be space available to run pipe below some ductwork, but then it is economically impractical to hang the pipe.

***

On “concealed” jobs (where all piping is concealed above a drywall or drop-ceiling), the main piping must be hung at a low elevation, beneath all other mechanical tradework. Many designers routinely set cross-main elevations at 7” to 9” (pipe centerline) above the highest drop-ceiling height in these instances. This is done because it is generally observed that the sprinkler trade, being the last of the mechanical trades to man a job, hang their pipe on concealed jobs below all the ductwork, storm piping, electrical cable trays, and the like; but also that the main must lay high enough to avoid hindrances such as ceiling speakers and recessed lighting fixtures. On “tight” jobs, where space available above ceiling is at the bare minimum, it may be necessary to run the main at an even lower elevation, being careful to route this pipe to avoid hitting all the recessed lights.

***

Before you lay out your branch-lines and fix their elevation, you need to spot all the sprinkler-head locations. The information you’ll need for this task is detailed more thoroughly in Chapter 10, and requires knowledge of spacing limitations. As previously mentioned, our example job is of a glass-door manufacturer, an ordinary hazard occupancy. The maximum head spacing for this tenant would be 130 sq. ft. The sprinklers must be positioned high enough to fuse from a collection of heat, so factory and warehouse sprinkler branch-line piping always run high, through the bar joists. The pipe will run through either an “A” or “V” space in these joists (Note Figure B-2 on page 151). To avoid running into joist bracing material, your safe bet is to space the sprinkler lines an even number apart from one another (i.e., 10’, 12’, or 14’). The spacing between sprinklers in light and ordinary hazard occupancies is only allowable up to a 15’ maximum.6

Once you have determined the distance from branch-line to branch-line, you can set the number of sprinklers on a line. In the Figure A-2 example, the branch-lines are spaced 12’ apart, and the sprinkler-heads are 10’7” apart on-center, giving you a coverage per sprinkler of (12’ × 10’7”) 127 square feet. Your distance from the sprinkler-head to a wall is not to exceed one-half the distance between sprinklers in any direction (as noted in NFPA #13–1999 ed.5-5.3.2).

***

Notice that we are supplying seven sprinklers from a single riser nipple, as opposed to six, or eight. The east half of the building, framed by the I-beam, creates an “area” of (23’ × 74’) 1702 sq. ft. Since our sprinkler spacing cannot exceed 130 sq. ft., and 1702 ÷ 130 = 13.1, we know that we will need at least fourteen automatic sprinklers to protect that
23′ × 74′ area. Twelve sprinklers would not be enough (for any ordinary hazard occupancy). If sixteen sprinklers were to be designed, the heads would be spaced 9′3″ apart, center-to-center, giving you a coverage per sprinkler of (12′0″ × 9′3″) 111 sq. ft. But under normal circumstances a contractor would much prefer to install fourteen sprinklers in this area rather than sixteen, for the same reason that one would only install one unit heater (and not two or three) in a room if just one could adequately do the job.

* * *

To set the elevation of the piping, we need to collect the following facts: the building in Figure A-2 has a flat roof, the underside of which is 15′ high. Its bar joists are all 6′2″ apart and 20″ deep. The supporting I-beams all have a depth of 24″.

We have an obligation to keep our cross-main as high as it can reasonably be situated, to maintain clearance for the building owner. Our main piping would be safely installed at a centerline elevation 6″ below the bottom of the solid I-beam. This would translate to an elevation of (15′0″ − 24″ − 6″) 12′6″. Hanging the branch-lines to run through the center of the bar joists is also a safe bet, so we would be inclined to have these installed at an elevation of (15′0″ − 10″) 14′2″. Attention must always be given to the HVAC contractor, the no. 1 suspect in all sprinkler installation cases of conflict. If his large airhandling equipment is to be installed on the roof, we must be careful to avoid running sprinkler piping below that area or areas. A basic goal of the sprinkler designer is to avoid situations where field labor must cut pre-fabricated piping because it will not fit where it is intended to go.

Referring again to the example sketched in Figure A-2, the fire sprinkler branch-lines could be placed 11′6″ apart in order to reduce the overall sprinkler head spacing to (11′6″ × 10′7″) 121.7 sq. ft. It may even be that this arrangement will work well for installation, and the piping may be hung in that fashion without field adjustment. In fact, the only field adjustment necessary for a branch-line obstruction, consisting of steel bar-joint bracing in this case, would be to lengthen or shorten the riser nipple (fed by the cross-main) to an elevation without obstruction for the line path. But our job is not to take chances. Running the lines 11′6″ apart would increase the possibility of positioning the sprinkler within 3″ of a joist web, which is a code violation as well as a sprinkler spray discharge interference. Making use again of the information derived from Figure B-2, I would recommend the 12′0″ spacing to reduce your odds of running into structural members.

CITATIONS


ENDNOTES

1 As a general rule, 1 1/2″ to 3″ from the centerline of the joist is the usual spot for the pipe to hang. See “Piping Methods and Details,” Chapter 13.
2 An installer will appreciate a note stating from which side of the joist you intend to hang the cross-main.
3 The optimum location for the main piping is to cross under the shallowest I-beam.
4 Such an area created by ceiling-level beams is sometimes called a “trave,” or a “bay.”
5 You will never encounter a single-story building with a perfectly flat roof without pitch. This is strictly a hypothetical example.
6 Sprinklers may be positioned further apart only if special extended-coverage sprinklers are used, in accordance with the manufacturer’s specifications for installation.
Further Specifics of Design Basics

W

e now have completed the first three steps in the fire sprinkler system design process. That is, we have become familiar with the building plans, have blocked out the building plan (see Figure A-1) on our own company sheet, and we have laid out the system itself (see Figure A-2). The next step in the process (outlined in Chapter 2) is to calculate the hydraulics of the system in order to properly size the piping so that it will carry the necessary volume of water to extinguish a fire typical of the hazard being protected.

Since the subject and methodology of hydraulic calculations is to be discussed in a later chapter, and since the example project is very small, we will opt to size the piping by the pipe schedule method. Pipe schedules are depicted in the most recent (1999) edition of NFPA #13 in Chapter 8-5. "The piping schedules listed in the NFPA Sprinkler Systems Standard are based upon extensive and carefully controlled tests, providing consistently dependable sprinkler protection with practical economy" [1]. The NFPA #13 section numbered 7-2.2 allows the use of the pipe schedule method for new system installations of 5000 sq. ft. or less (this is indeed true in our case), and if the system hazard is either light or ordinary. As previously mentioned, the nature of the example building tenant’s business (manufacture of glass products) identifies him as an ordinary hazard risk. This can be verified, on page 168 of the current NFPA #13, under section A-2-1.2.1.

Pipe schedule tables have changed fairly gradually over the years since their inception. The very first ones adopted by sprinkler system installers were written sometime around 1880. The Underwriters’ Bureau of New England published the following pipe schedule table in 1896, presumably to be used with black steel piping installations. It read that “in no case shall the number of sprinklers on a given sized pipe exceed the following:

<table>
<thead>
<tr>
<th>Size of Pipe</th>
<th>Maximum No. of Sprinklers Allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4”</td>
<td>1 sprinkler</td>
</tr>
<tr>
<td>1”</td>
<td>2 sprinklers</td>
</tr>
<tr>
<td>1 1/4”</td>
<td>4 sprinklers</td>
</tr>
<tr>
<td>1 1/2”</td>
<td>8 sprinklers</td>
</tr>
<tr>
<td>2”</td>
<td>16 sprinklers</td>
</tr>
<tr>
<td>2 1/2”</td>
<td>28 sprinklers</td>
</tr>
<tr>
<td>3”</td>
<td>48 sprinklers</td>
</tr>
<tr>
<td>3 1/2”</td>
<td>78 sprinklers</td>
</tr>
<tr>
<td>4”</td>
<td>110 sprinklers</td>
</tr>
<tr>
<td>5”</td>
<td>150 sprinklers</td>
</tr>
<tr>
<td>6”</td>
<td>200 sprinklers</td>
</tr>
</tbody>
</table>

This schedule is considered ample for general practice” [2]. Rules for pipe schedule tables today are made separate for factors such as type of pipe used, hazard involved, and distance between sprinklers on a branch-line. (Today, the use of 3/4” pipe is not permitted in any case.1) The current edition of NFPA #13 utilizes five different pipe schedule tables (down from six in the 1989 edition). The one that we are concerned with for our example is specifically noted for ordinary hazard occupancies where steel pipe is used, Table 8-5.3.2(a), and in part, dictates the following:

<table>
<thead>
<tr>
<th>Size of Pipe</th>
<th>Maximum No. of Sprinklers Allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td>2 sprinklers</td>
</tr>
<tr>
<td>1 1/4”</td>
<td>3 sprinklers</td>
</tr>
<tr>
<td>1 1/2”</td>
<td>5 sprinklers</td>
</tr>
<tr>
<td>2”</td>
<td>10 sprinklers</td>
</tr>
<tr>
<td>2 1/2”</td>
<td>20 sprinklers</td>
</tr>
<tr>
<td>3”</td>
<td>40 sprinklers</td>
</tr>
<tr>
<td>3 1/2”</td>
<td>65 sprinklers</td>
</tr>
<tr>
<td>4”</td>
<td>100 sprinklers</td>
</tr>
<tr>
<td>5”</td>
<td>160 sprinklers</td>
</tr>
<tr>
<td>6”</td>
<td>275 sprinklers</td>
</tr>
</tbody>
</table>

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The code notes that this table applies only where the piping supplies sprinklers protecting a single level or fire area, and when the distances between sprinklers on a branch-line is 12’ or less.

Now that you are becoming more familiar with NFPA #13, you will find it to contain a mountain of rules, notes, recommendations, and exceptions. In fact, the answer to whatever design question you have can be found somewhere in NFPA #13. The more you read, the more well versed you will become in this highly persnickety volume of rules. The best way to accumulate this knowledge is slowly but surely. There are a lot of rules to learn. None are very complicated, there are just a lot of them. It would be of benefit to you if this pamphlet was the only reading material that you brought with you on trips to the commode for a month or two.

An engineering manager receives numerous inquiries on a daily basis from new engineers regarding questions of code. A good manager will respond to over half of these questions with another question:

**WHAT DOES THE BOOK SAY?**

This, of course, would necessitate that the new engineer become familiar with NFPA #13, get into the habit of referring to it, begin to know where to find information in it, and reinforce the notion that the pamphlet is a wealth of specific answers to code questions for various applications.

Refer now to Figure A-6. As you can see by the sample drawing, the pipes have all been sized in accordance with the above-referenced (1999 vintage) pipe schedule table; except for the 4” system header valve, and the 3” cross-main between branch-lines “F-B” and “H-D,” where the system piping shown exceeds the minimum required. The reason for this is material availability. Depending on the part of the world you’re from; different size pipe, fitting, and valve materials are more readily available than others; and at very reasonable cost. For example, 4” valves are more commonly used by contractors and are always in stock at supply houses.² So even though it is perfectly permissible to use 3” valve and header components, their use may not in fact represent a cost savings at all. Exceeding the minimum pipe sizes is always permissible. For a short period of time, almost all sprinkler contractors routinely upsized pipe sizing by one rank in the pipe schedule table. In other words, if 2” pipe is called for, they would install 2 1/2” pipe.³ This practice, however, has not been widely used for over forty years.

The reason for not downsizing the cross-main (see Figure A-6) from 3” to 2 1/2” to 2” is that downsizing grooved-end cross-main pipe results in the need for expensive reducing-type fittings. The expense incurred virtually offsets the cost-savings realized by a relatively short length of pipe downsizing. Also, should the structure experience a building addition somewhere down the road, the sprinkler system can easily be added on to right at the end of the existing cross-main, and the new piping added will be hydraulically calculated so that the existing system design, and main piping, could remain in place without any changes needed.

**DIMENSIONING PIPE LENGTHS**

The next step for this project is concerned with “cutting” the pipe. Let us first look at the branch-line running north/south and labeled “H-D” in Figure A-6. The shop wall-to-wall interior (north/south) running dimension is 74’0”. Since seven sprinkler-heads are supplied by this branch-line, we would evenly space those sprinklers (74 ÷ 7) at 10’7” intervals, with the end sprinklers being located 5’3 1/2” off of each wall. The cross-main has been situated 1 1/2” to the south of the bar joist shown. Therefore, as the bar joists are 6’2” apart, the cross-main dimension from the north wall [(6’2” x 5) + 1 1/2’] is 30’11 1/2”.

Subtracting all known dimensions from this 30’11 1/2” figure, we can ascertain the length of the 1 1/4” sized starter piece on branch-line “D.” Mathematically, 30’11 1/2” – 5’3 1/2” – 10’7” – 10’7” = 4’6”. The center-to-center length of the starter piece must be 4’6”.

Similarly, the dimension from the cross-main to the south wall can be figured to be 43’1/2” using the same method of measurement and spotting the main location of the joist that it is hanging from. Double checking, to make sure of this figure, 30’11 1/2” + 43’0 1/2” does equal the overall 74’0” total. So the 1 1/2” (south) starter pipe piece is figured by subtracting 5’3 1/2” (end-head from south wall) and the (three) 10’7” pipes from the 43’0 1/2” figure, which equals out to an even 6’0”. The south starter piece length will be 6’0”.⁴ Bear in mind:

**QUICKLY DOUBLE-CHECK YOUR DIMENSIONS WHENEVER YOU CAN!**

Notice the 1” drop to the sidewall sprinkler shown beneath the dished-in overhead garage door tracks. The sidewall sprinkler there is a necessary inclusion, by code, and its presence covers a fire that could occur when the door is in the open position. The location of the 1” drop was figured from the architectural floor plans, and it is best to locate this drop anywhere from 6”–7” outside of the masonry wall opening for the garage door.

The pipe dimensions for lines “G-C” and “F-B” are figured in the same manner as line “H-D,” since they are nearly identical. Notice the arm-over on branch-line “B,” and center-to-center distance used for this arm-over was 3’0”. If the branch-line is in a “V” space in the joist web (study Figure B-2), the it will be located in an “A” space after the arm-over (with 20” deep bar joists). This is what we want. With the branch-lines centered at 10” above the bottom of the joist, a 2’0”, 3’0”, or 4’0” arm-over is much safer than something like 2’7” because of the possible angled steel pipe obstructions when running pipe through the bar joists.
CONSIDERATIONS FOR OFFICE AREAS

All walls shown in this example are assumed to be full-height, and extend all the way upwards to the roof deck. The drop-ceiling height shown in the office area is presumed to be 12'9" high. The pendent sprinklers shown should (be attempted to) hit the ceiling-tile centers, even if the architect does not specifically require them to be so located. Hopefully, this will mean that when the 1′ drops to the pendent heads are installed in the field, at the very least they will not land on a light diffuser, or ceiling grid T-bar. For reasons of economy many of the smaller room areas have ceilings installed consisting of 2′ × 4′ acoustical panels. It is common practice to situate the pendent sprinklers for these ceilings at a “quarterpoint,” which is 12″ × 12″ in from the (either) end of this panel. This practice enables the builder to later change the size of the ceiling tiles to 2′ × 2′ if he so desires, by only adding one new 2 ft. long T-bar, and without moving sprinkler-heads. If the pendent sprinkler-head was originally located dead-center in the 2′ × 4′ tile panel, the builder could only accomplish his task by also having the pendent sprinklers and corresponding supply piping moved.

You may well wonder why sprinklers are not also installed in the dead space above the drop-ceiling. Well, it is because this building is of noncombustible construction. The code calls for the installation of automatic sprinklers in concealed spaces only when they contain, either wholly or partially, exposed combustible construction. “The intent is that sprinklers are not required if a concealed space is constructed of non-combustible materials, has no combustible surfaces, and has no storage occupancy” [3]. Without a combustible load, a fire could not start, nor could it spread, in this area.

The sprinklers have been spaced in the office area in accordance with light hazard occupancy spacing requirements. The heads are all located within 7′6″ of any wall, their spacing between heads in any room does not exceed 15′ and their total square foot coverage does not exceed 200 sq. ft.5 The small “main” pieces running east/west have been deliberately situated so that they can be hung directly below a bar joist, implementing economic hanging. No two sprinklers are closer than 6′0″ without a wall between them. This is not allowable because it could result in a “cold-soldering” situation, whereby the spray from the first operating sprinkler cools the fusing elements of the nearby sprinkler, preventing (or delaying) it from properly operating.6

As you become more familiar with laying out sprinklers in office areas, you will find that a little more latitude is allowed by the standards for small rooms of light hazard occupancy (see both 1-4.2 and 5-6.3.2.1 of NFPA #13, 1999 ed.).

Next, looking at Figure A-3, what we have done is take the architect’s planned office floor dimensions one step further. By comparing his reflected ceiling plans to the floor plan dimensions, we can actually figure the dimensions of all the end-ceiling tiles. We know that the interior ceiling pad dimensions are all 24′ × 24″.6 This makes it very easy to figure pipe lengths between sprinkler-heads. For example (see Figure A-5), the distance between the two westermost sprinklers in the general office area is 5 ceiling pads, or ten feet. The floor plan dimensions for the manager’s office, as an example, are (see Figure A-3) 8′2″ × 11′6″. Knowing this, and subtracting the overall lengths of the interior ceiling pads, we can correctly deduce that the end tiles are 1′9″ and 2′1″ respectively, because the T-bars are installed to support an even-length ceiling tile on each opposite wall, as a rule. To help yourself in “cutting” pipe lengths in the office, it is a good idea to fix the odd (not 2′0″) lengths of all the end ceiling pads, and note them on a separate “scratch” plan, which is the intended representation of Figure A-3.

As another example, there is one sprinkler each in the plant office and the manager’s office. To determine the length between the two heads, simply add the three full tiles, the two half-tiles (that contain the sprinklers), the two end tiles, and the wall thickness (6′). This totals 6′0″ + 2′0″ + 1′9″ + 1′7″ + 6″ = 11′10″. For the next example, let’s look at the 1 1/4 piece running east to west. Here we would add (from left to right) half of the first end tile, the wall thickness, the next end tile, a full tile, and a half tile [1/2′0″ + 6″ + 1′1″ + 2′0″ + 1′0″] to arrive at the total length of 5′7″ 1/2″.

Also note the 1 × 0-3 “nipple” piece in the entry room on branch-line “A.” That is the smallest pipe length on the job, and this is getting close to the shortest piece of threaded-end pipe that can physically be fabricated, which is 2″ long for 1″ and 1 1/4″ pipe.7

Since your job entails a lot of adding and checking, it will become necessary for you to commit the following table to memory. All pipe lengths are cut to the nearest half-inch, so these decimal equivalents will be used by you extensively when using an electronic calculator to add figures.

<table>
<thead>
<tr>
<th>Decimal Equivalents of a Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1/2″</td>
</tr>
<tr>
<td>1″</td>
</tr>
<tr>
<td>1 1/2″</td>
</tr>
<tr>
<td>2″</td>
</tr>
<tr>
<td>2 1/2″</td>
</tr>
<tr>
<td>3″</td>
</tr>
<tr>
<td>3 1/2″</td>
</tr>
<tr>
<td>4″</td>
</tr>
<tr>
<td>4 1/2″</td>
</tr>
<tr>
<td>5″</td>
</tr>
<tr>
<td>5 1/2″</td>
</tr>
<tr>
<td>6″</td>
</tr>
</tbody>
</table>

Again, memorizing these decimal equivalents is imperative. I do not know of a single sprinkler engineer who does not have these figures at instant memory recall.

The suspended ceiling height for this area, as previously mentioned, is 12′9″. In actuality, the builders would most probably opt to hang the drop-ceiling at a shorter height,
more like 9’0”. In that case it would be prudent to drop the 2”
office feed piping a little (3”–5”) outside the office demising
wall, with an auxiliary drain (see NFPA #13: 5-14.2.5) at the
bottom, and run the piping at an elevation of around 9’8”.

Please note that for all light hazard occupancies in new
system installations, “quick-response” type fire sprinklers
are advised. This recommendation first appeared in the 1996
NFPA #13 edition. This type automatic sprinkler obviously
possesses a much faster response-time index than a typ-
ical sprinkler, and for that reason is desirable for early
fire suppression. The reason that the quick-response type
sprinkler-headers are not required for ordinary or extra hazard
occupancies is that, due to the fast-response nature of these
heads, the possibility of too many sprinklers opening in an ac-
tual fire would then exist. The authors of the NFPA #13 code
are cognizant of the fact that when the danger of a large-scale
fire is present, then the more prudent approach to take with
regard to fire suppression, is to place a higher priority on
not wasting available water by running that risk of too many
sprinklers activating, whose discharge may be spent on areas
that will not actually be part of the fire.

**TAKE-OUTS**

By now I’m sure that you’ve noticed the second, heavier-
lined, pipe length dimensions on Figures A-5 and A-6. These
refer to the end-to-end shop cut pipe lengths. This is the actual
cut length of the pipe to be installed, figured by subtracting
the two take-outs from each end of the pipe.

The dimensions marked “X” in the above drawing refer
to the take-out for each end of the pipe. These are used with
steel piping made-on to class 125 standard cast-iron fittings,
an industry norm. A complete take-out table for threaded pipe
and fitting sizes up to 8” appears in **Figure C-1** on page 159
of this text. To see how this works as related to our example,
let’s look at the piece of 1 1/2” piping on branch-line “A.”
Its length, from center-to-center of fitting, is 3’9”. Refer to
the column headed by 1 1/2” at the top of the table, under
“size of piping being cut,” on Figure C-1. Then look down
the column to find the “X” dimension take-out for the size pipe
(at a right angle) on either side of the 1 1/2” pipe shown on
the Figure A-6 plan. The size of those two pipes are 1” and 2”. We
must shorten this 3’9” length by those two takeouts, which
(from the Figure C-1 table) are 1” and 1 1/2” respectively.

Therefore, since those two take-outs total 2 1/2”, the actual
cut-length of the pipe should be (3’9” − 2 1/2”) 3’6 1/2”.
In other words, with those fittings (cast-iron tees) made-on
either end of the 3’6 1/2” piece, the center-to-center pipe
length will be exactly 3’9” from fitting to fitting. In cases
where the take-outs work out to a 1/4” or 3/4” fraction total
exactly, it is best to round the total down, or possibly make
that up with another length of pipe on the same run.

For one more example using the takeout (Figure C-1) table:
the end 1” branch-lines should be a 10”” total length. These
need to be adjusted by their two take-outs, and each of these
would be found by the 1/2” “piping” at a right angle. We use
1/2” in this case because the fittings used are either 1 × 1/2
elbs or 1 × 1/2 tees to accommodate the 1/2” thread
on the sprinkler-heads. Thus, the total take-out is 11/16” +
11/16”, which is rounded to 1 1/2”.

The 2 1/2” and 2” fittings in our example project, used for
the riser pieces off of the cross-main, are actually pipe-o-lets
welded onto the 3” cross-main. As you can see in Figure A-6,
these are strategically welded on the main in exact locations
that we determine to properly supply the branch piping. The
“X” dimension on the Figure B-1 depiction shows how the
pipe-o-let take-out is measured. The table in **Figure B-3** lists
the take-outs for the welded pipe-o-lets, with female threaded
ends. Now let’s look at the riser piece feeding branch-line
“F-B,” “G-C,” and “H-D.” The overall length of the riser
pieces, center-to-center, would (14 2/” − 12 6”) be 18” to
delineate the elevation change in the piping. The take-out at
the top of this riser piece, figured from Figure C-1 (cutting

2” pipe with a 1 1/2” pipe piece as the largest right angled
pipe), is 1 5/16”. The take-out at the bottom of the 2” riser
piece, taken from **Figure B-3** (cutting a 2” pipe-o-let outlet
in the 3” run), is 2 3/4”. The total (1 5/16” + 2 3/4”) take-
out then, is 4 1/16”, rounded to 4”. Thus, by making the cut
length of the riser piece 1 1/4”, the installers will be hanging
the branch-lines at the elevation (14’2”) desired, 1’8” higher
than the centerline of the (12’6”) cross-main elevation.

**NOTED DIMENSIONS**

Also note that the plan elevations noted on Figure A-6
are accompanied by a figure in [ ] brackets, with a minus
sign. This is for the installers’ use in hanging the piping,
and refers to the distance from the centerline of the piping to the underside of the roof deck. This is the real figure they will be utilizing, as it is impractical for them to continue measuring a distance like 14 2/3" from the floor to the piping, to insure that the lines are essentially level. Also for the benefit of the installers, there are numerous dimensions shown on the plan. These measure the distances from the intended pipe positions to walls, joists, beams, or column lines.

YOU CAN’T SHOW TOO MANY DIMENSIONS ON THE PLAN!

As the job progresses, an installer is much more confident and assured if he can refer to dimensions on the plan to see how accurately his field installation is corresponding to the blueprint. Some teamwork comes into play here. The more dimensions that the design technician shows on his plan, the easier it makes things for the sprinkler fitter. It also lends some flexibility to the field installation, because the job installation does not always start “solid” from the point of the building’s water supply. Thus, the first piece hung in the field may be a cross-main piece located somewhere in the middle of the building. This process cannot be implemented accurately without using your dimensions as critical points of placement.

One such reference point in our example would be either of the two 5 6/16" dimensions off of the 24" I-beam separating branch-lines “F” and “G” (on Figure A-6). Please note that even spacing is intentional. Because the steel beam is entirely solid and of sufficient depth, it happens to be a sprinkler spray obstruction. When preparing your sprinkler-head spacing layout, you will save yourself a lot of time and trouble if you simply treat a beam in the middle of a room in the same manner as you would a wall.

To be absolutely certain of code compliance with respect to sprinkler elevations, always refer to Section 5-6.4.1 in (1999 ed.) NFPA #13.9 The allowable distances noted below roofs, beams, or ceilings is always measured to the sprinkler-head deflector. In our example, this distance shall be between 1" and 12" beneath the underside of the roof deck. “The closer sprinklers are placed to the ceiling, the faster they will operate . . . (but sometimes) serious interference to lateral distribution of water from sprinklers by structural members (can result from close placement)” [4]. For all cases, “the minimum of 1 in. is to permit installation and removal of upright sprinklers” [5]. In our project example, with piping at a 10° centerline down from the underside of the roof deck, our sprinkler deflectors would be positioned 6 1/2" to 7" down, which meets the requirement.18

Every sprinkler system must include an inspector’s test connection, which should be installed at an area remote from the water supply and system header. Our example inspector’s test valve is shown on Figure A-6 and is piped off of branch-line “D”. “The primary function of the wet system inspector’s test is to test the operation of the water flow alarm device(s) at a flow equivalent to that of one operating sprinkler. The purpose of the remote branch-line location is of course to provide the most severe testing requirement” [6]. It must include a 1" gate or globe valve, and is also used to bleed air out of the system when first filling it with water, or refilling after a drain-down. The test valve should be installed at a readily accessible height and location. At least 4' of pipe, on a wet system, should extend down beyond the valve prior to the point of outside discharge, to guard against a pipe freezing situation. Note the 1 x 2-0 armover on branch-line “D”. This is to “catch” a hanger on that armover to support the vertical pipe drop.

To fully comprehend the way the cross-main is to be engineered requires a first-hand examination of grooved pipe fittings. All manufacturers of these fittings have brochures and “cut sheets” that detail material specifications, take-outs, and other data pertaining to these fittings. Those listed in Figure C-2 are taken from the Pipe Fitters Handbook, distributed by the Grinnell Supply Sales Company, and are fairly standard with respect to the fittings detailed. The grooved fitting ends butt up to the pipe (prepared with grooved ends), and are bolted and coupled together on the outside with a rubber-gasketed grooved coupling.10 This is the easiest and fastest method for cross-main installation.

Refer again to Figure A-6. The two 3" cross-main pieces are each 20" in length. Stock lengths of steel pipe usually arrive at the fabricator’s shop in 20- or 21-foot lengths. The fabricator will then cut or roll-groove the ends of this pipe, or on the desired cut-lengths. The end of the 3" main in Figure A-6 is simply capped off with a 3" grooved coupling and a grooved plug of “cap.”11 The centerline of the pipe-o-let shown will be welded 90° from the end of the pipe. This places the actual end of the 3" pipe (5 6/16" – 9") at 4 9/16" from the east wall of the building. On the west end of the main, the first welded outlet is shown 4 3/8" from the beginning end of the main. Again, this is a pipe “end-to-center” (E-C) dimension. Since the system riser is 10 1/2" off the west wall, and we want the branch-line positioned at 5 6/16" off the wall, we simply subtract 10 1/2" and the take-out for the grooved elbow to arrive at 4 3/8". The take-out (see Figure C-2) for the 3" grooved elbow is 4 1/4", which we would round up to 4 1/2", to compensate for the very small gaps that may occur during installation within the grooved couplings between grooved pipe ends.

To avoid any possible errors in our calculations, we always want to double-check our cross-main lengths. To do so, grab your calculator and add: 10 1/2" (wall to centerline of riser dimension) + 4 1/2" (fitting take-out) + 40" (main piping) + 49" (pipe end to wall dimension). This equals, fortunately, 46 0/6" even, which is the overall east-to-west interior wall dimension. Again, by being cognizant of the critical nature of cross-main placement, we will eliminate headaches down the road.

THE SYSTEM HEADER

The architectural plans for this project did not come furnished with any preliminary sprinkler system layout. We have
prepared this on our own, or what is commonly referred to as “design-build” procedure. The plans did come, however, with a preliminary layout for the system “header,” which is shown on Figure A-4. It is well depicted and gives us valuable information. For one thing, it lets us know (in our case) that the system control valves shall be of the indicating type (required by code anyway) and that they are to be electrically supervised or, in other words, equipped with tamper switches. Since a flanged elbow (and not a flanged tee) is shown placed at the point of tie-in to the incoming water supply, we can deduce that no “domestic” water (for the plumber’s use) will be supplied by this incoming service. It is a “fire main” only.

The preliminary detail also shows the components required for every wet-pipe automatic fire sprinkler system: namely, a flow switch (to sound an alarm in the event of waterflow), a main system drain valve, some device type containing a check valve, a cabinet containing a stock of spare sprinklers, a water pressure gauge, and a fire department connection. These are all necessary and required system components. The detector-check valve will meter the water used in the course of fire-fighting or system testing, for which the municipality will not charge the owner. This valve also contains a weighted check valve responsible for two important duties. First, it locks the water into the system piping at city (static) pressure. Second, it guards against “backflow,” insuring that the stagnant, contaminated water that sits in the sprinkler system will not possibly “back up” into the drinkable city water supply. “Situations where concrete evidence links a fire suppression system with public water contamination are virtually non-existent” [7].

The fire department (or “siamese”) connection is mounted on the outside of the building, so that in the event of a fire, the local fire company may connect a 2 1/2” hose to the connection from a fire hydrant. Turning on the hydrant will then boost water volume and pressure levels in the already operating sprinkler system. Of due importance, in the event of accidental valve closure, this fire department connection, upon activation, will then become the only water supply source for the sprinkler system. An outside bell or gong (usually 10” diameter) will be placed directly above the connection on the outside building facade. It will sound when activated by the flow switch, and will hopefully assist firefighters as to the actual location of the fire department connection. This bell should be shown on your plan.

The fire department check valve, of course, prevents system water from flowing out of the fire department connection. A more complete docket of the rules regarding this connection can be found in Section 5-15.2 of NFPA #13, and it is important to remember that the parameters allowing for this connection elevation are between 1’6” and 4’0” above the outside grade (ground) level.

We need to prepare a scaled section plan showing the details of the system header. This is shown on Figure A-8, and labeled “East Elevation” (or what we would see if we looked towards the west). The dimension of the incoming water service, which we have noted from our field survey, are 10 1/2” and 2’ 11 1/2” off of each wall. This survey is important, because a report from a phone call to someone “on the job” may have produced dimensions of 1’0” and 3’0” off each wall, which were figured to be “close enough.” This survey also determined that the end of the flanged-spigot was at an elevation of 11 1/2” above the finished floor, that the piping was plumb, and that the flange was installed in the “two-holed” position.

The installation is considered two-holed if this line parallels the nearby wall.

Incoming 4” water service, flanged

The sketch above is a cleaner version of our survey notes. If the installed flange is not two-holed, an adjustment needs to be made, because then our fittings and valving will be out of kilter, and not able to run south along a line parallel to the west wall of the building. The same concept holds true with regard to pipe elevation if the vertical feed is somehow slanted and not truly plumb.
The take-outs for flanged fittings are figured in much the same way as grooved fittings, as they butt-up to pipe ends and are bolted together. Figure C-3 shows the take-out dimensions for different types of flanged fittings. Note the 4'0" dimension on Figure A-8, giving the center-to-center length from incoming water service to the riser itself. This has been determined by adding the take-out for the 4" flanged elbow (6 1/2"), the O, S, and Y valves (manufacturer listed take-out: 9" each), the detector-check valve (manufacturer listed take-out: 1'4 1/2"), the 4" flanged tee (6 1/2"), and adding an additional 1/2" to allow for the incremental small gaps between flanges due to the inclusion of rubber gaskets. The fact that the riser is now determined to be situated 6' 11 1/2" from the office demising wall, perfectly coinciding with the desired location of the 3" cross-main beneath the bar-joint, is just a convenience for the purposes of this book’s example. Usually, a tee-off main or the riser would armoress to connect to wherever the cross-main needs to be. The 1'6" centerline of header elevation (see Figure A-8) has been determined by adding the 6 1/2" flanged elbow take-out (as noted in Figure C-3) to the 11 1/2" incoming face-of-flange elevation above floor.

The center-to-center system riser length (12'6" – 1'6") of 11'0", needs to be adjusted by take-out for shop cutting. Using the take-out for the 3" grooved elbow (rounded to 4 1/2") at the top of this riser, and the take-out for a 4" flanged fitting (6 1/2") at the bottom, we arrive at the 3 x 10-1 exact cut for our riser. Outlets for riser components will be welded on, cut, or tapped in the fabrication shop (see Chapter 7, “Stocklisting”).

AT THE END OF THE JOB

Every plan must have a title block, and ours is noted in Figure A-7. This is self-explanatory. NFPA #13 does require that each fire sprinkler plan include the name and address of the installing sprinkler contractor.

To complete our work, we still need to add some miscellaneous details, add some plan notes, conduct a field check survey, and then stocklist the job. These duties will be discussed in later chapters. At some point, our design work is complete, and the stocklist sent in for fabrication. I have one final note to make in this chapter, and it is regarding the very over-zealous, God bless them, and over-cautious design engineers. Let me make this analogy: if you are taking your family on a long road-trip, you would naturally check your vehicle over before leaving. You’d check the oil level, tire pressure, coolant level, and the windshield solution supply. The next day, you may check all the hoses and belts, check your filters, and look for cuts or bubbles on all your tires. Then you might pull out your sparkplugs to see if they’re clean and properly gapped. Still worrying, you decide that you had better clean your fuel injectors.

Finally, you leave on your journey and what happens? Ten miles out of town you run over a railroad spike and have a blowout.

Well, guess what? The very same thing can happen on sprinkler jobs. No matter how much you over-engineer, fret each detail, and double-check every single dimension; some crazy development beyond your control arises which necessitates some late-in-the-game redesign. A room needs to be enlarged to make way for some equipment, structural steel sizes changed at the last minute, some authority decides to reject already accepted design criteria, or any of a number of unforeseen calamities can occur. It doesn’t always happen, but my point is that you must be confident enough in your work to complete it on time and move on to the next project. If you think you’ll be able someday to engineer a “perfect” job every time, forget it. The sprinkler trade often falls victim to the blunders of other trades, architect mistakes, and general construction mismanagement.

Reading this chapter should give you a good feeling for the full scope of the engineer’s design work on a given project. Granted, the project example used was not overly complicated. The best way to learn is by doing, and by constantly asking questions to all those possessing experience: be it installers, salesmen, or designers. By doing this, your own expertise will continue to grow.

CITATIONS


ENDNOTES

1 The use of 3/4" fire sprinkler system piping for steel pipe installations was disallowed beginning in the early 1940’s. Today, code permits 3/4" use only in plastic pipe or copper tube.
Most supply houses and sprinkler fabrications shops contain very little 5' material, and some don’t even stock 3 1/2'' material due to the costs associated with stocking slow-moving inventory.

This will resolve some confusion if you’re ever analyzing an old existing installed system that appears to have odd discrepancies in pipe sizing.

The center-to-center distance, between the two starter sprinkler heads off the cross-main, does not equal out to 10'7'', but is 1'' off. This simply makes up for the fact that the previously mentioned 74'0'' figure divided by 7 (sprinklers) did not precisely divide out to 10'7'', but was the closest approximation.

Table 5-6.2 on page 35 of (the current) NFPA #13 outlines all rules for maximum square foot coverage limitations.

It is fairly rare to encounter a job using ceiling tiles other than 24'' × 24'', 24'' × 48'', or 12'' × 12''.

The smallest nipple pieces are 2 1/2'' long for 1 1/2'' and 2'' pipe, and 3'' long for 2 1/2'' and 3'' pipe.

If mechanical-tees are used in lieu of welded outlets, the take-outs are very similar, almost interchangeable.

Actually, the first chapter that you will want to read and understand thoroughly in NFPA #13 is Chapter 5. It is aptly entitled “Installation Requirements.” To make head or tail of any unfamiliar terminology, refer to the definitions noted in Chapter 1. The revised 1999 edition of NFPA #13 published a restructured format for its Chapter 5, although the requirements remained largely unchanged.

The mechanics of all flanged, grooved, and threaded pipe assembly cannot be done justice in verbal dialogue. You will be much better informed with a visual examination if you are not already familiar with this.

This will also serve as a flushing connection—see NFPA #13 5-13.17.

These are electric monitoring devices that give an indication of any valve tampering or disruption and warn of possible valve closure.

The minimum size of the system main drain piping is 1 1/4'' for 3'' sprinkler system risers, but 2'' for any larger sized risers.

These are the flanged gate valves shown in Figures A-4 and A-8. They indicate valve (open or closed) position. The abbreviation stands for “outside stem and yoke.”

This 9'' take-out figure is standard, as is 7 1/2'' for 2 1/2'' valves, 8'' for 3'' valves, 10 1/2'' for 6'' valves, and 11 1/2'' for the 8'' valves.

See Sections 5-6.3.4 and 5-7.3.4 in NFPA #13.

When using quick-response sprinklers in a light-hazard occupancy on a wet-pipe system, the designer will want to utilize the design area reduction graph shown as Figure 7-2.3.2.4 on page 85 in NFPA #13, in his hydraulic calculation.

In the event you encounter some type of structural construction consisting of all solid beams (steel or concrete) or steel Z-Purlin construction, refer to Chapter 5-6.4.1.2 in NFPA #13.

Have the gauge installed at an elevation close to the average American’s eye-height, which is 63 inches.
Additional Engineering Responsibilities

The design engineering of a fire sprinkler system shop drawing was briefly discussed in the previous chapter. The novice engineer will be able to rely on the expertise of the architect’s consulting engineer and the fire protection professional who sold the system installation contract, to insure that the specified design criteria for the sprinkler system are valid. As the beginner progresses in practice and experience, and his knowledge of codes becomes more complete, a subtle inherent responsibility will become evident. That is, he will be expected to be more and more aware of certain “red flags,” or clues, that will give him definite indications when prescribed design criteria, or specified system layout, is probably insufficient. One example of a “red flag” would be a job consisting of a tall warehouse, and the intention of the owner to pile the warehouse stored commodities quite high. There are systems in service today, designed in accordance with NFPA #13 ordinary hazard requirements, that protect products stored in racks to heights exceeding 20’. Such systems may be quite easily overwhelmed by a fire in this scenario. The fact is that any building containing any commodity piled to an elevation in excess of twelve feet is outside the scope of your typical light, ordinary, or extra hazard commodity classifications.¹

It may be unsafe to install fire sprinklers in rooms containing normal or high-voltage electrical service equipment.¹ It may not be advisable, due to the risk of considerable water damage, to install sprinklers in rooms designated to house computers or computer tape storage. The architect, owner, or local fire prevention bureau will have to be consulted in these instances.

Fur storage vaults, dwelling units, elevator machine rooms, stairway towers, exterior docks, and library stack rooms are examples of areas within a structure that require special consideration, and requirements governing these are included in NFPA #13. Additional regulations are also mandated for stages, vertical shafts, paint spray booths, floor openings, cooking equipment and connecting ventilation, and wall openings for conveyors. Sprinklers need to be installed beneath decks, platforms, combustible exterior canopies and docks, and exposed duct-work in excess of 48” in width.

Design criteria for some occupancies are contained in their own NFPA standard completely. The old NFPA #231 pamphlets, which covered high-piled storage, rack storage of materials, rubber tire storage, plastics, idle pallet storage, and roll paper storage, have now been incorporated into Chapter 7 of NFPA #13. “In storage properties, the leading occupancies in which these (storage) fires occur are agriculture products, which account for 38 percent of fires” [1]. Residential occupancies, aircraft hangars, buildings containing flammable and combustible liquids, and explosive materials are examples of structures whose design alternatives and requirements also need to be explored in separate NFPA standard publications, for a greater inroad to understanding.

LOCATE SPRINKLERS IN AN OPEN SPACE

As you will discover when perusing through Chapter 5 of NFPA #13, there are critical rules which deal with potential spray obstruction. For example, the sprinkler piping itself can pose such an obstruction, and therefore any sprinkler on pipe 2 1/2” or larger needs to be “sprigged” upwards above this large piping, usually by using a 1” nipple piped off of the large pipe. “The discharge pattern of upright and pendent sprinklers is a half paraboloid pattern filled with spray. In order to permit the distribution of water over the area which the sprinkler has been designed to protect, there must be no obstruction to the spray pattern. The rack storage fire tests and other tests with solid piled storage have shown that sprinklers are effective with 18-in. clearance” [2]. Hence, the established rule for clearance between top of storage and ceiling sprinkler deflectors has been fixed at 18”. Regarding sprinkler discharge patterns in general, “sprinkler-head areas will overlap. The
sprinkler pattern will equal a 16-foot diameter circle at a point 4 feet below the sprinkler-head at 15 GPM" [11]. This particular spray pattern model assumes an end-head pressure of 7 psi, with a nozzle possessing a K-factor of 5.65. Per NFPA #13, it is required that the sprinklers be installed in each instance so that the sprinkler deflector is parallel to the ceiling. This requirement is also in the code in an effort to minimize obstructions to spray patterns.

**SOME OTHER RED FLAGS**

Aerosols can become flying items of airborne flames when set on fire. Alcohol or battery storage presents a more severe fire risk. The presence of these, and any visible vessels, or large drum storage products, also need to be investigated and questioned by the alert design engineer.

Indeed, areas are usually defined as hazardous, and must be "red-flagged" immediately by a fire protection engineer, when they contain materials such as combustible dusts, vapors or gases, or combustible fiber. Paint or ink mixing, oil refinery, chemical processing and/or plating areas within a manufacturing plant often possess the need for high-hazard technical design assistance. The NFPA department of the insurance carrier, or the NFPA standards themselves, provide assistance. The NFPA standards have become all-encompassing. To cite one example, "NFPA 325M, Fire-Hazard Properties of Flammable Liquids, Gases, and Volatile Solids," lists flammable liquids, gases, volatile solids and their properties" [3].

The point is, obvious and less-obvious high-hazard risks can never go completely ignored, by a design professional at any phase of construction. Consider this: "It is not advisable to install sprinklers when the application of water, or of flame and water, to the contents may constitute a serious life or fire hazard, as in the manufacture and storage of quantities of aluminum powder, calcium carbide, calcium phosphide, metallic sodium and potassium, quicklime, magnesium powder, and sodium peroxide. The manufacture and storage of such materials should be confined to specially cut-off, unpriknlered rooms or buildings of fire-resistive construction" [4]. Clearly, there are dangerous situations. In other red-flag predicaments, it is simply not worth the trouble of designing a fire protection system that will not be effective, or may badly compound problems. The "any protection is better than nothing" theory does not always make sense. "Survival in today's world of construction means stopping risks and the risk takers who think they're doing someone a favor by taking shortcuts" [5].

**THE CONSULTING ENGINEER'S ONUS**

None of the above dialogue is meant to make you feel overwhelmed by responsibility at the onset of your training. More often than not, any unusual hazards of the type discussed are well known and recognized as such by the building planners in their early going. Hopefully, a good preliminary fire sprinkler design can be used as a guide in these cases; and if one is prepared, this is a big plus as well as a relief. A preliminary sprinkler design package, complete with job specifications, is often used by architects and building planners on any building design. They may need this package to acquire a city permit, or simply for organizational purposes. It is also a cost-effective architectural plan component for the following reasons:

- A sprinkler design bid package avoids disorder by clarifying the items that are definitely included in the contract.
- A blueprint detail of the system design made available for insurance review prior to bidding eliminates all confusion and future problem areas.
- The local requirements and code adoption can be established ahead of time, pinpointing design criteria.
- Proposal amounts are reduced considerably because the estimator will not routinely "up" his bid to cover job intangibles and bidder uncertainty.
- In a retrofit situation, a cost savings is realized in the bypassing of a general contractor or construction management firm.
- It is imperative that a water supply and hydraulic analysis be performed to determine if a fire pump is a necessity and, if so, at what gpm and psi rated capacity.
- For complicated systems or buildings, or in retrofit projects, there will be fewer "cost extra" standoff dilemmas—probably none—because the bid package parameters eliminate "gray" areas.
- Allowing a sprinkler contractor to "design-build" the preliminary system opens up a conflict of interest situation, where the contractor may have his own financial interests at heart. The policy of the preliminary design is to work with the owner's representative to minimize system cost while working within the applicable codes.
- A fire sprinkler design bid package meets the desired goal of a true competitive bid situation.

**HAZARD EVALUATION**

You, of course, still need to review the specifications and must consider design alternatives even when presented with a good preliminary plan. For now, getting back to the responsibilities of the sprinkler contractor's designer, you may wish to add the following initial steps in system design to the eight-step list already noted at the beginning of Chapter 2: the determination of occupancy, building construction type,
water supply, and the checking for any special situations. Occupancy determination is a key step, and probably the first one to be positively determined. The first phase of consideration when deciding any occupancy per se for our purposes involves building construction and its location. “The second phase of hazard evaluation involves building occupancy, of which there are three main classifications: Light Hazard, Ordinary Hazard, and Extra Hazard. Light hazards include apartments, churches, hotels, schools, office buildings, and similar structures where effective fire protection can be provided by lighter-than-average means. Ordinary hazard occupancies include general mercantile, manufacturing and other industrial properties” [6]. There are two subgroups under this class. This identification can sometimes be a tough judgment call in buildings that fall under the “mixed-use” category. “In such cases, the more stringent requirements of each of the occupancies involved must be applied” [7]. Clearly, in such cases, the pipe sizing required may well be quite different for the different areas of the building. Say, for example, one end of the building is a large (light hazard) cafeteria seating area and the other end is used for rack-storage of furniture products. Whatever the case, the piping for the highest hazard occupancy needs to be hydraulically calculated or by other means sized first. This will affect the pipe sizing for all areas that the feed-main piping for the higher hazard area passes through.

The term “mixed-use” occupancy does not refer to something like a building containing some industrial process, and offices attached. The mixed-use terminology generally comes into play when one or more secondary occupancies (that are usually ordinary or extra hazard) constitute more than 10% of building square footage. “Once an area has been classified, all project disciplines must be aware of this classification, because materials and devices must be appropriate for the location . . . designers should ensure that specified devices are installed” [8]. Anytime that a hazard classification change takes place, this can impact other trades, suppliers, and building design features.

**ON-THE-JOB RESPONSIBILITIES**

The later steps in the designer’s job regimen involve necessary procedures for the plan approval process. These include plan and calculation submittals, and also submittal of material specifications (“cut sheets”), if required by the project engineer. A follow-up call is often necessary to make sure that these items have been received, and to get an estimated date of plan review completion.

It is the engineer’s responsibility to his employer to insure that his design is economical and amenable to the estimator’s cost estimate. This may necessitate a review of his estimate sheets, and will require discussions with the estimator regarding the exact type, model, and quantity of any of various materials that were figured in the base cost.

The engineer is expected to cooperate with the sprinkler company job superintendent during all phases of construction. At the onset, the superintendent will need blueprints and a copy of the stocklist. Other forms and items that he will need include completed hydrostatic test papers, a completed hydraulic placard for each system riser (see example on Figure D-1), and a maintenance manual. For years NFPA #13 required that the installing contractor provide the building owner with the NFPA #13A pamphlet, covering recommended practices for maintenance and testing. The proviso has been changed recently to (see Section 10-4 of NFPA #13) a larger standard, NFPA #25.

**CRITICAL DESIGN CONSIDERATIONS**

Section 8-1.1.1(4) of NFPA #13 requires the plan depiction of a full-height cross section or schematic diagram through the building, if required for clarity. It usually is a good idea to show some sort of cross section on the plan for everyone’s benefit, even if it is an extension of the header and riser diagram. If you do so, show the piping location referenced with dimensions (see Figure E-2). All risers should also be detailed in a section view, showing pipe sizes, and drawn to scale. The section does not need to be artistically fancy, one as simple as the example depicted on Figure E-1 will suffice, so long as it gives the viewer a clear picture of the intended pipe location.

The design engineer must always be cognizant of the possibility of accidental water damage. For instance, a sprinkler that is designed in a position 6’6” above the finished floor, has a greater risk at this low elevation of an accidental impact to a sprinkler-head, causing water discharge. It is wise to note on your plan where protective cages (headguards) should be installed to properly guard the sprinklers.

If, for example, the warehouse piping (see Figure A-6) had to be installed at an elevation of 14’10”, the sprinkler-heads would then be installed, for lack of space, in the pendant position. As the sprinkler pipe would not act as a protective barrier in this instance, the exposure of the sprinklers would also call for headguard protection.

Accidental water damage can be extensive, and expensive. It can result when ambient temperatures get either too hot or too cold. An environment can become very hot: such as near an operating unit heater, or in a poorly ventilated attic in summer, or near a blow-off valve on steam piping. In these cases, the temperature rating of the automatic sprinkler needs to be altered, in strict accordance with the practices noted in Section 5-3.1.4.2 of (current edition) NFPA #13.

If the room to be protected is too cold, such as a meat freezer, and the system piping is a wet-pipe system, then our sole alternative would be to install a dry-pendent sprinkler in that room. Another situation for the dry pendent’s use can be seen in our example in Figure A-5. Suppose that the
mechanical plans show no duct diffuser or heater of any type in the “entry” room, and this building is located somewhere in Minnesota. In similar cases, it has happened that the water inside the drop-nipple has frozen. The resultant water damage comes when the frozen pipe interior thaws, and the expansion (with heating expanding the water) of the icy water causes either the fitting to crack, or the fusible elements of the sprinkler to burst. A dry pendent head utilized in this application is a remedy for such a possibility.

Dry pendent sprinklers contain a basic pendent sprinkler connected with 1″ threaded steel pipe which is sealed at the inlet (top) side, preventing condensation or water entry. This drop length must be of the exact dimension necessary to place the sprinkler at the desired ceiling level when the entire dry pendent is made into the fitting to which it is attached. The steel pipe or tube interior is actually a vacuum, which cannot freeze. The exact operating description of the dry pendent sprinkler is detailed on manufacturer’s cut sheets, and is dependent on heat activation of the fusible sprinkler elements. When these parts fuse, they release a bushed cap or seal which then releases one or two long piston rods (or “stems”). Continuing the chain reaction, these release the top O-ring seal and bearing at the top of the apparatus, and the resultant water release from the system flushes these interior components right out the sprinkler orifice as it delivers water.

The shortest dry pendent (or dry upright or dry sidewall) sprinkler that can be made is about 3 1/2” long. These are custom-made to length in the factory, cut to the nearest 1/4 of an inch. They can be ordered out to any reasonable length, but are only approved up to 48″ long. This may be because there has to be sufficient clearance beneath the installed sprinklers to allow for the long piston rod stems (or “guide tubes”) to be flushed all the way out, so as not to interfere with proper operation. Another nuance to bear in mind is that these dry sprinklers can only be made into a threaded tee and not an elbow. The tee is often installed on the pipe in “bullhead” fashion, although this is not a necessity. For example, in the previously mentioned case (see Figure A-5), the sprinkler fabrication shop would make-on a 1″ tee to the 1 × 1 1/4 1/2″ piece, if it was going to supply a dry pendent head, and not a 1″ 90° elbow. One last note of mention: dry pendent sprinklers are expensive and become much more expensive with increased length. In the examples of a freezer or cold entry (or lobby) room, if the dry sprinkler looks to be any longer than a 20′ order, you will be economically better off to drop the 1″ wet pipe down to a screwed coupling, and install the dry pendent sprinkler from that starting point.

***

Refer again to Figure A-6. All grooved couplings on the feed (or “bulk”) and cross-main piping should be shown. Indicate the exact style, finish, and thread type somewhere on the plan for the desired fire department connection; as it may be important to those reviewing the plan. If you want to try and shop-cut the 4″ piece of piping that feeds the connection itself, the end of the 4″ pipe should be figured to extend 1 1/2″ past the outside wall when using a standard 2 1/2″ × 2 1/2″ × 4″ siamese connection. On branch-lines, use only stock fittings (see Figure D-2 for a listing of cast iron fittings that are commonly made and readily available).

Groove all piping 2 1/2″ and larger wherever possible. 2 1/2″ threaded piping is fine, but if it requires field cutting for adjustment there is trouble, for this can’t be done. It has to be re-ordered from the fabrication shop, and this wastes valuable labor time. The sprinkler fitters have a power machine, to cut and thread piping, on every job. It is portable and efficient, but some limitations accompany its practicality. For one thing, it cuts piping only in 2″ and smaller sizes. Also, it cannot cut piping to lengths shorter than 6″.

**COMMUNICATE**

It is usually the duty of the design engineer, to consult with the local fire prevention bureau (in most instances) prior to plan drawing and submittal. The questions posed to them should include the number of plans they require for submission, if a permit fee is required, what specific codes they have adopted, if any type of special backflow preventer is required, if they require insurance company approved drawings, and what existing water flow test information they may have for the job-site vicinity. Every phone call you make to these people is appreciated, and usually informative. It’s good public relations for your company as well.

The design engineer is often asked to attend a pre-construction or job coordination meeting, with the general contractor’s job foreman, and personnel representing the other subcontracting trades. The sprinkler engineer is the person the sprinkler contractor will want in attendance at such a meeting. As coordination is a major concern, you will want to prepare yourself with a review of your design elevations and positioning of all the drawn sprinkler piping. Top priority will be to establish clearances at this meeting for all your risers and main piping. Also, in areas with drop-ceilings, you must establish a clear elevation at which your sprinkler fitters can hang the concealed piping. This figure will be of great interest to several other trades as well. At the time of this meeting, you should know the following:

1. Location of water supply tie-in inside building
2. Location of fire department connection
3. Routing of plans for approval
4. Type of sprinklers and escutcheons
5. Wiring of alarms, bells, and tamper switches
6. If the water supply is to terminate in a flanged tee, the plumbing contractor should be asked to supply that fitting.
(7) Flow test information
(8) Additional permits if required

If any of the above items are still a question mark at the job meeting, you must press for some answers. You will also at this time ask any specific questions that you have regarding the architect’s job specifications.

ALWAYS BE ON THE ALERT

The engineer often does work in existing buildings. Although the contracted work may not be specifically involved, the fire sprinkler professional is one of the few people who can recognize existing system deficiencies and report them. “Sprinkler systems must . . . be evaluated after any alteration or renovation to ensure that they have not been obstructed and that the system is still adequate for the hazard at hand. It is not uncommon to find a small office installed on the manufacturing floor after a facility is built that was never equipped with sprinklers. Another common error is storing a commodity that was not anticipated when the sprinkler system was designed. Closed valves are still a leading cause of sprinkler failure, so diligence must be exercised to ensure that all valves are in their proper position” [9].

If, in the course of your work, you notice that sprinkler- heads have been painted,10 don’t you think that an owner or plant manager would like to be alerted to this fact? Another deficiency that is often spotted is the lack of any sprinkler protection in a fire pump room. The entire premises would be in danger after a full-scale blaze in the pump room. I am not suggesting that you undertake a temporary career change while on field survey and become a fire inspector. However, you become responsible to a certain degree if you do detect an existing installation or design flaw, or omission of proper protection. Rather than ignoring this, look at it as a way of marketing more sprinkler work for your employer.

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One last aviso before finishing this chapter should be discussed, and it requires visualization. Look at branch-line “F” in Figure A-6. Suppose the lengths of pipe to be installed between sprinklers were actually 15’ long, and the bar joists were only 3’1” apart, and only 10’’ in depth. Could an installer (sprinkler fitter) be able to physically get the piping into the joists for routing?11 The best way to check if the lengths of pipe are not too long to fit through the bar joists, or through small rooms, is to ask a sprinkler fitter or sprinkler superintendent. He will often tell you to “cut the pipe in half” to be safe.12 In either case, you have at least consulted someone on the matter who should have a better feel for this type of engineering decision. Field labor is a great source for expertise and answers to numerous questions that you will have throughout your work as a designer.

CITATIONS


ENDNOTES

1 All buildings today contain an “electrical equipment room” or similar area. How to safely protect this room or area has been debated for many years. Some municipalities simply ask that you omit automatic fire sprinklers from this room altogether. With due consideration to life safety, I would recommend sprinkling these rooms using a high or extra high (286° or 360°) temperature classification for the sprinklers, thereby insuring that by the time of sprinkler activation, the fire is in a later stage of development, and any building occupants have long vacated this area. High temperature-rated “on-off” or “flow-control” sprinklers could also be safely specified for electrical room protection.

2 Article 10 of the BOCA National Building Code suggests alternative suppression system choices for a very wide variety of hazardous occupancies in its Table 1003.3 entitled Guide for Suppression System Agent Selection.

3 Requirements for hydrostatic pressure testing of installed systems for leakage is covered in Section 10-2.2 of NFPA #13, and required for all new installations and additions. The unwritten industry standard is that twenty sprinklers constitute the benchmark used to define a system addition or modification of “any appreciable extent.”

4 In special applications, where it is likely that foreign material or sludge may accumulate heavily in ordinary drop-nipples servicing pendent sprinklers, dry pendent sprinklers are a design option—even though a cold environment may not be present.

5 Factory Mutual and Underwriters Laboratories are the usual inspection agency laboratories that test most fire protection products for approval.
A dry pendent sprinkler will be easily installed into larger fittings with a 1″ outlet, or a $1 \times 1 \times 1$ tee or a $1 \times 3/4 \times 1$ tee, but not a $1 \times 1/2 \times 1$ straight tee.

When a tee is installed bullheaded onto the pipe, it is screwed into the odd angle female outlet of the fitting. The direction of water flow with this configuration cannot continue straight on, it must make either a right or left 90° angle turn.

Any piping to be installed that will pass through an outside wall should be galvanized.

A standard fire hydrant with pumper connection should exist at the jobsite within 300 ft hose lay distance of the siamese connection location. Some authorities require that this distance be lessened, and I have seen the requirement made as close as 75′.

Painting is the primary, but not the only, example of a problem known as loading in which a buildup on the sprinkler would delay or prevent proper response. Any sprinkler subject to loading that cannot be readily dusted or blown away must be replaced” [10].

Or, in the case of an existing suspended ceiling, could the longer pipe lengths be angled through a ceiling opening and placed in position for installation, given the close confinement of the limited available field space?

For example, if this were the case for the last piece on branch-line “F,” you would check the total take-out for a 1″ screwed coupling, which is 1 inch. So, if a piece 5 2/2″ with a $1 \times 1/2$ reducing elbow made-on, and a piece 5 2/1 1/2″ with a 1″ screwed coupling made-on, were sent to the job and installed, the end sprinkler would be positioned in the same intended location.

See table 7-2.3.1.1 in NEPA #13.
Finishing the Plan

This chapter deals with the items numbered #6 and #7, which were previously mentioned in the engineer’s job description list at the beginning of Chapter 2. By the time you are ready to add any needed plan details and general notes to the plan, you will have completed all of the basic engineering necessary to lay out the system completely. In other words, the building has been blocked out, the sprinkler system piping laid out, pipe sized and dimensioned, and the supply header has been detailed. The plan at this point looks much like the drawing on page 249 labeled Figure A-6.

It is important to take your time and not rush to arrive at this final phase of your work. As any good engineer will tell you:

MISTAKES ARE MADE WHEN YOU’RE IN A HURRY!

This rule goes for any phase of your work, including the task of putting the finishing touches on the plan. This plan will be distributed to a number of parties, with your initials on it, and any mistakes will be glaring. Any omissions will be as obvious as a big smile with a missing tooth.

***

One component necessary for nearly every job is the site plan, which is sometimes referred to as the plot plan. A “key plan” is something quite different. The key plan usually references the areas noted on the particular plan in use to a specific portion of the entire building. As examples of these, notice the shaded areas of the building plans depicted on Figures E-3 and E-4 (pp. 183–184). Note the column lines and point of compass, in Figure E-4, which adds further clarification.

A site plan example is shown in Figure E-6. This should always be a scaled drawing, showing the location of the building with reference to nearby streets and the sprinkler system’s water source. It is important to note on the site plan the size of the city water main and underground feed piping to the building. Of due importance is the notation of the fire department connection (FDC) location and the nearby fire hydrants. If possible, the two hydrants nearest to the fire department connection should be shown. This allows the fire prevention bureau to note the lay distance for hoses from the hydrants to point of building connection. As a general rule, hydrants will be spaced approximately 300’ apart in commercial areas and 600’ apart in areas zoned for residential use.1 The site plan is also an opportunity to note separation of contractor responsibility. For example, the Figure E-6 plan may include a note such as “all underground piping work shown on this plan is to be done by others.” Sometimes the underground water feed is a fire main only, in which case the sprinkler fitter’s union claims that work. A detail such as the one shown in Figure D-4 might be used in such an instance, giving dimensions with which to spot the intended incoming water supply location.

On rare occasions and usually in larger cities, a location plan is asked for. This gives the plan reviewer clear information as to the whereabouts of the job-site that may be difficult to ascertain just from the building address. Something simple will suffice, such as the example shown in Figure E-7. Referring to this plan, note the shaded area that identifies the building locale. The initials marked “NTS” (jokingly referred to as “not too sure”), actually stand for “not to scale” and should be used anytime the detail or plan shown is drawn from rough approximation.

***

The “field check” is a necessary engineering function that will take place just prior to stocklisting the job for fabrication (see Chapter 7, “Stocklisting”). I guarantee that you will learn something every time you visit a jobsite in any phase...
of construction. I would also like to pass along a fundamental premise to bear in mind on any field check, and that is:

WHEN YOU’RE ON A JOB, TAKE YOUR TIME AND OBSERVE!

I might add this note as well: always ask an installer to critique your engineering skills. This he will gladly do, and you would be wise to listen closely to what he has to say. For one thing, it is in their best interest for engineered plan quality to increase. If you seize the opportunity to ask the sprinkler fitters how you can improve your work, you will become much better at your job, believe me.

The field check is your one occasion to check to see if field conditions are exactly as they were presupposed to be. For example, was the water brought in to the correct location, or even the right room? Was the steel set at the correct elevations? Is the ductwork being installed where it is supposed to be? Are there any visible obstructions where our cross-main is to be installed? Should any holes be cored in any concrete walls or floors? What is the elevation of the bottom of the ductwork? Will there be any problem hanging the pipe from building structural members? You get the idea.

The field check is a troubleshooting phase of the engineering, a time to look for problems before they occur. This phase is important because “engineering revisions by crisis” is simply too costly, and can hold up the overall construction process. You may dislike the chore of revising work that you have already plan-engineered, but it is much cheaper than revising the work at a later date.

***

I would also encourage you to show a detail or two on any fire sprinkler plan.

A PICTURE IS WORTH A THOUSAND WORDS!

This axiom applies directly to the job of sprinkler design. For one detail example, refer to Figure E-5. The fitter will not really be sure that the 1 1/2” vertical piece is to be installed inside the wall shown, unless this is detailed on the elevation. Remember, looking at a two-dimensional blueprint in the field is not the easiest task, especially for someone not schooled in blueprint reading. The section shown in Figure E-8 is another good example of a plan depiction that will save the fitter time in the field. The dimensions delineated by you give the fitter exact coordinates with which to carry out his work.

Details shown in Figures D-5 through D-8 are examples of plan depictions that are about as detailed as you will want to get. In certain decorative or “fussy” building areas, the detail is utilized to get across as much specific information as you need to deliver. In these examples, obviously, the sidewall sprinkler positioning is critical to the job, and the detail conveys this message. Note the detail shown in Figure D-3. Sprinkler feed main piping in this case needs to be run through an existing area that is congested with some round ductwork and an electrical cable tray. It would be next to impossible for the installer to understand precisely what he is supposed to do with his pile of pipe and grooved fittings, without the benefit of this detail. Again, specific dimensions must be provided.

Figure D-9 shows a section detail of a “double riser-nipple,” which is often used for efficient installation in a case where branch-lines running on either side of a cross-main must initially be run at separate elevations. Again, the detail (which need not be very fancy) gives the installer a clear picture of intended pipe routing. Time is of the essence when drawing. The detail shown in Figure D-10 is very nicely done, but probably too fancy for our purposes. However, since the detail is a supplement to the delineations shown on the plan, all information that needs clarification must be detailed. Incidentally, all details thus far referred to in this chapter have been “double-line” drawings. You should always draw whatever is most comfortable to you. But there is absolutely nothing wrong with the use of “single-line” drawings, such as that displayed in Figure D-11, or in previous examples noted in Figures E-1 and E-2. The only idea or method not to be compromised is that of getting your message across.

A detail may be so cluttered that it becomes necessary to include your own reference marks. This is usually done in instances where a lot of valving and other system components are to be installed. Referring to Figure E-9, we can see that the pipe dimensions shown are made clearer by this method, and the entire picture is cleaner. The exactness of the engineering is less apt to be compromised through the use of these circle references.

***

Very often, the two-dimensional plan itself is not scaled large enough in certain areas, to include all noted information. When this occurs, an “enlarged plan view” is the only means by which to show all the engineered pipe offsets and routing changes. In both examples noted as Figures E-10 and E-11, the plan’s scale is 1/8” = 1’0”. By enlarging the plan view to a scale of 1/4” = 1’0”, we are simply adding space for our dimensions and notes. This method will be utilized most often in cases where the building is already existing (and the possibilities of long straight piping runs are limited), or (as in Figure E-11) there is a stairwell or some other location involved that requires valving, drains, and/or alarm zoning. The numerous detailed notes are an obvious necessity and simply cannot fit on the plan at the smaller scale. Speaking of stairwells, and referring specifically to the example shown in Figure E-12, the stairways in a high-rise building are usually areas that will require an elevation to be drawn. The dashed line in Figure E-12 refers to existing fire protection piping. Again, a picture is
worth a thousand words, and the numerous dimensions in Figure E-12 will assist you in your plan engineering as much as it will help the sprinkler fitter in installing system piping. They establish the “starting point” benchmarks for the system design.

The many examples and details used for reference in this chapter are definitely not typical of the usual sprinkler engineering project but are simply included to convey the idea that details are a necessary plan component. A detail such as the one depicted in Figure D-5, while simplistic, may be just as necessary as any other.

An additional plan component that may be required is an engineer’s (or architect’s) stamp. There is, as of this date, no actual fire protection engineer’s stamp that is either recognized or approved on a national level. If a stamp is a requirement, and cannot be overlooked, it will be necessary to consult with the Authority Having Jurisdiction (AHJ) to determine exactly what his requirement is.

Two details that are most often used are shown in Figures D-12 and D-13, and both are used in cases where pendant sprinkler location is to be “intentional,” with the usual required placement to be within one inch of the geometric center of the ceiling grid panel. Both configurations allow for 360° flexibility for the 1” arm that supplies the 1” drop to the sprinkler-head. Figure D-12 is typical of the situation where drops from an existing system must be relocated for construction remodeling. In new construction, Figure D-13 is most widely used. This “mutual” or “return-bend” arrangement, also noted in Figure 5-13.19 NFPA #13, is paramount for the avoidance of sediment accumulation in the 1” drop. An often overlooked requirement of NFPA #13 when using either method can be found in Section 6-2.3.4 of the 1999 edition. This stipulates the rules governing the length of the armover that can be installed with or without an additional hanger. By code, an unsupported armover may not exceed 24 inches in length.

***

Finally, the last addition to the sprinkler plan will be a listing of explanatory notes. This text includes some examples (Figures E-13 through E-15) of general notes. These can include a legend of symbols as well. The notes are necessary for thorough completion of work, and should most importantly, convey the scope of work, design criteria used, type of material used, building construction, and the nature of the hazard being protected. Do not forget to include the following, if applicable, amongst your plan notes:

- type of sprinkler-heads
- type of pipe and fittings
- type of hangers
- whether or not pendant sprinklers are to be “centered” in ceiling tile panels
- required hydrostatic testing
- occupancy of building
- flow test results
- hydraulic design data
- the inclusion/exclusion of tamper switches
- NFPA #13, or other, code compliance
- items of fire protection work that are not within the scope of the contract
- the sprinkler-head count
- typical suspended ceiling height
- which side of joist or beam to hang the cross-main

You may also wish to refer to Section 8-1.1.1 on page 137 of NFPA #13 for a complete list of standard required elements of working plans. That list, however, is not relative to every job that you will engineer. For example, on a small job that consists only of the relocation of existing sprinklers, it would take longer to engineer the project than it would to install it, if Section 8-1.1.1 was strictly adhered to.

One final note to be made is especially relevant for beginning engineers. Office personnel, and field labor management, will be glad to look over your completed work for you. Ask for suggestions relative to the plan’s thoroughness and completion. This will give you a frame of reference for knowing when the plan is actually finished. It’s always better to be safe than sorry, and two heads are better than one. Also, three heads are better than two, and I promise these will be the last worn-out cliches used in this book.

ENDNOTES

1 NFPA #24 requires that hydrants be located at least 40’ away from any structure. That rule in origin is for firefighter protection from wall collapse. Also, a hydrant located very close to a building may become so hot during a fire that it is actually unapproachable and unusable by the time of fire company arrival.

2 The survey equipment you will want to bring along on a field check will include a telescopic measuring pole, two 8’ folding carpenter’s rulers, a 50’ measuring tape, a flashlight, and a hard hat. And don’t forget the blueprints.

3 In this example, “GR.EL.” refers to a grooved elbow, “T.B.E.” refers to pipe threaded on both ends, and “G-T” refers to pipe with one grooved end and one threaded end.

4 The “FL-FL” reference in this example refers to a piece of piping with companion flanges made on each end. “C.O.J.” refers to a piece of piping that is to be “cut on job.” Since the exact elevation of the incoming water service is uncertain or not known, the actual length of the riser piece cannot be prefabricated.

5 In this example, “E-E” references the pipe dimension as “end-to-end.” “F-F” refers to “finished floor.” The $ notation refers to a “centerline” of pipe elevation.

6 The sprinklers depicted are those of the recessed pendant type (Figure D-12) and the “phantom” or concealer type (Figure D-13). The “BCI” reference stands for “black cast-iron.”

7 Valve electrical supervisory switches.
CHAPTER 7

Stocklisting

A necessary function of the engineer’s job is that of stocklisting, which consists of the preparation of stocklist forms for the fabricator’s use. The stocklist is a complete listing of all the materials that the installer will need for the job. It usually includes all engineered pre-cut pipe pieces, with made-on fittings; and all sprinkler system components that are to be delivered to the jobsite. The stocklist is ultimately utilized by the contractor’s accounting department to “cost-out” the job, to determine actual material costs when figuring the actual project profit/loss numbers.

Many fire sprinkler engineers consider stocklisting to be overly tedious. The fact of the matter is that stocklisting is always a time-consuming activity. Any mistakes made are costly ones. Some shops employ a separate individual who stocklists all the engineered projects himself, and this work is actually his major specialty and job function. However, some engineers use the stocklisting task as a time to double-check their engineering work as they pick material, and thereby prefer to complete the stocklists themselves. Stocklisting is not hard to do, but must be completed in a thorough fashion.

There are numerous forms that can be used for the stocklisting assignment, and the most standard are shown in Figures A-9, A-10, and A-11. These samples are representative of part of the complete stocklist that would be sent to a fabrication shop for the plan example shown in Figure A-6. The foreman of the fabrication shop will normally have his own forms for the stocklister’s use, and to minimize any risk of error or omission it is best to use the forms that the fabricator is familiar with.

After the fabrication is completed, branch-line piping arrives at the jobsite bundled and tagged. The stocklist numbers should be noted on the sprinkler plan so that the fitter can distribute the bundles to the corresponding building areas. Larger jobs have piping “color-coded” for this purpose as well. In other words, the paint used to mark the piping can be changed for the differing stocklist numbers. This way, the fitter will instantly know (by seeing the paint marking color) whether the specific cut pipe is to be installed in the attic, offices, second floor, or whatever area is earmarked for that color pipe mark. The paint used for this purpose is made in a variety of colors, the most commonly used being white, yellow, and orange. Our project example is really too small a job to worry about color-coding, but can be easily done nonetheless. For this situation, piping on the north side of the cross-main could be marked white, and the pipe on the south side of the cross-main could be marked with yellow paint. Of course, the plan notes should reflect this as well.

***

Refer first to the partial stocklist sheet shown in Figure A-9. The pipe fabricator will cut and thread both ends of the pipe pieces noted, make-on the corresponding cast-iron fitting, and mark and bundle the piping by line. It is obvious to see how this method of preparation saves field installation time. For Line “A,” note the seven drop pieces that have a 1 × 1/2 reducing coupling (RC) made-on. Since we are anticipating a suspended ceiling height of 12’9” in the project office area, we are (by using fitting take-outs on the 1” drops) attempting to send these drops out “pre-cut.” The more conservative and common method for picking the 1” drop-pieces would be to figure the drop lengths about 6” too long, have the reducing coupling made on, with the pipe marked TOE on the stocklist. In our case, we would want to send out seven 1” × 2’0” pieces to the job, for the fitter to field cut. This method is often preferred by the installers, as they can then cut the drop to the exact desired length to fit, without the “nearest one-half inch” constraint of the shop cut. They can
more easily install the pendent sprinkler at the exact elevation needed by cutting the drop in the field.

Note that the fitting outlet sizes on Line “A” are 1”, to be used for the drops to the pendent heads. The outlet sizes on Lines B, C, and D are 1/2” for the upright sprinkler-heads that will be screwed directly into those fittings. When large-orifice sprinklers are used, these outlet sizes would have to change to 3/4” to accommodate the larger thread size of the large-orifice sprinklers. Always double-check these typical fitting sizes on your stocklist.

The list for the “D” branch-line is missing the final piece to be run outside the building. This also is an item that is usually preferred to be field-cut. In our case, a 1” × 1” piece of galvanized pipe could be sent to the job (with a 45° galvanized elbow made-on for the discharge end), but the installer is usually comfortable with cutting this piece in the field himself.

Listing the cross-main pieces correctly is very critical. The welded pipe-o-let sizes are listed and dimensioned in the Figure A-10 example. In the event that mechanical-tees are used in lieu of pipe-o-lets, the hole-saw sizes shall be noted on the stocklist form instead of the pipe size for that outlet. As an example, the hole-saw size needed for a 3” × 2” mechanical-tee is actually 2 1/2” (diameter), that will service the 2” piping off the cross-main. So it is easy to see that it is important to make this (outlet type) distinction clear to the fabricator.

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Figure A-11 depicts a partial listing of the loose material needed for the project. Note that the size and (left-hand) location of the meter bypass has been indicated for the detector-check valve. This insures that the location of the metering trim on the valve will be properly situated. The necessary nuts, bolts, and gaskets have been listed so that the header components may be properly assembled with correct materials. A standard 3” companion flange will require four 5/8” × 2 1/2” bolts for assembly, and a standard 4” companion flange always requires eight 5/8” × 2 3/4” bolts. A wafer check valve (refer to Figure A-4 or A-8) is not manufactured with flanged-ends, it just sits between two flanged-end spools or fittings. Hence, the 9” long pieces of all-thread rod (noted on the Figure A-11 list) are tightened with nuts to secure that valve in place, and actually span from end-to-end of the valve to the flanges on either side.

The Figure A-11 loose material list is shown for illustrative purposes, but it is far from complete. You will need to review your engineered plan and “pick” (list) every loose item of material that you know will be needed on the job. You should, over time, compile your own checklist to make certain that you are not forgetting any items, or use this check-list noted below:

- sprinkler-heads
- all hanger material
- grooved fittings (incl. grooved caps)
- drain valves
- inspector’s test valves
- wall plates
- escutcheons
- metal or plastic signs (and chains)
- hydraulic placard
- extra random fittings and/or rod couplings
- friction clamps
- pipestands
- any 1/2” or 3/4” plugs (if needed for hydrostatic test)
- ball-drip assembly
- pressure gauge and trim
- siamese connection and plate
- flow switches and bells
- tamper switches
- mechanical-tees
- 1” drops
- spare-head cabinet (and wrench)
- extra unistrut (if required)
- nuts, bolts, gaskets

Remember, an installer will not mind an error made in stocklisting as much as he will an omission. The key thing to keep in mind when preparing the stocklist is to be as thorough as possible. Every job, upon completion, will have leftover materials to be picked up anyway, so if extra or unneeded material is sent to the job at the onset, it is of no major concern.

Also, don’t pick a product that isn’t made by any manufacturer. This potential misnomer usually comes into play when picking flanged, grooved, or cast-iron threaded fittings (see Figure D-2). For example, when down-sizing grooved main piping, carefully check the manufacturer’s data sheets to see what products he has available for this purpose. Product diameter-size availability for grooved products are much more limited than what is available for cast-iron fitting downsizing. This is especially true in the larger pipe sizes.

Although the stocklist examples noted in Figure A-9 marked line designation by letter, any kind of designation is okay. Numbers are most often used to denote branch-line bundles. Typical lines will use the same number. (Lines E, F, and G on Figure A-6 would have the same stocklist number notation.) Any simplification that can be made when preparing a stocklist is beneficial, providing that the stocklist is complete and without omission.

ENDNOTES

1 Items such as ladders, hand tools, pipe dope, power machines, cutting oil, and the like, are normally not included on the engineer’s material stocklist.
Some CADD systems have an automatic stocklisting feature built in to the program. Since this is an enormous time-saver, and the possibility of stocklisting error virtually eliminated, this is a very desirable feature of any CADD system.

Red and blue, on larger jobs, may also be used.

The T.O.E. designation refers to “thread one end.”

For 2 1/2” flanges, use (4) 5/8” × 2 1/4” bolts. For 5” or 6” flanges, use (8) 3/4” × 3” bolts. For 8” flanges, (8) 3/4” × 3 1/4” bolts are used.

This is not to say that stocklist number and letter designations are critical elements of every engineered plan. It is common on very small installations, and certain construction projects that involve primarily the relocation of pendent sprinklers; for the plan to show no stocklist reference designations at all.
CHAPTER 8

Areas Subject to Freezing

The prospect of pipe freezing and the subsequent pipe rupture that results will surely cause such a considerable amount of water damage that no rational thinker would want to take even the slightest risk of installing water-filled fire sprinkler piping in an area that may experience freezing temperatures. In winter months, fire sprinkler contractors have historically kept their workers busy with the numerous “freeze-up” service calls for piping repair. Even though many precautions are taken by building owners to insure that a proper level of heat is maintained in building areas that are protected with fire sprinklers; sudden cold snaps, overlooked areas, vacant buildings, power outages, and a myriad of other costly mishaps seem to occur time and again. These occurrences keep the phone lines busy at the contractor’s service desk. All these calls, of course, will require repair work to wet-pipe systems.

Despite the annual barrage of freeze-ups to wet-pipe systems during the cold months, a wet system is always the first and foremost type of suppression system to be recommended for a typical austere building structure. The real beauty of the wet-pipe system is that it is “the most reliable and simple of all sprinkler systems since no equipment other than the sprinklers themselves need operate” [1]. Hence, in a case where only 50% of a 20,000 square foot building is heated, it would be most wise to protect that building with two separate systems (one wet and one dry), to maximize fire safety for the 10,000 square foot heated area.

AUXILIARY DRY SYSTEMS

Suppose that a three-story medical building in Iowa is to be completely sprinklered. The building will naturally be heated year-round, all except for the high wood-truss attic. The insulation for the third-floor offices is to lay at the bottom of the roof trusses, just above the third-floor ceiling. In this case, the most prudent system of protection for the building would be wet-pipe, with an auxiliary dry system for the attic area. A closet or storage room, located preferably on the third floor, would be the ideal place to situate the dry-pipe valve, system control valve, and air compressor. A typical detail of such an arrangement is shown in Figure F-1. The piping shown below the control valve in that detail is wet-pipe: containing water under pressure. The piping above the dry valve is all dry-system piping, and contains air under pressure. The dry-pipe system operation is simple enough: an air compressor maintains compressed air in the dry-pipe system that holds the dry valve closed, thus preventing water from entering the attic piping. Should a fire occur, the fusing of an attic fire sprinkler would lead to air discharge. When the system air pressure drops below a predetermined point, the dry valve will trip, and the system will fill with water. This operation will also sound the fire alarms. The air compressor generally required should be such that the air supply can fill the system to 40 psi within a half-hour. The NFPA design requirements for dry-pipe systems are found in Chapter 4-2 of NFPA Pamphlet No. 13.

“The dry-pipe system can be somewhat slower reacting than a wet-pipe system. This may be cause for some concern in view of NFPA #13. The code states water must discharge out of the most remote part of the sprinkler system within sixty seconds after the first sprinkler opens. Testing of a dry piping system will indicate whether or not water can be discharged within sixty seconds. If it cannot, an accelerator or exhaster should be added to hasten response time” [2]. Where dry-pipe systems are used, the delay in water discharge from the earliest operating ceiling sprinklers will allow heat to spread and open a larger number of sprinklers beyond the immediate fire than would be the case with a...
wet-pipe system. To compensate for this, the design area of sprinkler operation is usually increased by 30 percent for dry pipe systems” [3].

ANTI-FREEZE SYSTEMS

The aforementioned “60-second delay” is not an issue for the auxiliary anti-freeze system. Although not recommended for piped systems exceeding 40 gallons in total volume, anti-freeze or “glycerine” loops that supply small systems are quite effective for fire-fighting. The anti-freeze solution used, obviously, protects the piping in the unheated area from freezing. Upon sprinkler-head activation, this solution mixture discharges quickly, followed immediately by the sprinkler system water.

Chapter 4-5 of NFPA Pamphlet No. 13 outlines regulations governing anti-freeze systems in great detail, and Figures 4-5.3.1 and 4-5.3.2 of NFPA #13 shows the most common “loop” arrangements for supply piping and valves. A typical single-line diagram of an anti-freeze loop is included in this text’s appendix, denoted Figure F-2. It is important to note that the gravity-type fill cup can be placed almost anywhere downstream of the gate and check valves for this system and is normally installed at a high point of that piping.

The downside of installing an anti-freeze system, from a building owner’s perspective, is the future maintenance that will be required on the system for periodic testing of the anti-freeze fluid. Also, there is an inherent toxicity (particularly when a propylene glycol solution is used) that can endanger any adjoining system water supplies. The dry-pipe system is the safer system with regard to potable water. Glycol (and all other anti-freeze solutions) is heavier than water, and to safeguard against any glycol leakage back into building drinking water, a reduced-pressure backflow preventer is often mandated by authorities to be installed somewhere on the system. This drives the anti-freeze system cost up considerably, due to the high cost of backflow preventers in general, plus the installed cost of an expansion chamber that is required.

Although the anti-freeze piping will not scale and corrode as dry-pipe will (and thereby reduce friction loss in the pipe), this discussion of pros and cons is not to imply that dry-pipe systems are not efficient. “According to fire records, more sprinklers open on the average at fires with dry pipe than with wet pipe systems; this tends to show that the control of fire is not as prompt with dry pipe systems. However, in most classes of occupancy, and especially those of light and moderate hazard, dry pipe systems have shown generally good results and, when properly maintained, can be relied upon to satisfactorily extinguish or control fires” [4].

FACTORS TO CONSIDER

The disadvantages of the dry-pipe system that a designer should be aware of, are as follows:

(1) Additional costs involved:
- material costs for the air compressor, pressure switch, control valve, dry valve, and related piping
- labor costs for mounting air compressor, pitching system pipe, and electrical wiring
(2) There is a longer lag time for water to hit a potential fire after the sprinkler fuses.
(3) This system is periodically noisier due to the operation of the air compressor.
(4) There are more chances for some type of mechanical failure. On an auxiliary dry system, there is one more valve that could be accidentally closed.

Labor costs for dry-pipe system installations are driven up to some degree by pipe pitch requirements. A fitter installing dry-pipe system piping without the use of a level is simply not doing his job. A designer must take into account the NFPA #13 pitch requirements for all dry-pipe system designing, especially with regard to cross-main elevations. On a dry system, the NFPA code requires a minimum pitch of 1″ over every 40 linear feet (to drain back to the low point) on the cross-main, and 1″ over every 20′ on the branch-lines. Obviously, it is imperative that the dry-pipe system can be drained dry after each instance of the dry valve tripping. Where low points are encountered on the dry system piping, either an auxiliary drain valve or a drum-drip assembly must be installed.

Another factor that will drive up the cost of a dry-pipe system is dry pendent sprinklers. Their material cost is dependent on the length of the sprinkler itself, but nonetheless they are much more expensive than standard sprinklers. Since the dry pendent sprinkler extends upwards into the line fitting (to avoid “ponding” of water above the dry pendent), the fitting to which the dry pendent head is attached must always be a cast-iron screwed tee or a 1″ welded pipe-o-let. “Hooker” type fittings, reducing elbows, and screwed 90° or 45° elbows do not have the physical space required to affix properly a dry pendent sprinkler. Please note that Section 4-2.2 of NFPA Pamphlet #13 (1999 Edition) contains an exception that allows for the installation of standard pendent sprinklers in areas of dry-pipe systems that are heated. In order to avoid the accumulation and clogging in the 1″ drops from pipe scale and debris, however, these standard pendent sprinklers must be installed using the “return-bend” method. For examples of this method, see Figure D-13 and/or NFPA #13: Figure 5-13.19.

For dry-pipe or auxiliary anti-freeze systems, Sections 4-7.5 and 5-14.3.2.3 of the 1999 edition of NFPA #13 require
that galvanized piping be installed in any outdoor areas. Typical examples would include outside porches, retail “garden shop” areas, and long exterior shipping/receiving docks. Please take note that “XL” steel piping is not galvanized in its interior, and in case you’re wondering, CPVC (plastic) piping is not allowable for dry-pipe system installations.

SPRINKLER SYSTEM CONVERSIONS

A designer is sometimes called on to prepare plans for an existing dry system to be converted to a wet-pipe system. This is very simple, and barely merits discussion. All that is usually necessary for this process is the addition of a flow switch, some re-piping with regard to the inspector’s test connection, and, of course, the removal of the dry-pipe valve, valve trim, and the air compressor. What will require more extensive

<table>
<thead>
<tr>
<th>Piping</th>
<th>Multiplier</th>
<th>Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule 40 1” pipe</td>
<td></td>
<td>311 total ft. × .045 = 14.0</td>
</tr>
<tr>
<td>Schedule 40 1 1/4” pipe</td>
<td></td>
<td>63 total ft. × .078 = 4.9</td>
</tr>
<tr>
<td>Schedule 40 1 1/2” pipe</td>
<td></td>
<td>85 total ft. × .106 = 9.0</td>
</tr>
<tr>
<td>Schedule 40 2” pipe</td>
<td></td>
<td>70 total ft. × .174 = 12.2</td>
</tr>
<tr>
<td>Thinwall 2 1/2” pipe</td>
<td></td>
<td>53 total ft. × .283 = 15.0</td>
</tr>
<tr>
<td>Thinwall 3” pipe</td>
<td></td>
<td>100 total ft. × .433 = 43.3</td>
</tr>
<tr>
<td>Schedule 40 4” pipe</td>
<td></td>
<td>28 total ft. × .660 = 18.5</td>
</tr>
<tr>
<td>Thinwall 4” pipe</td>
<td></td>
<td>265 total ft. × .740 = 196.1</td>
</tr>
<tr>
<td>Total system capacity</td>
<td>=</td>
<td>313.0</td>
</tr>
</tbody>
</table>

All system low points must be equipped with auxiliary drains. The ideal scenario of all system piping pitched to drain back at the main drain valve is an extreme installation rarity. The designer will need to search out all sections of trapped piping.

(6) The fire department connection should be piped from between the dry pipe valve and the system control valve.

(7) The hydraulic design for the entire system must be reevaluated, calculated, and analyzed.

(8) It is imperative that the incoming water supply, header, and dry valve, are situated in a heated room. We want to maximize component accessibility and eliminate the potential for freezing.

(9) The authority having jurisdiction must be consulted if the existing piped system is a “grid” type. The AHJ must also approve existing piping and system materials.

The volume calculation noted above, must be made for any new dry system installation to verify that the code’s system volume limitations are not exceeded. An example of a volume calculation follows. It is hypothetical. Note that linear footage is used for this calculation of one entire system:

If the above example recorded all system linear footage (after the dry valve) correctly, then the system volume in gallons is easily added up in one column to find the total. Table A-4-2.3 in NFPA #13 gives you the gallon capacity multipliers to determine system volume for this calculation. Note that the total system volume of 313 gallons does not exceed the 750 gallon system capacity for one dry valve, as noted in Section 4-2.3.1 of NFPA #13.

* * *

The dry-pipe system design is comprised of pipe and fittings and sprinkler-heads, just as the wet-pipe system. As previously stated, the big difference between the two system types is that one network of pipes holds water under pressure, and the other holds air under pressure. Certain insurance carriers that are sensitive to the increased corrosion potential on dry-pipe systems may require the use of galvanized pipe and fittings for all dry system installations. This possible requirement needs to be investigated before you begin the design process. Especially in areas near the salt-water coastal regions, steel piping may be required to be galvanized both inside and out to guard against leaks in pipe walls caused by corrosion, as well as scale and rust clogging of branch-lines, valves, and sprinkler-heads.

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ENGINEERING DESIGN OPTIONS

Preaction and deluge systems are variants of the dry-pipe system. There are several varieties of preaction systems. In a nutshell, the deluge system utilizes open nozzles in lieu of sprinkler-heads, with electrical or other types of actuation devices to sense a fire and thereby open the clapper of the deluge valve for water discharge out of every system nozzle. With a preaction system, conventional sprinkler-heads are used along with the electrical or pneumatic actuating release system. Just as with a wet system, water application begins when the sprinklers fuse. Since the preaction system water is delivered faster than with a dry system, a reduction in fire damage is realized. However, the additional mechanical and electrical components that a preaction system contains increases the risk of failure and reduces (to a degree) system reliability. If a preaction or deluge system is called for on a new project, the system descriptions are normally well detailed ahead of time by the project consulting engineer, and fall under the category of special hazards protection. The systems themselves are not difficult to design, however some research into code requirements will be necessary when designing your first preaction or deluge system. These are discussed thoroughly in Chapter 4-3 of NFPA #13. These special systems are installed in many different types of occupancies, and not necessarily those without adequate heat.

Bear in mind when designing any of the aforementioned systems that the required valving takes up more space than does that of a typical wet-pipe system. If a room or area has not been designated for valve placement, this detail needs to be ironed out as soon as possible. Finally, when in doubt as to a rule of design, ask yourself: “What does the book say?” NFPA #13 will contain the design or code answer you’re looking for in questions regarding all of these system types.

CITATIONS


ENDNOTES

1 In addition to damaged property space and extensive content loss, it should be noted that, until repairs are completed, a building goes without any system protection from fire following a freeze-up.
2 This is known as the differential pressure principle. When the water pressure over-come the decreasing air pressure, a clapper inside the dry valve opens or “trips,” allowing the flow of water. This water of course, will soon find its way to the fire.
3 See Chapter 11, “Basics of Hydraulic Calculation,” for a discussion on the most hydraulically demanding design areas for calculated systems.
4 A wily sprinkler contractor will install the reduced-pressure back-flow preventer (R.P.Z.) right at the anti-freeze loop itself, to minimize component size. It should be noted that there are certain complex problems associated with the inclusion of reduced-pressure backflow preventers in fire suppression systems, and several of these inhibit fire-fighting capabilities. Additionally, there are recent reports that the check valves inside some R.P.Z. models may not re-open all the way after they have shut down a time or two. This partial re-opening may not pose a big problem for a domestic plumbing system, but could be a disastrous occurrence on an automatic fire sprinkler system.
5 The reduction in scaling and corrosion, then, will also extend the life of the piping system.
6 The “drum-drip,” or dry system auxiliary drain, is detailed on Figure 5-14.2.5.3.2 in NFPA Pamphlet No. 13. The 2” × 12” “condensate” nipple allows for the collection and removal of water and moisture from the system without allowing for the kind of air loss that may inadvertently trip the dry valve.
7 For case of (future) removal, it is always a good idea to use a nipple and cap instead of a threaded plug for the unused outlet of all screwed tees, and on low point drain valves, on dry systems.
8 The volume calculation is also handy when designing anti-freeze systems, to determine the amount of solution needed.
9 When calculating, please note the C-factor for galvanized pipe in Table 8-4.4.5 of NFPA Pamphlet No. 13.
10 Virtually all galvanized pipe on the market today is galvanized both on the interior and exterior. The possibility of pipe corrosion from the outside is of concern when the system pipe is exposed to conditions of climate such as freezing, frost, heat, or humidity.
11 The new “LDX Lo-Pressure” dry valves can eliminate the need for accelerators because they operate using lower air pressures, which provides for faster water transit times.
Without pipe hangers to support sprinkler piping, there is no fire sprinkler system. Hangers are every bit as important to the overall physical system as are fittings, pipe, and valves. A common blunder made by the beginning designer is to ignore this fact completely. As a result, his plan may show routed piping depicted in an area where there is nothing of any structural strength from which to hang pipe. Hence, the designer must always be cognizant of his strategy for pipe hanging on a given project and how that will affect his system design.

Referring to the Figure A-2 project example, we can see that we have planned to hang the cross-main directly beneath a bar-joist, running the cross-main in the same direction as the bar-joist. This has been done for the following reason: the branch-lines (which always run perpendicular to the main piping) must always run perpendicular to the bar-joists for reasons of economy. In our case, the branch-line piping will be hung (see Figure G-1) by means of a top-beam clamp, 3/8" threaded rod, and a standard swivel-ring. This is the same hanger type which will be used to hang the cross-main piping, and is a relatively inexpensive hanger. It is also a simple, labor-saving, hanger to physically install. The clamp affixes easily to the top of an ordinary bar-joist (or beam), and holds the hanger rod securely in place to support piping in reliable fashion. Suppose that the cross-main ran in some location in between two bar joists. Then some type of hanging method would have to be utilized. One such “spanner” type hanger is depicted in Figure G-2. Material-wise, this is a considerably more expensive hanger, mainly due to the expense of the unistrut, or whatever material is used to make the long span between roof joists for support. Labor-wise, the installation of this hanger eats up quite a bit of field time to add to the job expense. Although it is necessary to utilize the spanner or “trapeze” hanger in some installations, it is the designer’s responsibility to try and lay out his system so that the use of the spanner-type hanger is eliminated or at least minimized.

The job specification for a U.S. government-specified project that I was recently involved with required the following rod sizes for fire sprinkler pipe hangers:

<table>
<thead>
<tr>
<th>Pipe to Be Supported</th>
<th>Rod Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” through 2”</td>
<td>3/8”</td>
</tr>
<tr>
<td>2 1/2”</td>
<td>1/2”</td>
</tr>
<tr>
<td>3”</td>
<td>1/2”</td>
</tr>
<tr>
<td>4”</td>
<td>5/8”</td>
</tr>
</tbody>
</table>

This specification can aptly be called “overkill.” While the individuals who scripted these requirements openly admitted doing so only because of a desire for conservative measures, the NFPA standards are what normally must be adhered to. These requirements, as outlined in Sections 6-1 and 6-2 of NFPA Pamphlet No. 13, require hangers and rod sizes of 3/8” for the above-captioned pipe sizes, and 1/2” hanger and rod for 6” and 8” nominal pipe sizes. In general, each section of branch-line piping shall have a hanger. For cross-mains, there shall be at least one hanger between each branch-line. The distance from the end-sprinkler on any branch-line and the last hanger shall not exceed 3’ for 1” pipe, 4’ for 1 1/4” pipe, 5’ for 1 1/2” and 2” pipe. The length of an armover to a sprinkler-head shall be equipped with an additional hanger if it is in excess of 2’ for any size steel piping.

These NFPA requirements are not only field-proven, but they have been mandated by code for such a long time that the materials provided by hanger manufacturers and suppliers are now appropriately standardized. For example, if you were to purchase a 4” swivel-type pipe ring, you can rest assured that it will be equipped with a nut that accepts a 3/8” threaded rod. Similarly, the nut on a 6” swivel ring will be provided for 1/2” rod attachment.
NFPA #13 provides an illustrated prospectus of “approved” hanger types. In the 1999 edition, these are shown on page 210. The reality of pipe installation, however, is that the fitter is responsible to securely fasten piping to building structural members, and the means by which he does so is not going to be questioned provided that the end result of secure fastening without exceeding ordinary load requirements is accomplished. The designer’s real job is to route his pipe so that something actually exists that the piping can be affixed to dependably, and that affixing or hanging can be done in quick and inexpensive fashion.

Figures G-3 thru G-8 show typical means by which sprinkler piping is hung, and I would say that these, along with the top-beam clamp, cover about 99% of all sprinkler pipe hangers installed today. Any hanger manufacturer, such as Elcen, Persing, or ITT Grinnell, publishes pamphlets and catalogues illustrating their complete line of available hangers. You would do yourself a favor by thumbing through one of these to become familiar with hanger options that are available for unusual situations. One such hanger that sprinkler contractors like to stock is the extension C-clamp, which is a top or bottom-beam clamp that is of such width that a hanger can be affixed at a spot a few extra inches further from a joist or beam. If these hanging devices are on hand in the field, they often solve a hanger problem for the fitter in certain instances without much expense. The bulk of the other out-of-the-ordinary hangers on the market, however, are usually more expensive and generally reserved for use in unique situations where typical hanging methods cannot be used.

***

It should be understood that the toggle-type hangers (see Figure G-10) should only be used as a last resort. The only time that I have heard of a problem with sprinkler piping actually falling down due to insufficient hanger support was when toggles have been involved. It is generally recognized that a metal lath and plaster ceiling is good support for sprinkler piping when toggles are utilized. But when toggles are affixed to any horizontal surface sheathing that cannot support the weight of a human being, such as a drywall ceiling, metal duct exterior, or stucco covering, then you better think twice about your hanging methodology. At any rate, if you are ever inclined to use toggles for hanging sprinkler pipe, do so only after you have contemplated the following:

1. Consult with others in your company, and perhaps even a structural engineer. Explain what you are doing to the building owner’s representative.
2. Avoid using toggles on any pipe size larger than 2”.
3. Use additional hangers, spaced closer together than normal for additional support.
4. Bear in mind that strict adherence to the NFPA code prohibits the use of toggle hangers on any pipe size larger than 1 1/2”. Also, hanging from hollow tile is okay, but hanging from gypsum wallboard is not permitted.
5. Strongly consider the use of some alternative type of light-weight piping in the areas where the toggle hangers are to be utilized.

A field installation time-saver is the engineered “cut” hanger rod. These can be easily figured on any typical sprinkler job. In our project example, top-beam clamps are to be used (see Figure G-1). In this case, the top of the hanger rod is installed at an elevation about even with the underside of the roof deck. Hence, there is no take-out to be made on the hanger rod except for that of the swivel ring itself. The take-outs to be used for pipe rings by the design engineer are as follows:

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Swivel Ring Take-Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td>1 1/2”</td>
</tr>
<tr>
<td>1 1/4”</td>
<td>1 1/2”</td>
</tr>
<tr>
<td>1 1/2”</td>
<td>2</td>
</tr>
<tr>
<td>2”</td>
<td>2”</td>
</tr>
<tr>
<td>2 1/2”</td>
<td>2 1/2”</td>
</tr>
<tr>
<td>3”</td>
<td>3”</td>
</tr>
<tr>
<td>3 1/2”</td>
<td>3”</td>
</tr>
<tr>
<td>4”</td>
<td>3 1/2”</td>
</tr>
<tr>
<td>5”</td>
<td>4”</td>
</tr>
<tr>
<td>6”</td>
<td>5”</td>
</tr>
<tr>
<td>8”</td>
<td>6”</td>
</tr>
</tbody>
</table>

So, in our project example, were we to shop cut hanger rods for field use, we would simply subtract the appropriate take-out figures from the known distance between the roof deck and the sprinkler piping to figure the desired lengths. We know that our branch-line piping is to hang, at a centerline, 10” beneath the underside of the roof deck. So, 8” and 8 1/2” rod length should be shipped to the job for the branch-line hangers. And since our 3” cross-main pipe will hang 30” down from the roof deck, we can be assured that a 3/8” top-beam clamp, a 3/8” × 27” threaded rod, and a 3” swivel ring will be perfectly suited to provide for hanging the cross-main at the desired elevation.

Now suppose that the building in the project example had a basement, and the first floor consisted of a poured concrete slab. The hanger used for the basement piping then, would be some type of concrete expansion shell (see Figure G-3). Let’s further assume that all basement piping is to hang at a centerline elevation of 12” beneath the concrete ceiling. Well, you would have to study the manufacturer’s data sheet for the particular concrete insert that is to be put into use in order to determine the appropriate take-out. For example, the desired rod length to use for one-inch piping would be 11” long if a Phillips shell is used, 10” long for a powder-driven stud, and 11” long if a “drop-in” type shell is employed. In each case, a 9 1/2” long rod would suffice for 3” main piping, or 3/8” × 9” rod for 4” main piping.
The Coach Screw Rod (see Figure G-6) hanger requires only a ring to attach directly to the coach screw rod itself. If the length “X” is considered to be the dimension from the bottom of the wood structural member to the centerline of pipe, then the following table should be used to figure the cut dimension of the coach screw rod:

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>C. S. R. Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”, 1 1/4”</td>
<td>X + 1/2”</td>
</tr>
<tr>
<td>1 1/2”, 2”</td>
<td>X</td>
</tr>
<tr>
<td>2 1/2”</td>
<td>X − 1/2”</td>
</tr>
<tr>
<td>3”</td>
<td>X − 1”</td>
</tr>
<tr>
<td>4”</td>
<td>X − 2”</td>
</tr>
<tr>
<td>5”</td>
<td>X − 1 1/2”</td>
</tr>
<tr>
<td>6”</td>
<td>X − 3”</td>
</tr>
</tbody>
</table>

Don’t forget that pipe sizes 1” thru 4” would require 3/8” coach screw rods, while 5” and 6” piping would necessitate the use of 1/2” coach screw rods.

Since sway-bracing is used only in parts of the world sitting atop earthquake zones of sufficient seismic potential, sway-bracing will not be discussed here. Sway-bracing is a test component on NICET examinations, and it is important to be familiar with its purpose and technique. In Section 6-4.5 of NFPA Pamphlet No. 13, sway-bracing requirements are quite thoroughly defined and discussed in great detail. Be familiar with this, so that you are aware of where to reference this information when you encounter a project located in such a zone. Seismic zone maps are shown in the appendix of NFPA #13, on pages 216 and 217. As with all hanger methods, it is in your best interest to use only listed and approved pipe hanging techniques.

***

It is not hard to figure hanger rod lengths on a building with a sloping roof, or one that pitches down to low-point locations where the roof drains are situated. In such cases, a structural plan drawing is needed—one that shows the actual roof elevations at various spots. Through the use of interpolation, intermediate roof point elevations can be ascertained, and thereby all hanger rod lengths can be “cut” and noted on the sprinkler plan, so that the piping can be installed so that a relatively flat and even piping elevation can be maintained by the installers (utilizing the differing hanger rod lengths beneath the sloping ceiling). Often, these rod lengths will vary from piece to piece of installed pipe. This is an engineering exercise to be undertaken only if desired by the fitter. Many fitters insist that they would prefer to cut their own hanger rods. To conserve time, communication with field personnel is imperative, and you must be familiar with their preferences on installation procedure. So remember, always ask the installer how you can improve your engineering work to help him out as best you can, but do not waste your time with unnecessary, and thus, unappreciated figuring.

One question that I have heard from engineers regarding hanging beneath steel and bar joist construction is this: Why not run piping diagonal to the bar joists (at a 45° angle), so that you will always be assured of a joist spot with which to catch a hanger regardless of the direction of main or branch-line pipe? Although this question makes for good sense in theory, there are three obvious reasons why this idea is a bad one. First of all, it is unprofessional. Fitters derive a great sense of accomplishment from completing a well-installed job, and running an entire system at a 45° angle to the building’s structural layout would simply look bad. Second, the installer likes to keep his piping straight and true by using beams and joists as benchmarks. This he could not do if the piping was designed to run at an angle to the structure. And thirdly, there are many angled metal bracing pieces in between joists that would constantly prove to be obstructions to the pipe run, necessitating costly offsets. The tried and true method of pipe routing is always to run the branch-lines perpendicular to the joists.

One of the easiest hangers to install is the eye-rod or eye-socket. This is depicted in Figure G-7. A drive-screw is simply hammered in to a wood joist, with a washer attached, through the eye-socket. A rod attaches to the eye-socket easily for pipe hanging. There is only the ring take-out to be figured in for determining the rod length, but this depends on where on the wood joist the drive-screw is actually affixed. To be careful, figure this location to be right in the middle of the wood joist. As an example, if 2” pipe is to be hung one foot below the bottom of a 10” wood joist, I would send 3/8” × 15” eye-rods out to the job. To arrive at this figure, just take the 12” distance (pipe to bottom of joist) and add 5” for the length of rod needed to extend halfway up the joist, and subtract the 2” take-out for the swivel ring.

One example of a concrete expansion shell used for installation beneath concrete decks is detailed in Figure G-8. These shells can easily be installed on the side of a concrete “tee” or beam and used with an eye-rod type hanger. Again, there are numerous concrete shell types used today, and manufacturer’s cut sheets need to be consulted before trying to determine the exact lengths of bolts or rods to use with these shells. In the interests of uniformity and to reduce the cost of stock inventory, each sprinkler company usually tends to use the devices of one hanger supplier, and stock just one expansion shell type for this reason.

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Know what you’re hanging to. In pipe installer jargon, there is something called a “wow.” A wow is a major gaffe that is visibly apparent. I once saw a 6’ main installed 5’ above the floor passing right in front of a door to a shop office. That is a wow. Anyone who saw this great installation could only stand there looking at it and say, “Wow.”

Wows can also show up on a sprinkler plan. Let’s say you show an obstruction (such as a light fixture, beam, or some ductwork) on your plan, and then show your pipe running...
right through it. This obviously would bode badly for your reputation as a designer. Another “wow” example would be to show a long length of pipe running to a sprinkler-head, where there is nothing to hang the pipe from. Suppose you draw in the roof joists and then show your pipe running parallel to, but not near, any joists, without any explanatory note. The installer (who will nonetheless figure a way around this misnomer) will probably call you up and ask if you figured on using a “skyhook” to hang this piping. Not knowing what you’re hanging to can only make your design work appear less professional.

Refer again to Figure A-2, and, in particular, to the last sprinklers on the branch-lines. You will notice that they extend beyond the last bar joist, as opposed to being positioned directly beneath the last bar joist. There is a reason for this. It has to do with NFPA #13 subsection 6-2.3.2 that states that the distance from the hanger rod to the centerline of an upright fire sprinkler must be a minimum of three inches. In preparing his sprinkler layout, the designer must be aware of this code requirement in order to avoid making the field installation more difficult than it has to be.

In conclusion, keep in mind that a responsible sprinkler engineer is always able to explain his engineering decisions, and this includes his plan for pipe hanging methods. Hanging costs are included in job estimates, hangers are stocked in every fabrication shop, and they are an integral part of every job. Know this, and be conversant with the installing crew to understand their likes and dislikes of the various types of pipe hanging methods.

ENDNOTE

1 The metal bracing elements existent in steel beam and bar joist construction include pieces of angle iron that are not strong enough to provide support for sprinkler pipe.
System Code Requirements

Code compliance is the fundamental and most essential objective of sprinkler system design. A typical project plan sheet should list the following note very clearly: “All methods of system design and installation shall be in strict accordance with NFPA Pamphlet No. 13.” Pamphlet No. 13 is entitled “Installation of Sprinkler Systems,” which is an apt title considering that its stated intent is to provide the minimum design requirements for the design and installation of sprinkler systems. The design rules referred to include the adequacy of water supply, and the selection of system materials. Its real value as a national code has been the assimilation of past fire records and data by fire protection professionals, and the transfiguration of that collected knowledge into standardized requirements for design and installation.

As previously discussed, the 1999 edition of Pamphlet #13 has not been devised from scratch; rather, it has evolved from its first scripting. Since the original (1896) published standard, there have been over fifty revised editions. The entire fire protection community is entitled to propose recommendations for revision, and these proposals are explored and discussed by the Technical Committee on Automatic Sprinklers. The proposals for improvements and/or clarifications are directed towards parts of any of the thirteen chapters or the five appendices of NFPA #13.

To keep abreast of the intricacies of the standard is certainly as essential as knowing the basic procedures for system design as outlined in the previous nine chapters of this text. For example, let’s assume that the following two conditions exist in our design project example (see Figure A-6): 1) the 2′′ branch-line marked “A” that feeds the office piping is actually 2 1/2′′ pipe, and 2) the shop area of the building contains a long run of rectangular sheetmetal ductwork 10′′ in depth by 50′′ wide. These are simple enough changes and, more importantly, not uncommon conditions.

Now let’s look at the following related direct passages from NFPA #13:

5-7.5.3.2 Sprinklers shall be installed under fixed obstructions over 4 ft. (1.2 m) wide such as ducts, decks, cutting tables, and overhead doors.

A-5-6.4.2 On sprinkler lines larger than 2 in., consideration should be given to the distribution interference caused by the pipe, which can be minimized by installing sprinklers on riser nipples or installing sprinklers in the pendent position.

Since sprinklers shall be installed under ducts over 4 feet in width, the standard is referring to a mandatory requirement that an upright, sidewall, or pendent sprinkler be installed under the water spray obstruction that the 50′′ wide duct will become. The standard does not tolerate the possibility of a floor area in excess of 4′ (wide) to not be “covered” by the spray discharge from the installed sprinklers.

Second, Appendix A of NFPA #13 states that any sprinkler-head piped directly above 2 1/2′′ and larger piping should (not a mandatory requirement, but a wise recommendation) be piped upwards from the larger pipe by a sprig of some desired length. This helpful information that the appendix is providing is there not just to help the engineer do a better job, but to drive across the point of why the design recommendation will increase the efficiency of the system if and when it activates.

Obviously, neither of these two design addition/alterations could be made by an engineer who is not familiar with the above-captioned NFPA #13 rules.

Suppose the sample building has a crawlspace. The decision on whether or not to install sprinklers in that crawlspace hinges on the designer’s proclivity to reference Section 5-13.7 for the necessary rules which govern that situation. Making no reference at all to 5-13.7 of course leaves everything up to random guessing.
Similarly, the design engineer must be fully aware of the scope of the work covered by Pamphlet #13. For example, “NFPA 13 doesn’t provide sprinkler system information about the storage of flammable liquids, combustible liquids, or aerosol products. Instead, it references NFPA 30, Flammable and Combustible Liquids, and NFPA 30B, Manufacture and Storage of Aerosol Products, for this information” [1]. One must still be cognizant of the NFPA codes in order to realize that he or she must refer to other standards in special situations.

CUSTOMIZING YOUR WORK TO THE JOB AT HAND

Every sprinkler installation is unique, and differs in the many aspects of construction and often, possible installation procedure. As has been stated previously, there is nothing in the NFPA codes that is overly hard to comprehend, it is just that there are so many requirements that it is difficult in the early stages of design work to remember them all. That difficulty is offset by an acquired ability to know where to look for the written requirements.

As the engineer’s job progresses from project to project, it becomes apparent that the uniqueness of each job means that different rules will be applicable to one project that may not come into play at all on the next. In character, the engineer must be adaptive enough to mentally organize himself differently to each job. The key question the engineer must ask himself at the onset of each project is, “What is incidental to this occupancy?”

The successful bidder on any given project is a salesman/estimator already familiar with the nuances of that project. The better he is in communicating those nuances to you, the better off both of you will be. Many companies ask that the salesman get the engineering process off to a good start by filling out a contract information sheet. A typical example of this form is shown in Figure F-3. Properly filled out, this is an extremely helpful and handy form. Generic in scope, however, it cannot answer every question that will crop up on a design project. For example, will the fabrication shop provide lengths of sprinkler main in 20’ or 21’ lengths? What are the stock hanger rod lengths provided—6’, 8’, or 10’? Is there a specified temperature rating for the sprinklers? Who are the other subcontractors on the job? What is the makeup of the building’s roof construction? What is the current status of construction progress? Has the water main been brought in to the building yet? Do catalogue cuts need to be submitted to anyone? Are any special materials, such as hose valves or fire extinguishers to be provided? If it is a toss-up labor-wise and material-wise as to which would be more efficient, what type of piping layout (loop, grid, or tree) is preferable?

Obviously, these are all questions that cannot be answered by the NFPA codes, and are reliant on good inter-office communication. But it is clear that the answers to just about any other design question will be found in one of the NFPA standards, most likely NFPA Pamphlet #13. Many of that standard’s key requirements will be discussed in this chapter. As a model, this text will use the 1999 edition of NFPA #13.

CODE SPECIFICS

Chapter 5 (entitled “Installation Requirements”) of NFPA #13 would be a good pick if you were trying to select the first chapter of that pamphlet to read if trying, as a novice, to acclimate yourself to sprinkler system regulations. This chapter would be required reading for any Fire Sprinkler Design and Layout course in a classroom setting. It lists the protection area limitations for systems under Section 5-2. For starters, no one system riser shall provide protection over an area exceeding 52,000 square feet on any one building floor. It the occupancy of that area is considered to be an extra hazard occupancy, or one that contains stored commodity piled higher than 12’, then the maximum protection area shrinks to 40,000 sq. ft. Sprinkler-head spacing limitations are also discussed in this chapter in great detail. Without going into every exception, anomaly, and irregularity, a single sprinkler-head shall not cover a square foot area exceeding 100 sq. ft. for Extra Hazard, 130 sq. ft. for Ordinary Hazard, and 225 sq. ft. for Light Hazard occupancies—all for systems that will be hydraulically calculated. The 5-6.2.2 Tables of NFPA #13 cover these rules throughly.

Sprinkler-heads shall be distance no more than 15’ apart3 and not any closer than 6’ apart.4 For high-piled storage or extra hazard occupancies, the maximum distance is reduced to 12’. The deflector of the sprinkler-head shall normally be positioned (see 5-6.4.1.1) between 1” and 12” down from an unobstructed ceiling. But the highest sprinkler deflector may extend 3’ down from the highest peak of a pitched roof.5 No less than 18” (see 5-5.6) is the distance that shall separate the sprinkler deflector from the top of any piled storage in any case, when using standard sprinklers.

To determine if a pipe scheduled system can be used in lieu of a hydraulically calculated system, investigate chapter section 7-2.2. If the pipe schedule method is not an option, Figure 7-2.3.1.2 on page 83 of NFPA #13 will be an oft-used reference, for determining design density for the calculation; as will Table 7-2.3.1.1, for figuring allowances for hose streams in the same calculation (see the next chapter of this text). If you are wondering how to size the underground water supply piping, you need to check requirements numbered 9-1.3 and 9-1.4.

If you are referring to a copy of NFPA #13 as you read this, you will have already noticed just how specific and exacting the code tends to be. Although some of the code is verbose and redundant, the reason for the exactitudes is so that rules for every possible situation are covered. The size of the pamphlet has increased over time, but is really not much different from other volumes of rules today: consider that the raw text of the 1994 ASA Playing Rules for a simple game of amateur softball actually takes 216 pages to cover.
To make best use of this chapter, write down on a separate sheet of paper the NFPA #13 numerical chapter references for the various requirements, under a heading in your own words, as you read along. I like to keep such a sheet inside the NFPA pamphlet’s back cover to use as my own index. It’s a considerable time-saver. Remember, no one can commit all these rules to memory. The trick is to remember the key rules and be familiar enough with the format of NFPA #13 so that you can locate the rule you’re looking for in a hurry when the need arises.

The occupancy examples will be a code section referred to by you on virtually every project. You may as well index page 168 of your NFPA #13 copy with a tab. However, don’t forget also to consult Sections A-2-2 and 7-10 for occupancies of obvious higher risk.

Chapter 2 of NFPA #13 contains two tables, 3-2.3.1 and 3-2.5.1, which classify and outline characteristics of various type sprinkler-heads. Other important tables of note are the pipe schedule tables (contained in Sections 8-5.2 and 8-5.3), and the pipe dimension tables (A-3.3.2 and A-3.3.4). A sometimes overlooked table is Table 8-4.3.2, which gives the multiplier modifications for the C-factors, which are given in Table 8-4.4.5, that lay the groundwork for every hydraulic calculation you will make. Table 1-5 is the useful standard for abbreviations used in hydraulic calculations. Table 5-6.5.1.2 is a valuable tool in determining sprinkler-head positioning near large spray obstructions. And Table A-4.2.3, discussed in Chapter 8, “Areas Subject to Freezing,” gives you the numerical multipliers to determine gallon volume capacities for different pipe sizes. Percentages that make clear the anti-freeze solution ratios are found in Tables 4-5.2.1 and 4-5.2.2.

The size of the spare-head cabinet required for a sprinklered building can be determined by referring to Section 3-2.9.3. Section 3-2.6.3 prohibits the painting of any sprinkler-head. Note: inside of a paint spray booth, plastic bags (.003” thick) are typically used to cover sprinkler-heads to protect them from paint overspray.

Again, Chapter 5 of NFPA #13 is a plethora of critical information. To take advantage of sprinkler spacing concessions made for small rooms (as defined in Section 1-4.2), refer to Section 5-6.3.2.1 and specifically to A-5.6.3.2.1. Section 6-2.3.2 gives you the allowable distance between a sprinkler-head and a pipe hanger. Section 5-13.1 is an important listing of all the rules concerned with whether or not a sprinkler may be omitted from a small but combustible concealed space. Likewise, Section 5-13.9 discusses the possibility of sprinkler omission from certain areas of dwelling units. Section 5-15.2, which you should become very familiar with, outlines all the rules governing the piping configurations acceptable for fire department connections. It should be noted that certain authorities having jurisdiction require 4’ of piping between the fire department connection check valve, and the connection itself, to guard against a pipe freezing situation [see also A-5-15.2.3 and special note under Figure A-5-15.4.2(a)]. Section 5.14.2.3 gives you your dry system pipe pitch requirements, and 5-15.1.1 limits the system size that is allowed to be installed without a flow switch. Section 5-13.4 is an important reference for multi-story buildings, as it discusses protection around stairways, and is also the section where the design of water curtains is explained. Any system design that includes any hand-hose stations must be done so in accordance with Section 5-15.5.1.2 in its entirety. Actually, I could go on and on here. Suffice it to say, any question that you may have with regard to sprinkler installations in unusual situations can be answered by referring to a paragraph located somewhere in Chapter 5.

MAKING USE OF NFPA PAMPHELET #13

Chapters 7 and 8 are referred to most often when considering various hydraulic design options for sprinkler systems. When the building to be protected (usually a light-hazard type office or medical care-center) is comprised only of many smaller rooms, the Room Design Method outlined in Section 7-2.3.3 should definitely be utilized. However, the rules governing standard calculation procedure are found in Section 8-4.4, one of the most cogently written sections of Pamphlet #13. Before any engineer attempts to calculate any system to determine pipe sizing, the careful reading of 8-4.4 is a prerequisite.

Chapter 10-2.2 is the place where the rule of hydrostatic testing of pipe for leakage at 200 psi for a 2-hour duration is mandated. In Exceptions numbered 3, 4, and 5, the exceptions to that requirement for modified or repaired systems is noted. This is an important exception for contractors working on existing systems only to relocate pendant sprinklers, or modify small sections of that system. The NFPA #13 appendices contain numerous additional significant recommendations. For instance, A-4-2 advises against the use of dry-pipe systems where adequate heat is continually provided. Section 5-7.2.1, formerly in the Appendix, outlines the Protection Area rule so that the exact square foot coverage per sprinkler is understood by both the designer and the plan reviewer. Something that seems to come up time and again is the subject of portable closets. Section A-5-13.9.2 thankfully puts this subject to rest. Make a note of the fact that the installation of a sprinkler-head in one of these “wardrobe units” is not a code requirement, because sooner or later you will encounter a situation whereby this relatively minor issue will become the focal point of some plan review or permit issuance. Section A-9-2.1 gives a good procedural overview of how to conduct a flow test. Figure A-5-15.4.3 shows a suggested design for an inspector’s test connection on a dry system. In general, Appendix A of Pamphlet #13 is by design an information supplement for the readers’ benefit.

NFPA #13 is really the hallmark of standardized engineering criteria for automatic fire sprinkler systems. Life would be simple and easy for the designer if every system design made that was in complete compliance with NFPA #13 was readily accepted by plan reviewers, insurance companies, and other authorities. However, some insurance carriers and
even some municipalities will enact their own ordinances regarding fire protection, borne out of conservatism and some unexplainable desire for overkill, that are in excess of the NFPA #13 standard. There is not much the everyday design engineer can do about this. Nonetheless, striving to have a good handle on all the NFPA #13 rules and regulations is not only a credit to you as a professional, but will also contribute greatly to your own education and training.

**STUDY QUESTIONS**

Note: The following questions are to be used as an “open-book” type quiz. The answers to the study questions are not necessarily found within this text. Please make use of NFPA Pamphlet No. 13 when figuring question responses. You will have to reference additional NFPA standards in order to correctly answer the study questions following Chapters 12, 15, and 19 (answers appear on pages 281–282).

1. On a light hazard pipe schedule system, what is the maximum distance that sprinklers may be placed apart on a branch-line?
   A. 8’
   B. 10’
   C. 12’
   D. 13’
   E. 15’
   F. 16’ 6”

2. How many spare sprinklers must be on hand for a building with 305 installed sprinkler-heads?
   A. 6
   B. 9
   C. 12
   D. 15
   E. 18
   F. 24

3. The definition of the word “approved,” as it appears in NFPA publications, should be:
   A. acceptable to the authority
   B. all right to commence design and installation
   C. U.L. listed and F.M. stamped
   D. in accordance with product cut sheet data criteria
   E. listed by the National Fire Protection Association

4. Excluding events of major explosions or storage collapses, there has never been a multiple loss of life in a fully sprinklered building due to fire or smoke.
   A. true
   B. false

5. How many square feet of floor area can be fed from any 8” riser for ordinary hazard occupancies?
   A. 25,000
   B. 40,000
   C. 45,000
   D. 52,000
   E. 60,000
   F. 75,000

6. A warehouse contains a moderate amount of combustible liquids stored in sealed cans. Other materials and products are also stored in the warehouse. Its occupancy should be classified:
   A. Light Hazard
   B. Ordinary Hazard Group 1
   C. Ordinary Hazard Group 2
   D. Ordinary Hazard Group 3
   E. Extra Hazard Group 1
   F. Extra Hazard Group 2

7. A ceiling sprinkler deflector is located at an elevation 9 inches above the bottom of a nearby solid I-beam. In order for proper spray discharge beyond the beam, it must be located at least ________ from the beam.
   A. 9”
   B. 2’
   C. 3’
   D. 4’
   E. 4’ 6”
   F. 6’

8. What is the minimum clear space necessary below sprinklers?
   A. 1’
   B. 18”
   C. 2’
   D. 2’ 6”
   E. 4’
   F. 6’

9. Which of the following need not be included on a sprinkler shop drawing?
   A. location of bells
   B. point of compass
   C. column lines
   D. type of piping
   E. location of pipe bends
   F. type of hangers

10. What would be the temperature rating (degrees Fahrenheit), of a fire sprinkler that has its frame arms painted red?
    A. 135°
    B. 155°
    C. 212°
    D. 286°
    E. 360°
    F. none of the above

11. A laundry room has a total dimension of 24’0” by 31’6”. What is the maximum distance a standard sprinkler may be positioned from a wall?
    A. 5’3”
    B. 6’0”
    C. 7’0”
    D. 7’6”
The one of the following which is an objection raised against the use of a dry pipe system of automatic sprinklers as compared to a wet pipe system, is that with the former system:

A. it is more difficult to get complete coverage
B. the water drains off too easily
C. all system piping has to be properly pitched for drainage
D. freezing, which could cripple the system, is more likely
E. a smaller number of sprinkler-heads open
F. the time between the fusing of a sprinkler and the issuance of water is greater

An automatic sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve which is opened by the operation of a heat-responsive system installed in the same area as the sprinklers is called a:

A. deluge system
B. wet pipe system
C. hydrostatic system
D. dry chemical system
E. pre-action system
F. dry pipe system

A museum display room is 34' long by 25' wide. What is the least number of sprinklers needed to properly cover the room if the system is calculated?

A. 3
B. 4
C. 5
D. 6
E. 7
F. 8

An 8-foot wide slatted platform deck is installed in a warehouse. This is a deck that you can walk on, and spit through. There is ceiling sprinkler protection above the deck. Sprinklers should be installed beneath the deck.

A. true
B. false

To prevent cold-soldering of sprinklers in a commercial building, sprinklers shall not be placed closer than ______ feet apart, without obstructions or baffle protection.

A. 2
B. 3
C. 4
D. 5
E. 6
F. 8

With 6” wood joists, spaced 16” on-center, supporting a flat wood deck, what is the maximum distance beneath the underside of the wood deck that a sprinkler may be positioned?

A. 6”
B. 10”
C. 12”
D. 16”
E. 20”
F. 24”

What is the minimum pipe size for a flushing connection?

A. 1”
B. 1 1/4”
C. 1 1/2”
D. 2”
E. 2 1/2”
F. 3”

In the standard, which of the following would qualify as a “dwelling unit”?

A. fraternity house
B. shelter for homeless
C. hotel
D. nursing home
E. condominium
F. all of the above

A basic premise of proper sprinkler protection is that sprinklers be installed throughout all building areas.

A. true
B. false

How far apart may standard sidewall sprinklers be installed on a branch-line in a restaurant seating area?

A. 6’
B. 8’
C. 10’
D. 12’
E. 14’
F. 15’

An office with a suspended gypsum board ceiling, on a hydraulically calculated system, is 81' long and 55' wide. What is the minimum number of standard sprinklers necessary to properly protect the room?

A. 15
B. 20
C. 23
D. 24
E. 35
F. 36

The bottom of a 16” steel I-beam sits at an elevation of 15’. A run of 2” pipe crosses beneath the I-beam at a centerline 13’9” elevation. Using a 3/8” Jr. bottom-beam C-clamp and a standard swivel ring, what length 3/8” rod should be cut to complete the hanger assembly?

A. 12”
B. 14”
24. What would be the temperature rating (degrees Fahrenheit), of a fire sprinkler that has its frame arms painted white?
   A. 135°
   B. 155°
   C. 212°
   D. 286°
   E. 360°
   F. None of the above

25. Wet-type sprinkler systems are the most reliable fire protection systems known.
   A. true
   B. false

26. The total hanger rod take-out for a 4″ hanger assembly consisting of a 3/8″ top-beam clamp and a swivel-ring would be:
   A. 2 1/2″
   B. 3″
   C. 3 1/2″
   D. 4 1/2″
   E. 5″
   F. 6″

27. The total take-out for one 6″ grooved 90° angle turn elbow is:
   A. 2 1/2″
   B. 3″
   C. 4″
   D. 5″
   E. 6″
   F. 6 1/2″

28. How many square feet of floor area can be fed from any 4″ riser for light hazard occupancies?
   A. 25,000
   B. 40,000
   C. 45,000
   D. 52,000
   E. 60,000
   F. 75,000

29. Carpeting is stored in a warehouse to a maximum solid pile of 15′ in height. What is the maximum distance apart that the sprinkler branch-lines may be run if standard sprinklers are used?
   A. 8′
   B. 10′
   C. 12′
   D. 13′
   E. 15′
   F. 16 1/2″

30. A building owner would experience more maintenance and upkeep having a dry system as opposed to an anti-freeze system.
   A. true
   B. false

31. A library reading room has overall dimensions of 31′ x 25′. What is the maximum distance a standard sprinkler may be positioned from a wall?
   A. 5′3″
   B. 6′0″
   C. 7′0″
   D. 7′6″
   E. 9′0″
   F. 15′0″

32. The demonstrated effectiveness of pipe schedule systems is limited to the employ of only standard 1/2″ sprinklers and 3/4″ large orifice sprinklers.
   A. true
   B. false

33. The high-piling of combustible material at sprinkler-heads is undesirable principally because:
   A. sprinklers fail to operate
   B. water cannot reach the seat of the fire
   C. more smoke will be produced
   D. aisles are obstructed
   E. there is more content capable of burning

34. Anti-freeze loops are a design option only for small systems of less than a _______ gallon capacity.
   A. 10
   B. 20
   C. 30
   D. 40
   E. 50

35. One sprinkler protects a square-shaped washroom, with dimensions of 14′ x 14′. The sprinkler-head is positioned in the geometric center of the room, which puts it exactly 9′ 10 1/2″ from any corner. This sprinkler positioning is acceptable.
   A. true
   B. false

36. The stock of spare sprinkler-heads to be provided shall include all sprinkler types, and all sprinkler temperature ratings, for sprinklers installed in that particular building.
   A. true
   B. false

37. What is the largest area that one sprinkler system may be designed to cover for a tire manufacturing plant?
   A. 25,000 sq. ft.
   B. 40,000 sq. ft.
   C. 45,000 sq. ft.
   D. 52,000 sq. ft.
   E. 60,000 sq. ft.
38. What is the hydrostatic test pressure that a newly installed sprinkler system must maintain for acceptability?
   A. 50 psi  
   B. 100 psi  
   C. 150 psi  
   D. 200 psi  
   E. 250 psi

39. The closer that sprinklers are placed to the ceiling, the faster they will operate.
   A. true  
   B. false

40. Locating sprinklers too close to the ceiling may result in serious interference to lateral distribution of water from sprinklers by structural members.
   A. true  
   B. false

41. The standard symbol for a chrome pendent sprinkler-head on a fire sprinkler shop drawing is:
   A. a circle  
   B. a double circle  
   C. a triangle  
   D. a circle with a “X”  
   E. an octagon  
   F. none of these

42. The distance between the ceiling of an office and the structural concrete above it is 3’6” and 24” bar-joists support the concrete floor. This is new construction, and the suspended ceiling height is 10’6”. To satisfy all parties involved, and to make the most efficient design for a quick and proper job installation, the pipe centerline elevation above finished floor that the designer would choose would be closest to:
   A. 10’0”  
   B. 10’10”  
   C. 11’3”  
   D. 11’10”  
   E. 13’0”  
   F. 13’9”

43. A particle-board manufacturing plant will be protected by a number of hydraulically calculated automatic fire sprinkler systems. The overall dimensions of this plant, completely rectangular in shape, will be 500’ × 850’. How many separate systems shall be installed in the plant?
   A. three  
   B. four  
   C. six  
   D. seven  
   E. nine  
   F. eleven

44. What is the maximum distance allowed between pipe hangers for 1 1/4” steel piping?
   A. six feet  
   B. eight feet  
   C. ten feet  
   D. twelve feet  
   E. fifteen feet

CITATION

ENDNOTES
1 See Section 1-4.1 in NFPA #13 for the interpreted definitions of “should” and “shall.”
2 We would probably call for a 1” × 0-2 sprig off of the 2 1/2” line to supply the single sprinkler-head, previously referred to on Line “A.”
3 This rule changes when using sidewall sprinklers, see Table 5-7.2.2.
4 If sprinklers are situated any closer than 6’ away from one another, the danger of coldsoldering becomes a real possibility. The spray from the first fusing sprinkler-head may immediately cool the fusible elements of the second sprinkler-head, preventing its operation.
5 All sprinkler deflectors shall be installed parallel to the slope of the ceiling under a pitched roof.
6 See Section 1-4.2 for the standard’s examples of a “dwelling unit.”
7 The explanation for seemingly excessive requirements mandated by the insurance underwriter is that, although the fire sprinkler engineer simply moves ahead to the next design project once the fire protection system for a given building is approved and accepted, the insurance company has to live with insuring that building for the next 75–100 years or so, its entire “design life.”
A discharging sprinkler-head will provide a nearly uniform spray of water over a given area. When the water strikes the sprinkler deflector, it breaks into a circular pattern, often overlapping the spray discharge from an adjacent sprinkler. Any automatic fire suppression system will by design, distribute water (or a foam solution) to a specific area. The application rate (or “density”) of this distribution is frequently expressed in units of gallons per minute per square foot. The worst potential fire situation is used to determine the number of discharging sprinkler-heads needed to keep that fire in check. The density, and number of sprinklers desired, will determine the system’s water supply demand. Obviously, this demand is a variable based on occupancy characteristics. To insure an adequate supply of water, and uniform water discharge from the sprinkler-heads, accurate pipe sizing to the sprinkler-heads must be ascertained, and this is accomplished by the exercise of hydraulic calculations.

The need that was originally satisfied by the onset of hydraulic calculations was the need to accurately determine if an existing building water supply would deliver the predetermined amount of water over a specified area for that specific hazard. Through this concept and the use of hydraulic calculations, the pipe sizing could always be adjusted through the use of hydraulic design to insure that the system would be laid out and devised properly, and satisfy the applicable standards. Although the origin of hydraulic calculations came much sooner, 1966 was the first edition of NFPA Pamphlet No. 13 that contained rules that regulated hydraulic calculation procedure. Because of the economies realized through the exercise of hydraulically calculating an automatic fire suppression system, its popularity gradually began to rival the traditional use of the pipe schedule system. By 1981, the Viking Corporation estimated that 20 percent of automatic fire sprinkler systems installed based their pipe sizing on the hydraulic calculation method. Calculated gridded systems, which didn’t even garnish a mention in NFPA Pamphlet No. 13 until 1975, offered so many design advantages that the popularity of the pipe scheduled systems lessened through the years of the 1980s and 1990s. Today, of course, all new fire sprinkler systems installed must be hydraulically calculated unless they meet the criteria noted in NFPA Pamphlet No. 13 under Chapter 7-2.2.1, which states that only systems that cover square foot floor areas of less than 5000 sq. ft. or systems situated in the high pressure city water supply zones may be pipe scheduled.

THE PROJECT EXAMPLE

Let’s suppose that the project example depicted in Figure A-6 must be hydraulically calculated instead of pipe scheduled. The first thing the designer must do is lay out the system before he can begin his hydraulic calculations. The design would, at this point, look as it does in Figure H-1. The designer must then ascertain the occupancy hazard of the building, and he must determine the design density and the assumed area of operation. Page 168 of the current 1999 edition of NFPA 13 lists occupancy examples, and, of course, this project example, that of Glass Products Manufacturing, would indicate an ordinary hazard group I occupancy hazard. We would then turn to Figure 7-2.3.1.2 in NFPA Pamphlet No. 13 to look at the area/density curves. It has been fairly common knowledge in the industry that to make the most economic use of piping material utilized in the job installation, that the lowest points on the curve should be utilized when selecting a point from the area density curves. So what we would want to use is the lowest point on the ordinary hazard group I curve which would call for a design density of .15 gpm per sq. ft. over the most hydraulically demanding 1500 sq. ft. area. The most hydraulically distant area is not necessarily the most remote area, and it is also of note that this area needs to have all sprinkler-heads supplied by the...
same cross-main. The first step in the hydraulic calculation process is to select the location for this 1500 sq. ft. area and note it on the plan. In our case, as noted in Figure H-1, and duly noted in Chapter section 8-4.4.1.1 of NFPA 13, we have simply taken the figure 1.2 and multiplied it by the square root of 1500, since 1500 is the square foot size of our hydraulically most demanding specified area. This gives us a figure of 46 1/2", thus establishing the minimum length to be used for the long end of the rectangular remote area, which is always parallel to the branch-line. A simpler way to do this would be to divide the 46.5 figure by the spacing between sprinklers on the end branch-line, which is 10'7" in our case: that would yield a figure of 4.4. By always rounding that figure up, we arrive at the number of sprinklers on the branch-line that need to be calculated. In this case, 4.4 rounds up to 5, so we have five heads that we need to open on that end branch-line. Since our remote area is covering 1500 sq. ft. and our square foot sprinkler coverage in this case is 10'7" × 12' or 127 sq. ft., then we would divide 1500 by 127 to arrive at a figure of 11.8. This rounds up to the number 12, which is the minimum number of sprinklers that need to be "opened" in the calculation. The twelve sprinkler-heads that we will be "flowing" for this calculation do comprise the entire remote area of calculation, and their collective activation represents the system’s response to a hypothetical fire. It must be realized that by completing our calculation successfully, we are simply proving that the system’s pipe sizing will be of sufficient diameter to deliver the required volume of water to the area of fire origin, at the minimum required pressure, in order to extinguish potential fires in their early stages.

We can safely assume, given ordinary hazard group I conditions, that the water discharged from the twelve sprinklers will, at the very least, be adequate enough to hold this fire in check until the arrival of the local fire company: “[Chapter 8] of NFPA 13, ‘Installation of Sprinkler Systems’—a standard with years of field experience—establishes the correct procedure for performing hydraulic calculations for an automatic sprinkler system. If the design criteria calls for a specific density over an area of sprinkler operation, this NFPA 13 procedure can be used to verify that the system design will provide such a density” [1]. This portion of the standard is without a doubt performance-based, “given that a performance-based code is defined as one that gives the engineering design specifications for meeting stated performance objectives, and identifies acceptable calculations methods” [2]. It is a well conceived and very cogently written portion of NFPA 13.

One assumption that the standard makes is that the response time for sprinkler actuation will be timely, similar for all the different sprinkler-heads and certainly quick enough for fire control. Another inherent assumption of the calculation theory is that two fires will never occur simultaneously in different parts of this building. I would say this is a fair assumption to make for our purposes and certainly makes good sense. Before proceeding, I would like to point out that the hydraulically most demanding specified area noted in Figure H-1 is actually 1524 sq. ft. This is because the twelve sprinkler-heads in the shaded area each cover 127 sq. ft. in floor area, so if you multiply out the 127 by 12 you obtain the 1524 figure. A good case could be made that there actually exists on the area/density curve a point that could be construed as .149 gpm per sq. ft. at 1524 sq. ft. Certainly, if .14 over 2000 is a definite point on the ordinary hazard group 1 curve, then the figure for density in gpm over square feet has to be less than .15 for an area of 1524 sq. ft. of sprinkler operation. However, this is overly nit-picky, and you would be hard pressed to get this to fly from an authority having jurisdiction, so that practice should not be really investigated unless the figure you come up with when multiplying out your sprinkler square foot coverage is closer to 1600 or 1700 sq. ft., and you can ascertain, visually, a clearer point of (gallons per minute) density on that curve.

**PRIMARY CALCULATION CONSIDERATIONS**

Turning again to our example in Figure H-1, which shows the fire sprinkler system as it has already been designed in Figure A-6, we must note that there will be sprinkler-heads on either side of the cross-main. Therefore, we need to label the branch-lines on either side of the cross-main on the plan, and the normal method is to label the branch-lines with a letter inside an octagon or six-sided hexagon shape so that corresponding points can easily be noted between the calculation sheet and the blueprint itself. The first step in our hydraulic calculation process then would be to calculate the short line labeled either “C” or “D” on our plan on Figure H-1. Figure H-2 shows the worksheet that we would use, and it has been filled in on that figure, as well as Figure H-3 (for a complete hydraulic calculation of the project example). Please note once again that the area selected as the remote area is indeed the most remote because it is the furthest from the water source in the building. We are opening up five heads on the end branch-line of this example because we have simply divided (1.2 times the square root of 1500) 46.5 by the distance between heads on that line. The number of sprinklers calculated will be twelve, and we arrived at that number by taking 1500 and dividing it by the square foot coverage of each sprinkler. These figures are always rounded up as we are always interested in looking at the worst possible case scenario of fire origin, with respect to code compliance.

The worksheet used in Figures H-2 and H-3 are designed for a hand calculation. This worksheet form is just one of many used in the sprinkler industry today. If a hand calculation is to be made instead of a calculation made with the use of a computer-generated program, then hydraulic tables must be used in conjunction with the worksheet. Examples of these tables are shown in Figures H-6, H-7, and H-8. These are generally referred to as hydraulic data tables, and they are based on the Hazen-Williams friction loss formula. Through the use of tests and experience and experimentation, the
Hazen-Williams friction loss formula was developed, and it determines friction loss in pressure using three factors which are, gallons per minute of water flowing, the internal pipe diameter, and the “C”-factor. The C-factor is a friction loss coefficient developed in this formula for the specific type and harshness of pipe interior. The C-factor is independent of water velocity. For example, in a dry system, the C-factor is 100. This is a harsher factor than that used in wet systems, because in a dry system, the interior of the pipe will tend to flake and become more rough. Over time the oxygen in the dry pipe tends to cause more corrosion in what is referred to as pipe scaling in the interior of steel pipe. The C-factor we will use in our example is 120, as this is a wet system, and the C-factor values can be found on p. 141 of NFPA Pamphlet No. 13 in Table 8-4.4.5.

Now for our calculation, at point C or D, how much water needs to come out of one of those sprinkler nozzles? That’s easy. You simply take the design density, which is .15 gpm per square foot over the sprinkler’s square foot coverage, which is 127, and multiply the two figures. .15 times 127 (in square feet) equals 19.05, which we have rounded up to 19.1 on the worksheet. Note on the worksheet that \( Q \) stands for flow in gallons per minute and \( P \) stands for required pressure. We know that we will need 19.1 gpm in water flow to come out of the end sprinkler, and at least that much out of all sprinklers located in the remote area. This is 19.1 gpm per square foot of floor area, but at what required pressure? To ascertain that figure for the end sprinkler, we need to know the “K”-factor of the sprinkler-head (involved. The K-factor is simply a relationship between pressure (in pounds per square inch) and volume (in gallons per minute). This relationship naturally varies with the diameter of the water stream or the size of the sprinkler nozzle orifice. In our project example, the sprinkler-heads used are standard half-inch National Pipe Thread sprinkler-heads with a half-inch smooth bore orifice having a K-factor of 5.5.

The key formula to remember throughout the hydraulic calculation process is that \( K = Q/\sqrt{P}. \) Likewise, the \( \sqrt{P} = Q/K, \) and \( Q = K \) multiplied by \( \sqrt{P}. \) Again, \( Q \) refers to volume in gallons per minute and \( P \) refers to pressure. Looking at the worksheet on Figure H-2 under nozzle C-1, our end head pressure is 11.98. We arrived at this by first multiplying .15 \times 127 \) to arrive at the flow of 19.05. We then divide 19.05 by 5.5, which is the K-factor, and arrive at a figure of 3.4636, which we multiply by itself (3.46) to get the required pressure figure of 11.98. The next step in the calculation process is to run that 19.1 gpm backwards to the pipe piece referred to as C-1. The length of that pipe is 4.5′ center to center. Since the water flow will need to undergo a 90° turn at the T at the top of the riser nipple, we need to refer to Table 8-4.3.1 in NFPA 13 to determine the equivalent pipe length for the pipe length referred to a C-1 on the Figure H-2 worksheet. Referring to that table, a T that is a 1 1/4” fitting has an equivalent pipe length of 6′. Therefore, the total pipe equivalent length is 4.5′ plus that 6′ for the T that is at the top of the riser nipple and which adds to a total of 10.5′. We would then refer to the friction loss tables to determine that the friction loss through 1 1/4” schedule 40 steel pipe for water flow of 19.1 gallons is a total friction loss of .031 lbs per square inch (psi) per foot. We would then take the 10′6” pipe equivalent length figure and multiply that by .031 to determine that the total pressure loss is 0.33 lb per square inch (psi) for that section of piping. You may have noticed while looking at Table 8-4.3.1 that the equivalent schedule 40 steel pipe length for a 3/4” fitting has been noted. This is probably because 3/4” pipe used to be used a lot more in sprinkler system installations. The use of 3/4” steel pipe was eliminated in 1940 by NFPA standards to improve discharge at end sprinklers. 3/4” steel pipe is not allowed in calculated systems or in pipe schedule systems today (except for systems in residential occupancies). The old rules for limiting the number of sprinkler-heads on a branch-line do apply today on pipe schedule systems but do not apply for hydraulically calculated systems. One additional note: NFPA #13 allows the engineer to ignore the friction loss through the fitting that immediately precedes the sprinkler-head, if that sprinkler connects directly to the fitting.

Getting back to our project example, the next step that we want to take is to ascertain the K-factor of branch-line “C.” The total pressure at the top of the riser nipple would be the end head pressure of 11.98 plus the .33 friction loss incurred through pipe line “C” for a total of 12.31 psi. Now, we want to find the K-factor for this branch-line, and again by the formula \( K = Q/\sqrt{P}. \) So, we would take the square root of the total pressure of 12.31. This comes out to about 3.51. We would divide the 19.1 total gallons or \( Q \) by the Figure 3.51 to arrive at the K-factor for that line of 5.44. It’s important to note that on the worksheet, because we are going to need that figure when we balance the flows at the top of the riser nipple. Now, next, we want to calculate the long branch-line either H or G. We wrote down G on the worksheet, and again, we are going to start with the end head pressure of 11.98 just as we did on branch-line “C.” Again, we are working backward as we always are when we are hydraulically calculating any system. The first section in branch-line G is the 1″ piece that is 10′7” long. This is a center-to-center dimension, as seen in Figure A-6. From the pipe schedule tables, the friction loss per foot is .119 for 1″ pipe flowing 19.1 gpm. As you can see on the worksheet of Figure H-2, 10′7” which has a decimal equivalent of 10.58 times that .119 in friction loss in pounds per foot would total out to a total friction loss of 1.26 psi for that section of piping. Adding it to the 11.98—end head pressure totals 13.24. Now we come to the second sprinkler-head on the branch-line, and we need to know how much water has to flow out of that sprinkler nozzle. It is not going to be exactly 19.1 because that would not be possible. Due to the kinetic dynamic energy associated with the velocity of water traveling through the pipe and the volume of water needed to supply twelve sprinkler-heads with water during a hypothetical fire or five heads on a branch-line, we need
to ascertain that the end sprinkler is going to discharge the least amount of water in this scenario. For our purposes in our hydraulic calculation, to ascertain the gallon per minute flow of water that will be dispelled from sprinkler nozzle G-2, we take the 13.24 required total pressure that we have at the beginning of pipe section G-1 and take the square root of \( P \), which is the \( \sqrt{13.24} \) or 3.639. Multiply that by the K-factor of the G-2 sprinkler nozzle or 5.5 to come up with 20.01, which we have rounded to 20 gallons. Therefore, through piece G-2 we are actually flowing 19.1 plus the 20 gallons required at the sprinkler nozzle G-2 or 39.1 gallons through that 1” piece, which is also 10’7” long. The pipe schedule tables tell us that the friction loss per foot through 1” schedule 40 pipe for 39.1 gallons is .45 psi per foot, and multiplied by 10’7”, the total pressure loss through that section of pipe would be 4.76 psi. Adding this to the previous figure of 13.24, we now know that at the end of the second section of 1” pipe (working backwards) we would need 18 lb of pressure at that point to insure that the end head pressure would still be 11.98.

The next piece to work backwards through on line G is the 1 1/4” piece, which is also 10’7” long. As you can see by the worksheet on Figure H-2, we have taken the \( \sqrt{18} \) and multiplied it by the K-factor (again) of 5.5 to ascertain that we will need 23.3 gallons flowing through nozzle G-3. G-3 would be the third sprinkler on that branchline, working backwards.

Incidently, regulations noted in NFPA Pamphlet No. 13 strongly discourage the use of sprinklers with different K-factors in the same sprinkler system. This is only reasonably permissible in very special situations.

Referring now to Figure H-7, we need to ascertain the friction loss in pounds per foot through 1 1/4” schedule 40 pipe flowing 62.4 gpm. As you can see on the worksheet, this has been noted as .281 psi. The .281 figure was actually interpolated from the pipe friction loss tables. You will note that the friction loss in psi per lineal foot of pipe for 62 gpm is .278. For 63 gpm, it is .286. The process of interpolation then would simply be taking the figure of eight, which is 286 – 278-and then multiplying it by .4 because the figure we are actually interpolating to is 62.4. As .4 \( \times \) 8 is 3.2, so we would add 3.2 to the .278 figure to arrive at the interpolated .281 psi per foot friction loss figure that we have actually used on the worksheet. Thus .281 \( \times \) 10.58 equivalant pipe length (G-3) gives us the 2.97 pressure loss for that section of piping. The fourth head on the branch-line referred to as G-4 needs to be opened next. And, looking at the worksheet, you can see that we have ascertained that a flow of 25.2 gpm would be necessary for that nozzle. Again, we have arrived at that figure by taking the square root of the total pressure figure of 20.97, multiplying it by the 5.5 K-factor for the sprinkler nozzle, to obtain 25.2. This, added to the 62.4 gpm figure gives us the information that 87.6 gpm needs to flow through that 1 1/2” section of pipe. Again, looking at the friction loss tables on Figure H-7, we can obtain the friction loss figure in psi per linear foot of .248 for the 1 1/2” pipe size section.

That 6’ long section terminates in a 1 1/2” black cast iron “T,” and the equivalent pipe length for that fitting is 8’. Hence, the total length of that section would be pre-supposed as 14’, and multiplying the 14 by the .248 figure, we arrive at the total friction loss of 3.47 psi for that section.

That completes the calculation for branch-line G, which now has to be balanced with branch-line C so the two flow together down the 2’ riser nipple to the 3’ cross-main. I should hasten to point out that the hand calculation method is a step-by-step process that dramatically increases in speed with practice and experience.

The section on the worksheet labeled Figure H-2 under riser nipple in the notes column is actually an extension of the branch-line G calculation that is adding the sprinkler flow from nozzle C-1 before it runs all the water down the riser nipple. We cannot flow just 19.1 additional gallons from sprinkler C-1, because we have to balance the two flows, and the way we do this is to start with the total pressure, which is 24.44 from the end of branch-line G, and we take the \( \sqrt{24.44} \) and multiply it by the K-factor, not for sprinkler nozzle C-1 but for branch-line C-1, which is 5.44. That gives us the 26.9 total flow in gpm that we need to add to the branch-line G gpm flow. This gives us a total of 114.5 gallons we are running through 2” pipe.

I would like to note at this point that Factory Mutual standards ask that maximum water velocity not exceed 20’ per second in branch-lines in gridded systems. This is a “tree system,” so that regulation would not apply. The industry generally recognizes a barometer of 32’ per second as the maximum water velocity through branch-lines, but the National Fire Protection Association does not limit the velocity of water in pipe in any of their standards. Our project example is not in danger of violating any of these regulations, and in fact, the highest water velocity recognized so far would be where the 62.4 gpm needs to travel through the 1 1/4” piece of pipe. The actual formula for water velocity in pipe is gallons per minute times a constant of .4085 divided by the interior pipe diameter squared. Looking at Figure H-2 under nozzle type G-3, we would figure this water velocity as 62.4 gpm times the constant of .4085 and divide that by the interior pipe diameter of 1 1/4” pipe, which is 1.38 squared, which would give a figure of 1.9044. Completing the division, we could ascertain that the water is traveling through that pipe at a speed of 13.39 ft. per second, if our calculations are accurate and, of course, this is well below either the 20’ or 32’ per second figure.

As this point in the chapter, the reader may be reading along at a steady pace and following this description of the hydraulic calculation process very well. However, if you seem to be vaguely bumping along through the reading right now, or feel somewhat lost, please don’t give up yet. This material is not that difficult to grasp, it just takes more time to do so, and it may be that you have been reading at too fast a pace. If you feel that your understanding of the process at this point is incomplete, I would encourage you to simply begin again,
this time reading a little slower so that you will allow yourself an adequate amount of time to digest everything.

**CROSS-MAIN CALCULATION PROCEDURES**

The cross-main calculation for the project example is noted on Figure H-3 which is, of course, a worksheet extension of Figure H-2. As stated earlier, we are starting at the end of the cross-main with a required pressure of 25.85 psi. We are working backwards. We know that 25.85 psi is a required pressure at this point to insure that the end-head sprinkler can discharge 19.1 gpm at a required pressure of 11.98 psi. Figure H-8 is the hydraulic table based on the Hazen-Williams friction loss formula for 3” light-weight steel pipe. The interior diameter of this pipe, as you can see, is 3.26” (which is also referred to as thin wall pipe or schedule 10 black steel pipe). We need to run 114.5 gallons from branch-lines DH to CG through the 3” thin wall pipe. From the friction loss table, we know that the friction loss in psi per foot is going to be .013 for this piece of pipe (because the C-factor of 120 is used on wet systems). We need to run this 114.5 gallons through 12’ with no direction in flow, so we take the 12 x .013 to realize that our total pressure loss is 0.16 for that section of piping. Before we can run the water from CG to F, however, we need to add the gallons coming from branch-line CG.

Referring to Figure H-2, we have ascertained a K-factor of 22.52 for branch-line CG. That was arrived at by taking the \( \sqrt{25.85} \) figure, which gives us 5.084, and then dividing 114.5 by that 5.084 figure. So then if you would look at Figure H-3, we would take our 26.01 total pressure, which is required at the bottom of the riser nipple for CG, take the \( \sqrt{26.01} \) and multiply it by the 22.52 K-factor to realize that the required flow for the branch-line labeled CG would be 114.852 gallons which, as you can see on the worksheet, has been rounded to 114.9 gallons per minute (the hydraulic characteristics of branch-lines DH and CG being identical).

So, then the section of 3” pipe between F and CG will carry 114.5 plus 114.9 or 229.4 gpm. The friction loss for that figure, taken from Figure H-8 friction loss table, would be .048, and multiplying that by the 11’ length, we would then note the pressure loss of 0.53.

We can now see where it was necessary to accurately ascertain the K-factor for branch-line F because we now need to know how much flow in gallons per minute needs to be added at this point to supply the two sprinklers on branch-line F. As you can see by the worksheet, this is a total of 44.8 gallons (which totals 274.2 gallons), which will be realized (if the calculation works) as the total gallons per minute necessary to supply the twelve sprinklers sufficient water at a sufficient pressure for this hypothetical fire that we are proving, by this hydraulic calculation, can be extinguished. In theory, if all the pipe sizing was perfectly balanced, we would really only need .15 multiplied by 1500, or 225 gpm of water flow, to extinguish a fire utilizing the ordinary hazard group I design density. However, since no system can be perfectly balanced, the water flow is always going to be somewhat higher than 224 gpm using a .15/1500 design criteria. In our case, we will see that it is 20 percent or more higher than that.

**COMPLETING THE HYDRAULIC CALCULATION**

As we are done with our cross-main calculation at this point, we would start the calculations through the feed main, which is very simple, and it involves taking the 274.2 required gallons per minute and running it through the feed main piping. After branch-line F, we are running 16’7” to the center of the riser. Adding the 7’ fitting length for the 3” elbow at the top of the riser, we total a decimal equivalent for the pipe length of 23.58 and multiply that by the .066 friction loss figure (that we have interpolated from Figure H-8) to realize the 1.56 friction loss for that section of piping. Since the 3” riser is a flanged-grooved piece, we know that this will have to be schedule 40 piping, since thin wall piping cannot be threaded or otherwise prepared for flanged application. The fitting referred to as a T is actually the flanged T at the bottom of the riser piece. Please note on the Figure H-3 worksheet that we have also taken a static loss of 6.27, and that was ascertained by multiplying the elevation of the highest sprinkler deflector, which is noted at 14’5.5”, by a static loss of .4335, which is the pressure loss for elevation. When we add the 6.27 pressure loss figure to the total pressure and the friction loss through the riser piece, that totals 36.68 psi, which would indeed be the required pressure at the bottom of the riser or the base of the riser, which is the information that needs to be noted on the hydraulic placard. Any installed system should have a hydraulic placard hanging from the riser by means of a steel chain, and this is an important system component because it contains the pertinent hydraulic information that will be needed at a later date in the event of building additions or system additions, and may also be of interest to a system inspector.

The next entry on the worksheet is the 4” header, which is composed primarily of fitting components and their equivalent pipe lengths. Please note that the equivalent pipe length for the 4” elbow is 6’, which is the appropriate number of feet to add for a flanged elbow, which is considered to be a 90° long turn elbow by the NFPA 13 standard. The data sheets from the manufacturer of the 4” detector check valve suggest that an equivalent length of 14’ be noted for that valve.

The last entry in the hydraulic calculation worksheet is for the 4” underground piping run, and we have information provided to us that the point of connection to the city water system is 100’ from the point of water source entry into the new building. We have added that 100’ plus the 8’ rise into the building along with the equivalent lengths for fittings to arrive at the total pipe equivalent length of 145.2’. It’s important to note that we have utilized the C-value multipliers noted in Table 8-4.3.2 of the 1999 edition of NFPA
Pamphlet 13 when ascertaining our equivalent pipe lengths for the 4" underground pipe (which has a different C-factor than the overhead piping for this system). Most underground pipe used today has a C-factor of 140 and Table 8-4.4.5 lists the C-factors recognized by the National Fire Protection Association. Some conservatism has been injected into these noted C-values. However, these are the C-factors that we are concerned with using.

It is interesting to note that brand new steel pipe has a Hazen-Williams coefficient very close to 140, but new overhead wet system piping utilizes a 120 C-factor because after a few years of use, that actual Hazen-Williams coefficient naturally (albeit slowly) deteriorates.

Again, this method of hand calculation cannot be completed without the use of friction loss tables, and that would include friction loss tables for underground piping as well. At the conclusion of your hand calculation, you need to double-check that you have added the proper gallons per minute for outside hose streams, which, in our case with an ordinary hazard occupancy, would be 250 gpm. This number represents a guessed estimated hydrant use volume figure during a hypothetical fire and is an NFPA 13 requirement noted in Table 7-2.3.1.1. Another item to check at this point is to make absolutely certain that you have included a figure for pressure loss through elevation for the system. Since our pipe centerline in our piping design noted on Figure A-6 is a 14 2/3" elevation, we added 3 1/2" to that to make sure that the 14 1/2" figure would accurately represent the highest installed sprinkler-head deflector.

You may wonder why on branch-line H the sidewall sprinkler-head situated beneath the overhead garage door tracks was not included in the calculation. Although the writers of the NFPA codes have bounced back and forth on this issue over the years, the current section numbered 8-4.4.4, exception No. 2, allows for the omission of one level of sprinklers from the calculation when sprinklers are provided above and below obstructions in the remote area.

**PROVING SYSTEM ADEQUACY**

No one ever really hydraulically calculates a fire sprinkler system without first being aware of the characteristics of the local water system, and, more specifically, the local flow test results. The graph sheet used to plot the flow test (also called hydraulic graph paper) is shown on Figure H-11. The horizontal coordinates of the graph sheet are scaled to the 1.85 power because, in the Hazen-Williams formula, pressure in psi is proportionate to the flow in gpm to the 1.85 power. The local water flow test for this project example yielded a static pressure of 50 lb in psi, a residual psi of 42, at a total gpm flow of 605. This has been plotted on the hydraulic graph paper, as has our total system demand that our hydraulic calculations proved to be 524.2 gpm at 40.16 psi. This point falls under the curve with a cushion of a little more than 3 psi. Many designers would be very comfortable with this demand placement. Some designers like to “squeeze” the piping down enough so that their calculation demand point is much closer to the water flow test curve thereby maximizing economies for the system. This is a dangerous practice, I believe, for four reasons. First and foremost, the sprinkler system installation may not go in exactly as it was designed. As you now know, a shift of pipe here and there, adding a few feet of pipe, adding pipe offsets, and so on, will adversely effect the outcome of the hydraulic calculations. It doesn’t take much to necessitate the addition of two or three required psi for the system. Second, the water flow test itself may be inaccurate or simply an approximation. Also, many water supply systems deteriorate as the age of their underground piping increases. Third, it is very possible that a pressure restrictive device may be installed on the sprinkler system at a later date. Pipe strain- ers and backflow preventers are the typical villains in this instance, and they can restrict water pressure considerably. The fourth reason for allowing a 3–5 lb cushion or more in your hydraulic calculation is that these systems will have a very long life. I can’t tell you what the average age of a fire sprinkler system is. But I do know that many systems in existence today are already over 100 years old. The odds are great that the occupancy or hazard that the system is protecting will change. In our example, if the glass manufacturer’s business goes south and the new tenant of this building is an auto repair garage, our system design has been invalidated. Furthermore, odds are that if this tenant change occurs forty or fifty years after the fire sprinkler installation, no change will be made to the sprinkler system. Hence, this margin of safety consideration with respect to both pressure and gpm should be recognized by the individual making the hydraulic calculation.

**SOME FINER POINTS**

The reason noted in the preceding paragraph for conservatively providing around a 5 psi cushion between the system demand point and the water supply curve, were elaborated on by Pat Brock in a 1990 magazine article. Mr. Brock points out that the water flow tests conducted for the purpose of plotting a water supply curve rarely take place during the most demanding time of the year (typically July or August) for city water systems, or at the most demanding time of the day (at or around 6:00 P.M.); so the hydraulic calculation may not actually be addressing the true worst-case scenario. In addition,

In our society, occupancy changes seem almost inevitable. If such change is to a higher hazard category, the system surely will become nonstandard. You will note that I did not say that it is possible for a system to become nonstandard. I said that it is destined to be. I say this because of the list of possible changes that can affect the system demand. One or more of these changes is almost certain to occur . . . Some
Water traveling inside pipe possesses kinetic energy, and that energy increases with the speed of the traveling water. The pressure that comes from that movement of water is called velocity pressure. In our hand calculation, we used total pressure minus the velocity pressure. It’s possible to calculate the velocity pressure in a hand calculation, but it’s extremely cumbersome and does not produce any great yield. Typically, if the tedious trial and error velocity pressure calculations are included in a hand calculation, you may see a savings of one or two psi. But since velocity pressure is so small compared to the total pressure, the effect on the end result of the hydraulic calculations is minute. Just for fun, we included (in Figure H-5) a computer-generated calculation program for the project example using the same input data as we used on the hand calculation. The computer-generated program includes velocity pressures, as you can see in Figure H-5. The end result of the computer-generated calculation was a slightly less system gpm demand at a slightly higher pressure. The sprinkler industry utilizes many different computer programs for calculations, and I believe that some of them would have shown a smaller pressure requirement in this case. However, this program showed a 41.0 psi system demand requirement because it was automatically boosting up its end-head pressures so that (correctly) the second head gpm requirements would not fall below 19.05 gpm.

This is an automatic response that the computer undertakes in instances where its original calculation is adversely offset by the velocity pressure calculations that cause the second head discharge level to fall below the minimum required. Even so, it is an accurate method for calculating systems, and it realizes a time savings because the designer does not have to constantly refer to the friction loss tables for his friction loss per foot figures. As Pat Brock has succinctly pointed out, “The use of velocity pressures (in calculations) is the designer’s option. If your computer program will not use velocity pressures, it is okay. Your designs will be acceptable and more conservative. . . . My recommendation is that velocity pressures should not be used. Not using them introduces some additional margin of safety. I feel this is important” [4].

It is necessary when using the computer-generated calculation programs to include the exact pipe interior diameter in inches, which will vary by type of pipe or tube used. It is also important to make certain, as you would on a hand calculation, that the C-factors being used are always accurate.

**SYSTEM VARIATIONS**

In Figure H-9 and H-10 examples, a C-factor of 100 is used because in this calculation example, we have taken the project example and assumed that it is a dry-pipe system. One of the disadvantages of a dry-pipe system is that since the piping must first discharge air after the sprinkler fuses, there could be, for example, a 60-second delay before water is discharged on the fire. For that reason, the NFPA 13 standard requires that the size of the most demanding remote area be increased by 30% so that more heads are opened in the hydraulic calculation, as would be the case in an actual fire scenario. In this case, instead of a 1500 sq. ft. remote area, a 1950 sq. ft. remote area would be required. The remote area, as noted in Figure H-1, would then include sixteen sprinklers instead of twelve. The C-factor of 100 used adversely affects the Hazen-Williams formula by increasing the friction loss through the steel pipe about 40 percent.

As you compare this example with the Figure H-5 calculation, you can see that although the end-head pressure requirement is the same, the high friction loss through each section of pipe builds up to a point where, as you can see in Figure H-10, the total system demand becomes larger in pressure and volume. The demand point for the dry system is radically different than the demand point for the wet system, as you can see in Figure H-11. In order to make a dry-pipe system hydraulically acceptable for the municipal water zone supplying the Jones Glass building, system pipe sizing would have to be increased to a point where almost 15 psi is removed from the dry system demand generated in the first calculation (Figures H-9 and H-10). This would surely include increasing the size of the system’s header and cross-main.

Another option the designer has is to use a large orifice sprinkler for this occupancy. The large orifice sprinkler has a 17/32” smooth bore orifice which usually has a K-factor anywhere from 8.0–8.2. In this case, with a K-factor of 8.00, our end head pressure would calculate out to about 5.67. However, NFPA 13 requires that a 7.0 psi minimum pressure is required at the end (or any other) sprinkler. Any calculation that we would run utilizing the large orifice sprinklers would then have to start at 7.0 and discharge that much more water for each sprinkler we opened due to the higher K-factor. As a result, we may have to install larger piping to compensate for the increased water volume requirement in order to insure that our demand point fell under the water supply curve previously noted.

Some authorities may ask for a higher minimum operating pressure for the sprinkler-heads. For example, some authorities having jurisdiction may require a minimum operating pressure of 10 psi for sprinklers located outdoors. However, the 7 psi minimum operating pressure requirement has been
the general standard since 1966. The reason for this originally was that tests conducted by testing agency laboratories utilized a flow of 15 gpm per sprinkler, and 7 psi is required to generate this flow through a standard fire sprinkler. This rule has managed to stick around in the codes for quite some time and no one has complained yet.

In my opinion, the hand calculation method used in this project example is the most straightforward, simple, and cogent fashion in which the designer can prove his hydraulic calculation. This method also provides worksheets that are the easiest to read and follow. As stated earlier, practice makes perfect, and this certainly holds true for the practice of hydraulically calculating any automatic fire suppression system. Even though someone can develop the ability to hand-calculate quickly and accurately, that person will always be able to be even faster when using a computerized hydraulic program. Nonetheless, his understanding of balancing flows and sizing pipe will be more honest, and honed a little better because of his familiarity with the basic skills that are acquired while learning to prepare calculations by hand on a worksheet. Also, I would not recommend that anyone hydraulically calculate the fire sprinkler system without a thorough and very careful review of the regulations outlined in Chapter 8-4 of the 1999 edition of NFPA Pamphlet 13. There are only three pages to review, and good examples are provided.

The fact is that hydraulically calculated systems today are so prevalent in fire sprinkler system design that every designer must have a good grasp of the hand calculation method simply to be conversant enough in the intricacies of hydraulic calculations. I would recommend that every new designer hand calculate several jobs before moving onto the quicker method of calculating a system with the aid of a computer program simply because he will then be better versed in the characteristics of water flow and water flow options for the different systems he will be designing. With practice (and always bearing in mind the characteristics of the available water supply), the process of proving pipe size selection with your own calculation will probably become the most enjoyable part of your work in design.

CITATIONS


ENDNOTES

1 Almost all hydraulic principles and formulas are based in origin on experiments conducted by John Freeman in 1888 and 1890.
Preparation for the NICET Examination

NICET stands for the National Institute for Certification in Engineering Technologies. The National Society of Professional Engineers in 1961, founded the Institute for the Certification of Engineering Technicians (ICET) to service the career needs of the more specialized technical members of engineering organizations. NICET really grew out of ICET in 1980, and soon began to grow as its own entity quite rapidly in the field of fire protection engineering.

The NICET organization formally began in 1981 as the result of a merger between ICET and another similar agency (ETCI) that was in the business of providing certification programs for engineers, technologists, and technicians. Today, NICET management is quite careful with their terminology, often stressing that they certify technicians rather than engineers. The administrators of NICET, which is located in Alexandria, Virginia, are also quick to point out that their major function as an independent establishment is to evaluate the credentials, competency, and qualifications of individuals applying for certification. They are a national institute maintaining professional relationships with individuals, and are normally not involved in any dealings with state agencies.

Having said all that, let me say frankly that NICET has evolved on a national scale into the primary means of recognizing competent fire protection engineers in the specialized design discipline. This has occurred for three reasons. First, the NICET certification format is a well conceived, well rounded, and sound program. Second, there has not been much for NICET to compete against, and so, when some means is needed to identify or confirm that some individual is indeed qualified to design a fire protection system, then NICET, almost by default, has become the popular body of authorization. Finally, and most importantly, the National Fire Sprinkler Association (NFSA) has been instrumental in promoting NICET testing in a noteworthy effort to improve the overall state of engineering affairs in the fire protection industry nationwide.

The following quote is taken directly from the job specifications for a U.S. government project in June of 2000 under the heading “Contractors Qualifications,” and states in part: “Design and installation of this project shall be accomplished by a contractor who . . . employs or contracts on a regular basis for system design, a professional engineer or at least one person having passed the elements for a NICET Level III rating in automatic sprinkler design.” Because many are aware that satisfying requirements such as this “Boiler-Plate” specification is becoming the norm, the endeavor to obtain NICET certification is a no-lose proposition for any fire sprinkler designer.

Fire protection engineers may become certified through NICET at separate levels of proficiency in the following three subfields: automatic sprinkler system layout, special hazards system layout, and fire alarm systems. There are four levels of certification gradation in each subfield. They are as follows:

- level I (TT): Technician Trainee
- level II (AET): Associate Engineering Technician
- level III (ET): Engineering Technician
- level IV (SET): Senior Engineering Technician

Basically, passing a sufficient number of written “work element” examinations is required in order to attain certification at the various levels. Over time, as much as thirty hours of testing may be involved, before a level IV certification is attained. In addition to the written tests, NICET evaluates the applicant’s work experience as well, and personal recommendations and other forms of written verification will become part of the evaluation process. Also, at least two years of on-the-job experience is required for a level II certificate, five years for a level III, and a minimum of ten years for the level IV (SET) certificate. Finally, the level IV candidate in automatic sprinkler system layout must provide documentation
that they have attained an advanced position of responsibility in the workplace.

The documentation provided to NICET must show that the candidate had individual responsibility or supervisory responsibility for at least one major fire protection system, to include hazard analysis, design calculations, approvals, proposals, system installation, check-out, and final approval test. If all of these components cannot be documented for a single project, the candidate must show evidence of having had responsibility for each of these components on a variety of major projects, over time. [1]

Within the subfield of automatic sprinkler system layout, there are over seventy work elements that comprise the applicant’s testing material. These cover a wide range. For level II testing alone, the following work element titles are offered for applicant testing: requirements of spacing, classification of occupancies, selection of fire pumps, building codes, fundamentals of hydraulics, fundamentals of physical science, metric conversion, basic principles of combustion, construction plans, and fire protection plans and symbols. The major bulk of the tests are formatted and arranged in the form of multiple-choice questions. The exam is open-book, so you can bring along as many NFPA (and ASTM) standards as you like. But because of the time restraints, you will have to be very good at quickly referencing the needed information in the correct standard. There are no “trick” questions. The locations and times for the examinations are planned long in advance, and a proctor is always present.

***

I have compiled a brief checklist that should help you to prepare for each written NICET examination that you take.

1. Get to the test site at least 20–30 minutes ahead of time.
2. On the day prior to the exam, spend at least four hours just reading through NFPA #13 and other NFPA pamphlets.
3. Ask for preparation advice from others you know who have taken the exam.
4. Bring a calculator to the test. Any hand calculator that includes a built-in hydraulic program is not permitted.
5. Make sure that you bring along blank hydraulic worksheets, hydraulic graph paper, and your friction loss tables.
6. Commit to memory key formulas that you use, including those for water volume, and for compiling water flow test information.
7. Bring a small dictionary.
8. You may wish to contact NFSA or AFSA for a NICET study guide.

Never allow yourself to get frustrated during any part of the test. It’s important to stay relaxed and also not to waste too much time on a single question or work element. Any failed work element can be retested at a later date. However, you are allowed three tries on any single work element. Three strikes and you’re out. The study questions at the end of this chapter (and also following Chapters 10, 15, and 19) are elicited in much the same way as those on the NICET exam. Again, the entire exam is open-book, so you may as well bring as many codes and standards as you can carry. The standards that are adopted at the annual NFPA meeting in May are incorporated by NICET in their following (February) test cycle. The whole process that culminates in receiving your certification is time-consuming, so the sooner that you get started with the testing, the better for you.

***

For some reason, many applicants have a lot of trouble with two of the basic core work elements. These are basic principles of combustion and fundamentals of physical science. I suppose that since the typical designer does not usually make use or apply these fundamentals in his daily work regimen, his work experience will not cause him to maintain this information fresh in his mind. Hence, he may also get tripped up by the fundamentals of mathematics test section.

Obviously, there is not enough space in this book to outline all of the rudimentary aspects of mathematics, physical science, and combustion theory. I do want to touch briefly on some basic concepts that come into play with regards to fire prevention and fire protection engineering technology. For one, three pre-existing conditions must be present for fire to start: there must be a (fuel) substance that will burn, there must be plenty of oxygen (air is about one-fifth oxygen), and the fuel must somehow be heated to its ignition temperature (the minimum point at which oxygen will rapidly unite with the fuel, also called “flashover”). Fuel, or matter, exists in three different states: solid, liquid, and gas.

Pure matter, of which oxygen is an example and which exists as a gas, cannot be broken down into other components. In this pure and simple form, matter is referred to as an element, of which there are only about 100. Elements may combine to form other forms of matter and these are called compounds, of which there are literally hundreds of thousands. Oxygen and hydrogen are elements but can be combined to form water, which is a compound. Matter may be changed by the reaction resulting from some form of energy being applied. Energy has been defined as the capacity to do work or something that produces a change in matter. Kinds of energy are heat, light, sound, chemical, electrical, mechanical, gravitational, and nuclear. When heat is applied to water, for example, at some point water changes from a liquid to a gaseous state. Both matter and energy may be described in terms of measurement. Since matter occupies space, it may be measured in terms of volume. The volume is expressed in units such as cubic feet or . . . gallons. Mass is the term used to describe how much matter there is in a given element or compound. [2]
Pressure, a measurement of force, is often expressed in terms of “head.” This is the height of any column of water necessary to exert a pressure of 1 psi at the base of the column. This would be 1 divided by .433 lb/sq. in. or 2.31’. A fire pump’s pressure rating is often expressed in terms of \( H \), or total head in feet. As one example, a fire pump noted to have a pressure boost of 200′ has an actual pressure rating of 86.6 psi.

Chemical reactions are changes which occur when forms of energy such as heat are applied to substances, forming new substances. Under the right heat conditions, fire is a chemical reaction between the substances oxygen and combustible fuel. The result, combustion, produces “products” well-known to us as ash, gases, and other carbons.

As previously stated, water is normally a liquid compound consisting of the basic elements oxygen and hydrogen. And, as we all know, this compound becomes a solid at freezing temperatures. Water has a very high boiling point (100°C/212°F). What the layman calls “steam” is the visible moist vapor that rises from water when it is subjected to heat. Steam is the gaseous substance into which water is converted under heat and pressure. Nothing happens molecularly, it just changes states. There is a physical change but absolutely no chemical change. When water converts to steam at 212°F it leaves behind the impurities (that’s how you distill water). Pure water is a poor conductor of electricity, but the impurities found in natural water transform it into a good conductor of electricity. It takes one BTU of heat to raise the temperature of one pound of water 1°F. Another way of saying this is that the “specific heat” of water is one. Vaporization takes place when water is converted to steam. “It doesn’t take much to extinguish a fire in an enclosed room, since water expands into steam 1700 times its original volume” [3].

The following comes from a report of an actual fire that occurred in a North Carolina furniture warehouse:

The fire began among rags soiled with a flammable stain that had been left overnight with other combustible trash in a plastic trash barrel instead of in the metal trash cans with self-closing lids provided for such material. The rags spontaneously ignited, and flames spread to the other rubbish and a work bench, melting a nearby 165°F fusible link of a roll-down, 3-hour fire door. Three 165°F overhead sprinklers also activated and contained the fire. [4]

What happened in this case was that some old rags soaked with oil or paint were tossed aside nonchalantly. The oxygen from the air slowly united with the oil in the rags: this process is called oxidation. And when enough heat accumulated (as the rate of oxidation increased) the rags caught on fire. The subsequent burning (or combustion) produced additional heat, causing oxygen to unite with other substances much more rapidly. Although oxidation does not always lead to combustion, in this case it did, and actually many fires are caused exactly like this example. The ignition (or “kindling”) temperature of the soiled rags was relatively low. Steel or copper sprinkler piping combines with oxygen at such a slow rate that their actual ignition temperatures are very high. Some substances have already combined with oxygen as much as possible. Asbestos is one. Other examples include brick, stone, and sand. Essentially, they do not have an ignition temperature.

* * *

In summary, a little bit of basic knowledge of all aspects of fire protection is helpful for NICET testing. It would be wise to bring along a reference book, discussing some basic properties of physics, to the examination if you will be testing such related work elements. Any questions regarding matter, density, specific gravity, general gas laws, fluids, or pressure will be quite basic. Some advance study would be prudent as well, so that you are basically familiar with the concepts. This also holds true with other “fringe” work elements, such as land surveying or corrosion. A normal grasp of these subjects is all you will need.

As of August, 2000, there were more than 9000 active NICET certifications in the United States in fire protection engineering technology, of which 3076 are specifically for automatic sprinkler system layout. Four hundred and forty-four individuals nationwide have Level IV active status in this subfield. NICET revises these statistics quarterly, breaking them down by state; and a “directory” including names, states, and towns may be ordered by calling 1-888-476-4238. Nationwide, there are currently 576 NICET Level I certified engineers (in automatic sprinkler system layout), 568 are certified Level II, and 1188 are certified Level III. It is generally recognized by most that a level III sprinkler designer is a fully competent engineering technician. I know a number of individuals who have attained this level with very little study or preparation for their NICET testing. However, everyone tests differently. The best way to approach the NICET certification process is with a reasonable amount of sound preparation, followed by a lot of persistence.

STUDY QUESTIONS

Note: The following questions are to be used as an “open-book” type quiz. Please make use of NFPA Pamphlet No. 13, and any other material sources, when figuring responses (answers appear on page 281).

1. On a wet system, 382.5 gallons are flowed through 50′ of 3′ lightwall pipe. In psi, what is the total friction loss incurred?
   A. 6.02
   B. 6.11
   C. 6.26
   D. 7.86
   E. 8.36

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2. Only the minimum 15 psi is available at the highest sprinkler on an attic sprinkler system. This is a large-orifice sprinkler with a K-factor of 8.1. How much water (in gallons per minute) will be delivered by this one sprinkler?
   A. 5.3
   B. 15.0
   C. 21.3
   D. 21.9
   E. 31.0
   F. 31.4

3. Which of the following need not be included on a sprinkler shop drawing?
   A. flushing connections
   B. point of compass
   C. type of sprinklers
   D. address of contractor
   E. a hanger detail
   F. gallon capacity of dry systems

4. A branch-line supplies five large-orifice sprinklers with a K-factor of 8.2. The pressure on this line is 40 lb. If all heads open, what is the total discharge in ten minutes?
   A. 259 gallons
   B. 519 gallons
   C. 1,153 gallons
   D. 1,787 gallons
   E. 2,593 gallons

5. What is the overall capacity of 18′ of 4″ thinwall steel pipe?
   A. 7.8 gallons
   B. 11.9 gallons
   C. 13.3 gallons
   D. 15.3 gallons
   E. 18.7 gallons

6. A standard sprinkler with a K-factor of 5.65 protects 138 sq. ft. in a general office, and sits at the end of a branch-line. In gallons per minute, what is the minimum flow required from this sprinkler in a hydraulic calculation (gpm per sq. ft.)?
   A. 13.80
   B. 14.82
   C. 14.95
   D. 21.00
   E. 28.25

7. The maximum distance allowed standard sprinklers is:
   A. 10′
   B. 12′
   C. 16′
   D. 15′
   E. 20′

8. What are the two most common types of sprinklers? (circle two)
   A. foam
   B. chrome
   C. pendent
   D. sidewall
   E. upright

9. When a fire occurs under a sprinkler system, sprinklers operate:
   A. all sprinklers in the room in which the fire occurs
   B. only those which are heated to fusing temperature
   C. all sprinklers on the system
   D. all sprinklers in the hydraulically designed area
   E. only one

10. What is the maximum number of sprinklers permitted on a standard sprinkler branch-line on a pipe schedule system?
    A. no limit
    B. 16
    C. 12
    D. 10
    E. 8

11. When sprinklers are located on a smooth ceiling, they must be spaced equal distance between columns.
    A. true
    B. false

12. The standard size sprinkler orifice is:
    A. 3/8″
    B. 7/8″
    C. 3/4″
    D. 1/2″
    E. 5/16″

13. When designing a sprinkler system using hydraulic calculations, the pipe size must be:
    A. at least as large as a pipe schedule system
    B. selected as necessary based on water supply, hazard of risk and cost
    C. able to supply water to conform to all points on the design curve
    D. selected by computer
    E. selected by the building owner’s insurance agent

14. What is the proper C-factor to be used when hydraulically calculating a dry system using galvanized steel pipe?
    A. 100
    B. 120
    C. 140
    D. 150
    E. 8.1

15. What is the static loss to be noted when the deflector of the highest sprinkler sits at an elevation of 15′ above grade?
    A. 6.5
    B. 7.0
    C. 15.0
    D. 34.6
    E. none of the above
16. Pendent sprinkler-heads in a supermarket are spaced 10′ × 12′ apart. Assuming a wet-pipe system, what is the minimum number of sprinklers that need to be opened in the hydraulic calculation?
A. 10
B. 12
C. 13
D. 17
E. none of the above

17. What is the friction loss rate, in psi per foot, if 72.8 gallons of water are flowing through 1 1/4″ pipe on a wet system?
A. .273
B. .373
C. .379
D. .382
E. .541

18. The first objective of all fire prevention is:
A. eliminating smoking in the workplace
B. safeguarding life against fire
C. reducing insurance rates
D. preventing property damage
E. confining fire to a limited area

19. What is the total take-out for a welded pipe-o-let 5″ × 3″ crossmain outlet?
A. 3 1/2″
B. 4″
C. 4 1/4″
D. 4 1/2″
E. 4 3/4″

20. All sectional and control values on a sprinkler system must be:
A. painted
B. locked
C. tagged
D. isolated

21. A dry-pipe valve on a dry-pipe system of automatic sprinklers should not control a system with a capacity of more than:
A. 250 gpm
B. 500 gpm
C. 625 gpm
D. 750 gpm

22. The pressure on a line of 1/2″ sprinkler-heads is fifty pounds. Ten heads have opened. What is the total discharge in five minutes?
A. 300 gallons
B. 1950 gallons
C. 2300 gallons
D. 2825 gallons

23. The minimum rod size for a hanger consisting of a welded-eye eye rod for 8″ pipe is:
A. 1/4″
B. 3/8″
C. 1/2″
D. 3/4″

24. Return bends are required when installing dry pendent sprinklers on dry pipe systems to avoid accumulation of debris.
A. true
B. false

25. A hanger must be placed at least _______ from the centerline of an upright sprinkler-head to avoid water spray obstruction.
A. 1″
B. 3″
C. 8″
D. 1″

26. Which of the following is the least important item to be shown on a sprinkler shop drawing?
A. unit heaters
B. storm piping
C. ductwork
D. overhead garage doors

27. To prevent cold-soldering of sprinklers, heads should never be placed less than _______ feet apart on a branch-line in an open warehouse.
A. 5
B. 6
C. 7
D. 8

28. For a single wet-type sprinkler system equipped with an alarm valve, no fire department connection, nineteen sprinklers, and a fire-only water service, _______ gate valve(s) and _______ check valve(s) are the minimum required number of valves for system header if there exists a city valve at the underground point of connection.
A. 2, 1
B. 1, 1
C. 1, 0
D. none of the above

29. A municipality is known to have a water supply of a highly corrosive nature. A building in this municipality will require one 6″ dry type sprinkler system. It will be all right to use schedule 30 black steel piping for this system.
A. true
B. false

30. A properly hung 6″ feed main supplies one 4″ standpipe on the lower level of a seven-story building. What is the total number of friction clamps necessary to properly support the standpipe?
A. 3
B. 4
C. 5
D. 6
31. What is the maximum distance between branch-line hangers supporting 1 1/2″ steel pipe?
   A. 10′
   B. 12′
   C. 15′
   D. none of the above

32. A 4″ cross-main supplies a water curtain consisting of a total of seven sprinklers. The length of the 3″ starter piece is 5′. How many total hangers are required to hang all piping on the branchline?
   A. 2
   B. 4
   C. 6
   D. 7

33. A single dry-pipe system may supply sprinklers on a gridded piping system, without a 60-second test, not exceeding _______ gallons in total system capacity.
   A. 500
   B. 600
   C. 750
   D. dry-pipe would not be permissible in this case

34. One single anti-freeze system located in Chicago, Illinois, has a system capacity of 45 gallons. Approximately how many gallons of propylene glycol must be contractor purchase in order to put the system in service?
   A. 23
   B. 27
   C. 33
   D. 45

35. In a sprinkler relocate situation using mutuals or arm-overs, and steel pipe, a hanger would be required to support the arm-over if it exceeds _______ inches in length.
   A. 12
   B. 18
   C. 24
   D. 36

36. Threaded 125 lb cast-iron branch-line fittings installed new, shall conform to what standard?
   A. ANSI B16.3
   B. ANSI B16.22
   C. ANSI A53
   D. ANSI B16.4

37. In an area subject to earthquakes, 4″ steel pipe must penetrate a fire wall. What is the minimum size pipe sleeve to be installed in order to provide proper clearance for the pipe?
   A. 5″
   B. 6″
   C. 8″
   D. 9″

38. Screwed unions are acceptable for piping sized less than:
   A. 1 1/2″
   B. 2″
   C. 2 1/2″
   D. 3″

39. It is permissible to bend a portion of 1/2″ all-thread rod to facilitate a sprinkler pipe hanger.
   A. true
   B. false

40. Which of the following differentiates dry type from wet type sprinkler systems?
   A. a low water pressure
   B. a high water pressure
   C. use of air under pressure
   D. size

41. What is the overall capacity of seventeen feet of 3″ thin-wall steel pipe?
   A. 6.5 gallons
   B. 7.4 gallons
   C. 8.6 gallons
   D. 9.8 gallons

42. What is the proper hydraulic design density to be used for a cannery, having unsprinklered combustible concealed spaces 2′ deep?
   A. .12, 3000
   B. .16, 1500
   C. .15, 3000
   D. .20, 2000

43. The air supply feeding a dry-pipe system in which the dry valve is located in a heated room shall be large enough so that normal air pressure in the system may be restored within _______ minutes.
   A. one
   B. two
   C. five
   D. thirty
   E. sixty

44. An audible water flow alarm shall sound on the premises within _______ minutes of the inspector’s test valve being opened.
   A. one
   B. two
   C. five
   D. thirty
   E. sixty

**CITATIONS**

ENDNOTES

1 NICET certifies technicians in over fifty separate fields in addition to fire protection engineering. These include civil engineering, marine, welding, aeronautical, underground utilities, highway engineering, electrical testing, and fire science, to name a few.

A future NICET fire protection engineering subfield, “Inspection and Testing of Water-Based Fire Protection Systems,” is currently in the works.

3 National Fire Sprinkler Association, Inc., Robin Hill Corporate Park, Route 22, P.O. Box 1000, Patterson, New York 12563; American Fire Sprinkler Association, 12959 Jupiter Road, Dallas, Texas 75238.

4 Nationwide, 772 individuals hold active certificates in special hazards system layout. That subfield will soon be broadened and reformatted, and titled “special hazards suppression systems.”
CHAPTER 13

Piping Methods and Details

It is the intention of this chapter to review and discuss the basic or common plan details that you will be preparing in your design work. None of these are overly difficult, and they all can be prepared without too much bother or time. Details serve as a supplement to the sprinkler plan, and without them the engineer’s intention cannot be as effectively conveyed. As has been mentioned previously, a picture is worth a thousand words, and this is the primary reason that plan details are a plan inclusion. They convey the piping method desired in clear graphic fashion.

The most common plan component, separate from the main building plan, would be the site plan. One is required on every fire sprinkler project that includes a fire department connection. It is always a scaled drawing. The site plan is of interest to the local fire prevention bureau in that it shows the locations of valves, incoming water supplies, siamese connections, and hydrants. The fire marshal will use his own engineer’s scale to figure the proposed distances between the existing fire hydrants and the fire department connection location. He can also ascertain the spot where fire engines would arrive and park, in the event of a fire at this site. The site plan shown in Figure C-9 is exactly the kind which you will want to include on a typical sprinkler plan. You may also want to include a note explaining which subcontractor is the one responsible for the installation of new underground supply piping.

Figure B-5 shows a remote supervisory valve and a dry valve that supplies an auxiliary system for fire sprinklers in an unheated attic. Again, this is a detail drawn to scale and one that is very necessary. The supply for the dry system comes from a 4” feed-main on the uppermost floor of this building’s wet-pipe sprinkler system. Note that on the detail, the dry valve trim has been roughly sketched in. This work is not really necessary, but it was included to show that the drop (4 × 4-8 1/2) will not interfere with the dry-pipe valve trim components. Please note also that there are seven different dimensions of walls or floors shown on this detail. This is as necessary to the field installer as the depiction of every system component, because it reassures the field foreman that all the assembly work being done is being installed in the correct place, and he should not have to move it later.

The same holds true for the header and riser section shown in Figure B-6. The dimensions help the designer to conveniently “lock in” the system component locations within the room. After the header design is drawn, all that’s really left to do is the math. And if the designer has the needed information (room dimensions, valve and fitting take-outs, and water supply location), then the rest is easy. Having pre-cut risers, incidentally, sent to the job means that the field installers can “start solid,” or begin piping the job right from the first flanged fitting. This can be a big time-saver.

Figures F-11 and F-12 have been included to illustrate the fact that plan details will clarify matters for everybody. In this case, with two new deluge systems being added on to a wet-pipe system, the sprinkler plan scale was simply too small. An enlarged plan view was needed, that shown in Figure F-12. An elevation of the proposed work was obviously necessary, and one is shown in Figure F-11. The two figures are different “views,” of the same thing. The new deluge system piping for the two systems are to run off in opposite directions. This is important information for all parties reviewing, installing, insuring, or owning the systems depicted on the plan.

In a high-rise or multi-story building, the fire sprinkler’s water supply originates from a riser or combination stand-pipe, usually located in a stairwell. To avoid cramming the sprinkler plan with hard-to-read dimensions, arrows, and tiny notes around the stairway, a detail should be provided. An
example of one such detail (which is actually an enlarged plan view) is shown in Figure B-9. As you can see, the scale ($1/2'' = 1'0'')$ has been “blown up” to allow space to include all of the necessary notes. Lots of dimensions are provided here, and elevations noted. Note the location of the flow switch. It must be situated upstream of the “test and drain” unit that is located in this stairwell, to insure that an alarm will sound when an inspector activates that unit. Two floor supports, or friction clamps, would be needed at this landing to support vertical piping running from floor to floor. These two vertical runs would be the $6''$ combination standpipe, and the $1 1/4''$ express drain. These can be seen in Figure C-5, which is an example of an overly fancy sketch of what you would view while standing on the stairway landing, looking up at the sprinkler-supply cut-in. In Figure C-5, the cut-in shown is actually attached to a welded outlet on a $4''$ rising. The $1 1/4''$ drain is piped down to the basement, discharging into a large floor drain there, and this effectively takes care of that sprinkler designer’s problem of where to drain all the separate floor sprinkler systems for the multi-story building.

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Many engineers like to use isometric details to show piping configurations. Some use them almost exclusively. I think that once you become familiar with isometric designs, you will understand how useful they can be for both the reader and the engineer. Note that on Figure C-6, the dashed lines on the isometric refer to existing piping while the solid lines refer to new pipe and components. Figure C-6 shows the intended design for a second dry system to be added onto an existing header. The inherent usefulness of the isometric is that it can facilitate three-dimensional viewing. This is helpful in instances where there will be a lot of risers, or where piping “snakes around” with a lot of ups and downs and offsets. Take a good look at Figure C-7. It may occur to you when looking at this isometric design, that it could be possible to draw an entire sprinkler system layout in isometric fashion. I don’t think that it has ever been done, although it is surely possible. As you can see in both detailed isometric examples, it is easy to include elevations and dimensions, while clearly showing all valves, components, fittings, and pipe routing. The isometric is simply an alternative method of expressing on paper your engineered design.

***

Sometimes special job conditions necessitate the inclusion of a detail on the sprinkler plan. Figure C-8, which is a CADD-generated drawing, shows the elevation change of sprinkler piping with respect to structural building members. This change may be because of roof pitch, or pitched piping, or both. The dimensions noted from the sprinkler deflector are measured to an imaginary line connecting the adjacent I-beams, which represent spray pattern obstructions. Note that dimensions from the ceiling are always distanced from the lowest underside portion of the roof deck. If you feel that it is necessary, hangers with exact cut dimensions could be added to this detail, something like that shown in Figure G-9. Most fitters, however, like to cut their own hanger rods for piping runs of this (Figure C-8) nature, and some claim that it is actually faster for them that way.

Figure B-4 is also CADD-generated. It shows the use of two riser nipples at a cross-main outlet. This representation is a little trick that is useful for engineers trying to save on fittings, and field installation time. The roof pitch on a building is sometimes so steep that it is evident that one branch-line elevation will not do. Either the branch-line has to change in elevation, or sprigs will have to be added, to guarantee that all the sprinklers can be installed close enough to the ceiling to meet code. The addition of offsets and/or sprigs, however, can be costly when a large number of branch-lines are involved. To avoid this, the designer of Figure B-4 ran his cross-main close to the centerline of the protected area, and ran the (two) branch-lines at slightly different elevations, so that all of the upright sprinkler-heads on either side of the cross-main would still be installed at an acceptable elevation without the use of sprigs.

In instances where the roof pitch is dramatic, two nipples made into two elbows can be installed after the riser-nipple tee; so that the entire branch-line can then be pitched (angled) parallel to the slope of the roof deck. All hangers for this branch-line would be of the same length.9

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In Figure F-7 you can see block walls depicted in the corner of a storage warehouse. The block walls run all the way up to the underside of the roof deck. The sprinkler system for this building was actually installed about twenty-five years after the building was originally erected. Please note the retrofit design with respect to the system piping by the block walls. You will notice that the minimum number of wall penetrations (two) are required with this design layout. The engineer was cognizant of the fact that it takes a long time for a fitter (or usually his apprentice) to break a hole through $8''$ thick concrete block to make way for sprinkler piping. Had the engineer forgotten all about the fact that someone has to undertake the time-consuming task of making holes in existing block walls, he may have unwittingly doubled the field work of not only hole-chopping, but hole-sealing as well.

Also in Figure F-7, note the $2 \times 2-8$ pipe piece that is run at a $45''$ angle between two roof joists. The designer is really offsetting that branch-line by $24''$, which will insure that the piping will simply jump one “A” or “V” pocket over in the bar-joist web. This is how he figured his pipe length for the armover.
The center-to-center pipe length of 34" is arrived at by multiplying the 24" length by a factor of 1.41. After take-outs for (two) 45° elbows then, the correct piece for the arm-over is 2'8" long. The entire length, from sprinkler-head to sprinkler-head, needs to be 9'11 1/2". The designer, before applying the take-outs, decided to split that 9'11 1/2" figure into the following three figures: 6'2", 2'0", and 1'9 1/2". The 2'0" figure represents the center-to-center length, on a straight path, that the 45° offset is occupying. He then subtracted the take-outs for the other two pipe piece fittings to arrive at the cut-length figures noted on the plan, in Figure F-7.

Another such 45° offset is shown on Figure B-8. Please note the offset piece of 1" pipe that is 2'3 1/2" in cut length. The offset was made to avoid hitting a recessed "can" light fixture. The 45° elbow is used in this instance, because if a 90° elbow was used, the pipe could have been shown to arm-over the required 1'8 1/2" but would have been in conflict with the light fixture installation. The desired length of 1'8 1/2" multiplied by 1.41 is equal to 2.41, or most closely 2'0" (or 2'3 1/2" after take-outs). The pipe piece noted as 1 × 1–4 1/2 in Figure B-8, was cut 1'8 1/2" short of where the 90° angle turn would have needed to be for correct sprinkler placement. The math is easy.

Now, if instead of a 45° elbow made-on to the 1 × 1–4 1/2 pipe piece, two 90° elbows are placed one on top of the other, then the new offset can be "turned" to virtually any angle offset. The problem for the designer would then probably be to figure the length of that offset. Let’s look at a hypothetical problem:

We have already figured the 29" length for the example to the left, above, by using the 1.41 factor on the 20 1/2" desired length. But that 1.41 factor can only be used when a "right" triangle is involved. Now, in the other example, let’s say that all we know is that we wish to offset over 38" (B) and offset up 18" (A). We can figure the offset center-to-center pipe length (C) easily, since \(A^2 + B^2 = C^2\), or 1444 + 324 = 1768. The square root of 1768 is 42.05, so we know that the length of "C" will be 42".

Another way of determining the length of "C" would be in the unlikely event that we know the exact desired offset angles that are noted in the triangle above. Then the trigonometry involved in figuring this offset would be as follows: \(C = \frac{A}{\cos(64.3°)}\). The cosine of the angle 64.3° is (from trig tables) 0.43366. So, we would ascertain the length of "C" by dividing the length of A (18") by 0.43366, to arrive at a figure which can be rounded up to 42". Conversely, the cosine of 64.3° multiplied by C (42") would give you the length of A, most closely 18".

The above trigonometry is used to figure lengths of a pipe "ring." These rings are usually installed as part of a deluge system, and are configured to protect a tall tank tower, as shown on p. 70.

In this example, eight 45° elbows are needed. Sidewall sprinkler nozzles, pointed at the tank, can be placed on intermittent fittings on the pipe ring. If the desired length of X is 12'10" (154") for example, then what is the length of Y? Well, Y would simply be Z doubled. Z would be equivalent to the tangent of 22 1/2° (0.41421) multiplied by R (65°), or 2.658. Doubling 2.658 gives you Y, which is most closely 5'4". A quicker way to do this math would simply be to extend the dashed-line triangle as shown, and multiply X by the tangent of 22 1/2° (.41421), to arrive at the figure (Y) of 5’4”.

** ***

An infinitely more common math problem for the sprinkler designer is the double 45° offset made with grooved elbows,
shown on Figure F-9. I will not go into a lengthy explanation here, but instead keep the pipe take-out discussion as simple as possible. In Figure F-9, the pipe starting elevation is known to be 9'5". How much does this rise when using a double (back-to-back) 3" grooved-elbow offset? Well, we know (from the manufacturer’s data sheets) that the take-out (T) of a 3" grooved 45° elbow is 2 1/2". Therefore the elevation rise will be $2T(0.707)$ or 5 $\times$ 0.707 or 3 1/2". The pipe elevation would rise from 9'5" to 9'8 1/2". The tricky part of this is to figure the overall length taken up by the double 45° offset. As you can see on the plan example, this is noted as 8 1/2 inches. That figure was ascertained as follows: $2T + (2T \times 0.707)$, or 5" + 3 1/2". This information is something that you should jot down, because it is a handy bit of reference that only requires that you know the 45° grooved (or flanged) elbow takeout. Also, remember that a pipe piece can be installed between two 45° elbows if the desired elevation rise needs to be more (in this example) than 3 1/2". For instance, let’s say that we wish the Figure F-9 elevation to rise from 9'5" to 9'11", a change of 6". Then 6" would have to equal $(2T + P) \times 0.707$, where $P$ is the length of piping between the two 45° elbows. $P$ then, would have to be a nipple 3 1/2" in length, because $2T$ (or 5") plus 3 1/2" gives you 8 1/2". And 8 1/2" multiplied by 0.707 is, most closely, our desired 6" rise.

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Some projects may not require as much cumbersome detail as we have thus far been discussing in this chapter. When such is the case, and designed piping can be repetitive and typical, the engineer can focus his attention on labor-saving installation techniques. The examples noted on Figure B-7 and Figure F-8 each display system configurations known as “grids,” which will be discussed in the next chapter. Pipe sizing on grid branch-lines almost always remains constant. In Figure B-7, the pipe ends have been “prepped” in the shop. By “prepped” we mean that the plain end of the pipe piece is simply cleaned (and marked) by using an “end-prep” machine. It is neither threaded nor grooved. In the field, the plain ends slip and lock or “fit” into a “fit-tee,” which is a rubber-gasketed fitting that has small lug-nuts which tighten the fitting to the plain-end pipe. Although lubricant is required, installation is quicker. There are also fit elbows, reducing elbows, reducing tees, et cetera. They often contain a 1/2", 3/4", or 1" threaded outlet for a sprinkler-head or 1" drop or sprig.

The plan shown in Figure B-7 lightly depicts a 2 × 4 acoustical drop ceiling in a large retail establishment. Note the small (1/16" = 1"") scale used in this drawing. This is not recommended. Even though there are dimensions, hanger rod lengths noted, pipe notations, and all the rest; a fitter would need a magnifying glass to read this blueprint in the field. No one provides the installer with a reading lamp. Figure F-8, drawn in fitter-friendly scale, depicts a grid branch-line between two cross-mains that utilizes grooved couplings and welded pipe-o-lets in lieu of fit fittings to save even more on field labor time. You will note that once the cross-main and the threaded riser pieces are installed, only five pipe pieces need to be hung, which comprise the entire branch-line. These are: the (two) thread-groove pieces to be screwed into the 2 × 2 × 2 screwed tee at the top of the risers, and (three) long grooved-end lengths of pipe. The sprinkler-heads are simply screwed in to the small welded outlets that are prefabricated on the branch-lines. Properly engineered, this job is field installed.
efficiently and very quickly. The use of either the fit fittings or the grooved/welded branch-line method can be utilized in any situation, but both are normally only used and best suited for grid applications where numerous typical branch-lines are required.

Figure F-5 shows a system design example in a very unusual building structure. The 2 1/2" branch-line shown is sized for a future sprinkler system addition, and has been installed in grooved-ends with welded outlets. The designer had to keep a couple of things in mind here. First of all, he had to place the grooved couplings in such a fashion that no two welded outlets on the same pipe piece would fall on either side of the concrete column that the pipe transversed. In other words, since the cored hole for the 2 1/2" pipe was not sized large enough to accommodate the pipe with an exterior welded outlet, then a single piece drawn with welded outlets on both sides of the cored hole simply could not be field installed.

Second, note that the three threaded pipe pieces noted as 2 1/2 × 2-0 (G-T), 2 1/2 × 8-3, and 2 1/2 × 3-6 will be installed starting from a threaded tee. If, at the bottom of the 2 1/2 × 0-7 drop piece, a grooved elbow or tee was called out, then you would double your field labor time for those pieces. What is the reason for this? Consider, when the fitter is making the 2 1/2 × 2-0 piece into the 2 1/2 × 1 screwed tee. He can’t do this working alone, because every time he turned the wrench on that piece, the 2 1/2 × 3-6 piece would just spin around in the grooved fitting. He would need a partner, holding a wrench turned to the left, on the 2 1/2 × 3-6 piece, to make on the 2 1/2 × 2-0 piece. That is why the designer, thinking like a fitter, made the decision to commence the line with the threaded fitting.

On a long branch-line containing both grooved and threaded fittings, you will want to always use the threaded fittings first whenever possible. Examine the example in Figure F-4. If the first piece on the branch-line was 2 1/2" instead of 2", you would want to send it out threaded, even though the general rule is to use grooved 2 1/2" materials whenever possible. In this case, if the fitting at the top of the riser nipple was the only grooved fitting, then it would make the installation of each branch-line a gigantic pain in the neck to field personnel. Note also on Figure F-4, that each branch-line terminates in a 1 × 1-5 capped pipe piece. This piece has been added on to the end of the line in order to catch the last hanger from a roof joist. Since that one-inch piping supplies no sprinkler, it technically could be sized 3/4" or even 1/2" if so desired. The cross-main dimension is distanced from the steel column (as it is in Figure F-7 also). This will give the fitter an exact measurement so that he will know the size of the bar joist from which to hang the cross-main. This task will more than likely take place prior to the erection of any interior walls, so a column measurement is preferable. A dimension noted from the main to an interior wall would be useless, obviously, if there is no wall there at the time of installation.

The example shown in Figure F-6 is included to show a project of combustible construction, on which sprinklers situated both above and below a drop-ceiling, are supplied by the same complement of piping. The notation shown as a double-circle with a line through it, depicts a screwed cross, with 1" pipe supplying an upright sprinkler as well a pendent sprinkler. That notation is not a standard symbol, however. The designer just took some liberty there and made his own symbol legend elsewhere on the plan. That symbol could just as well have been a solid circle, a double solid circle, or just about anything else provided it could be clearly distinguished from the normal symbols used for upright, pendent, or sidewall fire sprinklers. Note that in the areas where a short branch-line sits directly above another run of piping, the plan shows it to be slightly offset from that piping—out of necessity! The installer knows that to be the case, in part because of the fact that the riser connecting the two pipe runs was drawn and appears as two identical circles next to one another. If the engineer really wants to make his point that those two lines are intended to be situated directly above (or below) each other; he could draw in a measurement line from one pipe to the other on the plan, marking the dimension 0°0'.

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Finally, there is the matter of cut-ins to existing water lines in retrofit situations. An engineer needs to make a decision on this matter each time he has to use an existing fire sprinkler main to supply new sprinklers in a building or building addition. Clearly, the quickest and most popular method of doing this is by cutting a hole into the existing pipe, and then bolting on a mechanical-tee. Since the existing piping cannot always be completely drained of water, it is not advisable to cut the hole for the mechanical-tee in the bottom of the existing piping. The side of the pipe is always best for this. Often, the top of the piping is not a good place for the cut-in due to space limitations. The tool used for hole-cutting may not be able to mount on top of the existing main, because of the lack of room.

The second most popular method for making the cut-in, would be to cut out a section of piping (10" long for 4" pipe, 13" long for 6" pipe) in the existing main, and then roll-groove the ends of the newly cut existing pipe-ends in the air. Then a new grooved tee can be added in the existing run, to supply the new sprinklers. However, for various reasons, this method also is sometimes not a possibility.

Figure F-10 shows an alternative cut-in method that is perfectly acceptable engineering. Since a 3 × 2 1/2 mechanical-tee is not manufactured, this example shows two 2" feeds off the existing run supplying the new 2 1/2" desired sprinkler supply. This is accomplished, as shown, using (two) 3 × 2 mechanical tees. In the same fashion, (two) 4 × 3 mechanical tees could supply a 4" run off of an existing 4" feed. It is an acceptable practice.

When using the cut-in supply method portrayed in Figure F-10, be very careful of the selection of the smaller
pipe sizes that you are using to supply the new pipe. Two 2" pipe pieces will not adequately supply 4" pipe, because doubling the diameter of pipe increases its capacity four times. Making the proper calculations, you will note that even two pieces of 2 1/2" piping would fall short of adequately supplying 4" piping, as would one 2 1/2" and one 3" pipe piece. (At the very least, two pieces of 3" piping are needed.) The reason that the cut-in method shown in Figure F-10 is periodically used, is due to the time saved in field labor. All the grooved components can actually be shop-assembled to save additional labor time.

To summarize, any oddball pipe fitting configuration that you come up with must be well detailed. Anything that looks too “busy” on the sprinkler plan should probably be “enlarged” elsewhere on the plan, or otherwise detailed. The number of necessary plan details will naturally increase with the degree of complication involved with the intended piping design. On sections and elevations, enlarged plan views, and other details, you can get as “detailed” as you want: and this will simplify and clarify the message.

ENDNOTES

1 The site plan in the example is drawn in 1" = 60’ scale. Another way of saying this would be 1/60" = 1’.

2 Note the fire department inlet location of Figure B-6. For system headers with multiple systems, the fire department connection is to be situated between the system control valves and the supply control valve. For dry-pipe systems (like the ones shown in Figure C-6), the fire department connection must be installed between the system control valve and the dry valve.

3 Conversely, the short side of such a (45°) triangle would be ascertained by multiplying the dimension of the hypotenuse (long side) by a .707 factor.

4 As an example of this: the area of a flat circle that could fit inside 3" thinwall pipe (I.D. = 3.26") would be \( r^2 \) times pi, or 8.35 sq. in. The area of the flat circle that could fit inside 6" thinwall pipe (I.D. = 6.357") would be 31.74 sq. in. Therefore, since 3 × 8.35 sq. in. totals only 25 sq. in. (which is less than 31.74 sq. in); we can deduce that it will take more than three (actually, four) 3" thinwall pipes to adequately supply at 6" thinwall pipe run.

5 As another obvious option, the (single) riser nipple itself may be installed on an angle perfectly perpendicular to the pitch of the roof, which places the bullhead tee on the same angle (relative to the floor), and the entire branch-line would then run parallel with the roof deck. Some provision for drainage would then have to be made at the end of the lower-elevation side of the branch-line (See 5-14.2.5.2 in NFPA #13).
Options for Hydraulic Design

The most likely time that an engineer thinks of the word “option” in terms of piping layout, is when he is designing a fire sprinkler system for a building addition. Usually in these cases, an existing building is already sprinklered, with an automatic sprinkler system that was designed and installed without any thought to future building addition considerations. Suppose if you will, that the original building is equipped with a single, ordinary hazard occupancy, pipe-scheduled sprinkler system. A sprinkler contractor has been awarded the contract to sprinkler the building addition, which will be used for automobile repair. Both the addition and existing building are equivalent in height, and are each 20,000 sq. ft. in overall (footprint) area.

The salesman of this contract might say to you, “Design the added system piping in the most economical way you see possible.”

You reply, “I will have to hydraulically calculate the new piping.”

“I know,” says the salesman, “it is okay to add hydraulically calculated pipe onto an existing pipe-scheduled system.”

“Well,” you say, “should I add a new riser for the piping in the new addition?”

“No way, I did not figure in any cost to cover a new riser and valves!”

“Okay, but in your cost estimate did you figure on using a grid, or a tree, or a looped system, or what?”

“Look,” says the salesman, “I got the job. I just bid it as an ordinary job. Make a cut-in somewhere close to the new addition. Designing the system layout is your job. It’s an engineering problem. I can trust you. Just use your best judgment on this.”

Fine, now you can look at several options for designing the system addition. First of all, you need to ascertain the approximate pipe size that you’ll need to use as a supply. Since the overall area covered by the original system will now double—to 40,000 square feet—you can still supply everything with a single riser per Section 5-2 of the code. In this case, with an average water supply available, 4” pipe will probably be needed as a supply for the addition. Ideally, you could locate a 4” grooved cap at the end of the existing cross-main and continue on from there. You would hope to keep things simple. But you will not likely find a 4” grooved cap at the end of a pipe-scheduled system cross-main. Hopefully though, there is an offset somewhere in the existing system main where you could find a 4” grooved-elbow. Labor-wise, it would be an easy matter to replace the grooved-elbow with a grooved-tee, using the extra outlet as a supply for the new main. Similarly, you could replace a grooved-tee with a grooved-cross. Perhaps your best available alternative for a new cut-in would be a 6 × 4 mechanical-tee, in which case the new supply point would have to be closer to the original system riser, a little further away from the new addition and thereby more costly. These are all options to be considered, and a lot will depend on the direction of structural members, and the shapes of the building sections, when you are making your decision.

Suppose that the existing building has within it a long cross-main running parallel to the long end of the new addition. The possibility of two cut-ins is now evident as an economically worthwhile option. The two supplies could supply sprinklers in the new addition laid out in tree fashion, like the one depicted in Figure A-2. Or, the two supplies could be arranged with branch piping on a grid. If the shape of the building addition is long and narrow, it would be conducive to a grid installation, and could also require just one supply line instead of the two previously suggested. However, if the rectangular building addition shape is more square, a looped system (which would require the two supplies if it is to be inter-connected with the existing main) might be a better solution.

This chapter will focus on the last two options mentioned. A grid layout is a very popular piping design for fire sprinkler systems.
systems. Since the water supplying sprinkler discharge on a branch-line for a grid is situated between and fed through two cross-mains, the water supply for any discharging sprinkler will always come from two directions. What’s nice about this, regardless of how many sprinkler-heads on a branch-line will have to be flowed in the calculation, is that the branch-line pipe sizing will be reduced considerably as a result of carrying one-half the flow of necessary water (through the starting pieces of the branch-line) than you would need if utilizing a tree layout. As you will come to discover, the prudent use of water common to the nature of the grid layout will lessen the total volume flow of the hydraulic calculation. This reality can make for a smaller sized system riser, and in some borderline cases, could even avert the necessity of a (very expensive) fire pump installation.

THE GRID CALCULATION

The hydraulic calculation of a gridded system can be done by hand. This exercise takes anywhere from 8 to 10 hours of your time and, for that reason, grid calculations are routinely done on computer. To examine the dynamics of a computer-generated grid calculation, we will look at the example shown on Figures H-12, H-13, and H-14. The grid calculated there has one supply point, located between the pipe pieces marked #1 and #2. The grid “supply” main (to the left in Figure H-14) consists of schedule 10 black thinwall steel pipe, and downsizes from 4” to 3”. The “rear,” or “tie-in” main has been sized 2 1/2” for this grid. The designer has used 1 1/4” thin-wall pipe for his branch-lines. This size remains constant, with uniform fitting sizes, from cross-main to cross-main. In this case, to “make the calculation work” or, in other words, to insures that the total system calculated demand data was satisfied by the city water supply, the first four branch-lines were sized 1 1/2”. This decision helped to reduce overall friction losses, since the 1 1/2” pipe can “carry” more water from the supply main to the tie-in main at the onset of flow. and are spaced at 120 sq. ft. per head. The design parameters have dictated that a design density of .19 gpm/sq. ft. per sprinkler be used. Therefore, the end-sprinkler must discharge (.19 × 120) a minimum volume of 22.8 gallons per minute. The minimum end-head pressure required is figured by the formula \( \sqrt{P} = \frac{Q}{K} \), or \( \sqrt{P} = 22.8 \div 5.6 \). Hence, \( P = 16.57 \). The end-head pressure is 16.57 psi, and all sprinklers must flow a minimum of 22.8 gpm in the calculation. The grid is actually a continuing series of many loops. If the thirteen sprinklers in the remote area were actually to discharge, the water flowing towards them would naturally balance itself and take the easiest route. All the computer does, is to accurately forecast that activity, figuring the friction losses incurred along the way.

The grid schematic shown in Figure H-14 is a simplified version of the actual shop drawing. There are differing pipe lengths and pipe offsets (and differing pipe equivalent lengths) not shown on the schematic for purposes of simplification.

This is what the computer does: by trial-and-error, it “sends” different volume “flows” through all the various pipe pieces, until it balances all the intermittent loops so that the pressures balance closely enough in either (of many) loop direction. To understand this better, look at pipe piece #11. It is a 4” piece with an equivalent length (center-to-center) of 49 7/8” that is carrying 255.46 gallons of water to the fire. This volume of water “splits” at the next fitting juncture, with 5.69 gallons flowing down the long branch-line labeled #13, and the rest (249.77 gallons) continuing down the next length of 4” pipe, labeled as piece #14. And so it goes. You can track for yourself how all the flows are split. Many computer programs will list each actual volume flow on the (Figure H-14) grid schematic, next to the hydraulic reference numbers.

The computer has balanced the calculation flows as necessary by NFPA code (within .50 psi in either direction) and has also determined that the remote area shown is indeed the true hydraulically most demanding area. The sprinkler-heads themselves are discharging the following volumes in gpm:

Adding these together figures your total system demand of 309.44 gpm. The computer has split the direction of water flows to the sprinklers at the following: between points #56 and #57, #63 and #64, and between #71 and #72. For example, the sprinkler-head on the furthest branch-line where
the flow split occurs, is flowing 22.8 gpm, 15.38 of which is supplied from one direction through pipe piece #72, and 7.42 of which is supplied from the opposite direction through pipe piece #71.

Beginning at pipe piece #71, studying the hydraulic data, you can actually follow this flow in a single direction back to the water source, adding the single friction-loss (per pipe piece) figures to determine the friction-loss (loss of energy of flow) through the grid:

<table>
<thead>
<tr>
<th>Pipe Piece</th>
<th>Pressure Loss in psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>#71</td>
<td>0.04</td>
</tr>
<tr>
<td>#70</td>
<td>0.6</td>
</tr>
<tr>
<td>#69</td>
<td>12.48</td>
</tr>
<tr>
<td>#67</td>
<td>0.03</td>
</tr>
<tr>
<td>#59</td>
<td>0.41</td>
</tr>
<tr>
<td>#53</td>
<td>0.21</td>
</tr>
<tr>
<td>#50</td>
<td>0.26</td>
</tr>
<tr>
<td>#47</td>
<td>0.31</td>
</tr>
<tr>
<td>#44</td>
<td>0.4</td>
</tr>
<tr>
<td>#41</td>
<td>0.42</td>
</tr>
<tr>
<td>#38</td>
<td>0.43</td>
</tr>
<tr>
<td>#35</td>
<td>0.45</td>
</tr>
<tr>
<td>#32</td>
<td>0.47</td>
</tr>
<tr>
<td>#29</td>
<td>0.5</td>
</tr>
<tr>
<td>#26</td>
<td>0.53</td>
</tr>
<tr>
<td>#23</td>
<td>0.15</td>
</tr>
<tr>
<td>#20</td>
<td>0.16</td>
</tr>
<tr>
<td>#17</td>
<td>0.17</td>
</tr>
<tr>
<td>#14</td>
<td>0.15</td>
</tr>
<tr>
<td>#11</td>
<td>0.78</td>
</tr>
<tr>
<td>#8</td>
<td>0.17</td>
</tr>
<tr>
<td>#5</td>
<td>0.19</td>
</tr>
<tr>
<td>#2</td>
<td>0.21</td>
</tr>
<tr>
<td>Total loss</td>
<td>19.54</td>
</tr>
</tbody>
</table>

Starting from any “end-head” sprinkler, you could add the cumulative friction-losses in similar fashion, through any of the many possible routes through the grid, to see that the computer has indeed balanced the flows so that the pressure losses are balanced to within 1/2 psi on either side of the remote area. For the same (Figure H-14) grid, here are examples of three such routes:

<table>
<thead>
<tr>
<th>Pipe Pc.</th>
<th>Pressure Loss in psi</th>
<th>Pipe Pc.</th>
<th>Pressure Loss in psi</th>
<th>Pipe Pc.</th>
<th>Pressure Loss in psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>#64</td>
<td>0.17</td>
<td>#72</td>
<td>0.17</td>
<td>#63</td>
<td>0.04</td>
</tr>
<tr>
<td>#65</td>
<td>0.92</td>
<td>#73</td>
<td>0.92</td>
<td>#62</td>
<td>0.6</td>
</tr>
<tr>
<td>#66</td>
<td>8.02</td>
<td>#74</td>
<td>7.98</td>
<td>#61</td>
<td>12.48</td>
</tr>
<tr>
<td>#60</td>
<td>0.45</td>
<td>#68</td>
<td>0.07</td>
<td>#59</td>
<td>0.41</td>
</tr>
<tr>
<td>#54</td>
<td>0.7</td>
<td>#60</td>
<td>0.45</td>
<td>#53</td>
<td>0.21</td>
</tr>
<tr>
<td>#51</td>
<td>0.56</td>
<td>#54</td>
<td>0.7</td>
<td>#50</td>
<td>0.26</td>
</tr>
<tr>
<td>#49</td>
<td>3.15</td>
<td>#51</td>
<td>0.56</td>
<td>#47</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Bear in mind that “designers who use hydraulic calculation computer programs should be sure that the pressure terms used in the computer printouts are clearly defined in the printouts”[1]. Our example is simplified for ease of understanding. Also, velocity pressures in mains and branch-lines have not been used here. The exact number and type of fittings, and their equivalent-length determinations, are not shown. Today’s typical computer program for grids will throw in all those figures, and show them on the final calculation printout. Here we are more concerned with understanding the calculation itself and the computer’s execution of that calculation.

After the grid calculation is completed we know the end-head pressure and the psi loss through the grid. It is then a simple matter to run your total volume (in this case, 309.44 gpm) through the main that feeds the grid; and the riser, valves, and underground water supply piping, to complete the hydraulic calculation. As always, pressure losses for elevation, and any psi losses incurred through backflow preventers and/or strainers must be included. The sprinkler piping used in the new addition may not be of the same wall thickness as the existing pipe in the main building. Be careful when inputting interior diameter (I.D.) figures for existing feed main piping in any calculation, since those are more likely to correspond to Schedule 40 piping.

On this calculation example, maximum water velocity occurs at points 2 (6.63 fps), 26 (8.47 fps), 54 (9.51 fps), and point 66 (12.14 fps). This is of some interest to the authority having jurisdiction. To figure water velocity through any single length of pipe, the formula generally used multiplies the constant 0.4085 by the gpm flow, divided by \( d^2 \) (the interior pipe diameter squared). For example take piece #66: \( 0.4085 \times 61.8 \), divided by 2.0794, equals 12.14. This is the water velocity in feet per second.

Examining Figure H-13 more closely, you will notice very low flows and friction losses towards the beginning pieces of the rear (2 1/2”) cross-main. These would be nearer the front

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of the grid, further from the remote area. Since the flow in the rear (tie-in) main actually diminishes as it nears the water source, you could down-size a good portion of that end of this main with very little ill-effect on the calculation outcome. For example, let’s say that you entered the pipe pieces #3, #6, #12, #15, #18, #21, #24, and #27 as 2” thinwall pipe. I’m certain that the system demand end-result would show little change if this were implemented. This is because it is the nature of the grid system to flow less water in that area of the rear main. Again, the computer will balance the flows and so long as your hydraulic calculation proves effective and adequate, you will be validating the pipe sizes used.

Take a look at Figure H-14 again, and also Figures B-7 and F-8. In each of these instances we have a branch-line hung between two grid cross mains. Notice that there is usually an “overhang,” that is, a smaller section of branch piping supplying sprinklers from the grid cross-main but outside of the actual grid. The water supply for the overhang sprinklers comes from just one direction. That is fine, as in the case of Figure H-14, if only two sprinklers (i.e., no more than half the number of sprinklers opened on a single line in the grid calculation) are fed on the overhang line. Suppose that there were four sprinklers on the overhang, to the left of the corner juncture between reference points #67 and #69. Then you would have to run a separate “tree” calculation to justify the pipe sizing for those four sprinkler-heads. If you simply continued on with 1 1/4” piping (or whatever the grid branch-line sizing is) to those four heads, you have not proved anything out. The AHJ will say that in your grid calculation (see Figure H-13) you are showing a 53.66 gpm flow down pipe piece #67. Well, your entire calculation is based on the design fact that at least 22.8 gpm are necessary to supply flow to a single sprinkler in this building. The 53.66 gpm, then, will not be sufficient to supply three sprinklers on the overhang.

One other point that I should make about grids concerns certain instances where a high design density is required, and pendent sprinklers are to be used. This would occur usually in a high-piled storage occupancy (see Chapter 15). Let’s suppose that we are installing extra-large orifice (ELO) sprinklers (\(K = 11.4\) spaced at 96 sq. ft. on a wet-pipe system requiring a density of .75 gpm/sq. ft. This would be workable, and the remote sprinkler would therefore require an end-head pressure of 39.9 psi (and most likely a fire pump would be necessary to boost the water supply in this instance). Trouble with this calculation would appear because of the presence of a drop-ceiling; even a short drop to a fire sprinkler would have to be larger than 1” pipe. The tendency of the fire sprinkler contractor would be to speed up his grid installation by prefabricating numerous 1” (pre-cut) drops, as he would when sprinklering a retail store. You could not simply run your normal grid calculation program because of this: any fusing sprinkler-head would need to discharge \(.75 \times 96\) a minimum of 72 gpm. The 1” pipe is simply not large enough to accommodate this flow. So, not only would you have to install large piping for the drops, but a separate calculation would have to be prepared.

As an example, if the drops were to be schedule 40, 1 1/4” steel pipe, and were 1’ long, then you would first need to calculate the loss in psi through 7 equivalent feet of piping \((1′0”+\text{ the allotment for a 1 1/4” tee}^8)\) which, for 72 gallons would be \(7 \times .366\) (see Figure H-7) or 2.56 psi. Adding 2.56 psi to the end-head pressure of 39.9 psi, we come up with a total of 42.46 psi required at the tee at the top of the 1 1/4” drop. Don’t forget, \(K = Q\) divided by the square root of \(P\). So we would run the entire grid calculation using a different \(K\)-factor (which would be: 72.0 divided by 6.516,\(^9\) or \(11.05\)) and the starting minimum flow and pressure requirements would be 72.0 gpm and 42.46 psi respectively, for the grid calculation.

### THE LOOP CALCULATION

Getting back to the original hypothetical problem posed at the beginning of this chapter, there is almost always, the option of installing a looped system. Excellent examples of looped systems are shown in Figure A-8-4.4.1 (b) of NFPA Pamphlet No. 13.\(^10\) In these examples, the water supply flow to a single sprinkler comes from a single direction, but the flow can be split at the cross-main, allowing us hydraulically to down-size the main. If you have understood the intricacies of the grid calculation, it is easy to understand how to calculate a simple loop. You can even do this on a hand-calculation if you desire. It is a trial-and-error process, and the pressures must balance. Since only one loop is involved (as opposed to many loops in a grid), the engineering time factor is greatly reduced. When preparing any calculation.

The general hydraulic calculation process can be broken down into 17 basic steps. These steps are as follows:

1. Determination of Occupancy or Hazard Classification
2. Determination of Size of Area of Sprinkler Operation
3. Determination of required minimum density
4. Determination of the number of sprinklers to be contained in the area of sprinkler operation
5. Determination of the shape and location of the area of sprinkler operation
6. Calculation of the required minimum flow from the first sprinkler
7. Calculation of the required minimum pressure at the first sprinkler
8. Calculation of the pressure lost to friction between the first and second sprinkler
9. Calculation of the flow from the second sprinkler
10. Repetition of steps 8 and 9 until the first branch-line is completed
11. Balancing of pressures if the area of sprinkler operation extends to both sides of the cross main
12. Calculation of a \(K\)-factor for the first riser nipple
13. Calculation of pressure and flow demands for other riser
nipples within the area of sprinkler operation, using the
K calculated in step 12
14. Calculation of a new K for partial branch-lines
15. Calculation of friction and elevation losses to the point
of connection to the water supply system
16. Addition of hose stream requirements
17. Comparison of the calculated demand to the available
water supply [3]

The seventeen-step process noted above and formulated
by Pat Brock, would naturally be adhered to for a loop cal-
culation. The only difference would be that the “balancing of
pressures” (step 11) would again take place at the juncture
point of the two mains that comprise the loop.

The installation of looped systems most frequently occurs
on floors of high-rise buildings. This is usually due to the
fact that it is impossible to run lines through the core (middle
section) of the building where the elevators and stairwells
are located. (This makes for a somewhat impractical “tree”
installation). The example in Figure B-9 shows the combina-
tion sprinkler/standpipe supply for such a loop. The scaled
plan layout for this detail is shown in Figure C-10. The 2"
looped piping continues around the floor of the building in a
continuous loop. The designer of this system must be careful
to remember to include a couple of flushing connections on
the looped main. You will notice, in Figure C-10, a grooved
coupling shown between two 2" x 4'11" cut pipe lengths.
Since all of the 2" loop piping is threaded, it is necessary at
some point to install a grooved connection so that the pipe can
physically be connected together. Obviously, threaded piping
between two fixed points cannot all be inter-connected with
screwed fittings. This goes for branch-lines on grids as well
(see again Figure B-7). Although with shorter “prepped” grid
branch-lines it is possible to tie-in the line by “pushing” the
fit-tees (and omitting the grooved coupling), any threaded
branch-line of a grid usually commences with a short (12" or
so) thread-groove “starter piece” for the purpose of tying the
line together.

TO BEAR IN MIND

Three additional things to remember when considering the
design of a gridded system are:

(1) Grids are not permitted on dry-pipe systems or preaction
systems
(2) NFPA #13 code requires the installation of a 1/4" relief
valve somewhere in the grid11
(3) The tie-in cross-main of the grid is usually hung at a lower
elevation than the branch-lines, and thus will require the
installation of an auxiliary drain valve at some low point

Although both mains of a gridded (and not of a looped)
system may be hung from a single bar-joist, the standard
practice is that the rear main be hung as a “floater” main from
a “spanner” type hanger. Although this will increase hanger
material cost, this design layout method saves considerable
labor time by making for easier tie-ins, and thus an easier
installation. Time is money, especially where labor unions
are involved.

The designer should also be aware, when sizing the main
piping, of the possibility of future warehouse expansion. This
does not only include the potential of later building additions,
but also the likelihood of future offices or storage mezza-
nines within the building. It is easier to cut into larger piping
to supply sprinkler system additions, and if future building
renovation or addition is anticipated, this is to be considered.
There is code compliance, and then there is common sense.

Also (to digress a little), there is always a subtle moral code
involved in system design. Take for example, the engineer’s
occupancy call with regard to a “metalworking” occupancy.
This might involve a completely non-combustible operation,
or one that contains hydraulic oils, paint spray, combustible
metals, and combustible packing materials. So, just as the
judgment of an occupancy classification should not be rushed,
there could also be negative implications if the decision on
the style of piping layout is hurried. Future plans for the
building and site are to be considered. Although the time
of engineering may be lessened by an impetuous decision
(and no code violated), the careful consideration of hydraulic
design options will increase system efficiency and your value
as a designer.

CITATIONS
1. Warren Ng, “Pressure Terminology,” Fire Protection Contractor,
2. Robert M. Hodnett, editor, Automatic Sprinkler Systems Hand-
bok, The National Fire Protection Association, Quincy, Mas-
sachusetts, 1985, p. 314.
3. Pat D. Brock, “Critical Considerations in the Hydraulic Design
p. 15.

ENDNOTES

1 It is not okay to add pipe-scheduled system piping onto an existing
hydraulically calculated system.

2 Another way of accomplishing this could well have been to simply
upsizes the first two branch-lines to 2", or perhaps upsize the first
branch-line (only) to 2 1/2" or 3".

3 Simply put, the gridded system layout makes for more efficient
water distribution.

4 See Figure H-12. Most computer programs would also include a
heading of PSI/FT to show the friction loss factor used. In this case,
the 255.46 gallons lose 0.0157 psi per foot of 4" thinwall pipe.

5 See 8-4.4.2 in NFPA Pamphlet No. 13.

6 Figures are rounded by the computer program.

7 d² refers to the square of interior pipe diameter in inches. In our
example, piping diameters for the (Schedule 10) thinwall steel pipe
are as follows:

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter</th>
<th>Pipe Outside Diameter</th>
<th>Pipe inside Diameter</th>
<th>Thickness of Pipe Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot;</td>
<td>6.625</td>
<td>6.357</td>
<td>.134</td>
</tr>
<tr>
<td>5&quot;</td>
<td>5.563</td>
<td>5.293</td>
<td>.135</td>
</tr>
<tr>
<td>4&quot;</td>
<td>4.500</td>
<td>4.260</td>
<td>.120</td>
</tr>
<tr>
<td>3&quot;</td>
<td>3.500</td>
<td>3.260</td>
<td>.120</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>2.875</td>
<td>2.639</td>
<td>.118</td>
</tr>
<tr>
<td>2&quot;</td>
<td>2.375</td>
<td>2.157</td>
<td>.109</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>1.900</td>
<td>1.682</td>
<td>.109</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>1.660</td>
<td>1.442</td>
<td>.109</td>
</tr>
<tr>
<td>1&quot;</td>
<td>1.315</td>
<td>1.097</td>
<td>.109</td>
</tr>
</tbody>
</table>

Pipe outside diameters shown are a steel pipe standard. See also tables on p. 180 of NFPA #13.

8 See Figure H-4. “In cases where sprinklers are installed on sprigs or drops, the reducing coupling is ignored but the tee on the branch-line must be included” [2].

9 This K-factor represents the juncture point at the tee. The square root of P (psi) at the top of the drop would be the square root of 42.46.

10 By inter-connecting the branch-lines of those examples, by the way, a “looped-grid” system could be designed as an alternative.

11 See 4-1.2 In NFPA Pamphlet No. 13.
High-Piled Storage

The engineering of an economical sprinkler system is greatly improved by the competence of an experienced fire protection engineer. This holds true should the protected structure be an office building or a church, or a prison, or a pool hall. But the implementation of sound engineering practices becomes most critical when the occupancy in question has the potential for more dangerous and severe fires. When stored commodities are piled high in some fashion, there is reason enough to recognize that the occupancy, from a fire protection standpoint, is of a sufficiently hazardous potential. Fire itself, free from the typical effects of gravity, will dance quickly around stored fuel (horizontally and vertically), increasing flame spread and the intensity of combustion heat, and heat release, at alarming rates.

Fires in storage properties, account for 15.5 percent of nonresidential structure fires, 19.5 percent of associated property damage, 11.4 percent of associated civilian deaths, and 9.2 percent of associated civilian injuries. In storage properties, the leading occupancies in which these fires occur are agriculture products storage facilities (38%), unclassified storage facilities (23%), and general-item storage facilities (14%). [1]

In the last chapter, we concluded with a reminder concerning the importance of commodity classification relative to the hydraulic design criteria used in system design. Commodities are classified in Appendix A of NFPA #13 with respect to how difficult a fire will be to control (when these commodities comprise part of the “fuel”) with automatic sprinklers. As these listings appear in the Appendix, they are really recommendations rather than etched-in-stone requirements. The lists are a little brief and a little loose, forcing the design engineer to exercise his own judgment. Even more so, this judgment must be exercised when considering the commodity classifications for the protection of general storage, delineated in Chapter 2 of the NFPA #13 code standard.

### COMMODITY CLASSIFICATION

NFPA #13 defines high-piled storage as any rack, palletized, or solid-pile storage in excess of 12’ in height. In other words, once it becomes known that the height of storage or anticipated height of storage exceeds 12’, we must now delve deeper into the requirements of Chapter 7 in NFPA #13. The classification of commodities noted in Chapter 2 must first be established with certainty prior to pinpointing any hydraulic design criteria. In a nutshell, the definitions for the commodity classifications as they pertain to these standards are:

- **Class I**—Metal and glass products, food, electrical distribution equipment, cement in bags, inert pigments.
- **Class II**—Class I products in slatted wooden crates, solid wooden boxes, or multiple-thickness cardboard cartons; also wire coils or reels, beer or wine.
- **Class III**—Wood, paper and natural fiber cloth such as books, magazines, plastic-coated paper containers, leather, shoes, doors, window frames, wood or metal furniture, tobacco products.
- **Class IV**—Contain an appreciable amount of plastics in a paperboard carton, or certain plastic packing in paperboard cartons (for any Class I, II, or III product); also vinyl floor tile, wood or metal frame upholstered furniture, mattresses, some synthetic threads and yarns, metal (padded) bumpers and plastic-padded metal dashboards. [2]

While it is recommended that the system design should be based on the worst-case commodity scenario, the authority having jurisdiction (AHJ) may often make a “mixed-occupancy” ruling, for example, classifying the storage of several different commodities as midway between Class III and Class IV, and thereby assigning a design density by interpolation between density curves. It is of importance to note that certain special occupancies such as roll paper, baled...
fibers, pesticides, inks, aerosols, rubber tires, flammable liquids, and carpet storage; fall outside the scope of NFPA #13. This chapter will limit discussion to the most common systems found in warehouses encountered today.

COMMODITY PILING HEIGHT

You will notice that earlier I mentioned anticipated storage height. The reality of actual building storage and future building use is that due to the ebbs and flows of inventory management, storage is often piled in spots to the highest available height. However, we have no way to predict what the actual commodity storage height will be when a fire occurs. We have to rely on empirical guesswork. The design height can be determined in four different ways:

1. What the warehouse manager says the storage height will be limited to
2. The elevation of the bottom of the lowest beam or structural roof member of the building. This is also referred to by those in the commercial real estate business as the building’s “clear height”
3. The elevation of the bottom of the lowest steel bar joist web inside the building
4. 18’ below the deflector of the sprinkler-heads

In ascending order of common sense, with no. 4 also being the most conservative approach, the designer should make his “storage height” call based on one of the above criteria. Two things to consider here are: 1) the building height need not be considered if permanent storage racks are present and, 2) ceiling sprinkler density will not vary at very high storage heights (such as those in excess of 25’) where in-rack sprinklers will need to bear the brunt of the automatic sprinkler fire-fighting. Fire burns upwards and outwards. Another item to note is that “sprinkler activation can be delayed because of an excessive distance between the sprinklers and the fuel package. The hot gases from the fire plume entrain air, which will decrease its temperature by the time they reach the elevation of the sprinklers” [9].

“Fire severity is a function of height. The taller the burning materials, the more rapidly the flames will accelerate. Materials stored twice as high will burn much more than twice as fast.” [3] Since storage height plays such a critical role in the fire intensity, it becomes a very important engineering call, and that call directly impacts design density assignment. If a fire occurs, certain rack or warehouse areas will rarely be entirely filled with storage. But two certainties cancel out the effects caused by this additional presence of air space. Although upward fire spread will increase due to the vacant space, these spaces also allow for additional penetration by the sprinkler water discharging. “Overall, the purpose of storage facilities is to stockpile the maximum amount of material into the smallest possible space while maintaining effective accessing for material handling. From a fire perspective, this translates into squeezing the maximum amount of combustibles into the smallest possible space while maintaining plenty of air access for efficient combustion. The net result is a prescription for maximized burning of large quantities of materials. The type amount, and arrangement of combustibles present relates to the type of fire hazard present. Within the context of NFPA #13, fire hazard links the burning characteristics of a fuel with the ability of a sprinkler system to control or suppress the associated fire. Determination of the fire hazard represents one of the most critical decisions concerning sprinkler system design” [10].

CODE APPLICATION

Back in Chapter 2, we outlined a general chronological list of eight duties that would comprise a fire sprinkler engineer’s job description. The first item of that job description included the work of “collecting facts.” This particular work increases in strong measure when the designer is presented with a building to evaluate which contains high-piled storage. Suppose that you are asked to design a fire sprinkler system for the hypothetical Johnson Building. This is a large unheated warehouse built for the purpose of storing the different styles of vinyl floor mats manufactured elsewhere by one of the car companies. Boxes containing these are stored in solid piles to a maximum height of 23’. First, we know that the maximum spacing between sprinklers in any direction (per Section 5-6.3.1 of NFPA #13) will most likely be limited to 12’. The design criteria for the sprinkler system installed in the Johnson Building will be determined by regulations and design curves outlined in chapter seven of NFPA #13. The exact sequence of events for the procedure involved in design criteria selection are as follows:

1. Determine the commodity class. (This will be Class IV—see Section A-2-2.4 of NFPA #13.)
2. Decide if ordinary-temperature rated or high-temperature rated sprinklers will be used. (Either are fine. For the Johnson Building example, we will use high-temperature rated sprinkler-heads so that our required design density will be lower.)
3. Select the density and area of application from either Figure 7-3.2.2.1 if 165° rated sprinklers are to be used, or Figure 7-3.2.2.2.2 if 286° rated sprinklers are to be used.2 (See Figure J-1 of this text. These are the NFPA #13, Figure 7-3.2.2.2.2 sprinkler density curves, showing that for a class IV commodity stored to a height of 20’, we shall use a design density of .29 gpm/sf over the most remote 2000 sq. ft. for our hydraulic calculation,3 if the system in question is a wet-pipe system.)
4. Reduce or increase the required density for height of storage (See Figure J-3. This is the curve shown as
Figure 7-3.2.2.3 in NFPA #13. As you can easily discern, we will have to revise our ceiling density by a factor of 1.2 due to the fact that the storage height may well be 23′. Therefore, our revised design criteria will now change to .354/2000. 

(5) Increase operating area by 30% in accordance with Section 7-3.2.2.2.4 where a dry-pipe system is used (Right. Now we are looking at a design density of .354/2600.)

(6) Make certain that your final density is not less than the minimum noted for ordinary hazard group 2 occupancies. (See Section 7-3.1.2.2. This refers to the fact that our final density should not have been revised to a point lower than that depicted by the corresponding Figure 7-2.3.1.2 curve in NFPA #13. In this example, that would not occur unless we were reducing our density for storage heights of 12 1/2′ or 13′.)

So for the case of the Johnson Building, we will be designing a dry-pipe sprinkler system around the hydraulic design parameters of .354 gpm/sq. ft. over the most remote 2600 sq. ft. NFPA #13 code also mandates that a 500 gpm hose stream allowance be added to our hydraulic calculation. Our system design would also need to include a small hose system to supply 1 1/2″ hand-hose stations in the warehouse, in accordance with Section 7-3.1.1 and also Section 5-15.5.1.2 of NFPA #13, if this were a wet-pipe system.

ANOTHER APPLICATION EXAMPLE

Let’s now look at a second example, the Taylor Building. This structure houses the same commodities, but stores them on conventional pallets in double-row racks, with 8′ aisle separation, to a maximum storage height of 16′. The 38,000 sq. ft. building will be heated. The building engineer (owner’s representative) has informed us that in the interests of uniformity, he would like his sprinkler system design to be in step with his other facilities that are scattered around the country. So, we are to use 165° sprinklers at both the ceiling level and the in-rack.

What the Taylor Building will contain is fairly common. The racks are a structural framework into which forklift trucks can load commodities on wooden pallets. Racks like these vary in size, shape, and overall configuration. Requirements for most cases of rack storage, fortunately, are covered in NFPA #13. The storage of commodities in racks is more hazardous from a fire protection standpoint because of additional air pockets that allow the fire to continually breathe, and “fan the flames” so to speak. Also, there is no “suffocation.” In an actual fire the burning materials will not collapse and “smother” the fire before it can gather momentum, because the structural framework of the rack prevents that from happening. Racks would be good to use if you were building a bonfire.

In the case of the Taylor Building one important decision has been made for us by the building engineer: that of installing in-rack sprinklers.

In some cases, in-rack sprinklers can be avoided if a sufficiently powerful system is installed at the ceiling, but losses will be higher, and the factor of safety will be smaller. An in-rack sprinkler system will get water on the fire quickly. A small fire can be extinguished before it can grow to be a large fire. If installed carefully, in-rack sprinklers can be protected from mechanical damage by fork lift trucks, by locating them behind the steel racks. For additional protection, head guards of various types can also be added. [4]

An in-rack sprinkler is typically equipped with large water shields over the deflector that protect them from cold-soldering and may also aid in the collection of heat to insure timely fusing.

Overall, the rack storage requirements are more stringent, and rightly so. “In a warehouse, furniture such as sofas, rugs, and chairs is also “encapsulated” with plastic covers, making it impossible for sprinkler water to control fire spread by pre-wetting” [5]. The term encapsulated can, and has been, misconstrued by readers of the NFPA standards.

Encapsulated is a packaging method where a combustible commodity is completely enclosed by a plastic sheet on the sides and top on a pallet load. Totally noncombustible commodities on wood pallets enclosed only by a plastic sheet are NOT considered as encapsulated, nor does banding, stretch wrapping or individual plastic-enclosed items inside a large nonplastic enclosed container fall within the definition. [6]

In our Taylor Building example we are not concerned with an encapsulated product, but of course you will notice this terminology frequently in your use of the NFPA standards.

Please note Section 7-9.8 of NFPA #13 (1999 edition). If, in the example of the Taylor Building, we want to design a sprinkler system for the premises without the inclusion of in-rack sprinklers, we are then mandated by code to include column sprinklers. These are sidewall sprinklers, provided at all interior steel columns and positioned at a 15′ elevation, for the purpose of preventing those steel columns from buckling under as a result of the intense heat of a large fire. This is not to be overlooked.

NFPA #13 contains numerous density curves and we are going to run you through this one example to familiarize you with the process of selecting a design density. The storage racks in the Taylor Building consist of three-tier double-row racks, back-to-back, with a 12′ (longitudinal) flue space in the middle. One level of in-rack sprinklers will be located at the top of the second tier (in accordance with 7-4.2.1.1.3), with sprinkler deflectors to be situated 6′ above the top of that second tier of storage (in accordance with 7-4.2.1.1.2). This in-rack branch-line will be run in the flue, in the middle of the double-row rack.
The example building will contain three separate sprinkler systems, with three risers at the header: one for the ceiling sprinklers, one for the in-rack sprinklers, and one for the hand-hose stations. Refer to Figures J-4 through J-9 of this text. These tables and figures can be found in NFPA #13 and will comprise what we use to determine the design criteria for the sprinkler systems. Look at Figure J-4 and specifically curve “B.” This curve applies almost exactly to our situation in the Taylor Building, except that it applies to a nominal 20’ height of storage. The design criterion we are now utilizing, which will be revised due to storage height, is .37/2000 for our wet-pipe ceiling level sprinkler system. You can no doubt see by the Figure J-4 curve arrangements that the ceiling sprinkler densities are reduced considerably because of the presence of the in-rack sprinkler system. Figure J-5 gives us the total picture. We are protecting a nonencapsulated Class IV commodity (vinyl floor mats), with one level of in-rack sprinklers. Reading from left to right, you will notice that in-rack sprinklers are not necessarily mandated by code here, because our commodity is not encapsulated. If it were (see Figure J-9), our ceiling density requirements would jump dramatically, even with the mandatory inclusion of one level of in-rack sprinklers.

Getting back to the example, we will now revise our ceiling sprinkler density once, as allowed by Section 7-4.2.2.1.3. Section 7-4.2.2.1.5 [and Table 7-4.2.2.1.5 (see Figure J-6)] will not apply in our case because we are not installing more than one level of in-racks. Therefore (see Figure J-7) we will reduce our density by a factor of .65, that corresponds to our known storage height of 16’. Our revised design criteria then, will be (.65 × 37).24 gpm/sq. ft. over the most remote 2000 sq. ft. Although this exercise becomes easier with code familiarity, I find myself re-reading through NFPA #13 every time I need to apply it in the course of design work, due to the numerous rules and nuances involved.

Design criteria for the in-rack sprinkler system is quite a bit simpler to decipher. First (see Figure J-8), our in-rack heads will be spaced 8’ apart at a maximum. Second (see Section 7-4.2.1.4 of NFPA #13), we will open eight sprinklers in our hydraulic calculation of the in-rack system, as we will have one level of in-racks installed to protect the Class IV commodities. Finally, our sprinkler end-head pressure will be 15 psi, in accordance with Section 7-4.2.1.3 of the standard. We will most undoubtedly use standard 1/2” orifice sprinklers (see Section 5-12.2) for the in-rack heads (K-factor = 5.6). Therefore, as \( Q = K \sqrt{P} \), our end-head will discharge a volume of \( (5.6 \times 3.873) \times 21.69 \text{ gpm} \) to initiate the calculation.

**SPRINKLER OPTIONS**

We have a great deal of latitude with which to choose operating sprinkler types for the ceiling system. Naturally, large-orifice or (ELO) extra-large orifice sprinklers would make a good choice. The ELO sprinkler is not considered a “large-drop” sprinkler despite its 0.64’ nominal orifice size. The large-drop sprinkler is an upright head that will produce large water droplets that have a better chance of penetrating the fire plume produced by severe fires. It has a K-factor of 11.2, and comes equipped with a rather large deflector. Chapter 5-4.7 of NFPA #13 covers specific rules regarding the design requirements of large-drop sprinklers.

Until approximately 1970, sprinklers were upright, pendent, or sidewall and classified as either frangible bulb or solder-link type. Since then, automatic sprinklers have evolved into several specialized types that perform specific functions. Early-suppression, fast-response (ESFR) sprinklers are for use against high-challenging fires that grow extremely fast and have large increases in heat-release rates over a short period of time. These sprinklers respond quickly to a growing fire and deliver a heavy water discharge to “suppress” rather than “control” a fire. Deflectors and 3/4-inch orifices provide a broad spray pattern capable of suppressing fire located between sprinklers in high storage areas while maintaining a high-momentum downward core to penetrate and suppress fires directly beneath the sprinkler. ESFR sprinklers must be installed in accordance with strict guidelines to provide fire suppression. [7]

The minimum end-head design pressure for an ESFR sprinkler is 10 psi. Clearance from sprinkler deflectors to top of storage cannot be less than 36”. Other specific rules regarding design and installation of ESFR sprinklers can be found in Chapter 5-4.6 and 7-9.5 of NFPA #13, and head spacing rules are noted in Section 5-11.3 of NFPA #13. They can only be used in wet-pipe systems, for example, and only in buildings that are very high in terms of elevation. A lot of the current restrictions are due to the limited amount of fire testing that has been conducted at this time, as their existence is relatively new.

Sprinkler design is a valuable and critical function. Of all the people who have died in fires, how many do you think perished inside buildings equipped with automatic sprinklers? Not many. Perhaps a part of the job description of every fire protection professional should be dedicated to the promotion of automatic sprinkler systems. It couldn’t hurt. With regard to high-piled storage, believe it or not, the presence of . . .

Sprinklers are still rare in general-item storage facilities. Even if the focus is narrowed to general warehouses, only 15.7 percent of the fires that occurred in 1991 in such properties were in sprinklered warehouses. Since larger warehouses that qualify as highly protected risks to be sprinklered as a requirement of their insurance coverage, one must conclude that these warehouses represent only a fraction of all general warehouses, let alone all storage facilities. [8]

As time marches on, of course, the percentage of buildings containing high-piled storage that are properly sprinklered with surely increase. The potential for large fires in those
premises is great, and that’s a lot of work ahead for fire sprinkler system designers.

STUDY QUESTIONS

Note: The following questions are to be used as an “open-book” type quiz. Please make use of NFPA pamphlets and any related codes when figuring responses (answers appear on pages 281–282).

1. A sprinkler riser 20′ long, contained within a vertical shaft 23′ high, will require at least one support hanger.
   A. true
   B. false

2. Which of the following hangers may be used to support piping beneath wood joist construction?
   A. eye nut and rod
   B. coach screw rod
   C. eye rod
   D. all of the above

3. How many total 1/2″ fire sprinklers can be supplied by one 3 1/2″ riser, inside a textile-blending plant, on a pipe-schedule basis?
   A. 40
   B. 55
   C. 60
   D. 65
   E. 100
   F. 160

4. An existing fire sprinkler system has been renovated for a new building tenant. Thirty-five sprinklers have been added to the system in a large warehouse. A recent flow test of the public water service main in the vicinity shows a flow test of 65 psi static, 53 psi residual, at a flow of 1210 gpm. This is a wet-pipe system. The installed piping shall be hydrostatically tested upon completion of installation for two hours, at what psi?
   A. 50 psi
   B. 60 psi
   C. 115 psi
   D. 200 psi
   E. 240 psi
   F. no test would be required

5. Sprinkler-heads in severely corrosive atmospheres shall be coated with:
   A. lead
   B. wax
   C. zinc
   D. teflon
   E. A, B, or D
   F. none of the above

6. An overhead piping run connected to an adjacent wet-pipe system traverses 75′ across a shipping warehouse. What is the minimum size piping required for the drop down to the hand-hose station that it supplies?
   A. 1″
   B. 1 1/4″
   C. 1 1/2″
   D. 2″
   E. 2 1/2″
   F. 3 1/2″

7. From a code standpoint, what is the difference between slatted and solid shelves in rack storage occupancies?
   A. no difference
   B. slatted shelves are the same as open grating
   C. sprinklers need to be installed beneath solid shelves only
   D. only slatted shelves obstruct the flue spaces
   E. there is less damage potential with slatted shelving
   F. none of the above

8. If a fire breaks out simultaneously in five different parts of a large building, it is most reasonable to believe that the fire is the result of:
   A. lightning
   B. arson
   C. spontaneous combustion
   D. explosives
   E. cigar smokers
   F. carelessness

9. With 40 lb pressure at the head, sprinklers will discharge approximately how many gallons of water per minute, assuming standard 1/2″ heads?
   A. 15
   B. 20
   C. 25
   D. 35
   E. 45
   F. 60

10. Of fires in buildings equipped with automatic sprinklers, the percentage that are either held in check or extinguished by the sprinklers is nearest to:
    A. 10%
    B. 25%
    C. 50%
    D. 75%
    E. 80%
    F. 90%

11. The total take-out for a 4″ grooved 90° elbow is:
    A. 2 1/2″
    B. 3″
    C. 4″
    D. 5″
    E. 6″
    F. 6 1/2″

12. With open steel bar-joists supporting metal roof deck- ing, what is the maximum distance beneath the underside
of the roof deck that a sprinkler deflector may be positioned?
A. 6"
B. 10"
C. 12"
D. 16"
E. 20"
F. 24"

13. What would be an acceptable design criteria for the banded, palletized storage of laundry detergent to a 15' piling height, on a dry-pipe system, using 165° sprinklers?
A. .20/2600
B. .15/2000
C. .37/2000
D. .22/2600
E. .20/1950
F. .20/2000

14. Figure #1 shows an existing drop being relocated to a new sprinkler-head location. What is the dimension center-to-center, of the new pipe length?
A. 7'0"
B. 7'3"
C. 7'8"
D. 7'9"
E. 8'1 1/2"
F. 9'0"

15. Figure #2 shows one piece of 4" pipe choking the flow of an 8" water supply over a 2' span. All piping shown is Schedule 40 steel pipe. If additional 4" feeds could connect the 8" pipes by the installation of welded outlets or mechanical-tees, then the total flow would no longer be throttled. How many single 4" pieces (including the one shown) would it take to carry a sufficient supply of water so as not to retard the total gpm flow?
A. one
B. two

16. The deflector of a horizontal sidewall sprinkler shall be positioned anywhere between _______ inches and _______ inches beneath a smooth ceiling.
A. 1, 12
B. 4, 6
C. 1, 16
D. 6, 12
E. 4, 12
F. 6, 16

17. Fire sprinklers shall be installed beneath ductwork wider than _______ inches.
A. 24
B. 36
C. 48
D. 60
E. 72
F. 84

18. The 3'10" dimension on the 1 1/2" pipe in Figure #3 is a center-to-center dimension. What will the end-to-end cut dimension be for that 1 1/2" piece?
A. 3'7 1/2"
B. 3'8"
C. 3'8 1/2"
19. What is the end-to-end cut length dimension, after take-out, of the 2 1/2" grooved-end piece marked “A” in Figure #4?
   A. 7'6"
   B. 7'7 1/2"
   C. 7'8 1/2"
   D. 7'10"
   E. 8'0 1/2"
   F. 8'3"

20. In a one-story office building, what minimum size steel pipe is needed to supply a total of 165 sprinklers (pipe scheduled system)?
   A. 3"
   B. 3 1/2"

21. What minimum size machine-thread rod would be required to hand 5" pipe?
   A. 1/4"
   B. 3/8"
   C. 1/2"
   D. 5/8"
   E. 3/4"
   F. 7/8"

22. A wet-pipe system supplies 286° ceiling sprinklers only above 14′ high palletized rack storage of magazines in a 20′ high storage warehouse. The magazines are packed in plastic packing inside paperboard cartons. The aisles are four feet wide. What is the proper design density to be used?
   A. .258/2000
   B. .297/2000
   C. .348/2000
   D. .495/2000
   E. .580/2000
   F. none of the above

23. A sprinkler is located exactly 7′ from the face of a 3′ × 6′ heater, in the direction of hot air flow. Its temperature rating shall be:
   A. 135°
   B. 165°
   C. 212°
   D. 286°
   E. 360°
   F. none of the above

24. A small room as defined by NFPA standards is a room with a floor area of ______ square feet or less.
   A. 225
   B. 500
   C. 750
   D. 800
   E. 1000
   F. 1250

25. An upright sidewall sprinkler shall be mounted anywhere from ____ inches to ____ inches away from a wall.
   A. 1, 12
   B. 4, 6
   C. 1, 16
   D. 6, 12
   E. 4, 12
   F. 6, 16

26. At a minimum, how far must a sprinkler be from the web member of a 7/16" bar joist?
   A. 3"
   B. 4"
27. To secure two 8′ companion flanges together, one would most likely tighten 3/4″ nuts onto 3/4″ bolts that are ______ inches in length.
   A. 2 1/4″
   B. 2 1/2″
   C. 2 3/4″
   D. 3″
   E. 3 1/4″
   F. 3 3/4″

28. When field-checking the installed incoming water service on a job survey, it is advisable to examine and check:
   A. if the piping is plumb
   B. dimensions off of walls
   C. dimensions off of columns
   D. the elevation of the flanged-spigot end
   E. that the flange is “two-holed”
   F. all of the above

29. Who was responsible for developing the first automatic fire sprinkler that was commercially used to any extent?
   A. Henry Parmalee
   B. Henry Ford
   C. Henry Thoreau
   D. Henri Matisse
   E. Henry Aaron
   F. Josephine Cochrane

30. If the engineer’s design is economically friendly with the salesman’s cost estimate, that reflects the engineer’s responsibility to:
   A. his community
   B. the fire department
   C. the building’s insurance carrier
   D. his employer
   E. the National Fire Protection Association
   F. the Sprinkler Fitter’s Union

31. Automatic fire sprinkler contractors, situated north of the Mason-Dixon line, have historically kept their field labor personnel busy during the winter months by:
   A. installing dry-pipe systems
   B. installing only retrofit projects
   C. bidding on springtime construction work
   D. handling “freeze-up” service calls
   E. none of the above

32. A return-bend arrangement is suitable for installations that:
   A. require pendent sprinklers to hit the “quarterpoints” of 2 × 4 ceiling tiles
   B. will use “wet” sprinkler drops in heated areas of dry-pipe systems
   C. require pendent sprinklers to hit the “quarterpoints” of 2 × 4 ceiling tiles
   D. will use “wet” sprinkler drops in heated areas of dry-pipe systems
   E. all of the above

33. The take-out for a 4″ 90° flanged elbow is:
   A. 6 1/2″
   B. 8 1/2″
   C. 9″
   D. 10″
   E. 11″

34. NFPA Pamphlet No. 24 requires that fire hydrants be stationed at least ______ feet from a building.
   A. 5
   B. 15
   C. 25
   D. 40
   E. 50

35. It is critical to check which of the following conditions in the field prior to stocklisting:
   A. type of domestic piping being used
   B. location of floor drains and scuppers
   C. elevation of structural steel
   D. desired location for spare-head cabinet
   E. none of the above

36. What is the minimum size main system drain valve to be installed on a 2 1/2″ wet-pipe system riser?
   A. 1″
   B. 1 1/4″
   C. 1 1/2″
   D. 2″
   E. 2 1/2″

37. What is the shortest length of 3″ threaded steel pipe that can be physically fabricated and realistically installed without much chance for future leakage?
   A. 1″
   B. 2″
   C. 3″
   D. 4″
   E. 4 1/2″

38. In a single-story structure, what is the maximum floor area that can be protected by sprinklers, in an ordinary hazard occupancy, supplied by two dry-pipe sprinkler risers?
   A. 40,000 sq. ft.
   B. 52,000 sq. ft.
   C. 75,000 sq. ft.
   D. 80,000 sq. ft.
   E. 104,000 sq. ft.

39. In an actual fire, more sprinklers will tend to fuse if the system type is wet-pipe as opposed to dry-pipe.
   A. true
   B. false
40. One of the easiest hangers to install is the eye-rod and ring.
   A. true
   B. false

41. The outside diameter of a piece of 3” Schedule 40 steel pipe is:
   A. 3.000
   B. 3.026
   C. 3.260
   D. 3.375
   E. 3.500

42. When 1 1/4” pipe supplies the last sprinkler on a branch-line, the last branch-line hanger shall be no more than _____ feet from the end sprinkler.
   A. 2
   B. 3
   C. 4
   D. 5
   E. 6

43. Using standard sprinklers, what is the maximum area of protection to be covered by a single sprinkler-head located above a stage?
   A. 90 sq. ft.
   B. 100 sq. ft.
   C. 130 sq. ft.
   D. 168 sq. ft.
   E. 225 sq. ft.

44. What is the velocity of 88 gallons of water flowing in 3” lightwall steel pipe?
   A. 2.93 feet per second
   B. 3.38 feet per second
   C. 3.93 feet per second
   D. 3.99 feet per second
   E. 4.02 feet per second

CITATIONS


ENDNOTES

1. A well-developed fire, however, producing a vicious fire plume, would actually prevent the discharging water from ever reaching the fire source.
2. The reason that the required ceiling sprinkler densities are less when high-temperature rated sprinklers are used, is because fire testing has shown that less water is wasted in a warehouse fire when fewer heads fuse. The chance of additional sprinklers fusing (that are not close enough to the fire source to insure that the water is used prudently) is minimized by the use of the 286°F sprinklers.
3. See Figure J-2 and the NFPA #13, Figure 7-2.2.2.1 sprinkler density curves. You can see that our design density would start out to be .385/2000 if 165°F rated sprinklers were to be used.
4. Note Section 7-4.2.1.5 in the NFPA #13 standard. If, for example, the building in question had 6’ aisles, we would then interpolate a density curve midway between curves B and D.
5. There is one other possible density adjustment permitted by code and it requires the mindful application of Section 7-4.2.2.1.9 in NFPA #13. If the building height of the Taylor Building is less than 20’6”, then Figure 7-4.2.2.1.9 can apply in our rack storage example, but only if our density curve used was from Curves E, F, G, or H. Assume for the sake of discussion that it did. We would, in that case, be able to start with a design density of .36/2250, which could be revised to a final design density of .234/2000.
6. This table in Figure J-8 does apply and permits only 8’ maximum spacing for encapsulated commodity storage, see Section 7-11 and Table 7-4.2.1.2.1.
CHAPTER 16

Techniques for Retrofit Work

A

s far as it concerns us, a retrofit job consists simply of designing a fire sprinkler system for an already existing building. There are plenty of fire sprinkler designers who really prefer to engineer retrofit projects instead of new construction jobs. The task of collecting facts becomes basically field work, which they find easier. Everything you need to know is physically present, right there in front of your nose. Field survey time, however, will be substantial, and there are usually no architectural or other existing dimensioned plans to rely on when you’re at work later, at the drafting board. You will be depending entirely on your own field measurements. Maybe for this reason, I don’t know exactly, there are many more designers who prefer to work on brand new construction projects. Whatever the personal preference, a fire protection designer today will without question be working on retrofit projects from time to time.

The engineering of a retrofit job cannot begin without the re-creation of a dimensioned architectural floor plan. You must first determine what, if anything, you will have available as far as existing building plans, to start out with. Usually the owner of the building has in his possession some old and outdated building plan that will at least show the overall building layout and shape. You will need to obtain a copy of this to begin your own fire sprinkler design plan. Preferably for retrofit projects, 1/4″ scale should be used. If a 1/4″ scale is simply not possible due to the shape or size of the building, I would strongly recommend using a 3/16″ scale in lieu of the more common 1/8″ scale. The use of this larger scaled print will give you extra room to show an increased number of pipe offsets, and to include additional plan dimensions and notes. It is the nature of retrofitting (and I’m sure this goes for any construction trade), that the engineering takes much longer and the installation time will at least double; and the shop drawing you prepare will reflect that in its complexity.

If you’re fortunate, a building engineer or the owner himself may be able to come up with some worn, creased (and most likely obsolete) blueprint that looks like the one shown in Figure K-1. If it was once drawn to scale, do not put too much stock in that. First, it is rare for a building to ever get built exactly to plan. Second, you can get yourself into trouble by “scaling” any plan to arrive at your own dimensions for prefabricated pipe lengths. It is possible to luck out if the owner has in his possession a very good original architectural plan. The plan copy shown on Figure K-2 is an architectural floor plan for a school built in 1939. Were you to check the corresponding measurements from that floor plan in the school today, you would find nearly every dimension to be true. The walls, columns, and doors are still exactly in place according to plan. (That’s how things were built in 1939.) But the fact of the matter is that if you are to produce a retrofit design for such a building erected over fifty years ago, the original floor plans are usually long gone. So somehow, a re-created floor plan must be made. Suffice it to say, a lot of your engineering time on any retrofit project will be spent "surveying," that is, measuring the existing building.

Everything has to be measured. That includes the rooms, the ceiling grid, all structural components, elevations in all corners and bays, the supporting beams and columns, ceiling fixtures, thickness of walls, and other elements pertaining to the construction of the structure.1 When making your initial survey, you will want to bring along some kind of plan layout to work off of. Figure K-3 shows an enlargement made on a photocopier of the hypothetical Smith Building, using the (Figure K-1) plan provided. For your survey, you would bring, in addition to the plan: a 50′ steel measuring tape, a flashlight, a 6′ or 8′ aluminum ladder, and two 8′ folding carpenter’s rulers.2 A hand calculator will also prove to be helpful.

Be very mindful of the fact that when you are initially measuring room and building dimensions in the field, you are already starting the engineering work on that project. This is due to the fact that the more accurate the survey, the more effective the field installation will “fit.” Also, while there is a
finite number of items to survey in the field, always measure what you see in case you need that information later. This goes for particulars such as light fixtures, unit heaters, ceiling fans, ductwork, and the like.

MEASURE AND QUANTIFY THE EXISTING BUILDING IN THREE DIMENSIONS

One of the first sets of dimensions that need to be established are those comprising the outside of the building. Do not fail to make these measurements. They are of great assistance, as you will see, in double-checking your survey figures. You should make these measurements using the 50’ tape. Figure K-3 shows the results of our first afternoon on the job. Many of the dimensions shown had to be revised while working in the field. For example: the north/south dimensions to the interior building column originally did not add up. We were aware of the fact that the outside dimension of the east end of the building was 85’0” and, by measuring near the overhead garage door, we determined the outside wall thicknesses to be 10’. So, the two north/south interior dimensions should total (85’0” – 10” – 10”) 83’4”. Since upon double-checking, we found that we were somehow in error, we carefully re-measured our interior dimensions to discover that we were previously in error, and in fact the two dimensions were really 37’9 1/2” and 45’6 1/2” (which add up to 83’4”). Only by double-checking ourselves were we able to catch this mistake.

Double-checking the opposite Smith Building wall dimensions (80’1” + 75’0” = 150’1”) let us know that we were still on the right track. Likewise, adding the east/west building column dimensions (14’5 1/2” + 30’0” + 29’8 1/2” + 10”) let us know that we were still measuring accurately, since they were consistent with the corresponding (75’0”) outside building measurement.

This measuring naturally eats up a lot of time. This is a necessary evil of retrofit jobs. To measure long outside runs of the building, for example, you will have to find something on the outside of the wall to hook your tape to, and measure in series, and then add together several figures to arrive at (for the east Smith Building wall) the 80’1” total dimension. Sometimes this has to be a two-man effort. Measuring from column-to-column inside an existing building is far easier, but can pose problems as well, especially when the occupancy is crowded. The 50’ tape is ordinarily sufficient for these measurements although (when you least expect it), someone, oblivious to what you are doing, may accidentally step on your tape while you are retrieving it. This blunder usually results in a broken tape, and improvised measuring for the rest of the day. The good news is that when measuring from column-to-column inside the structure, you will normally find that all columns are separated by the same distance. This is not to suggest that you should refrain from measuring each bay. As a result of today’s fast-track construction techniques, I would not be at all surprised to walk into a recently erected warehouse with architecturally planned 30’ bays—only to find by careful measuring the columns, that these bays are actually 29’10”, 30’1”, 29’9”, and 30’4” in width!

The method of double-checking comes in handy for areas that contain many rooms, not only to verify the room dimensions but also to check for wall thicknesses (see Figure K-4). Several linear measurements have been made inside rooms in the office area of the building. It was tempting to measure these rooms at the ceiling, done primarily by adding up the ceiling tiles. This technique is a little quicker, a short cut. To be as accurate as possible, however, the floor should be measured to fix this dimension; which would have to be done anyway, if the ceiling makeup was plaster, gypsum board, or some other material type (or if the ceiling was not flat). The engineer must be careful in his survey to measure wall-to-wall and to allow for the thickness of the floor moulding in this measurement.

The example shown in Figure K-4 shows our known field-measured dimensions. Do these make sense, and what then, are the wall thicknesses exactly? We have already measured enough of the office walls to figure that they are all about 5” in overall thickness, but we will double-check to make sure. Adding our dimensions from top to bottom of the Figure K-4 plan, 8” + 9’1” + 4’8” + 11’7” + 8’10 1/2” + 35’2 1/2” + 10”, we arrive at a grand total of 78’1”. That sounds close enough. Now, subtracting that from the 80’1” (outside) measurement, leaves us with 24” to compensate for the five inside walls. From our survey observations, we know that all wall thicknesses on that run are of uniform width. But 24 divided by 5, however, is 4.8—a figure that does not correspond to any typical fraction. What we would do here, is simply “assign” wall thickness dimensions of 5”, 4 1/2”, 5”, 4 1/2”, and 5” respectively, to those walls, to keep things as accurate as we can for our purposes in recreating an architectural plan. The fact that all of the linear dimensions now correctly total to the 80’1” known dimension gives us the confidence to continue. In the end, your prefabricated engineered piping will only fit as well as your original field survey was accurate! While we’re not trying to make a Swiss watch, we are keeping things fairly precise for our purposes. Actually, with the double-checking method, as long as you are within an inch or so of the other corresponding figure total, it’s time to move on.

The remainder of the building shall be measured as previously described, until you have the entire building dimensioned. You will notice in Figure K-3 that numerous elevations have been field measured. The office ceiling heights are duly noted. The figures that are circled in the warehouse area represent elevations that have been calibrated with the use of a fiberglass telescopic measuring tool. This is an important survey accessory that costs around $150. It stands about 5’ high, and can extend upwards to a maximum of somewhere between 20 and 35’, depending on the model purchased. If one of these is not available to you, then you will have to make your survey elevation measurements by some alternate creative means. Measuring for heights along a wall that is
close to a mezzanine or a stair is one way to accomplish this without sacrificing any accuracy at that location, provided that the mezzanine floor is close enough to the underside of the roof deck so that you can reach to measure it with one of your 8’ rulers. The method of “counting bricks” on a wall is an acceptable technique only for getting an idea of the ceiling elevation within a foot or so. But do not count bricks to ascertain any elevation used to cut piping for a fire sprinkler shop drawing.

We have determined a sufficient number of elevations in the Smith Building example survey to get a good idea of how the roof is pitched. This roof pitches down to the north end of the structure. Often, a roof will pitch down to “lowpoints” inside the building, and these are easy to spot because of the storm drainpipe running down alongside certain building columns. We need to get an exact idea of the manner of roof pitch for the entire building. This is necessary in order to set our pipe elevations at a location where the running length of piping will not interfere with anything, and also so that hangers of differing lengths may be “cut” to accurately hang the level pipe run.

**PREPARE THE DESIGN AND LAYOUT BY SURVEY**

After the initial survey work is completed, it’s back to the drafting board to make a scaled background plan. Again, 1/4” scale is recommended. Your finished plan will wind up with a “messy” look if a smaller scaled plan is used. Before your next field survey, make a blue-print of the new background plan, to be used for future field notes. You will be performing your layout design in the field, figuring routing and setting all of your piping dimensions off of wall and column lines. Most of the ductwork, lights, structural steel, and all existing obstructions will be plainly visible. Use your flash light and try not to miss anything.

You will need to determine the lead-in location for the underground pipe. That exact determination is best done while working on-site. There is a closet noted in Figure K-4 that exists on the street side of the building. This is an option. However, a more practical spot for the lead-in would be someplace in the warehouse section of the building (south end) that is close to the city water main, as this area will allow more working space for the installation of the valving, riser components, and the fire department connection. When locating the lead-in at a specific spot in any shop or warehouse, keep it away from electrical equipment. However, it is preferable to “group it” near other mechanical equipment for reasons of aesthetics. Be aware of the fact that the installation of the underground feed piping is more economical when only the excavation of earth takes place. We do not want to cross it underneath driveways or wide sidewalks, as patching is an additional expense to the overall job.

The first and most important piping to be field engineered is the main piping. This is crucial to the layout of the entire job. All cross-mains and feed-mains drawn should be dimensioned with elevations noted, off of columns and walls. We would like to minimize the amount of cross-main piping offsets. Above office ceilings or in other cramped spaces this is sometimes a very difficult goal to realize. Figure K-5 is a copy of one retrofit design in which the installation of the cross-main was going to be particularly difficult in any case, due to the lack of available space. Over a very short span, that 3” main had to be offset six times. If this is the best that can be done, so be it. There is just so much that the engineer can do to make things as amenable as possible to the installer when physical space is tight. The important thing to remember is to design the system cross-main so it is routed in locations where the hanging of the pipe will not present a major time-consuming problem. Numerous offsets are often necessary in cramped locations. Spaces in-between roof lines and drop-ceilings are typical examples of this, as are any areas loaded with mechanical equipment such as electrician’s cable trays, steam piping, HVAC exchangers, storm piping, large ductwork, and so forth. Should you have to deal with some very large HVAC equipment inside any building, the rule-of-thumb is to keep the main piping as far from that equipment as is reasonably possible.

Cross-main lengths used on the job may need to be cut down to 10’ or 10’6” lengths rather than 20’ or 21’ lengths, depending on whether or not it will be possible to transport and/or position something that long exactly where you want it to go. In certain locations it just may be that a 7’ length of pipe is the longest piece that can be installed. You will have to imagine yourself burdened with the fitter’s dilemma, and ask yourself how long a pipe piece could be, and still make for a realistic installation possibility in the desired space. Another concern is typical of a situation that arises during high-rise building retrofits: Without question, a 20’ length of pipe simply will not fit inside a freight elevator (and carrying it up the stairwell won’t work either!).

After the cross-main locations and elevations are fixed, it is time to move on to the design of the layout and routing of the branch-lines. Since you now have a scaled print, it will be wise to try and mark this print to scale in the field. Do this as you go, branch-line after branch-line. This will help you to ascertain the number of branch-lines that will be required in certain areas. Do not blindly run any lines on a retrofit project. You will need to visualize every branch-line run within the structure. This goes for all piping above ceilings! Look for obstructions. You may need to occasionally change piping elevations on the same branch-line. Be as thorough as possible, and field-design even the inspector’s test connection, drains, and the fire department connection. Situate your runs of (non-warehouse) piping in unobtrusive areas, and remember to limit the number of necessary wall penetrations. Do not concern yourself with (shop and warehouse) uniform head placement. As long as the sprinkler spacing is okay, just make certain that everything will fit reasonably well and that the number of piping offsets is kept to a minimum.
MAKE A COMPREHENSIVE EFFORT

The retrofit project design process is identical to any other fire sprinkler design project, except that most layout decision making is done in the field. The basics of design engineering still apply: determine the occupancy, establish any system divisions, check for special situations, locate hangers, size piping, complete details, size the water supply, and so on. The building construction type should be noted on the plan. The building (usually) needs to be completely sprinklered, so all concealed spaces and areas above ceilings need to be investigated—and protected in accordance with Section 5-13.1 of NFPA #13. Naturally, many more elevations and dimensions will need to be detailed on a retrofit plan. As you near the end of the job, just to make sure that you haven’t missed anything, you may want to reference this checklist:

- Show all ceiling grid lines.
- Show all lights and diffusers in concealed areas.
- Detail riser(s).
- Show unit heaters and skylights.
- Size beams and bar-joists.
- Show adequate dimensions for all piping.
- Indicate pipe elevations, especially relative to the ceiling or top of steel.
- Note hanger type, and detail any special hangers.
- Include inspector’s test connection(s).
- Make certain that pipe lengths are not too long to fit through small rooms, bar joists, or above ceilings.
- Include all required system components, such as hose stations.
- Note all headguards, check for corrosive atmospheres, check for unheated rooms.
- Make sure that all areas of occupancy that differ from the norm are properly protected.
- Include a site plan showing the fire department connection.
- Include a building cross section.
- Include heads beneath overhead garage door tracks, and ductwork in excess of 48" in width.
- Provide auxiliary drains on all “trapped” system piping, see if any floor drains are present to accept the discharge.
- Include hydraulic reference points.
- If this is a system addition, show a sufficient representation of the existing sprinkler piping to make clear the hydraulic supply situation.
- Show location of bells and spare-head cabinet.
- Include point of compass.
- Make enlarged detail for areas that include numerous offsets in a tight space.
- Complete plan notes.

If the retrofit system is dry-pipe, the principle notion to bear in mind is that all piping must be properly pitched, so allow adequate room so that the pipe can be pitched; and try to keep the number of required drains to a bare minimum. While there may not be a general contractor, job specifications, or a construction manager involved with a retrofit job, you are nonetheless responsible for code compliance and coordination with any other trades that may be present. Efforts must be made to comply with local code, and to determine the nature and adequacy of the existing water supply. In addition, a structural engineer may have to be consulted if there is the possibility that the existing structure cannot handle the additional load that the new sprinkler system will present. Indeed, his input will be essential if you encounter an instance where your only available option is to cut or core through a beam to route concealed piping.

As always, you need to check for the existence of special hazards. “Containment of hazardous and flammable chemicals—whether manufactured by themselves or as a process byproduct—is something many industrial facilities must address. During the retrofit of these facilities, an attempt must be made to identify weaknesses in design, construction, and operations and maintenance” [1]. In the course of your survey work, should you run into an occupancy that contains a lot of plastics, for instance, or a stock of small liquefied petroleum tanks, you need to consult with someone—don’t ignore it.

RECENT EXAMPLES OF RETROFIT DESIGN WORK

You are going to encounter many different structures in which the retrofit installation of sprinkler systems will be quite difficult. Hospitals, churches, residences, museums, hotels, and office buildings are typical challenges. They each have their own range of complications which we can hopefully unravel. When piping must be concealed, sometimes the only alternative is to rough the pipe in first, then add soffits, and then cut the finished drop or arm-over for the sprinklerhead. Usually, a dry system or anti-freeze loop is needed to protect the attic, or the space above the ceiling of the uppermost floor. Each separate retrofit job is obviously going to present its own separate engineering problems. A recently documented retrofit job consisted of retail space on the first two floors, with the middle seven floors destined to be a hotel, and the top three floors planned executive suites. All the rooms in the hotel and executive suites are individually shaped, fully furnished, self-contained suites with heating/air conditioning units and kitchenettes. The building is a U-shaped atrium concept with every poured-in-place support beam and column of a different depth and width. The building and subsequent additions consist of three very different construction techniques. This type construction generally presents special routing problems for the fire sprinkler piping lines. [2]

The building described above is certainly a mish-mosh, and the engineer will have to be patient enough to deal with
the lack of typical circumstances. Obviously, the quality of engineering design (and prefabrication) will directly affect the labor time on this job. As an example of a more unusual situation, a 200-year-old windmill that was deemed a historic landmark was retrofitted completely for fire protection in 1992. This tall (75’) structure was originally built in the Netherlands, disassembled and shipped in pieces, and then reassembled later on the shores of Lake Michigan.

The fire protection for this windmill consists of a dry pipe schedule system for the first through sixth levels, a deluge system of open sidewall sprinklers at the seventh level to protect the brake mechanism, and a self-contained dry powder system for the rotating dome. Much thought and care was taken to keep the piping as inconspicuous as possible. This was accomplished by using dry pendant sprinklers and running the piping next to and above the structural wooden beams. The structure, being an octagon and sloping inward at each level, made prefabrication of the piping a design challenge. However, the installation of the piping was made with a minimum of cutting on the job. [3]

So the point is, that what originally might appear to be an engineering nightmare can, with a little common sense and a lot of diligence, work out just fine for everyone involved. In the case of this windmill, the contractor “had an interesting, challenging, and unique structure in which to make a fire protection installation, and in the end, . . . was proud to have been involved in safeguarding this historic landmark for future generations to see”. [4]

***

What follows is one last engineering reminder for this chapter. Caution must be exercised when adding new sprinkler system piping on a project where some sprinklers already exist, and local code mandates a retrofit backflow preventer installation for all fire sprinkler system piping. The high pressure loss characteristic of backflow prevention devices are such that they could very well invalidate the original system’s hydraulic design. “This is especially key for property located in a low-pressure (25–40 static psi) zone” [5]. The original sprinkler system certainly was not designed with the expectation of an added pressure-restricting device in its future. “The primary design flaw of the backflow prevention device is that it appreciably restricts fluid flow, and pressure loss through the device becomes greater as demand for fluid increases. For example, in some devices, 450 gallons of water will lose 11 pounds of pressure while passing through a 4” reduced-pressure backflow preventer” [6]. Anytime that you add a backflow prevention device to a system employing existing automatic fire sprinklers, NFPA code now mandates that a hydraulic analysis be reperformed on the existing system. [6] But consider these statistics:

A survey of 178 fire chiefs in 38 states found that backflow preventers had been retroactively installed in 39% of the communities. In 32% of those communities no steps were taken to accommodate the additional friction loss. A majority of communities (57%) are likely to face this issue in the future . . . to prevent further deterioration of fire sprinkler system integrity. The future may hold many cases where fire sprinkler systems fail to control fires and the additional friction loss of a retrofitted backflow preventer is a major contributing factor! [7]

As with any endeavor, the designer gains acumen with increased experience. The more retrofit projects engineered, the easier and more smoothly they go. The key is to consider all of your options, and be flexible. Your design strategies are going to have to be more creative than normal. You will find that more sidewall sprinklers and 45° elbows will be utilized. Also, the use of fit-fittings, poz-lok connections, and other labor-saving products will be strongly considered. Dimensions on the plan, and especially elevations, need to be plentiful and accurate. The task of laying out a retrofit fire sprinkler system must be recognized as one that requires a lot of field survey time. Don’t rush it. Your job can be expressed as one that requires simultaneous designing and field-checking, and that is a time-consuming task.

CITATIONS

ENDNOTES
1 In some cases, there is also existing fire sprinkler piping to measure.
2 There is also a product called a telescoping leveling rod that is very useful in discerning the elevations of both the building structure and also future piping runs.
3 Many other examples in this text depict engineered retrofit designs, including Figures numbered B-8, B-9, C-10, D-3, D-6, D-7, D-8, D-10, D-12, E-2, E-10, E-12, F-7, and F-10.
4 If 1/4” scale is used, and all you have with you is a carpenter’s ruler, remember when making your field notes that 1” on the ruler is equivalent to 4’ on the plan.
5 In an uppermost building floor that just has a short combustible unheated space above the ceiling, rather than run an entire second
complement of piping (that would have to be dry or otherwise protected from freezing), sprigging up into that space with dry sprinklers is the smarter, easier, and more economical way to provide fire sprinkler coverage.

6 See Section 7 of NFPA #1, and Section 5-15.4.6.2 of NFPA #13.

The graph above is a generalized representation of the engineering time that will be necessary to complete working shop drawings and computer-generated hydraulic calculations for a typical 150-head automatic sprinkler system project. Specific duties are separated in chronological fashion.
The Role of Fire Pumps and Their Usage

Worldwide, fire pumps are constructed and purchased to effectively protect buildings and property from fire loss by pumping water to standpipe systems and/or automatic fire sprinkler systems. They are present in numerous buildings, new and old, to make large amounts of water available for automatic fire protection use. By pumping water at boosted pressures to standpipe systems and automatic fire suppression systems, they insure that the systems are adequately supplied for effective operation if and when the need arises to combat a fire. These systems of protection, of which fire pumps are often an integral component, automatically detect fire, sound alarms, start the automatic fire-fighting operation, and remain in operation for as long as is necessary to control, suppress, or extinguish the blaze.

Fire pumps are particular to those structures in which the existing local water supply pressure needs to be augmented when measured against the demand factors, namely, building height, size, construction type, and hazardous degree of contents. The services of a fire protection engineer are needed to make the decision regarding if, what, where, and how the fire pump will be implemented to supplement the water supply available from a public main, pressure tank, river, reservoir, gravity tank, suction tank, or well. If the existing water supply is of adequate volume, the pump may be necessary to make up for a pressure deficiency. All pumps raise the existing water supply pressure, which greatly assists the sprinkler system design technician as he goes about his task of making system pipe size determinations. In all cases, a fire pump installed along with a reliable power source and a bountiful water supply is desirable due to the hydraulic advantages of a readily available high-pressure water supply. And, the approved installation of the complete fire pump package ultimately secures lower insurance premiums for the building owner.

Five men representing various insurance companies organized the NFPA Committee on Fire Pumps in 1899. The early fire pumps were manually started. What has been long documented is the fact that the possibility of fire exists in all buildings. Without the undertaking of safe fire protection measures, all structures are at some degree of risk. Fortunately for today’s pump manufacturers, fire protection is an accepted commercial building norm in the United States, and, as a result, the market here for fire pumps continues to flourish. The rest of the world lags behind North America in fire protection acceptance. In Europe, people will routinely pay higher commercial insurance premiums in order to avoid installing fire protection: the imprudent thinking there is that fire sprinkler systems give the buyer no return on his money. Only in recent years, and primarily in Great Britain, have overseas building authorities begun to require more stringent fire protection measures for new construction. These changes have been gradual, but each code change has increased the global fire pump demand by solid and definite increments.

Fire pumps are often referred to as booster pumps because they boost the water pressure within a piping system. When asked for an example of a building that contains a fire pump, high-rises most commonly come to mind because the need for increased water pressures is evident. Contrary to the general view, these are not the only structures that are in need of fire pumps. The chief factor in ascertaining the need for a fire pump is usually the degree of the hydraulic demand of the fire protection system. Changes in the way that fire sprinklers are now manufactured have affected fire protection system design considerably over the last twenty years. Additional specialized types of fire sprinklers have been listed and introduced successfully in the marketplace over that period of time. Certain sprinkler heads have carved their own niche in the market because they have been designed to more effectively perform under different specific conditions. One example of this is the ESFR (early-suppression, fast-response) sprinkler. Subsection 5-4.6 of NFPA #13 concerns itself exclusively with requirements governing this type of fire sprinkler, which is a popular choice of protection when the building occupancy...
consists of high-piled storage of product. High-piling means high danger, exponentially more dangerous by the foot. A fire in such a warehouse develops very fast and produces accelerated heat-release rates. The ESFR sprinkler head will fuse more quickly and will deliver a heavy water discharge in order to suppress a potentially pernicious fire raging below. The larger orifice and deflector are features of the sprinkler that account for the broad spray pattern of water that is dense enough to penetrate and battle the fire. A typical water supply, however, will probably not be enough to satisfy the pressure and volume requirements for the system in which ESFR sprinklers are installed. The ESFR is one of a number of new types of “storage sprinklers” that provide a high water density for warehouse applications, but require very high end-head pressures that necessitate the presence of fire pumps to augment the systems. Increased water supply demands often mean that a fire pump package will have to be called out and specified in the preliminary stages of construction planning.

THE HORIZONTAL ELECTRIC FIRE PUMP

The most common fire pump in use is the electric-driven, horizontal shaft, single-stage, centrifugal pump. This pump type is readily arranged for automatic operation. The horizontal split-case pump is noted for its generous water passages, efficient operation, and easy access to all working parts. The water flow enters at one or both sides of a bronze disc (called the impeller) from the suction inlet in the pump’s casing. Power from an electric motor is directly transmitted to the pump through the shaft, which rotates the impeller at very high speeds. This rotation drives the water by centrifugal force to the discharge outlet. It is the action of the centrifugal force that provides the added pressure. “While centrifugal pumps remain the most common pump used for fire protection purposes, other types, such as positive displacement pumps, are also available and now addressed by the standard. In fact, Chapter 5 of NFPA 20 consists entirely of new information specifically addressing positive displacement pumps, which operate by discharging a set volume of water during each pump shaft revolution through a mechanical means, such as a piston plunger or rotary gear. Positive displacement pumps are most commonly used to pump foam concentrate into a foam system and for water mist systems that require very high pressures.” [1] Fire pumps must be directly coupled to the electric motor (or diesel engine) driver. Fire authorities around the globe do not allow anything other than a direct-drive unit. The only pumps that are allowed to be driven through a speed-increasing gearbox are the vertical turbine pumps.

VERTICAL TURBINE PUMPS

When vertical turbine fire pumps were first designed, the whole idea was to create something that would pump water from drilled wells, operating with suction lift. But because many reliable wells often contain a supply that is too small for standard fire pumps, the typical suction supplies for these pumps today are man-made reservoirs, wet pits, ponds, or underground tanks. The principle of pump operation for the vertical turbine is very similar to that of the horizontal electric, but the suction supply for the vertical turbine comes directly to the pump through a large vertical “column pipe” that is equipped with a basket suction strainer at the base. A nice feature of this pump type is that it is able to operate automatically without priming. A popular application of the vertical turbine pump today is within intermediary floors of high-rise structures, as they require minimum floor space. The water supply for these pumps comes from break tanks that are replenished from city supplies by a fill line equipped with float operated valves.

IN-LINE AND END-SUCTION PUMPS

The vertical turbine is not to be confused with the “vertical in-line” pump, which is a variant of the horizontal end suction fire pump. Both of these pumps are real space-savers, which make them ideal for retrofit applications. They are easy to maintain. Both pumps are single-suction pumps in which the (flow) suction comes in from the end. NFPA #20 defines the end suction pump as one that has its suction nozzle on the opposite side of the casing from the stuffing box and has the face of the suction nozzle perpendicular to the longitudinal axis of the shaft (see Figure 17.1). The “stuffing box” refers to the housing where the packing is “stuffed in.” The fluid flow makes a 90° radial turn through a radial vane impeller. It should be noted that for these vertical right-angle gear drive pumps, the Factory Mutual Research Corporation will not approve mechanical seal fire pumps because the seals can lock up when used infrequently. The vertical in-line, shown in Figure 17.2, has the motor placed on the pump itself. The axial motor shaft is perpendicular to the inlet. So, the suction is from the bottom, with the inlet and outlet flanges on the same linear plane, and the principle of centrifugal force still applies. The difference between the two pumps is basically the motor positioning in the mounting configuration. The
pump and impeller are aligned identically in each case. The vertical in-line fire pump is desirable for pump capacities of up to 750 GPM due to its aforementioned compactness, and its more moderate price. It requires no foundation and is very reliable. The pump motor, mounted vertically, will “float” on the in-line arrangement as it expands and contracts during operation.

DIESEL-DRIVE PUMPS

Diesel engine driven fire pumps are becoming a common choice for pumps necessary in areas that are subject to frequent power outages. These pumps should be located in a separate pump house or a pump room that is entirely cut off from the main structure and properly ventilated. Additional air flow through this room is normally required due to the radiated heat from the engine and also from the engine exhaust piping. Approved diesel engines for fire pump service have their rated hp given for a particular elevation above sea level with a corresponding ambient temperature. If the diesel driven fire pump is to be installed at a higher elevation or expected temperature, the useful power from the diesel will be less. The pump distributor must be aware of these conditions in order to allow for this reduction in useful power when selecting an engine. Other factors affecting diesel-drive pump equipment selection include fuel supply, the most reliable type of control, and the optimum starting and running operation of the diesel engine. Each engine must be provided with two storage battery units. It should be noted that each storage battery unit must now possess twice the capacity necessary to maintain the manufacturer’s recommended cranking speed (at 40°F) throughout a three-minute “attempt to start” cycle. The battery cables are to be sized expressly in accordance with the diesel manufacturer’s data sheets. Lead-acid batteries are still acceptable and widely used. The code outlines their specific recharging procedures and current output rates. Only nickel-cadmium batteries are to be used for diesel engine drive pump projects in Europe, a much more costly installation. But the (LPC) code writers there are cognizant of the fact that facility and mechanical maintenance in Europe is typically poor. Lackadaisical facility and mechanical maintenance is also not uncommon in the United States.

PUMP SELECTION

When the decision has been finalized, through careful consideration with a fire protection design engineer, to purchase a fire pump for a given facility; the first step a buyer should undertake is to contact several fire pump distributors in his area. He is going to have to be cognizant of several facts that the distributor will need to know. Of primary importance, what are the minimum volume (GPM) and pressure ratings for the desired pump? And, what options are available pertaining to the type of pump to be installed? While the distributor will certainly have his own suggestions regarding pump type, he will need to know the following information: (1) the size of the (proposed) incoming water service, (2) the suction pressure available from the existing water source, (3) the desired motor voltage of the pump motor, and (4) the desired hand, or impeller direction. This last item has to do with the pump location within the proposed piping configuration. As an example, if you are sitting on the pump motor (facing the pump), and the suction is to your left, then you will need a left-hand pump. The pump shown in the floor plan (Figure 17.3) is a left-hand pump.

The fire pump is a heavy, multicomponent piece of equipment. It will be installed during construction, but may not be put into practical use for twenty or thirty years or more. The fire pump manufacturer is responsible for providing shop-tested fire pumps that live up to the NFPA conformance standards as well as those established by Factory Mutual. To ensure that the pumps provide maximum reliability and adequate pressure and volume discharge characteristics, testing agency laboratories such as Underwriters Laboratories and Factory Mutual will have investigated the properties of these products by witnessing manufacturer’s tests and reviewing the data. These agencies have tested fire pumps for decades, ironing out many potential mechanical problems through their testing and approval processes. These necessary
steps are undertaken and carefully studied prior to the listing and acceptance of the various fire pumps that are on the market. Still, many things can go wrong during shipment or installation, such as cracked housings, snapped shafts, or seized bearings. New fire pumps shipped to a jobsite with incorrect pressures due to errors must be returned to the factory for modifications and a new label. The drives on many pumps must include anti-reverse ratchet mechanisms to guard against reverse rotation on shutdown due to water draining down the pump column. Restarting an engine during reverse rotation can result in serious damage.

Responsibility for proper maintenance of the fire pump and related equipment lies in the hands of the safety professionals. While maintenance has a lot more to do with persistence than decision making, the same level of accountability exists. Ensuring that the equipment is in proper working order, of course, is the paramount objective. Some of the more important items to check at recurring intervals would include controller alarms and lights, any battery cables (for diesel drives), any oil or coolant levels, proper functioning of relief valves, packing gland adjustment, and sufficient lubrication of the motor pump and bearings. Of peak importance, the safety engineer must make certain that the fire pump is started and tested and regular intervals. An annual test is generally recognized as the minimum fire pump test requirement.

Fire pumps come equipped with relief valves in order to minimize the possibility of pump damage due to overpressurization. “Circulation relief valves are used to prevent a fire pump from overheating when the pump is operation but no water is being discharged through the system. This is known as the churn condition. When operating in the churn condition, the temperature of the water in the fire pump continues to increase until it reaches the boiling point, causing significant pump damage. A circulation relief valve acts to discharge a small amount of water from the pump under churn conditions to prevent heat buildup. NFPA 20 has been revised to require that the circulation relief valve be installed on the discharge side of the pump before the discharge check valve.” [2]

The biggest threat to fire pump integrity occurs in instances where the unit has been off-line for an extended period of time. Inspectors have often discovered that these pumps are unable to start because they have “locked up” for any variety of reasons. The only way to avoid this calamity is through good maintenance practices and, again, by exercising the pump unit at regular intervals. It is important to recognize that ignoring proper maintenance can potentially lead to trouble. NFPA #25 recommends that electric motor driven pumps be run for a minimum of ten minutes every week (30 minutes per week for diesel engine driven units). It also states that a Preventative Maintenance Program be established on all components of the fire pump assembly. Recommended testing, inspection, and maintenance parameters for pumps are also outlined in Chapter 11 of NFPA #20. The NFPSA also has a booklet on these start-up performance requirements, acceptance testing, and operation methods.

ENERGY FOR START-UP AND OPERATION

The fire pump controller is a listed device that is completely wired, assembled, and tested prior to shipment. It must be situated within sight of the pump motor, but not so close as to “borrow trouble” by inviting the danger of escaping water from the pump relief valves, fitting connections, or system drains. Among the controller’s many required features are the motor starter, external disconnect switch, a circuit breaker, alarm relay (through an independent power source), and a pressure switch that is manually set to cut in and out at pressure settings determined in the field prior to acceptance testing (more on that later). NFPA-conforming controllers must have a manual start. This starter must be able to operate without any other device necessarily actuating. For all fire pump installations, controllers are also normally wired for manual shutdown. In every case, careful consideration must be given to the dependability of the project wiring system and the property’s electrical supply to ensure a safe amperage draw. The electrical contractor must verify that the entire arrangement is in proper working order at the time of start-up.

Fire pump controllers that comprise a complete fire pump control system are constructed for use in commercial and industrial applications, as well as for high-rise residential buildings. “The full voltage or across-the-line controller is the most economical of the starting methods. This type controller and starting method is the most simple in design and is the most widely used. When the controller receives a call to start, it engages the starting contractor for full voltage starting and a full design torque. The disadvantage to this type starting is the high demand placed on the electrical service. The electrical service shall be adequate enough to withstand approximately 600% of full load current without causing the voltage to drop below 85% of rated voltage.” [3]

The 50/60 Hertz operation relates to motor running speed. This is of importance because faster running speeds mean smaller pump equipment packages. And, of course, the size of the pump equipment directly relates to the price of the pump. Electrical power supplies worldwide are roughly 33% 60-hertz and 67% 50-hertz. The 50-cycle supply is the norm in many countries. The most popular speeds employed (but not all) are 1450 and 2900 rpm for 50-hz, and 1750 and 3500 rpm for 60-hz. If a high power supply is needed for very high speed pumps but is unavailable, the usual avenue to then pursue is to consider a diesel-drive pump installation (if permissible by local EPA authorities). Under the NFPA codes, the electrical power must be sufficient to cover the total predicted flow condition (end of the pump performance curve).

THE CODES

Fire pumps are manufactured in accordance with the requirements of U.L. and F.M., and are in compliance with NFPA #20: Installation of Centrifugal Fire Pumps. European
fire pumps of similar capacities are much less expensive to purchase because of the looser requirements of the Loss Prevention Council (LPC), as compared to those of NFPA. The LPC is an outgrowth of the FOC, a group of insurance companies that issued fire protection rules and regulations. That was disbanded in 1993 so that a larger, single incorporated standard could be established.

The latest (1999) revised edition of NFPA #20 contains many revisions to the code, particularly in Chapters 2, 6, and 7. To the great relief of loyal readers of this pamphlet, the section reference numbers have been kept more or less constant for many years, thus eliminating the frustrating cross-referencing headaches one encounters, for example, when attempting to accomplish the same with different editions of NFPA #13. The latest version of NFPA 20 now requires that all electric motors for fire pumps be specifically listed for fire pump service. Section 2-9.6, concerned with installation, specifies that the suction piping for the pump be laid out below or at the plane of pump intake so that no air pockets will form. These will cause cavitation, a condition whereby air that repeatedly enters the pump casing area will eventually cause mechanical operative damage to the pump and motor. (This is a simplified explanation of what is really a very complex phenomena, but suffice it to say that whatever the causal intricacies, the resulting condition of vapor pockets in liquid flowing through the impeller that collapse with a water hammer effect is known as cavitation). Horizontal centrifugal pumps are particularly susceptible to cavitation. If the cavitation is severe, the inevitable result is pump failure if that condition goes on undetected, ignored, or otherwise not corrected. The eccentric tapered reducer shown in Figure 17.4 has been installed in such a way as to avoid any air pockets developing in the supply piping.

Section 2-9.9 in NFPA #20 warns against placing any device in the suction piping that may restrict the fire pump discharge flow, leading directly to cavitation because pockets of vapor will form in the volute casing when decreased pressure there falls below the pressure corresponding to liquid temperature. NFPA authorities are wisely encouraging the placement of pressure-restricting devices after the pump discharge rather than before it, to avoid this occurrence. However, this section now includes the following under “Exception No. 2” which reads: “backflow prevention devices and assemblies shall be permitted where required by . . . the authority having jurisdiction.” Exception No. 3 allows for suction pressure sensitive flow control valves to be installed in the suction piping, presumably to be installed in conjunction with a backflow preventer or other such pressure-restricting devices. Further on, under Section 2-21, the standard mandates that when backflow preventers are situated upstream of the pump, it must be by a minimum of ten pipe diameters from pump suction and, that under these circumstances, the final pump performance will not experience a negative suction pressure read at 150% of rated capacity discharge. Obviously, the pump’s factory certified performance test data curve (a hydraulic performance curve) is going to vary when compared to the field performance curve plotted at start-up, when a pressure-restricting device is thrown into the whole mix.

CODE INTERPRETATIONS

The Wausau Insurance Company’s Interpretive Guide summarizes their own additions and exceptions to NFPA #20. Specifically, under 1-2.1 (Purpose): “All fire pump installations shall be designed by an individual NICET certified Level III or IV in Water-Based Fire Protection Systems Layout.” Moving on, under 2-1.2 (Water Sources): “Limit suction pressure in the underground supply main to a minimum 20 psi unless local purveyor allows less.” NFPA #20 (2-19) notes that the discharging pressure of jockey pumps shall be “sufficient to maintain the desired fire protection system pressure.” The Wausau official interpretation of this reads “jockey pumps shall maintain fire pump churn pressure plus any static supply pressure.” These and other notations in general clue the reader to the insurance company’s consideration of NFPA #20 as a minimum standard. Indeed, the Wausau guide also makes the statement that for their clientele, a “should” in NFPA #20 always means “shall.”

Other HPR carriers, notably FM, IRI, CIGNA, Travelers, Kemper, and others, also have their own engineering guidelines. Their guidelines for engineers also include amendments relative to the requirements of NFPA #20. Many require a bypass to be provided for all fire pumps, and a minimum distance of ten times the pipe diameter between the pump suction flange and any directional change fitting. (If that requirement seems a little unrealistic to you, that’s because you are probably acknowledging real-world conditions). On the same note, they disallow the installation of closed-loop flow meter test arrangements, which are allowed by NFPA #20 under Section 2-14.2. The central reason for this is that the closed-loop flow meters have a tendency (especially over time and for larger capacity pumps) to provide inaccurate flow-test readings.

FIELD ENGINEERING CONCERNS

Fire pump systems that are started by pressure drops are generally systematized by setting the fire pump start point
manually at 5 psi less than the jockey pump start point setting. The first settings made in the field, however, are the jockey stop and the fire pump stop points, which should equal approximately the fire pump shut-off pressure plus the minimum static suction pressure. The jockey pump (cut-in) start point is normally set 10 psi less than the (cut-out) stop point. It should be determined initially that the pump is primed and the casing is full of water. After starting the pump, bearings should be scrutinized for signs of overheating. Proper alignment should be observed, and the foundation bolts should be checked for tightness. Any "knocking" heard from the pump or fluctuating reads on the pressure gauges may indicate problems with the suction intake.

SIZE AND SAFETY

Selection and determination of fire pump capacity is performed by fire protection design engineers usually using their own experience and empirical guesswork. They also take into account the input of the local authority and the insurance company engineer. For a given demand, the pump size can be selected by dividing the total suppression system demand (including the hose allotment) by 1.5 and then selecting the next largest available pump size. This is the usual cost-effective method undertaken. Generally speaking, listed pump capacities will be any of the following GPM: 25, 50, 75, 100, 150, 250, 300, 400, 450, 500, 750, 1000, 1250, 1500, 2000, 2500, 3000, 4000, or 5000. Returning again to the Wausau Interpretive Guide (2-1.2): “Select the fire pump based on the total required fire protection systems demand. In no case shall the total demand exceed 120% of the rated fire pump capacity. Total demand will always include ceiling sprinklers, in-rack sprinklers and inside hose and may also include outside hose.” This is typical of most insurance carriers—not just Wausau. In fact, some carriers require the total demand not to exceed 100% or 110% maximum. It is important to bear in mind that on a typical project, Section 7-2.3.1.3 of NFPA #13 reads that “where pumps, gravity tanks, or pressure tanks supply sprinklers only, requirements for inside and outside hose need not be considered in determining the size of such pumps or tanks.”

If an additional safety factor is required, or when a number of standpipes are present, it may be desirable to increase pump capacity. It is the responsibility of the design engineer to ultimately plot the combined public water supply and pump curves against the system demand on N1.85 graph paper. For proper pump sizing to be verified, he has two conditions to check: first, that the churn point (0% rated flow) combined with the suction static psi does not have a total pressure in excess of the working pressure of the system; and second, that the 150% rated capacity design point does not draw the suction pressure to a (psi) point low enough that full pump operation may actually run the risk of collapsing city water mains. If either of these conditions present themselves, an alternative pump design is usually available.

The need to combat fires aggressively is a staple of the very noble goal of maintaining life, property, and the continuation of business enterprise. In consideration of today’s skyrocketing property values and expanding businesses, complete fire suppression systems augmented by properly designed fire pump packages are a necessity to achieve total security throughout the industrial environment of larger buildings, warehouses, and other more hazardous occupancies. The potential for large fires pose the primary danger for which all fire protection professionals must be concerned.

CITATIONS

Basics of Fire Pump Layout

It is not the intent of this chapter to investigate every type of fire pump and automatic controller, the intricacies of pump gauges, relief valves and other trim components, nor the importance of proper maintenance of fire pumps. Rather, we will direct the focus to the designer’s task of engineering proper fire pump layouts for automatic fire sprinkler systems. From job to job, this engineering is rarely typical. It would be unusual to be able to simply trace your fire pump layout from the last job, and have the replication work for the present project. The design must be tailored efficiently, and with precision, and in accordance with the requirements presented by each separate project.

Requirements governing the design and installation of fire pumps are contained in NFPA Pamphlet #20: “Centrifugal Fire Pumps.” A centrifugal pump is defined as one in which the action of centrifugal force provides the added pressure. There are other NFPA standards containing advisory information on fire pumps, and these include NFPA #13, NFPA #14, NFPA #22, NFPA #15, NFPA #16, and NFPA #24. Laying out a fire pump along with its accompanying bypass configuration becomes much easier with increased experience, but it is not a simple task. The NFPA #20 Interpretive Guide published by Wausau Insurance requires that the individual designing any fire pump installation be certified by NICET in automatic sprinkler system layout, at either level III or level IV.

The purpose of a fire pump is to supplement the available water source used for the automatic fire sprinkler system supply by adding pressure to the system water. While the supply normally will be a city water main, it can also be a reservoir, river, pond, tank, or well. The major component of a centrifugal fire pump is the impeller. Inside the pump casing, the impeller is rotated at a very high speed, driven through the pump shaft by power from the electric motor (or diesel engine). The larger the impeller diameter, the greater the rated speed. This operation can also be termed as the conversion of kinetic energy to velocity and pressure energy. Two (or more) self-contained impellers may be part of the interior pump component assembly for fire pumps that must deliver higher pressures.

The fire pump manufacturer is responsible for providing shop tested fire pumps that live up to the NFPA conformance standards. To insure that the pumps provide maximum reliability and adequate pressure and volume discharge characteristics, testing agency laboratories such as Underwriters Laboratories and Factory Mutual will have investigated the properties of these products by witnessing manufacturer tests and reviewing the data. These necessary steps are undertaken and carefully studied, prior to the listing and approval of the various fire pumps that are on the market.

PROPER PROXIMITY OF THE PUMP

Section 2-7 of NFPA #20 (1999 edition) talks specifically about “equipment protection.” Fire pumps should be housed in separate, heated, non-combustible, sprinklered, fire pump rooms or small buildings. Proper ventilation and adequate floor drainage must be provided for these areas. NFPA #20 mandates a minimum clearance of one inch around pipe that passes through the walls or ceilings of this room. The fire pump room also should be located as closely as possible to the areas where fire protection is most imperative. Some insurance companies require an outside access to the fire pump room. Of utmost concern would be any history of power outages that may be unique to a certain property. Since the fire protection system(s) design would be immediately invalidated by a power outage, steps must be taken to investigate this thoroughly. A wise building owner, and certainly his insurance carrier, will be quick to spearhead such an investigation.
All standard fire pump design requirements are noted in NFPA #20. Chapter 2 of this pamphlet, while not long in length, is heavy in content, and should be read and re-read thoroughly before designing any fire pump installation. It fortunately is quite clear-cut in terms of establishing its requirements.

As mentioned in the previous chapter, the suction piping for the pump, in accordance with Section 2-9.6 of NFPA #20, must be laid out (below or at the plane of pump intake) so that no air pockets will form. These will cause cavitation, a condition whereby air that frequently enters the pump casing area can eventually cause mechanical operative damage to the pump and motor. (Another drawback of cavitation is that no air pockets will form. These will cause loosening to an elevation of 2’0” above the pump room floor, and then drops to an elevation of 2’0” before supplying the fire pump; then an air pocket will certainly develop in the upper corner of the highest elbow when the pump is in operation at high speed. Of course, this piping configuration is to be avoided. If it cannot be avoided, there is then no remedy for the situation. One possible alternative, though, is to install a small manual air release valve on the top of the previously described elbow (also, on the top of the 8” grooved elbow in the suction piping as depicted in Figure K-7). Hopefully, a building engineer who is alert to the predicament could periodically open that valve to bleed off the air manually, until the water squirts out. As this concept involves suction piping, you should make every attempt to design the installation so that a straight run of suction piping (a distance of at least five times the suction pipe diameter), be in place between the pump suction flange and any elbow or directional change tee. If this is “impossible” to do, it is advisable to install a flanged spool of some length to affix on to the pump suction flange. This not only wards off the chance of cavitation, but improves the fluid flow and gives you the increased probability of passing the acceptance test of the installed pump.

WHAT THE CODE DICTATES

In accordance with NFPA #20, a backflow prevention device should not be installed in the suction piping in order to avoid possible cavitation. Also, it stands to reason that due to the number of check valves present in a fire pump and bypass layout, the need for additional backflow prevention is not of paramount concern here. Section A-2-9.9 of this code reads, in part, that “due to the pressure losses and the potential for interruption of the flow to the fire protection systems, the use of backflow prevention devices is discouraged in fire pump piping. Where required, however, the placement of such a device on the discharge side of the pump is to ensure acceptable flow conditions to the pump suction. It is more efficient to lose the pressure after the pump has boosted it, rather than before the pump has boosted it.”

Butterfly valves in the suction piping are also prohibited, as they can cause excess noise and turbulence. However, Section 2-9.5 allows for the use of butterfly valves in suction piping provided that they are not situated within 50 feet of the pump suction flange. NFPA #20 also recommends that the city water supply gate valve be located as far as practical from the fire pump suction flange.

A listed check valve must be installed close to the pump discharge. This enables pump pressure to be locked into the fire protection system(s). A gate valve must be installed following that check valve. This valve must not be omitted. It is in place so that it can be shut while someone is working on the fire pump, then the pump bypass can still be in service to feed the sprinkler system while pump maintenance is taking place.

Two and one-half inch hose valves are used when fire pumps (of 150 gpm or greater capacity) are tested. The point of the fire pump test, in addition to checking the power supply function, checking the adequacy of the pump suction, and verifying the smooth operation of the entire apparatus; is to validate that the fire pump can indeed deliver a minimum volume of 150% of its rated capacity. (The 150% requirement represents a built-in safety factor of the product.) The number of 2 1/2” hose valves to be included on the pump test header depends, naturally, on the rated pump capacity (see Table 2-20 in NFPA #20). For example (see Figure K-8), six 2 1/2” valves are required in a 1500 gpm pump installation.

Table 2-20 is referred to often by the designer, although the suction and discharge flange sizes are not always adhered to by the fire pump manufacturers. However, this (Figure K-8) information is nonetheless a valuable reference for our design purposes. Note that the pipe sizing for the hose header (test) supply must be increased is situations where long runs of piping will connect the installed pump test header with the fire pump assembly.

The data sheets of many pump manufacturers refer to “head in feet.” Head in feet is determined by dividing psi by 0.433 factor. So, conversely, head in feet multiplied by 0.433 is equivalent to the pump pressure rating in psi.

The fire pump controller shall be a listed device. It is completely wired, assembled, and tested prior to shipment. It must be situated within sight of the pump motor, but not so close as to “borrow trouble” by inviting the danger of escaping water from the pump valves, connections, or system drains. Among the controller’s many features are the motor starter, external disconnect switch, a circuit breaker, alarm relay (through an independent power source), and a pressure switch that is manually set to cut in and out at psi settings determined in the field prior to the final acceptance test. They are normally wired for manual shutdown in all fire pump installations. In every case, careful consideration must be given to the dependability of the project wiring system and the property’s electrical supply, to insure a safe amperage draw.
FIRE ALARM CONTROL PANELS

Since we’re on the subject of electrical control equipment, we will briefly discuss the operation of the fire alarm control panel, which is typical to all fire sprinkler system installations. In general, all fire protection electrical devices will be tied in to a central (or remote) alarm station and the local fire department, by signals that are transmitted through a multi-zone fire alarm control panel. Inside the door of this panel will be listed information such as the phone number of whatever company monitors the property, and an account number for the property. As most panels are of a “dual-connect” nature, the panel information will also tell you if the signal goes to the police department or the fire department.

The fire department will receive just one signal, signifying either “fire” or “trouble.” The “trouble” signal may even be a burglar alarm notification. An example of a “fire” signal would be flow switch activation. There is a pressure switch in the discharge line of the pump that is activated by the increase in pressure when the fire pump starts to run. This causes the panel to transmit the “pump running” zone signal. While the fire department receives a “fire” signal in either case; the central station would receive the “waterflow” signal and the “pump running” signal separately, and their communication system would record the exact times when these signals were received.

Examples of “trouble” signals would include “tamper switch,” “low building temperature,” “low power” (to an electric fire pump), and “low water supply.” The “fire” signals are primary, and the “trouble” signals are secondary. As an illustration, let’s suppose that you inserted a dollar into a Wurlitzer jukebox. With this dollar, you could play six 45 rpm records from the following selections:

001—Heat Wave Linda Ronstadt
003—Disco Inferno The Trammps
005—We Didn’t Start the Fire Billy Joel
007—Smoke Gets in Your Eyes The Platters
009—Great Balls of Fire Jerry Lee Lewis
011—I Wish It Would Rain The Platters
013—Light My Fire The Doors
015—Before the Deluge Jackson Browne
017—Smoke on the Water Deep Purple
019—Fire and Rain James Taylor
021—Jumpin’ Jack Flash The Rolling Stones
023—When You’re Hot, You’re Hot Jerry Reed

You could make the casual observation that this jukebox parallels the rudimentary make-up of a twelve-zone alarm panel. Let’s suppose that you make, in order, the following selections: 007, 003, 001, 015, 011, and 009. A Wurlitzer jukebox would play your selections in the order that they were signaled in. But a fire alarm control panel, specially programmed for detection and notification, does not necessarily transmit data in the same fashion. Let’s assume that a monitoring station representative is at work one day when a fire breaks out in the Smith Building. He may receive the following signals:

1:31 P.M. Smoke Detector (2nd Floor Balcony) Zone 7
1:33 P.M. Water Flow Indicator Zone 1
1:33 P.M. Pump Running Zone 3
1:45 P.M. Pull Station (Warehouse Receiving) Zone 15
1:47 P.M. Smoke Detector (Duct Air Return) Zone 11
3:06 P.M. Valve Position Indicator (Tamper Sw.) Zone 9

In a fire, the smoke detector close to the fire usually activates first. Both the fire department and the central station receive this signal. The central station receives all signals as they come in, from the alarm panel. There may be some delay—but with the newer, technologically advanced control panels and equipment, the signals take just seconds to arrive on a direct connect.

What the central station receives is dependent on how the programming is set up on the fire alarm control panel. Notice that the central station received the water flow (zone 1) signal second, and then the pump running (zone 3) signal; even though the second signal received by the alarm panel was actually “pump running.” This happened because the water flow (fire) primary signal took precedence over the secondary “pump running” signal.3

In this example, the central station noted the time when a firefighter closed a control valve (3:06 P.M.) to limit the degree of water damage, after the fire had been safely controlled. The central station will also record the time that the various zones are restored on the panel.

As another example, let’s suppose that some arsonist was paid to start a fire at, let’s say, a race track. After starting the blaze and before leaving the building, he notices that the building is equipped with automatic sprinklers. He thenlocates the control valves for the sprinkler system and closes them just as the flow switch in the riser (monitoring water flow) signals the increased flow. Seconds later, a second flow switch (that was installed to sub-divide the system) in a cross-main 500’ away signals “fire” in that zone as well. The fire alarm control panel would notify and the central station of the two “fire” signals immediately, as they would automatically take precedence over the tamper switch “trouble” signal. The central station would also know instantly of the locations of the flow switch zones that were activated. The fire department would receive just one signal: “fire.”

Of course, there are other signals that the alarm panel will sometimes transmit to the central station. These are less often utilized, about equivalent in frequency to a “B” side selection made on the juke-box. Let’s suppose that for a quarter you had one selection and picked song 006 (the flip side of 005) on the jukebox. While not an actual zone, that selection could correspond to one of the “buttons” that are integral to
the control panel for less-important signals such as system reset, city disconnect, or alarm silence. These are usually used when the alarm system is being tested, and the monitoring station should receive a phone call from someone prior to any testing—letting them know that they are temporarily taking the panel out of service.

Frequently with alarm systems, problems can occur. They are not fail-safe systems. Any fault or problem that exists in a fire alarm system that prevents detection of a dangerous condition is referred to as “Failure to Alarm.” Conversely, and of equal annoyance, an alarm signal that does not represent a dangerous or unwanted condition is called a “False Alarm.” This is caused either by some fault in the system, subscriber error, or by telephone line problems.

FIRE PUMP PERFORMANCE CURVES

Returning to the main topic of engineering design, Figure K-6 depicts two standard head discharge curves. There are three limiting points that determine the shapes of these curves: shutoff, rating, and overload. Depending on the requirements of the testing agency laboratory, the total head (in psi) of a centrifugal pump at shutoff shall not exceed 120 or 140% of the rated head at 100% capacity with the discharging valve(s) closed. This does not mean that the pump has been manufactured to deliver 120% or 140% of the rated head, it simply cannot exceed this figure. The total head in psi at shutoff is typically 120% of the pump’s psi rating, and is commonly called the “churn” rating. You may want to contact the manufacturer to find out what the churn rating actually is for a particular pump model. In some cases the churn rating is no higher than the rated head at the rated flow. On the other hand, diesel driven pumps typically have a churn rating of 140%.

In the case of curve #1 in our Figure K-6 example, the churn rating is plotted as 84 psi for a 750 gpm pump rated at 70 psi. Curve #2, representative of a 1000 gpm at 50 psi fire pump manufactured also to deliver 120% of the rated head at churn, is plotted with a churn rating of 60 psi at 0 flow, or shutoff.

The second curve point to be noted when establishing the fire pump curve is rating, which is a known point that is easy to plot. Obviously, this point on curve #2 would be the conjunction of those points representing 1000 gpm and 50 psi. All fire pumps must furnish not less than 150% of rated capacity at not less than 65% of total rated head; this in accordance with NFPA #20 (3-2.1) and BOCA (F-514.2) requirements. The overload point then, for curve #2 in the example, would be noted at 32 1/2 psi (65% of 50 psi) with respect to the point corresponding to 1500 gpm (150% of rated capacity) on the discharge curve. The actual pump discharge curve supplied by the pump manufacturer may also show a “break” point on the curve just beyond overload. Referencing Figure K-6 once again, the overload point for the curve #1 (750 gpm at 70 psi) fire pump curve would be (750 × 1.5) 1125 gpm at 45 1/2 psi (65% of 70 psi).

SIZING THE FIRE PUMP

Sometimes the gpm capacity required of a newly installed fire pump is determined by the number of standpipes in the building. In general, standpipes are situated in stairwells, within 100’ of an outside wall, and all no more than 200’ apart. When any number of standpipes are present, 500 gpm is allotted for the first standpipe, and 250 gpm for each standpipe thereafter. So, supposing that a building contains a total of three standpipes, it is safe to assume that the authority having jurisdiction will require a 1000 gpm rated capacity pump.

For the hypothetical Smith Building, we are going to assume that a fire pump will be required due to design demand. There are no standpipes in the building, our aim is simply to boost the volume and pressure supplied by the city water main. This main has already been flow tested with the following results: 55 static psi, and 25 residual psi with 1100 gpm flowing. This flow test “curve” is plotted in Figure K-6. As a designer, which fire pump would you recommend, presented with only the two choices (750 gpm at 70 psi, 1000 gpm at 50 psi) shown? This actual pump capacity recommendation would depend on many factors, one of the most important being the building use occupancy, which directly impacts the outcome of your hydraulic calculation and determines worst-case system demand. But the answer to the question is really a no-brainer: because the (curve #2) 1000 gpm fire pump would be completely unacceptable in this case. This unacceptability is evident because of the inherent danger of collapsing the city water main when that pump strives to deliver 150% of the rated capacity (see Figure K-6), which all pumps are designed to do at a minimum. In other words, when the pump suction approaches pulling 1500 gpm from the city water supply, the city pressure (residual psi) will drop to a level below 5 psi, and most likely would NOT be able to deliver the 1500 gpm, exhausting the underground main. If the city water main were to collapse at this point, our city water supply would instantly become no supply at all. The pump bypass would be of no use, and the fire sprinkler systems would have no water to discharge until the fire department connection was charged. Therefore, in this scenario, a 750 gpm fire pump would be the largest capacity pump that you would recommend.

Choosing the 750 gpm pump for installation at the Smith Building project, the curve of an actual available water supply would be determined by adding an accurate curve depicting the water flow test results at the jobsite, to the manufacturer’s factory-tested pump discharge curve. This assumes, of course, that there is sufficient correlation between factory tests and field performance of the pump. In the Figure K-6 example, we would add the (“curve #1” and “flow test”) points of 84 and 55 psi, to establish a new point of 139 psi at 0 flow.

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Similarly, we could add 70 and (most closely) 40 psi to reach a (total) point of 110 psi at a flow of 750 gpm. For a third point we could add (most closely) 48 and 25 psi to establish the (total) point of 73 psi at 1100 gpm flow. Connecting those three points would roughly give us a graphic curve of the total available supply with the pump in operation. To plot a more accurate available water supply curve, we would add additional correlating points of both the water flow test and pump performance curves. As always, the curves are plotted on \( N^{1.85} \) hydraulic graph paper.

**DETAILING THE PUMP PLAN**

Look once again at the Figure K-7 example. At the upper left of this depiction is a jockey pump. The pressure and volume rating of the typically installed jockey pump is about equal to the demand of one discharging sprinkler-head, although that is not the function of the jockey. The job of the jockey pump is to maintain the boosted system water pressure, to keep up with the fluctuations caused by small pressure leaks. Were it not for the jockey pump, the small system pressure drops that periodically occur (falling below the controller’s cut-in psi setting) would cause the fire pump to have to start and stop in numerous instances over time, when there was no fire. For this reason, jockey pumps are commonly installed in congruence with fire pumps. The associated jockey pump piping and trim is field installed. No real design work is involved here except finding a location for the jockey and noting that on your plan.

The city water supply gate valves and metering device for the Figure K-7 pump room example are located some distance away from the fire pump. If we count the two gate valves situated at the unseen incoming water supply header, we arrive at a total of seven required gate valves (including the sprinkler system gate valve at the base of the riser) for this installation. This is typical. Note that two check valves are required: one in the pump discharge piping, and one in the bypass. The installed pump is to be a “right-hand” pump. We know this to be a fact, because if you are figuratively sitting on the motor (facing the pump), and the suction is coming from your right, then you’ve got to order a right-hand pump from the manufacturer. An example of a designed fire pump layout requiring a “left-hand” pump is depicted in Figure K-19.

The fire pump bypass need not always be laid out on the floor. Figures K-9, K-10, and K-11 are corresponding plan depictions of a fire pump layout design with the bypass run overhead of the pump itself. As you can see by the plan shown (Figure K-11), this design method considerably conserves floor space. The abbreviation L-H on this plan refers to the fact that we are designing for a left-hand pump, and the F.D. notation simply shows existing floor drain locations. There are two things wrong with this (Figure K-11) installation, both previously discussed and both, unfortunately, unavoidable. First of all, this is a basement installation and the pump suction elevation falls below that of the incoming water supply. Hopefully, the domestic piping that draws supply from the \( 8 \times 3 \times 6 \) flanged tee will be something that sufficiently limits the amount of accumulated air in that tee. Second, local authorities mandated the inclusion of a backflow preventer in the pump suction piping. Their hands were tied, they claimed, by local code. Since they were not of sound mind to waive the code in this instance, the backflow prevention device had to be installed as shown (to guarantee receipt of an occupancy permit for this new building). As a prudent design alternative, this backflow preventer could be placed in the pump bypass (so the pump would suffer no ill effects), a proposal that unfortunately did not meet with local criteria for approval.

As a general rule, a minimum of 1/2” scale should be used to detail the fire pump and bypass layout, with at least two separate views. This 1/2” scale has been used in the example shown in Figures K-12 through K-14, depicting both a plan view and an elevation. The bypass is not shown in the (Figure K-14) elevation section; but the 6” line to the test header is shown, running above the fire pump at a 6’4” centerline elevation above the floor.

**INSTALLATION CONSIDERATIONS**

On all jobs, the size of the fire pump room is important, and normally a room sized to about 12’ \( \times \) 20’ is adequate. As you can see in Figure K-12, this pump room is slightly smaller than that. It is of due importance to include automatic sprinkler protection inside the pump room, but it’s not necessary to show that piping on your pump layout details. That pipe will be shown on the sprinkler plan itself. Also, although these examples vaguely note the routing of jockey pump supply and discharge lines, and the (brass) sensing lines, these are not really critical additions to the pump plan. As previously stated, that piping represents field-engineered piping that the installers will route as they see fit to do. What is very necessary is a clearly delineated layout, complete with dimensions and accurate spool lengths. Remember to keep in mind that many small gasket separations between flanges can eventually add up to an inch or so.

The Figure K-14 example shows an elevation of 2’1” to the centerline of the first flanged elbow. Being of new construction, the pump layout was originally drawn before the underground feed pipe was stubbed in, and the plumbing contractor tried to install this so that the 8’ flanged-spigot piece would be set in place 12’ above the (future) poured floor. He was close. It actually wound up at an elevation of about 16’ above the finished floor. That was okay, but as you can see on Figure K-12 the vertical feed wound up being fixed too close to the wall shown at the bottom of the plan. Whatever the circumstances, the engineer must always reserve the time for a return trip to the jobsite on a new construction project, to field-measure the incoming water location.
He can then proceed to make the final necessary plan adjustments.

Figures K-15 through K-17 are shown to depict an already existing fire pump, which is being retrofitted to add a pump bypass and relocate a fire department connection inlet. This entire plan layout is shown on Figure K-15 with the explanatory plan notes shown on Figure K-17. Figure K-16, drawn to 1/2” scale, shows an elevation in the pump discharge where a 10’ drop will feed an underground loop servicing several buildings. Here you can see why the fire department connection inlet needed to be relocated. Under the old setup, a closed valve (the one marked “1” on Figure K-16) would block any attempted hydrant feed to the underground loop through the fire department connection. The existing 4” inlet was functional but not properly positioned: one of the chief purposes of the fire department connection is to serve as a secondary water source (in an actual fire) in the case of accidental valve closure. The new inlet location, as shown, configures the piping to guarantee that intention.

Figures K-15 through K-17 depict a right-hand diesel engine driven fire pump installation. Regulations governing diesel drive pumps are outlined in Chapter 8 of NFPA #20. The pump room will contain the diesel engine driven pump and a stock of fuel. It must be suitably cut off from the main building, by fire separation. Sections 8-3 and 8-4 of NFPA #20 include general requirements for construction of the pump room and the fuel supply that it contains. Note that the 4” discharge line for the relief valve (in Figure K-15) is sized in accordance with Table 2-20 of NFPA #20 (see Figure K-8) for 1000 gpm pumps. All requirements governing the installation of relief valves are outlined in Section 2-13 of NFPA #20. Relief valves are required on the discharge of diesel engine driven pumps, as they are liable to over-pressure.

Figures K-15 and K-16 are not true shop drawings as they appear, because the pipe lengths for the flanged spools need to be pre-cut before the foreman can schedule a day to have the new bypass piping installed. You will also notice in this example an absence of dimensions, and this is because most of the piping and components are already in place. Note that the new bypass includes a check valve and (two) O, S, and Y gate valves. This is in accordance with Figure A-2.9.4 of NFPA #20. Should this diesel drive pump somehow fail to operate, it would become a definite impediment to the firefighting capability of the water supply. Since existing city water pressure is sufficiently strong, the addition of the new bypass makes good sense.

The Figure K-19 example is representative of a building, containing an existing 8” fire sprinkler system, that experiences a tenant change to a higher-hazard occupancy; and thus necessitating a retrofit fire pump installation. While the 8” supply header and 8” system riser will remain in place, the new fire pump (and bypass) are being added to boost system water pressure to satisfy the (new) higher required sprinkler system design criteria.

FIRE PUMP TESTING APPARATUS

Currently, it is usually required that the hose header for pump testing be an “outside” hose header, mounted on an outside wall as shown on Figure K-14 and (inferred) on Figure K-9. The practice of installing inside hose headers (as in Figure K-16) was once so prevalent that fire pump companies manufactured a large cast-iron contraption called an “inside hose header.” This was placed after the check valve on the pump discharge, and came equipped with an abundance of flanges and outlets, making it look like some kind of large fluid strainer.

The hose header (Figure K-16) for pump testing is located right inside the pump room. In this case, only about 15’ of hose (for each 2 1/2” valve) would be laid inside the pump room during a test of the fire pump. After the 15’, this hose run is out the door where the water discharge can be measured for flow. Prior to pump testing, the 8” O, S, and Y valve marked “1” as well as the 8” O, S, and Y valves marked “19” will be closed. There are instances where it will not be convenient to run future pump tests on the installed equipment because of their proximity inside the building. The fire pump may be earmarked for a location that is just too far away from an outside wall. Figure K-18 shows an installation in which a flow meter has been installed in the fire pump layout piping for measuring water flow during fire pump tests. NFPA #20 regulations governing flow meters are noted in Section 2-14.2. The use of a flow metering system to test pumps will conserve water use. More importantly, it is a fairly easy operation and eliminates either the expense of hiring someone to conduct the entire test or your own considerable time and effort, consisting of hose setup, testing, teardown, field report preparation, and so on.

If you are able to understand the Figure K-18 example, then we can conclude this chapter. The pump and layout shown is not a generic case. For one thing, it contains both a conventional hose header and the material means by which to test the pump discharge with an installed flow meter. The annubar flow sensor shown in the pump bypass will average velocity pressures that it senses, as well as detected downstream pressure, and send this information through an instrument line to a listed and readable flow meter. The annubar sensor must be situated in a straight pipe run, the exact length of which is noted specifically in the manufacturer’s data sheets. The exact positioning of the annubar in this straight pipe run is also critical to accurate meter performance. Typically, the downstream pipe portion will be shorter in length.

You will have to study Figure K-18 to understand this flow meter testing operation. Notice that the 4” O, S, and Y valve marked “c” is usually kept shut (it’s not part of the actual, true pump bypass). Now if the electrical power to the pump should fail, water to a fire area will first flow around the regularly laid out bypass in a clockwise rotation for this example. However, for pump testing when using the flow meter, the “c” valve is opened and the (three) “x” valves are closed. The
flow of water during that pump test will move in a counterclockwise rotation around the (slightly larger) improvised bypass.

There are several other novel parts of this Figure K-18 layout. For one thing, a strainer has been installed at the incoming service. That component addition is due to the presence of mussels (shellfish) in the water supply, which draws from a large lake. The extra 2 1/2” hose valve included after the first check valve is present only because the owner’s representative decided that he would pay for that added protection, at that particular location. (This pump actually supplies a deluge system in an otherwise nonsprinklered building.) The pump itself (a 400 gpm model taking 6’ suction) is a vertical in-line electric pump. The pump motor actually sits on top of the pump itself, conserving floor space. It also has the ability to operate without priming. The fire department connection location (Figure K-18) seems almost useless at first glance. But its placement is rational, because although the building is very large it actually contains a plentiful number of interior fire hydrants.

Other than the out-of-the-ordinary quirks mentioned in the preceding paragraph, the Figure K-18 pump layout is quite standard and completely in accordance with NFPA #20 requirements. The building engineer has an option for fire pump testing: he can either use the hose header method and physically measure water flow from the test hoses, or he can read the flow range meter to ascertain the volume of discharge. The entire layout can be contained inside of a 12’ × 20’ fire pump room in the interests of equipment protection. What is important to come away with is the fact that the designer has engineered a lot of piping, valves, fittings, and so forth, to accommodate the desired fire pump installation; and has done so in suitably efficient fashion. There are a total of six flanged spools to be installed, but the number of fittings and required valves has been kept to a minimum.

***

The plan details and layout drawings noted on all fire pump plan examples have been two-line drawings. This is not absolutely necessary, but it certainly looks more professional and is much more viewerfriendly. Consider the number of people who are going to be using your pump plan: an insurance company engineer, a construction consultant, several local fire prevention bureau officials, the architect, the building owner, the general contractor, and not the least of all by any means—the installers and their foreman. For everyone on the list, a picture is worth a thousand words. Individuals are going to be consulted for advice regarding your pump and bypass layout, so you may as well make a good, clear plan for yourself—as it will be scrutinized prior to the installation phase. And just as it holds true for fire sprinkler system engineering, the inherent design goal is that everything will fit as planned and can be installed as it is designed.

ENDNOTES

1 The antidote for this problem would be the installation of a diesel driven fire pump, either singly or as a back-up.
2 Loss of water supply pressure in the sprinkler supply can be monitored with a supervisory pressure switch. Care must be exercised to adjust the switch below the lowest pressure available during peak water usage to avoid nuisance signals.
3 The fact that a pump is running does not necessarily mean that there is a fire in progress.
4 See A-2-7 in NFPA #20 for a general discussion of pump room or pump house construction recommendations.
Residential Fire Sprinkler Design

Much has been written and will continue to be written about residential fire sprinkler systems. This is because the public acceptance of residential sprinklers has been very slow. There are various organizations (primarily representing home builders) whose lobbyists actually are fighting the efforts of those who are attempting to promote this obviously needed advancement in codes and legislation for fire protection. Surrounding the bulk of this chapter concerning design engineering, at the beginning and the end, I would like to include some referenced material that refers not to the how but to the why of residential fire sprinkler inclusion.

People have known for a long time that once a fire gets rolling, it obtains the impetus and force of a hurricane and you can’t stop it. You probably recall reading about the great Chicago fire of 1871. What you may not know is just how devastating that fire was. It completely destroyed 2.7 square miles of homes and businesses, including the entire commercial district. Ninety thousand people were left homeless. The destruction included a total of 17,450 buildings. Imagine that. Relief funds poured in from all over—including one million dollars from 29 foreign countries. President Ulysses S. Grant sent one thousand dollars of his own money.

There are approximately half a million residential fires annually in the United States, which account for about 175,000 injuries. Eighty percent of the annual fire deaths happen in homes. Roughly, one person out of every 50,000 will die in a residential fire this year in the United States. Most residential fires start in kitchens, chimneys, living rooms, and bedrooms. A home is engulfed in flames generally 15 minutes after a fire begins.

There is a definite cost involved with the inclusion of a residential fire sprinkler system. For a new home of 1500 sq. ft., this cost can run upwards of $3000. For a new 4000 sq. ft. home, figure on increasing that figure to $6000. These estimates are on the high side because I don’t want to mislead anyone into thinking that residential sprinkler systems are inexpensive. However, the facts remains that residential fires are the core of the problem that fire protection professionals nationwide are spending their careers trying to solve. The second fact staring building code officials in the face is that with a properly designed residential fire sprinkler system in place, two or fewer sprinkler-heads will generally control all residential fires.

The following report of a recent fire in the state of Washington is illustrative of the benefit and security that residential sprinklers provide:

An unattended cooking fire that was extinguished by a single sprinkler caused only minimal damage to an apartment building. Local firefighters, praising the value of sprinklers, compared this blaze to one of similar origin that started in a building un-equipped with sprinklers and destroyed two apartment buildings.

The eight-unit apartment building was one of 13 buildings in a complex that contained 132 units. The two-story, 4250-square-foot building was of unprotected, wood-frame construction. The fire started when a 16-year-old girl frying chicken in a pan of oil on the stove in a first-floor apartment left the food unattended, and the grease ignited. When she noticed the fire, she tried to extinguish the flames by pouring water on the pan, but the water spread the flames to the countertop and cabinets, and the girl fled the apartment. Fortunately, a detector activated, and a single sprinkler located in the kitchen operated and controlled the blaze.

Fire officials compared this blaze to another unattended cooking fire that happened in the same community three years earlier. That fire occurred in an apartment building with similar construction with twice as many units and smoke detectors but no sprinklers. The blaze burned for several hours, completely destroying two units and damaging six others, resulting in more than $162,000 in damages. Following the fire that was quickly extinguished, the fire department issued a press release saying that the value of residential automatic fire sprinklers is once again confirmed. [1]
The problem is all about human fatalities as a result of residential fires. Data from NFPA reports 3250 civilian deaths in residential fires in 1998; 2775 of these occurred in one- and two-family dwellings, a 2.7 percent increase from the previous year. This data also documents 17,175 civilian injuries in that year resulting from residential fires. Today’s solution to the problem is residential fire sprinkler systems, a solution that has a history of success. The city of Scottsdale, Arizona, instituted an aggressive sprinkler ordinance in 1986 that required all new single-family homes to have fire sprinklers installed. The Arizona Republic reports that a ten-year study documents not only that fire damage over that span was significantly reduced, but also that irrefutable evidence revealed that eight lives were saved by the residential sprinklers in that city since the ordinance adoption. This leads any discerning mind to ask: why shouldn’t we take advantage of this technology? In an age where we have microwave ovens, cell phones, fax machines, and garbage disposals, one thing we know for certain is that the general public possesses a purchasing appetite for anything new to keep their homes in order and up to date. Fire sprinklers are representative of a technology that is affordable, available, and never fails to work. As we speak, two percent of all new homes in the United States are being built with residential fire sprinkler systems, and that figure is on the rise. About 700 American cities have already adopted ordinances similar to that of Scottsdale.

Fact: there was a time not too long ago that smoke detectors met with public resistance. Fact: in 1948, just 2.3 percent of American households had a television. The irony today is that people will install lawn sprinkler systems to water their grass but resist a home fire sprinkler system that will protect their own lives while they sleep. People under the age of 19 account for one-quarter of all residential fire deaths. While statistics drive home the importance of residential sprinklers, public apathy remains its biggest impediment towards progress.

The writers of the national fire codes, aware of this impediment, began the development of NFPA 13D, “Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings,” in the summer of 1973. Life safety has always been the primary goal of 13D, with the key to fire control being the rapid application of water. Substantially lower costs compared with traditional fire sprinkler systems are achieved by allowing piping to be required only in the heated areas and by steering the code towards system design that is compatible with residential construction techniques. Combined sprinkler/plumbing systems have been acceptable since the adoption of the first 13D code in 1975. The philosophy of the valve and piping arrangements have been kept simple so that the average person could realistically install one of these systems himself. And, they work—quickly and automatically. Ninety percent of home fires are contained by the operation of just one sprinkler.

“Installed fire protection is an important aspect of effective loss prevention and control because most systems function automatically, without human intervention. Anytime human actions are involved in an operation, those phases of the operation are subject to the problems of human behavior. Installed fire protection systems function without this human interaction. This enables the systems to perform their functions with a higher degree of reliability. By removing the need for human attention, we also enable these systems to provide protection to a facility 24 hours a day whether the building is occupied or not. Since many large-loss fires occur in the midnight to four A.M. period this is a major advantage.” [7]

PROJECT DESIGN CONSIDERATIONS

As a result of years of fire testing, both NFPA 13D and NFPA 13R have evolved into recognized standards by the model building codes. The “D” refers to dwelling and the “R” refers to residential. “It is important to understand the difference in the residential sprinkler system standards. The scope of each standard identifies where the specific system is intended to be installed. An NFPA 13D system is intended for one- and two-family dwellings and mobile homes. The model building codes consider the (13D) system acceptable in multi-family dwelling units if there is a two hour fire wall located between every two units. An NFPA 13R system is intended to be used in any residential building up to 4 stories in height. This would include one- and two-family dwelling units, multi-family dwelling units, apartments, townhouses, condominiums, hotels and motels.” [8] You can add fraternity and sorority houses and dormitories to this list. Due to the most recent evolution of enacted legislation and ordinances, the NFPA 13R systems have given fire sprinkler designers the lions share of the residential workload.

The task of designing a residential fire sprinkler system is not a project that will arise often for the typical design engineer. When it does, the building use is most often that of an apartment building, a remodeled residence equipped with living units for the handicapped, or a large single-family residence. The basic design criteria used for these residential occupancies is quite different from the norm in many ways. The fire protection designer must be completely familiar with the content of NFPA Pamphlet No. 13-R, entitled “Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height.” Although the title is long, the standard is not. It is a little over 1/16” in thickness. The design engineer should consider this rather thin standard as a supplemental text to NFPA #13, as he carries out his work of design. NFPA #13 applies except when modified by NFPA #13-R. Exactly as he does with commercial and industrial projects; the designer blocks out the building, lays out the system piping with dimensions, calculates
the job, then sizes the piping, and adds additional dimensions and notes and details. It sounds easy and it is. The only tough part of this work is becoming familiar with another set of separate requirements.

If the residential occupancy is close to a municipal water main, all that is really needed supply-wise for a typical home or apartment complex is a 1 1/2” water line. This can be decreased for a small home, and I would increase that piping to 2 1/2” for a larger apartment building. Interior piping for the building can be steel, copper, or plastic. Except for the basement, all piping is typically concealed for residential work. For this reason, the option of running all steel pipe is not to be overlooked, since a nail driven into a wall can easily be driven through plastic pipe. However, in fitter’s jargon, CPVC plastic piping is “lightning.” The installation of plastic pipe is very fast. As long as the installer can stand the fumes from the glue (solvent cement), and manage to finish the day without an overabundance of accumulated glue on his gloves and hands, he will usually prefer to use CPVC because of the fact that his work is done quickly.

The letters in the abbreviation “CPVC” stand for chlorinated polyvinyl chloride.

Plastic pipe is widely used in house plumbing, and for good reason: It’s less expensive, lighter, and easier to work with than metal pipe. And it’s highly resistant to corrosion. The best tool for cutting rigid plastic pipe is a tube cutter. It leaves a smooth cut that requires cleaning before assembling. You can also cut rigid plastic pipe to length in a miter box, using a hacksaw that has 24 or 32 teeth per inch. You can join rigid plastic pipe to metal pipe or a different type of plastic pipe with transition fittings. Never cement two different types of pipe together. [2]

In the interests of maximizing labor efficiency, much if not most of installed residential sprinkler work will consist of combined steel (for exposed basement areas) pipe and plastic pipe. The (steel to plastic) transition fittings manufactured are easy to install, because the outside pipe diameters of CPVC and steel pipe are identical. The most commonly used of these transition pieces are fitted in place using a grooved coupling and a CPVC “grooved coupling adapter.” Another oft-used CPVC fitting is the “adapter socket” or “adapter spigot,” which has brass threads used to make the connection to a sprinkler-head.

It is of the utmost importance that all plastic piping be concealed. The heat from a fire causes a degradation in the CPVC which releases toxic fumes and gases. The inhalation of those vapors (such as hydrogen chloride or other toxic compounds) will cause chemical injury to its victims, and can be lethal. The concern is for firefighters as well as building occupants. In addition to the initial ill-effects of breathing the toxic smoke; respiratory distress, ventricular contractions, and maladies to the eyes can plague victims for hours or even days after exposure.

Plastic pipe is not as rigid as copper or steel. CPVC piping must be supported in accordance with the following:

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Maximum Hanger Spacing</th>
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<tbody>
<tr>
<td>3/4&quot;</td>
<td>5'</td>
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<tr>
<td>1&quot; or 1 1/4&quot;</td>
<td>6'</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>7'</td>
</tr>
<tr>
<td>2&quot;</td>
<td>8'</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>9'</td>
</tr>
<tr>
<td>3&quot;</td>
<td>10'</td>
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</tbody>
</table>

Branch-lines should also be braced at a distance of no more than six inches from the tee or elbow drop to the sprinkler-head to prevent a “lift-up” caused by water hammer.

Throughout the year the CPVC material will undergo “thermal expansion,” that is, it will expand and contract with changes in temperature. The dimensions shown below (in inches) reflect the average CPVC pipe sizes:

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>3/4&quot;</td>
<td>1.050</td>
<td>0.884</td>
</tr>
<tr>
<td>1&quot;</td>
<td>1.315</td>
<td>1.109</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>1.660</td>
<td>1.400</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>1.900</td>
<td>1.602</td>
</tr>
<tr>
<td>2&quot;</td>
<td>2.375</td>
<td>2.003</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>2.875</td>
<td>2.423</td>
</tr>
<tr>
<td>3&quot;</td>
<td>3.500</td>
<td>2.951</td>
</tr>
</tbody>
</table>

All plastic pipe, or copper tube, will have a C-factor of 150.

Remember also, that local authorities may not be as receptive to plastic sprinkler pipe installation as you may think. A phone call made to receive a verbal okay is always recommended practice.

NFPA PAMPHLET #13-R REQUIREMENTS

The single element of your design which should be flawless is the determination of which rooms sprinklers are to be installed. The NFPA #13-R code is devised around the concept of protecting primary places of anticipated fire origin. Section 2-6 of NFPA #13-R is very specific in this regard. In general, sprinklers can be omitted in small bathrooms and closets, porches, floor/ceiling spaces, crawl spaces, and attics. Due to these loose parameters, you can almost always utilize a wet-pipe system for your design.

You will have to continually rethink the usual sprinkler spacing rules. Although we’re dealing with a light hazard occupancy, residential system sprinklers cannot exceed 144 square feet in maximum coverage. No two sprinklers can be closer than 8’ apart (in the same room), and cannot be distanced apart by more than 12’. The sprinkler
must be no further than 6′ from a wall. These rules will only change if we are utilizing (and hydraulically calculating) listed special discharge sprinklers. You would then apply the data from the manufacturer’s cut sheets with regard to spacing, and pressure and volume discharge, if these extended-coverage type heads are approved for residential use.

You will never flow more than four automatic sprinklers in your hydraulic calculation. Rules for the calculated system design must be carefully studied in Section 2-5 of NFPA #13-R (1999 edition). An alternate design approach may be necessary if the most hydraulically demanding compartment of the dwelling unit has a sloping, “cathedral” type ceiling. If special extended-coverage residential sprinklers are used, you must ignore the discharge figures noted in Section 2-5.1.1, and increase the end-head pressures and volume flows accordingly.

How is the header to be configured? In a word, strangely. The installed header does not resemble a typical fire sprinkler system header. NFPA #13-R is again quite specific, and offers examples for this layout. Figure A-2.3.2(a) is the example that should be followed whenever possible. Figures L-1 and L-2 of this text show two examples of these types of installations. Notice how much they vary. You will find that when local authorities are consulted and have their say in the matter, they may decide to insist on requiring this or that. That is because the existence of residential systems is often new to a particular jurisdiction, or simply uncommon due to the current makeup of building codes. The funny thing about local authorities is that they seldom “go away,” so compliance is the norm rather than the exception. As a result, there is little that is yet recognized as “normal” as far as these installations go. Design your systems properly, in accordance with the standards, and this trend will gradually change.

For residential systems, an inspector’s test connection is not a requirement. The system drain valve (1” or larger) will double as an inspector’s test valve. When is a fire department connection required? Always, if fire hydrants are present in the immediate area. Or not at all, if the building to be protected is a single-story residence less than 2000 sq. ft. in total area. The answers to any question that you may think of, fortunately, can easily be referenced in the NFPA #13-R standard.

LAYING OUT THE SYSTEM PIPING

Where do I run the pipe? This is a good question, and the answer is important to remember. For the typical job, you will fan out your piping in the basement (almost always exposed, so this piping must be copper or steel) to supply the basement sprinklers. Be careful, basements always have steel beams to be routed under or around. From there, you should strive to run your piping vertically inside the walls of the upper floors of the residence. The end-result of this method will be a number of separate supply points originating in the basement piping layout.

The upper floor should always be designed with appropriately positioned sidewall sprinklers mounted on walls (see Figure L-6), supplied by small-sized risers from the floor below. This means that on the intermittent levels (of multi-story structures) the piping will in most cases have to be offset in order to “hit” the centerline of the upper-story wall with that riser. This arming-over of the pipe will either have to be done exposed (and then concealed behind a constructed soffit), or inside a wall—where the pipe will have to penetrate a stud or two. A third alternative and probably the best option, is to run this offset piping in one direction above the ceiling and between the wood ceiling joists. In any case, the offset lengths should be kept to a minimum for obvious reasons.

By now you’re probably getting the picture that your engineering will become much easier if CPVC piping is used. Cutting plastic pipe in the field is so easy that prefabricated CPVC pipe is virtually unheard of. Therefore, in a CPVC installation, you will be including many dimensions to show pipe and sprinkler-head locations off of walls in lieu of dimensioning actual pipe lengths.2 Certainly the major task will be to insure that the pipe routing is sound, avoiding obstructions and limiting (or completely omitting the need for) the number of joist or stud penetrations.

RESIDENTIAL SPRINKLER PLAN PREPARATION

Lots of notes on the floor plan will be necessary (see Figures L-3 and L-4). Notice the use of 3/4″ pipe in Figure L-3. This pipe must be included in the calculations, of course. But as we have alluded to earlier in this chapter, the use of 3/4″ pipe is permissible for CPVC pipe (and copper tube). Notice on Figure L-4 that only 1″ piping is used. When designing a residential installation, you do not want to include, for example, 1 1/2″, 1/4″, 1″, and 3/4″ CPVC pipe. Depending on the water supply and the way your calculations work out, you will want to use only 1 1/2″ and 3/4″, or 1 1/4″ and 1″ pipe. This makes everything infinitely simpler for the installer and for the person who is ordering the pipe and fittings. You will achieve this simplicity by minimizing the number of stock fittings and sizes of pipe on the job. The cost differential of those small-size fittings is so little, that you will not really be saving anything (when you factor in the time spent organizing the additional stock) by constantly designing the piping to the smallest hydraulically possible size.

The plan example shown in Figure L-5 is the basement level of a Bed & Breakfast. Because this basement will house a running reserve of commercial storage items, it was decided to protect the entire basement in accordance with NFPA #13 requirements. The design for the upper floors of the building will be in accordance with the regulations outlined in NFPA #13-R. Cut lengths for the exposed steel piping have been
noted, and you can also see the various risers that will provide CPVC (vertical) supply piping to the upper floors. The pipe pieces marked “COJ” (cut-on-job) in the Figure L-5 example will be threaded steel piping, cut to fit the exact spots for those retrofitted riser locations in the field. Of course, a power machine for cutting and threading the steel piping will be present in the basement of this project. By comparison to the upper floors, the installation of the basement piping for this retrofit work will be much noisier. For the upper floors, the installer’s total tool inventory will consist of a hacksaw, tube cutter, chamfering tool, glue brush, channel locks, sprinkler-head wrench, and a level. Needless to say, he will not complain too much about having the lighter weight pipe to carry up flights of stairs.

The residential sprinkler plan should reference specific manufacturers of any specialized installed materials. Your plan notes should include information on hydraulic design criteria, referenced codes, a hanger description, flow test results, type of piping used, a note regarding the (required) hydrostatic test, any detection and/or alarming that will exist to augment fire safety, type of building construction, and a head count. To be perfectly frank, the addition of this general plan note wouldn’t hurt: “Sprinkler-head locations are shown for coverage purposes. Actual positioning may vary slightly after installation due to field conditions.” After all, our piping will probably not be prefabricated, and we have no way of knowing where the wall studs are going to be.

You must also denote all your piping elevations, and where any headguards will be installed. All hanger locations should be noted and, as previously stated, more hangers will be required where CPVC piping is hung. Finally, in the legend, make some type of symbol to denote unsprinklered rooms such as closets and washrooms. Labeling rooms is much more important on any job that is not what we call “completely sprinklered.” A small residential room may very well be a washroom or a closet, but it also may be a laundry room, which would require a sprinkler-head.

THE INTENT AND SIGNIFICANCE OF PAMPHLET #13-R

You may be wondering exactly why the NFPA residential standards seem rather lax in their requirements.

The reasons for this are statistical in origin. Although the number of residential fires is very high, the likelihood of a fire starting in a private bathroom (for example) is quite remote. Without a combustible load, there is not much there to actually start a fire. The NFPA #13D Appendix lists the annual average of fires originating in bathrooms of one- and two-family dwellings at 1.7 percent. The NFPA #13R Appendix lists the average of civilian fire-related deaths as a result of a fire originating in a bathroom at 0.7 percent. These figures are less than those noted for exterior stairways and dining rooms. And, there is no breakdown in these statistics regarding the size of the bathrooms in question. The point to be taken from all this is that the codes have put into action a “level of protection” concept through the intent of sprinklering those spaces where fires normally occur. By sprinklering living quarters, kitchens, stairways, and basements, you are providing good protection and have covered about 99 percent of causal fire instances. [3]

The reality that flies in the face of those who set code requirements is, that the fire sprinkler system cost will skyrocket if a house is to be equipped with a fully standard NFPA #13 system. And also, since a home will lose its residential “feel” if too much cumbersome equipment (such as anti-freeze loops, large detector-check valves, air compressors for dry systems, and so on) is required, then some type of practical compromise is the probable solution.

Leaders of the larger fire protection engineering firms have been instrumental concerning concessions proffered in residential code negotiations. Their focus, founded in a commonsense approach, has set realistic goals to reduce fire loss. The NFPA reported 4,050 fire fatalities in American dwellings and apartments in 1990. According to Bert Cohn in an April 1993 article, “For poverty-level individuals living in substandard housing, however, the loss ratio is about 10 times a high (as compared to those living in code-conforming construction)” That echoes Richard Patton’s observation that for all fire related fatalities in the United States, “the not sprinklered home has been 80 percent of our fire death problem.” Should the pragmatic focus, then, be on the increase say, from 96 percent to 97 percent of system reliability? Or should it be in making tradeoffs and concessions so that amenable system cost is a possibility? . . . What is for sure is that every additional code requirement directly impacts system cost, and can incrementally reduce system acceptability by the public.

If fire safety professionals are serious about attacking the appalling numbers of residential fire deaths that statistics provide, the real villains in the equation are builders of substandard rural housing and the owners of slum dwellings. The statistic that needs to rise more than any other, for residential fire protection to achieve the greatest success, is the percentage of apartments, homes, and townhomes that are equipped with fire sprinkler and protection. [4]

Overall, the evidence supporting the life-saving benefits of fire sprinklers that are installed in any type of residential structure, is overwhelming. Statistics released by the Home Fire Sprinkler Coalition confirm that a sprinklered home reduces the risk of a fire-related death to anyone by over 80 percent, whether the system is designed as a fire-only NFPA 13-D or NFPA 13-R system or a combination plumbing fire sprinkler installation. One or two sprinkler heads generally control all residential fires, which will usually occur prior to the fire department arriving on the scene.

In the early 1800s, it was customary on the New England coast for homes to be built with a roof-mounted platform known as a “walk.” These were built for the purpose of facilitating the extinguishment of chimney fires with buckets of sand. With this fire protection feature installed, those
200-year old homes had more in-place fire protection constructed than most homes built today!

In the 1960’s, none of us could have imagined the common use of personal computers or even compact laser discs. The point is that we should be willing to use whatever technology is available to improve the quality of our lives. Why would we ignore advances in technology which would improve the safety of homes built from now on? Why would we choose to omit life safety from a new home?

There are a few simple truths about the use of residential fire sprinklers which the buying public should know:

- Fire sprinklers are a cost effective means of increasing the level of fire safety in homes.
- Fire sprinkler installation represents about 3% of total construction cost.
- Fire sprinklers have a proven track record of controlling and extinguishing fires, using a small fraction of the water needed to fight the same fire with hose lines.
- Fire sprinklers are state-of-the-art, built-in protection. [5]

The preceding four statements are factual. They are noteworthy because of the ongoing problem. I will conclude this litany of residential fire sprinkler promotion with a fire statistic that sums up the need for (code) changes: “In 1992, approximately 1 out of every 200 U.S. households experienced a fire severe enough to involve the local fire department” [6].

That having been said, I would like to conclude this chapter with a final recommendation to the novice designer of residential systems: Make sure that you visit the jobsite on your first project while the installation is taking place. The visual memory that you take with you will aid immeasurably in the design of future residential work. I say this because it is to your benefit to become accustomed to the format and techniques of residential construction. The residential construction style presents impediments to pipe routing not usually found in commercial projects. Also, keep blueprints of your completed work. You will find them handy to reference later, refreshing your memory for the next residential automatic sprinkler installation.

### Area of Origin in Fatal 1- and 2-Family Dwelling Fires

<table>
<thead>
<tr>
<th>Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living Room</td>
<td>39%</td>
</tr>
<tr>
<td>Bedroom</td>
<td>28%</td>
</tr>
<tr>
<td>Kitchen</td>
<td>16%</td>
</tr>
<tr>
<td>Storage Area</td>
<td>4%</td>
</tr>
<tr>
<td>Furnace Room</td>
<td>2%</td>
</tr>
<tr>
<td>Structural Area</td>
<td>2%</td>
</tr>
<tr>
<td>All Other</td>
<td>9%</td>
</tr>
</tbody>
</table>

### STUDY QUESTIONS

Note: The following questions are to be used as an “open-book” type quiz. Please make use of NFPA pamphlets and any related codes when figuring responses (answers appear on page 282).

1. What is most likely the churn rating of a (typical) 1000 gpm diesel engine drive fire pump with an engine rpm of 1750 and a pump pressure in head feet of 104?
   A. 45 psi
   B. 54 psi
   C. 63 psi
   D. 125 psi
   E. 145 psi
   F. 175 psi

2. Using standard discharge residential fire sprinklers, what is the minimum number of heads needed to protect a recreation room of 15’ × 38’ room dimensions, with a flat ceiling?
   A. none required
   B. four
   C. five
   D. six
   E. seven
   F. eight

3. A 500 gpm fire pump must have its supply for the test header piped across the valve house. What size should the pipe be?
   A. 3”
   B. 4”
   C. 5”
   D. 6”
   E. 8”

4. A two-story fully sprinklered office building, containing eighty-nine sprinklers, has a 4” single wet system riser. It is safe to assume that the building’s pipe schedule system is hydraulically adequate.
   A. true
   B. false

5. A sprinkler with a K-factor of 11.9 would be classified as a:
   A. large-drop sprinkler
   B. large orifice sprinkler
   C. extra large orifice sprinkler
   D. a or c
   E. none of the above

6. On a wet system 1116.1 gallons are flowed through 50’ of 5” lightwall pipe. In psi, what is the total friction loss incurred?
   A. 4.02
   B. 4.14
   C. 4.18
   D. 5.35
   E. 5.85

7. In inches, what is the maximum length a sprinkler deflector may be positioned beneath the peak of a pitched roof (beam and girdier construction)?
   A. 16
   B. 18
   C. 20
8. The walls and ceiling of a long linen closet in a four-story apartment building are surfaced with noncombustible materials. If the closet’s dimensions are 1’6” × 14’0”, how many standard residential sprinklers will it take to comprise proper coverage?
   A. none required
   B. one
   C. two
   D. three
   E. four

9. What is the minimum size underground piping feed to be recommended for a fire protection system containing a 1000 gpm horizontal electric fire pump?
   A. 5”
   B. 6”
   C. 8”
   D. 10”
   E. 12”

10. A warehouse contains suitcases, wrapped in plastic and individually stored in cardboard cartons. They are piled on top of one another to a height of 18’. What is the hydraulic design criteria for this occupancy, assuming that the building is to be protected with ordinary temperature classification rated sprinklers on a dry system?
    A. .285/2000
    B. .290/2000
    C. .385/2000
    D. .242/2600
    E. .335/2600

11. What product classification shall be used for idle wood pallets stored in 5’ high piles?
    A. I
    B. II
    C. III
    D. IV
    E. ordinary hazard group III

12. The valve on the discharge of a fire pump must be:
    A. a check valve
    B. an O, S and Y valve
    C. a globe valve
    D. no valve is required
    E. any U.L. listed valve

13. When a contractor completes an installation of a sprinkler system, he must submit for approval:
    A. shop drawings
    B. permit fee
    C. contractor’s certificate of test
    D. letter asking for approval
    E. a phone call

14. A horizontal fire pump which is rated at 1000 gpm at 100 psi will:
    A. produce at least 1500 gpm at 65 psi
    B. produce at least 120 psi at no flow
    C. produce no more than 100 psi at 100 gpm
    D. produce a maximum pressure of 100 psi
    E. produce a maximum flow of 1000 gpm

15. Figure #1 depicts four large-orifice sprinklers on a branch-line. After take-out, what is the cut length of the 2” piece?
    A. 12’10 1/2”
    B. 12’11”
    C. 12’11 1/2”
    D. 13’1”
    E. 13’0”

16. Figure #2 shows 2” threaded steel pipe. After take-out, what is the length of the 2” piece marked “B”?
    A. 8’2”
    B. 11’7”
    C. 11’9”
    D. 11’10”
    E. 5’8 1/2”

17. Figure #3 shows the inside dimensions of two bays in a sawmill. Assuming a hydraulically calculated system
21. The minimum rod size for a hanger consisting of a welded eye rod supporting 3" pipe is:
A. 1/4"
B. 3/8"
C. 1/2"
D. 5/8"
E. 3/4"

22. What is most closely the inside diameter of 2" schedule 40 black steel pipe?
A. 2.0
B. 2.1
C. 2.2
D. 2.3
E. 2.4

23. In high piled storage, glass bottles packaged in small cartons would receive what commodity classification?
A. I
B. II
C. III
D. IV
E. light hazard

24. Pipe used in sprinkler systems shall be designed to withstand this working pressure:
A. 100 psi
B. 125 psi
C. 150 psi
D. 175 psi
E. 200 psi

25. Figure #6 shows two 6" grooved elbows installed back-to-back. What is the total cut length of the 6" pipe marked “F”?
A. 8'2"
B. 9'8"
C. 9'10"
D. 10'0"
E. 10'5"

26. A Class I commodity in solid pile sits in a heated warehouse protected by 165° sprinklers. The piling height will reach 15 feet in most areas. What shall the design criteria be for the fire sprinkler system?
A. .22/1500
B. .144/2000
27. Figure #7 shows a die casting facility. Assuming that a hydraulically calculated fire sprinkler system is to be installed, what is the minimum number of sprinklers to be installed?
A. 102
B. 106
C. 108
D. 110
E. 115

28. The warehouse shown in Figure #8 will require a minimum number of ______ sprinklers for proper coverage.
A. 60
B. 61
C. 63

29. The standard for installation of sprinkler systems requires that storage be placed no closer than ______ feet to unit heaters in all directions.
A. 3
B. 4
C. 5
D. 6
E. 7

30. High temperature sprinklers on a wet system protect piles of books stacked to 20'. Using a 2000 square foot remote design area, what density in gpm/sf shall be used?
A. .18
B. .21
C. .28
D. .29
E. .38

31. On a fire pump of 2000 gpm rated capacity, what is the minimum recommended number of 2 1/2" hose valves that should be affixed to an inside or outside test header?
A. 4
B. 5
C. 6
D. 8
E. 10

32. At the water supply source servicing a wet-pipe residential fire sprinkler system, it is recommended that at least two pressure gauges be installed.
A. true
B. false

33. The smallest steel pipe which can be used to supply fire sprinklers is:
A. 1"
B. 3/4"
C. 1/2"
D. 1 1/4"
E. 1/4"

34. The maximum spacing for standard sprinklers in an ordinary hazard risk is:
A. 100 sq. ft.
B. 130 sq. ft.
C. 168 sq. ft.
D. 200 sq. ft.
E. 225 sq. ft.

35. An important factor in a dry-pipe system of automatic sprinklers is the air pressure. It is undesirable to have high air pressure and it has been found that the maximum which is necessary is how many pounds in excess of normal tripping pressure?
A. 5–9
B. 10–14
C. 15–20
36. To maximize the service life of an automatic fire sprinkler system, _______ pipe should be used, where only steel is specified.
   A. Schedule 40 black steel pipe
   B. Schedule 10 black thinwall steel pipe
   C. “XL” threadable light-wall steel pipe, galvanized
   D. Schedule 40 galvanized steel pipe
   E. either “Eddylite” or “Super 40” steel pipe

37. On a branch-line with ten sprinklers off of a properly hung cross-main, the starter piece is a 2” piece of Schedule 40 pipe that is 5’ long. How many hangers are required to hang that starter piece?
   A. 0
   B. 1
   C. 2
   D. 3
   E. 5

38. This sprinkler component, located at the system header, might discharge water at any time, not necessarily under fire conditions.
   A. double-detector check valve
   B. reduced-pressure backflow preventer
   C. chrome pendent sprinkler-heads
   D. a 2” angle valve
   E. fluid strainer

39. A warehouse room contains wood pallets exclusively, stored in solid pile to a maximum of 7’. Fire sprinkler design criteria for this room is dictated by regulations outlined in what standard?
   A. NFPA #13
   B. NFPA #30
   C. NFPA #25
   D. NFPA #13-R
   E. NFPA #80-A

40. Seven-inch diameter structural tubing supports a glass atrium. The wall of the tubing consists of 1/4” seamless steel. It is permissible to hang sprinkler piping from the tubing using 1/2” powder-driven studs.
   A. true
   B. false

41. Anti-freeze solutions must be tested for proper special gravity at which minimum interval?
   A. every 6 months
   B. annually
   C. every 2 years
   D. every 5 years
   E. every 50 years

42. The standard symbol for a sprinkler pipe hanger is a diagonal stroke imposed on the pipe that it supports.
   A. true
   B. false

43. A cereal mill located on the north side of Boston is determined to be an ordinary hazard group 2 occupancy. The design density for a hydraulic calculation in the heated mill could be:
   A. .18/1500
   B. .19/2000
   C. .21/1500
   D. .20/2000
   E. .22/2000
   F. .24/1500

44. On a light hazard pipe schedule system, what is the maximum number of sprinklers that can be installed on a single branch-line?
   A. 6
   B. 8
   C. 9
   D. 10
   E. 15
   F. 16

CITATIONS

ADDITIONAL REFERENCED MATERIAL

ENDNOTES
1 Although these numbers vary from year to year, please note that the United States has consistently had the highest loss of life and property damage figures among all nations world-wide. One illustrative statistic of this fact is that Chicago, which is half the size of Hong Kong, suffers three times the number of fire-caused deaths.
2 This will also apply for copper tube installations. However, steel piping should still be “cut” and prefabricated when used in residential applications. This includes (especially) the basement piping.
Chapter 20

Project Estimating

While working for a fire sprinkler contractor, one morning I completed work on my design project, and was literally left with nothing to do. Business at that time was slow, and I knew that there were few, if any, upcoming projects for those of us in the engineering department. I ventured into the office of my supervisor, as I had done several times that month, and asked him what work I could do that day. He was stymied, and probably somewhat annoyed, that I hadn’t just taken the opportunity to goof off a little bit. He said that he would soon come up with something for me, and as I said, business activity was in a slow cycle. Somewhat later, I was minding my own business (reading the sports page in my little cubicle), when one of the salesmen waltzed in. “Hey Bro,” he said as he dropped off a big roll of plans, “I need a cost estimate on this job. The bid is due at noon on Thursday, so get the numbers to me by 10 that morning. Try not to make any big mistakes.”

So, I had my work cut out for me. My task would not involve any techniques of salesmanship or interfacing with a client, but simply to tabulate expected costs for a potential project.

There are two ways to arrive at sprinkler bid amounts, and both are widely used. The first, normally put into use by a lazy (but hopefully experienced) contractor involves only a summary sheet (shown in Figure L-7). The second method, often used by a sharp sales engineer, is more time-consuming and would require the utilization of the forms shown in Figures L-7 through L-13. There are undoubtedly hundreds of similar but somewhat different project estimate forms in use today, which have been developed by many separate contracting firms, and also many printed “pick off” forms that are used to tally item-by-item estimated labor hour figures. The forms used as examples herein are not by any means standardized. The estimate form that could most closely be termed a “standard” that I have seen is shown in the Figure L-14 example, and in truth, corresponds more to the first method of job estimating noted above.

As I was to later discover, an engineer is an ideal contractor employee to figure the estimates from time to time. He could turn out to be the person in the contracting firm, at any rate, most likely to predict the most accurate cost of installing the upcoming job. (The job will be upcoming, that is, provided that his firm is the successful bidder.) This chapter will not concern itself with the fast-track techniques of the quick bid but rather, the more time-involved procedure of developing the second method of job estimating noted above. That method allows for a more controlled and realistic (and sometimes more conservative) business-conscious approach.

***

Cost-estimating in its finest form is a best-guess form of sales engineering, rather than an exact science. A good way to look at the bidding process is to view the contracting firm as a gambler: one who is willing to wager that he can install this job in exchange for a certain amount of cash, and in the end still wind up with a margin of profit. Fast-tracking the estimate, or simply computing a single-column total of “best-guess” numbers on a bar napkin is just a way of increasing your risk on the gamble. Again, the following commentary will outline a method that is time-proven to reduce the overall risk.

For our purposes, we will assume that we are to prepare a bid figure on the upcoming new construction project known as “Jones Glass.” Our salesman has red-lined a proposed fire sprinkler layout on the blueprint of the architect’s floor plan, and it looks a lot like what is shown in Figure A-2. This example is not a good one in the sense that such a small job is atypical, and therefore the “dollars per head” figures (used by most estimators as multipliers with which to check their totals by category) will not be relevant to the
usual job. On the other hand, this is a good example to review in the sense that very small projects involving entire single-system installations are often accidentally underbid (for the same reason of over-reliance on per-head “multipliers” to figure totals of categories such as shop time or material cost).

The first figure logged on the summary sheet (Figure L-7) is the material total. We want to pinpoint this cost exactly. The seasoned salesman will tell you that this is the hardest figure for him to arrive at. This is because his material figure is often “guessed.” For larger jobs, the bidder may simply review all the job particulars and then simply assign some type of numerical factor (like $34, or $46, or $58), multiply that by the number of estimated sprinklers required, and then Bingo! arrive at his material cost total. Certainly, the dice has been rolled that way on numerous occasions. Also on numerous occasions, an estimator who ascertained his bid amount in ten minutes receives the news that he has been awarded a contract in a cold sweat.

Prior to “picking” all the system fittings, valves, and other material items off the blueprint, it is important to make a preliminary hydraulic calculation in order to determine the probable sizes of pipes, fittings, and most importantly, the header and risers for the job to be bid. We are going to assume that the results of our preliminary calculation gave us the pipe and component sizes as shown in Figure A-6. We will be using black steel piping with standard cast-iron fittings for the upcoming installation. Marking these items one at a time, and totaling all the separate system material figures, will first be done on a separate scratch sheet. Then the totals are transferred and noted by specific category, as is shown on the example forms (Figures L-8 through L-13). Note that the material categories are plainly marked. You will note also that there are many abbreviations, such as POL (pipe-o-let), Red. (reducing), NBG (nuts, bolts, and gaskets), and WPIV (wall-post indicator valve).

The next step is a simple matter of multiplying the number of units (anticipated to be used) by the unit costs, as shown. A good estimator will be in contact with the firm’s buyer regarding these unit cost figures, because the prices of all system components fluctuate from time to time. (Don’t go by the prices shown in this text.) Larger contracting firms will supply their salesmen with a “Price Book” that is routinely updated, to limit errors in material cost estimating.

It is a good idea to add a little “fat” into the number of some units estimated, particularly elbows and grooved couplings. Note that in Figure L-12 there is vague $50 “extra material” cost, and in Figure L-13 there is a $15 cost for “extra hanger material.” These figures are included to cover unforeseen material expenses that are bound to accrue.

Please note again the summary sheet shown in Figure L-7. We arrived at our material total by adding the following estimated figures from the filled-out forms:

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specials</td>
<td>$285</td>
</tr>
<tr>
<td>Large valves</td>
<td>1565</td>
</tr>
<tr>
<td>Pipe</td>
<td>351</td>
</tr>
<tr>
<td>Small fittings</td>
<td>128</td>
</tr>
<tr>
<td>Large fittings</td>
<td>101</td>
</tr>
<tr>
<td>Flanged fittings</td>
<td>336</td>
</tr>
<tr>
<td>Extras</td>
<td>50</td>
</tr>
<tr>
<td>Valves</td>
<td>378</td>
</tr>
<tr>
<td>Hangers</td>
<td>121</td>
</tr>
<tr>
<td>Total</td>
<td>$3315</td>
</tr>
</tbody>
</table>

All the forms shown, especially the summary sheet, are used by estimators to eliminate the anxiety caused by wondering if anything was “left out” of the bid. Bidders have been known to have been awarded contracts, only to later discover that they left out something big (such as “material” or “markup”), or that they incorrectly noted the actual “total head count,” thereby misjudging the anticipated cost of many figures.

***

Experienced sales engineers are quite accurate in the estimating of the remaining figures on the summary sheet. For larger jobs, they may simply factor the labor hours. For example, if the project requires 650 sprinkler-heads, exclusively supplied by exposed (warehouse) piping, they may use a factor of say, 0.66, to decide that the total job should be installed in (.66 × 650) 429 labor hours. If all the piping is to be concealed, they may use a factor of 1.28, and figure their estimate based on the anticipation of (1.28 × 650) 832 field-labor hours. Believe me, with estimating experience, the salesman becomes very accurate. The real guesswork comes into play when estimating field-labor for projects of existing construction. On a distinctly tricky retrofit job, it would not be too conservative to triple the above-noted labor hour figures.

Five different salesmen could “labor” the Jones Glass project example and come up with five different figures. We have arrived at our total of hours by breaking the labor down into segments of operation:

<table>
<thead>
<tr>
<th>Task</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unload and distribute</td>
<td>4</td>
</tr>
<tr>
<td>Header</td>
<td>10</td>
</tr>
<tr>
<td>F.D. connection</td>
<td>2</td>
</tr>
<tr>
<td>Cross-main</td>
<td>8</td>
</tr>
<tr>
<td>Branch-lines</td>
<td>16</td>
</tr>
<tr>
<td>Cut drops</td>
<td>4</td>
</tr>
<tr>
<td>Supervision</td>
<td>4</td>
</tr>
<tr>
<td>Test and ship off job</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
</tr>
</tbody>
</table>

In Figure L-7, “overhead” refers to field-labor. The inserted figure of 56 refers to hours. This has been multiplied by the fitter hourly wage rate of $20 per. The (56 × 20) $1120 figure has been multiplied by .40, which is a built-in factor to cover
contractor benefit expenses for that employee, including insurance and taxes. Across the country, depending on union involvement, these figures vary considerably.

The labor category of “Header” would include time spent installing tamper switches, the pipestand, meters, and the spare-head box, riser trim, and the main drain. Labor time spent on the inspector’s test connection is included in the “Branch-lines” installation figure. The final 8 hours noted covers clean-up, hydrostatic system testing, and shipping off the job. The 8 hours shown for “Cross-main” simply means that a two-man crew should install the 3′ riser and the cross-main pieces on this job in half a day. Bear in mind that generally, labor figures will go up and down in relation to the number and type of fittings on the job.

All labor estimates are best-guess. For example, one installer may be able to cut sixteen 1″ drops to pendant sprinkler-heads in a day. Another fitter may be able to accomplish the same amount on a center-of-tile job, which requires two cuts per head. Most salesmen will again use a factor for this work. Let’s say that piping has been roughed in, and 100 short drops need to be cut to fit for the heads to be installed beneath the new drop-ceiling. The salesman will just figure 100 × .24, and allot 24 hours to cover this task. If relocating sprinklers from an existing system that will require very long 1′′ drops to be installed, he may figure 1.75 hours per head.

Many factors need to be considered when laboring a job. For instance, the task of unloading and distributing the prefabricated pipe will take much longer if the pipe has to be carried up a flight or two of stairs. Also, installation time increases with the height of the building. The size of the feed-main and cross-main piping also plays a big part: two men may be able to hang a dozen lengths of 3′′ main in a day, but only seven lengths of 8′′ pipe.

The project example cost estimate is based on the assumption that the sprinkler contractor is taking care of everything in-house. No work is being sub-contracted out. If the contractor does not have his own fabrication shop, he may contract out all of his (delivered) material supply and pipe fabrication to a single firm. The invoice from that hypothetical firm in our example (see Figure L-7) would hopefully total the cost estimate numbers for Material, Sales Tax, Shop (total), and Freight (or “cartage”). Respectively, $3315 + 199 + 208 + 42 + 100, a total invoice to our firm of $3864. In reality, their bill would be slightly higher to cover their own costs of doing business.

Our estimate of 16 hours shop time is fairly conservative. An in-house fabricator can cut and fabricate a typical 120-head job in 24 hours. His hourly rate of $13 shown in Figure L-7 is an assumed figure, of course, which gives us the (16 × 13) base “cost” estimate figure (of $208) in the column to be totaled. There are also costs incurred by virtue of his company benefit package.

And so it goes with the rest of the estimate. Everything is a calculated guess. The category of “fitter subsistence” represents additional union benefit and travel costs that contractors incur per day of union member employment. The $200 scaffolding figure covers the expectation that we will be renting a small electric rig for a week to be used for the installation. We are also certain that no insurance bonding will be required for this project, but that we will have to pay a small permit fee to the village.

The “total production cost” is the magic number of the estimate. If we are good, our actual installation cost will be within 5% of this estimate. The “markup” figure is a percentage markup on the expected production cost that the contractor sets wherever he wants. This figure ($1312 in our example) covers the contractor’s overhead, and also includes the job profit. The contractor will go up and down from our 20% markup, depending on how busy he is at the time of new bid proposals, how much he wants the job, and how greedy (or generous) he feels that day. As estimators, we don’t have to worry about the markup. It is really a representation of the ongoing dilemma of being the successful bidder versus realistically covering the cost expectation.

One more important note for estimators is this: we always need to check on the water supply for an upcoming project. First of all, that there is one. Second, we need to know the characteristics of the available volume and pressure. And of critical importance, we need to know where the fire department connection can be situated in an approved location on the building exterior. These are all cost-related issues.

Finally, your bid must qualify what is not included. In our case, we want to make it clear that our bid does not include the installation of the underground feed piping, any alarm wiring, and any painting of pipe or equipment. We are not providing any guarantee that installed pendent sprinkler-heads will necessarily be positioned in the geometric centers of ceiling tiles. (That would substantially increase labor time.) We are assuming that the entire building will be heated. There are other items we’re not including, of course. We are omitting pipe labeling. We are not including a fire pump, or hose stations, or any fire extinguishers. I suppose that how much you need to qualify depends on your firm’s relationship with the client, and/or your client’s reputation. Nonetheless, it helps to be specific.

I hope this discussion leaves you with additional questions, because any uncertainty must be resolved before you can estimate any job. This is because the estimating process is very involved. The final, generated, proposal figure is dependent on the various labor rates, available material prices, techniques of labor, and policy standards that are common to any one particular fire sprinkler contractor. Most salesmen find that they have to (grudgingly) revise their estimating style when they change companies.
As has been emphasized, the use of cost estimate forms is the best way to proceed confidently. These help you to be consistent, to be thorough, to be organized, to be accurate, and to be accountable. The inherent goal is to eliminate uncertainty. And with increased confidence in your estimate, you will never have to scratch your head or worry much about the erratic figures that the competition comes up with.

ENDNOTES

1 For example, the forecast for transporting pipe all day long to a 30’ high ceiling will greatly exceed the expected field labor time on a project having a 12’ high roof deck.

2 This refers to average business expenditures, or the “cost of doing business.”
Economies of the Design Function

The basic economy that the designer provides is that concise and accurate design which minimizes the overall risk of property damage. The inherent goal is always present, to insure the rapid extinguishment of a potential fire for all areas of the building.

Problematic dollar issues involved with maximizing economy in the system design can be viewed as a microeconomic factor as it relates to the entire fire protection community. As minor as that may sound, the most efficient design that maximizes individual system cost is a function of the designer’s job, and increases his value as a part of the installation team. Let’s begin the review of overall economy by evaluating the comparative costs incurred by the following three example installations:

![Diagram of three configurations: X, Y, and Z.]

Configuration “X” end-feed

Configuration “Y” center-feed

Configuration “Z” intermediate
We can design our piping to protect a hypothetical room (or a trave) by either of the above-diagrammed layouts. The pipe sizing noted is based on NFPA #13 pipe schedule tables for steel pipe. The sprinklers are spaced at 117 square feet per head: the branch-lines are spaced 9 feet apart on-center, and the sprinkler-heads are 13’ apart. The shaded circle represents an existing 3′ grooved tee on an existing standpipe. All main piping will be 3′ thinwall. The question is, which is the most cost-effective design?

As installation cost is labor-intensive, we must always look first at the labor differential, in terms of cost. Our firm may bill out installation labor at $50 per hour, but the cost of hanging one more length of 3″ pipe than configuration “X,” We will consider this to be an additional hour of field-labor, or a $30 cost to us. Configuration “Y” requires hanging four separate 3″ pipe pieces, as opposed to one for configuration “X,” which will estimate as accounting for an additional three hours worth of field-labor time.

Accrued expenses of engineering, freight, scaffolding, and shop fabrication may total up differently for the three examples, but those differences will be barely negligible. We do not need to consider these factors at all in a cost comparison. Figures L-9, L-10, L-11, and L-13) to assist in this analysis. The material cost breakdown that follows, omits the constant costs of the grooved cap, and 2″ pipe-o-lets, and the branch-line hangers. “Units” of piping shown below refer to the total pipe required in feet.

After all that figuring, we now know that the layout depicted in configuration “X” (the end-feed style) will be the least expensive and most economical way to configure the piping layout. The cost increase of the additional 2″ line piping in configuration “X” is offset by the limited use of the 3″ main piping, and one less cross-main directional change. Actually, while the difference in dollars doesn’t look like too much, configuration “X” beats the heck out of configuration “Y” in terms of cost percentage, a 46% savings.

Is this worth the time of evaluating? Yes and no. If you performed this type of analysis frequently, you’d drive yourself nuts. But if you do this every now and then, you will gain a feel for the economies involved for different configuration strategies. There may be certain instances that arise, where you will want to employ this method of cost comparison in order to settle an unresolved piping layout question in your mind. When that is the case, the cost estimate sheets are a handy reference.

***

All well-intentioned economies fall apart when the job does not “fit,” and something always seems to go awry due to a large variety of possible installation foibles and problems. The list is endless, and the causes are often unexpected. You, of course, must structure your design around current code parameters. There are a number of thoughts regarding strategy that, if kept in mind, will help to alleviate the amount of costly on-site engineering rework. These are:

### Presupposed Cost Comparison

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Cost</th>
<th>Configuration “X” Units</th>
<th>Total</th>
<th>Configuration “Y” Units</th>
<th>Total</th>
<th>Configuration “Z” Units</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1″ pipe</td>
<td>0.50/ft.</td>
<td>78</td>
<td>$39.00</td>
<td>156</td>
<td>$80.00</td>
<td>135</td>
<td>$67.50</td>
</tr>
<tr>
<td>1 1/4″ pipe</td>
<td>0.67/ft.</td>
<td>39</td>
<td>26.13</td>
<td>78</td>
<td>52.26</td>
<td>39</td>
<td>26.13</td>
</tr>
<tr>
<td>1 1/2″ pipe</td>
<td>0.81/ft.</td>
<td>78</td>
<td>63.18</td>
<td>39</td>
<td>31.59</td>
<td>78</td>
<td>63.18</td>
</tr>
<tr>
<td>2″ pipe</td>
<td>1.07/ft.</td>
<td>84</td>
<td>89.88</td>
<td>—</td>
<td>0.00</td>
<td>21</td>
<td>22.47</td>
</tr>
<tr>
<td>3″ pipe</td>
<td>1.76/ft.</td>
<td>21</td>
<td>36.96</td>
<td>68</td>
<td>119.68</td>
<td>42</td>
<td>73.92</td>
</tr>
<tr>
<td>3″ grvd. elbow</td>
<td>12.50</td>
<td>—</td>
<td>0.00</td>
<td>1</td>
<td>12.50</td>
<td>1</td>
<td>12.50</td>
</tr>
<tr>
<td>3″ gr. coupling</td>
<td>3.89</td>
<td>2</td>
<td>7.78</td>
<td>6</td>
<td>23.34</td>
<td>4</td>
<td>15.56</td>
</tr>
<tr>
<td>1″ red. elbow</td>
<td>0.71</td>
<td>3</td>
<td>2.13</td>
<td>6</td>
<td>4.26</td>
<td>6</td>
<td>4.26</td>
</tr>
<tr>
<td>1 1/4″ tee</td>
<td>1.46</td>
<td>3</td>
<td>4.38</td>
<td>6</td>
<td>8.76</td>
<td>3</td>
<td>4.38</td>
</tr>
<tr>
<td>1 1/2″ tee</td>
<td>1.91</td>
<td>6</td>
<td>11.46</td>
<td>6</td>
<td>11.46</td>
<td>6</td>
<td>11.46</td>
</tr>
<tr>
<td>2″ elbow</td>
<td>1.79</td>
<td>3</td>
<td>5.37</td>
<td>—</td>
<td>0.00</td>
<td>—</td>
<td>0.00</td>
</tr>
<tr>
<td>2″ tee</td>
<td>2.69</td>
<td>9</td>
<td>24.21</td>
<td>3</td>
<td>8.07</td>
<td>6</td>
<td>16.14</td>
</tr>
<tr>
<td>Main hangers</td>
<td>3.20</td>
<td>2</td>
<td>6.40</td>
<td>7</td>
<td>22.40</td>
<td>4</td>
<td>12.80</td>
</tr>
<tr>
<td>Labor differential</td>
<td>—</td>
<td>0.00</td>
<td>+</td>
<td>90.00</td>
<td>+</td>
<td>30.00</td>
<td>+</td>
</tr>
<tr>
<td>Total outlay (cost)</td>
<td></td>
<td></td>
<td>$319.19</td>
<td>$466.94</td>
<td>$364.92</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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(1) Be absolutely certain of the location and direction of the building’s structural members.

(2) Take your time when designing. Mistakes are made when you’re in a hurry. Or, when you are fatigued.

(3) Try not to make any mistakes on the cross-main piping. Get the elevation of the cross-main right on the money!

(4) Be constantly aware of all possible obstructions.

(5) For new system cut-ins on small additions, nothing slows up the job more than if the existing piping to be cut into has been incorrectly identified. This is not an uncommon mistake, but it can be easily avoided. First of all, don’t take somebody else’s word that the piping in question is 4”, or 5”, or whatever. Especially some plant manager, or building engineer. Fire protection engineering is the domain of the fire protection engineer. An easy way to identify existing pipe size is by reading a grooved coupling. The exact pipe size is always stamped on the fitting. If this is not possible, just wrap your steel measuring tape around the pipe. This won’t give you a true pipe circumference because of the thickness of the steel tape and the limitations of this kind of calibration. But it will give you a figure with which you can compare to piping of known size that you could measure in your own fabrication shop. For example, let’s say you measured the “circumference” of a cross-main that gave you a figure of 14 1/8”. That would be 4” pipe. A figure somewhere between 12 1/2” and 12 5/8” would be 3 1/2” pipe. For larger mains, a 17 1/2” measure means that you’re looking at 5” pipe, just over 20” relates to 6” pipe, about 27” relates to 8” pipe, and anywhere from 33 1/2” to 34” relates to 10” pipe. Since the outside diameter of steel pipe is a constant, these numbers will not change from Schedule 40 to Schedule 10 pipe.³

There are plenty of other ways that the designer can keep costs down to a minimum on any given project. Here are a few suggestions:

(1) Try to reasonably reduce the number of cross-main offsets.

(2) On dry-pipe systems, use regular (wet) pendent sprinklers instead of dry pendent sprinklers, for heated areas (see NFPA #13: 4-2.2).

(3) Due to limitations of vertical space on concealed jobs, it is often necessary that all sprinkler piping be run at the same elevation. That’s the way it is. However, when possible and when space permits, try and run the cross-main slightly lower than the branch-lines (perhaps by 7”), and use short riser nipples. At every branch-line connection, you save the expense of an additional pipe-o-let or mechanical tee.

(4) There will be a reduced labor realization if you reduce the number of branch-lines (especially on grids) by reducing the distances between sprinkler-heads on the branch-lines. Looking again at configurations X, Y, or Z, for instance, let’s say that those sprinklers protect a room or trave that is 26’ in width and 100’ in length. We would rather protect that area by installing two branch-lines, and space the sprinklers 9’ apart, then the way that it is shown.⁴ With this arrangement, we would save labor set-up time by reducing the number of branch-lines, and we would also save one welded outlet on the main.

(5) A very large grid will contain a considerable number of welds, fitting, and pipe lengths. The sizes of those pipes and components will be determined by a computer-generated hydraulic calculation. Prior to preparing that calculation, the designer should give some consideration to the option of up-sizing the feed-main that supplies the grid. For example, if 4” feed piping can do the job, consider changing it to 5” or 6”. (Or if 6” has been estimated, consider 8”) You may well discover that the accumulated cost total of your grid material will be greatly diminished (due to the smaller grid sizes) when using the larger feed-main. The cost decrease may be so great, that it will more than offset the cost increase of a larger riser and feed main.

(6) Use the right products for the job you are designing. Don’t shy away from any new valves, fittings, pipe, or sprinklers that are listed and approved. It wasn’t until 70 years after the first fire sprinkler nozzle was developed that the Viking Corporation patented the first dry pendent sprinkler. And you can bet that its introduction on the market was met with much resistance from the naysayers. So there’s no reason to ignore today’s newer sprinkler types and the design benefits that they provide.⁵ With correct application, economies of savings can be realized with a variety of new products.

* * *

I would like to make mention of less detailed and more macro-economic issues that have an effect on the business of fire suppression system design. A somewhat recent product advancement in the industry has been computer fire modeling. “Increased scientific knowledge about the nature of fires now permits accurate computer simulation of the progress of a fire in a particular site. Computer simulation can also measure the effectiveness of such preventive devices as smoke detectors, sprinklers, and fire-resistant materials” [1]. Consulting engineers may specify a special sprinkler type depending on the results of their computer fire modeling procedures. The computer model may test, for example, the outcomes of the existence of on-off sprinklers, extra large-orifice sprinklers, or dry pendent heads of various lengths. Response times of thermal fusible elements can be estimated using the computer model. In one documented case, it was assessed “that a quick-response 165°F sprinkler would respond in about 198 seconds...
compared to a standard 165°F sprinkler, which would respond in about 252 seconds. More important, the model indicated the first quick-response sprinkler would operate at a point where the fire’s heat-rate release was only about one-half the rate when the standard-response sprinkler would operate. That is, the fire would gain considerably less headway at the time the quick-response sprinkler would operate” [2]. If the new computer technology can improve the sprinkler system’s ability to control a fire in a specific area, then it will minimize exposure from fire in other areas of that building.

A consulting engineer is often responsible for the preliminary sprinkler system design and accompanying fire protection job specifications. A researched preliminary sprinkler design may build in parameters specifying that the installed system be engineered with the anticipated future building addition in mind. When a future addition is likely, the original installation must be designed so that the later addition can be made without major revisions to existing pipe. It is customary to upsize the header, riser, and cross-main pipes in these instances and to leave outlets (or grooved caps) for future system connections at expected convenient locations in the base building. “The cost impact of increasing the pipe sizes prior to construction is usually between 5 and 10 percent and is far less than the cost of substantially modifying a typical system which has been designed to meet the minimum demand permitted by the shell building prior to tenant improvements. These costs can easily be 20–50% more than the original cost” [3]. Reducing the cost of an installed system now (with the elimination of any safety factors) will serve us well only temporarily if it causes the demands of the later building addition to exceed original hydraulic demand. We certainly do not want to complete a design project, knowing full well that it may come back to haunt us in the future. “The sprinkler contractor is the key to the growth of the sprinkler industry. Not by keeping the cost low but by installing quality systems that work when a fire occurs” [4].

As will happen, you may find yourself in the role of the design engineer for the future building addition. This is where your ability to correctly analyze the hydraulic aspects of an existing system becomes critical. Another point that was made in previous chapters bears repeating here, and that is that fire sprinkler performance can be negatively impacted by changes in building use.

These changes include:

- Changes in occupancy, for example, revising office or production space to warehousing;
- Changing a process or materials, such as going from metal stamping to molded plastics;
- Building revisions, i.e., relocated walls, added mezzanines and ceilings below sprinklers, or the removal of heating systems in spaces with sprinkler piping subject to freeze.

Any of these may adversely affect the original operating design of the fire sprinkler system, possibly rendering it inoperable in the event of a fire. To avoid these problems, plus an assortment of costly code violations, … do a walk-through of your building at the blueprint stage of the revisions, thus allowing you time to incorporate the suggestions before the work is begun. [5]

***

With respect to damage resulting from fire, there are costs associated with prevention and there are costs associated with “fixing it” later. Restoration is a major-league expense. Anyone with the slightest grasp of economics would opt for prevention as a modus operandi. Let’s look at some numbers related to the economy of prevention. A smoker may purchase a cigarette lighter for 99¢ and a pack of cigarettes for $2.50. Statistically speaking, fires that claim cigarettes or lighters as their originating cause are responsible for over $500 million in direct property damage in the United States annually (not to mention over 1000 deaths and over 4000 injuries). “That works out to $6 to $7 per year in property damage for the pack-a-day smoker. If deaths and injuries are included, losses are $35 to $40 per year for a pack-a-day smoker” [6].

There seems to be no real end to large fire losses.

We continue to experience them, history repeats itself, and we learn truly little, if anything from the event. The events precipitating these losses are different, yet the reality is a repetitive scenario of:

- Delayed alarm;
- No emergency plan or drills;
- Extensive property and casualty loss;
- Locked, blocked, or inaccessible exit ways;
- Failure of, or lack of, or inadequate automatic fixed fire protection devices;
- Difficulty in effecting manual firefighting;
- Overcrowding or excessive storage;
- Combustible interior finishing.

At each of these events the issues of direct and indirect fire loss continue to exist. The sad scenario is that the loss figures seem to grow at each “event” with extended recovery periods or complete shutdowns almost becoming the norm.

We have to begin to learn that these losses will continue as long as behaviors can precipitate a fire situation, and that emergency and disaster planning by the corporation is no longer a luxury but a minimum expectation.

The issue of collateral economic damage faces both business and the municipality. … Unfortunately the reality of death and injury is overshadowed and forgotten as third party lawsuits ranging from psychological distress, to lack of use of property, to liability for specific injuries are filed with demands of billions of dollars.

Also, in some cases firefighters workers' compensation costs and death benefits can exceed fire loss. It doesn’t take much in medical expense, coupled with overtime and death benefits; coupled with equipment replacement and contamination fees to reach fire related costs of enormous proportions” [7].
We all realize that a little prevention can go a long, long way. Prevention is the heart of fire protection design. The more educated the designer, the better equipped he is to carry out his work. Any efforts that you make now to enhance your own knowledge will always prove to be of benefit at some later date. These efforts could include the pursuit of some degree, a NICET certification or certifications, or attending a private educational seminar. “It is time for educational progress in the Fire Protection Design Industry. In the short term, you should take advantage of the seminars, short courses and correspondence study programs that the universities and colleges have to offer” [8]. I have always felt that it is not difficult, by asking questions and through continued reading and study, for an experienced engineer to enhance his or her skills and continue to improve as a design engineer. The hard part, really, is at the very beginning—getting off to a good start with a foundation of basic fundamentals. Formal education in all aspects of fire science is available today if you look for it, and curriculums are suited to fit the needs of either the beginning, intermediate, or junior level engineers.

If the designer strives to acquire certain other abilities, these will augment his educational background to assist in the positive development of his own career. I would consider the following seven attributes to be noteworthy attitudes with which to supplement personal acquired technical skills:

- Be a team player. Be willing to coordinate your efforts with others in your firm or on the job.
- Establish good work habits.
- Have a flexible attitude. There are other solutions to engineering problems besides your own.
- Maintain a positive relationship with your immediate supervisor.
- Don’t be overly independent. Large projects can turn into nightmare assignments if you try to tackle the whole task alone.
- Keep yourself up-to-date with changes in industry technology.
- Make it your endeavor to improve communication skills. This includes the writing of reports, letters, and technical specifications as well as speaking talents.

* * *

To conclude this chapter on costs and economies, I want to make you aware of other perspectives. There are buildings designed today with less than a foot of room between the acoustical drop-ceilings and the structural steel, because the architect didn’t even consider the allowance of the extra space to include fire sprinkler piping. Or perhaps because the architect deemed the reduced construction cost (of a shorter standing building) to be a higher priority than the inclusion of automatic fire protection. (Luckily, a code official will sometimes intervene, and a fire sprinkler system is mandated to be installed at the eleventh hour.) I have even had an architect tell me once that in his opinion, fire sprinklers never save any lives. This is not a prevalent attitude, but one that still persists among certain individuals and groups in the construction industry. These people view the money spent on fire protection requirements as wasted, and will never invest capital in this direction unless they are forced to by code.

The development industry has lobbied vigorously against sprinkler protection claiming that it is too costly and does not save enough lives for the money spent. At the time of construction, sprinkler protection costs approximately one percent of the cost of the construction of the building. In most large buildings the contractor can save some of this money through cost reductions in other fire protection system trade-offs. Builders argue that after fire alarms, voice communication systems, emergency power, hose cabinets, fire separations, fire service elevators, smoke control systems, and other emergency systems are installed there is no money left for sprinklers. Automatic sprinkler protection is the best use of our fire protection dollars. When designing fire protection for buildings we should be installing sprinklers as the first line of defense. If costs are a concern, then we should consider deleting some of these other devices which will not be used if a sprinkler system is present to control the fire. . . Ask any of the relatives of the victims of the fire or the survivors of the fire if that is too much money to spend to save lives. [9]

If these two statistics won’t change someone’s mind about fire sprinklers, then nothing will:

- “Children under age 5 are at serious risk of being killed in a fire—more than double the average population” [10].
- “The NFPA has never recorded a fire causing multiple deaths (more than two people) in buildings protected by automatic fire sprinklers. NFPA has been gathering fire statistics since 1897” [11].

In my mind, that sums up the overall picture very concisely. In terms of dollars and cents, total direct property loss from fire is estimated to be in excess of $11 billion each year in the United States. Fire kills more Americans each year than all the floods, hurricanes, tornadoes, earthquakes, and all the other natural disasters combined.

The fire protection industry is very small in comparison to other vocations. Just by reading this text you have entered into a very exclusive minority. The business of fire protection has historically been lacking for want of more qualified engineers, and there is always a call for conscientious and bright individuals willing to continue giving the science of fire protection design engineering a good name.
CITATIONS


ENDNOTES

1 For this specific room, the end-feed style is the best configuration. This is not to suggest that the end-feed is always the preferred layout.
2 The new 1999 edition of NFPA #13 contains a reorganization of Chapter 5 written code regulations.
3 For branch-lines, a circumference measure of about 9” lets you know that you’re looking at 2 1/2" pipe, and a 7 1/2" measurement relates to 2" pipe. The “circumference” for 1” pipe is about 4 1/8”. Anywhere from 5 1/8” to 5 1/4” identifies 1 1/4" pipe. About 6 1/4” or 6 1/2” would correctly identify 1 1/2” pipe.
4 Be careful, however, that you do not exceed the maximum spacing parameters noted in the 5-6.2.2 tables of NFPA #13.
5 See Appendix “A” of this text.
Fire Sprinkler Application Review

Practically speaking, newly developed fire sprinklers cannot survive in today’s market without being U.L. listed and F.M. approved. There are presently ten fire sprinkler manufacturers in the United States who currently manufacture over 900 different styles of sprinkler heads. The latest of these fire sprinkler manufacturers to hit the streets is Victaulic, whose FireLock line initiated their sales distribution-operations in May of 1999, offering a nearly complete line of sprinkler types—including standard and quick-response styles, extended-coverage, residential, ESFR, VELO, and high-pressure (250 psi) rated heads for high-rise commercial applications. In addition to designing a product to meet NFPA requirements, no phase of developing a new line of sprinklers is more rigorous and highly scrutinized than the process undertaken in the agency testing laboratories. It is a long, expensive, and often frustrating procedure.

Fire sprinklers are tested for performance in actual fire scenarios, for response time, expected performance, and water distribution under various replicated field conditions and water supply characteristics. Testing activities have escalated particularly over the last twenty years due to advancements in technology represented by the many new styles of sprinklers offered for specific applications. Underwriters’ Laboratories has not only been busy with the testing of new products, but a lot of their work has also been focused on testing new modifications to existing sprinklers. These modifications include changes in material, orifice sizes, and different manufacturing processes for the deflector. Except for sidewall sprinklers, deflectors normally consist of a flat plate that deflects discharged water to cover a circular floor area, breaking up the water stream so that a desired water droplet size sprays out, creating an umbrella-shaped form. This pattern will be more horizontal than vertical, the wider the deflector. Some deflectors are “shaped” for more optimum hemispherical spray patterns. The deflectors on sidewall sprinklers are designed to throw water across a room in a crescent-shaped array.

To check for even water distribution, the Factory Mutual test follows a typical regimen. They start by flowing four sprinkler heads, checking the discharge by using sixteen collector pans inside a 4’ x 4’ “target,” and then calculating the delivered densities. The length of time taken for the test is three minutes, and this process is repeated using three different rates of flow. There are minimum pan requirements that must be met as well as a minimum “average discharge” demand. For example, you could have all 16 pans meet the minimum volume demand, but still not make the total water requirement for that particular test. If that phase of the distribution test is passed, it is repeated with six heads flowing at another predetermined flow rate. These tests are critical in concluding that the sprinkler frame design and deflector styles have been manufactured conjointly in an effective manner, to ensure consistently uniform spray patterns.

The same fire sprinkler that was originally tested and certified at Underwriters Laboratories way back when, may be back in the same Northbrook, Illinois, facility some fifty years later. NFPA #25 requires building owners to have periodic testing done on their (older) existing sprinkler heads. This inexpensive procedure may allow the system owner to sidestep the signing of an expensive head-changing contract. Sprinklers selected at random from the installation site are subjected to a sensitivity oven heat test to measure response time. A detailed report also evaluates the condition of heads, describes the sprinkler’s operation, and determines whether or not the sprinklers conform to the requirements particular to the type of room environment and location in the building it protects. U.L. will test any sprinklers except those that are damaged, painted, or manufactured prior to 1920. Those must be replaced in any case.

Sprinkler evolution has come in waves. More than 40 different manufacturers produced 90 different sprinkler heads between 1878 and the early 1900s. Uniform rules for standard sprinklers soon followed, as did more reliable fusible link technology that increased sprinkler response speed. 1954 is the “continental divide” of sprinkler development, the year when “old style” sprinklers were replaced with those having the improved and modified spray sprinkler deflector, researched by FM and known thereafter as “standard” heads. And probably jump-started by the fast-response sprinkler research done in the 1970s, we are still in the midst of a flurry of rapid change and development in sprinkler technology. Today’s new sprinklers are lighter, easier to install, less obtrusive in design, and have larger orifices and modified deflectors that expand possible areas of coverage. In addition and more importantly, they are designed more and more with specific applications in mind. As far as the sprinkler system designer is concerned, standardization has been replaced with
specialization. The “Installation Requirements” Chapter No. 5 of NFPA Pamphlet No. 13 has had to expand considerably with each successive edition to keep up with these industry advancements.

For a sprinkler to operate successfully, it must be close enough to a heat source to either melt a fusible element or fracture a glass bulb. Then, hopefully, the system is properly designed and is connected to a reliable water source. The control features of a sprinkler head are its operation, the orifice size, response characteristics, deflector style, and its temperature rating. During fire conditions, the sprinkler’s fusible alloy will melt and, subsequently, release some type of tension mechanism to operate the sprinkler. This mechanical configuration is designed in any number of ways to guard against any corrosion while providing dependability. What is installed most often today is the glass bulb sprinkler that is activated when the measured amount of fluid inside the bulb expands when heat is applied, shattering the bulb. The first bulb sprinklers marketed were the Quartzoid heads made by Grinnell, in 1921. The selling point of the above, you can add additional categories for large-drop, ESFR, ELO, VELO, dry sprinklers, in-racks, concealers, flush type, quick-response, window sprinklers, on-off, and extended-coverage. Actually, there is no end to this subheading list, as manufacturers continue to answer special fire protection needs with specific sprinklers. For example, the Central “CC1” sprinkler was pioneered to address the “above ceiling” fire challenge and has been designed specifically for placement in light-hazard combustible concealed spaces. The bottom line for designers and installers is that listed sprinkler heads must be installed onto piping and fittings in strict compliance with that sprinkler manufacturer’s published installation guidelines.

For general use occupancies, the standard sprinklers known as upright, pendent, and (horizontal or vertical) sidewall are the most popular heads used around the globe. These heads, rated to 175 psi, are available in varying orifice sizes and temperature ratings with either a standard or quick-response feature. They also come in different finishes for aesthetic reasons. Also, to take little away from the appearance of new construction, the pendent sprinklers come in flush or recessed styles. Good looks notwithstanding, sprinkler technological changes have primarily been reactions to demands that are financial in nature (so much is economically driven).

In general, the extended-coverage sprinklers feature larger orifice sizes to provide added coverage, meaning fewer heads, even when only normal water pressure is available. Why wouldn’t a contractor want to take advantage of the inherent savings available with extended-coverage heads? Fewer heads mean less fittings, and less made-on fittings mean less shop fabrication and less field labor. As one example, the Central ESLO extended-coverage light hazard pendent sprinkler has an orifice size of 0.70” and can cover a 400 square-foot area with a single sprinkler. If recessed, the escutcheon provides for 3/4” of field adjustment. That’s a lot of flexibility that speeds installation. Like most new sprinklers, it comes with special restrictions, such as a 9-foot minimum separation between heads. The designer has to be attuned to the installation criteria for each sprinkler type. With this ESLO, he will want to use it only where relatively flat ceilings are present, because the maximum ceiling slope allowable is 2” per foot.

Extended-coverage sprinklers became standard for use when the 1991 NFPA #13 Technical Committee completely reorganized the standard. Included in this edition was a reconceived Water Demand Requirement chapter, which permitted the pipe schedule design method only for new system installations less than 5000 square feet in area. In one fell swoop, pipe scheduled systems were shown the way to the retirement home. Extended-coverage sprinklers have special flow/pressure requirements, different for each head, and thereby can only be installed in hydraulically calculated systems. But because the grand majority of all fire sprinkler systems since 1991 had to be calculated anyway, it took no extra effort for the designers to incorporate extended-coverage sprinklers into their new designs. Only traditional thought stood in the way, and that thinking quickly flew by the wayside in light of cost savings.

Similarly, extended-coverage residential sprinklers quickly outnumbered sales for standard residential sprinklers. Why design for residential heads that the 13R or 13D standard requires to be a maximum of 12 feet apart, when you can use a Viking “Horizon” model that can be spaced 20 feet apart? The economics don’t even compare. And the new residential sprinklers are greatly improved in terms of design quality with each new issuance. The Grinnell Model F983 Designer, residential sprinkler, can also cover up to 400 square feet, can be installed on sloped ceilings, and only weighs 2.7 ounces. It has an 8-foot minimum spacing restriction, which is the same mandated by NFPA residential codes.

For ordinary hazard applications, a sprinkler such as Central’s ELO-16 with a larger (0.64”) orifice size can protect areas up to 16 × 16 feet due to its larger (11.4) K-factor. Sprinklers must be situated at least 12 feet apart to guard against a cold-soldering condition. These sprinklers have special installation criteria, are available for either upright, pendent, or recessed pendent positioning, and are intended for use with hydraulically designed systems using presupposed flows and pressures. The Central VELO sprinkler has similar criteria, possesses a K-factor of 14.5, and can cover a 20 × 20 foot area with a minimum design flow of 60 gpm per sprinkler at 17 psi.

For many years, the architect’s preferred choice for pendent sprinklers was the Viking (chrome) flush sprinkler that featured a one-inch female threaded attachment. All that protruded from the ceiling was the fusible link apparatus, which had visual appeal. Better yet, it didn’t “look” like a sprinkler. Although the 1” drop had to be cut in the field to an exact length, that was the norm at the time for all pendants. Engineers still specify certain flush heads today. But the popularity of the flush sprinkler was gradually replaced by the “phantom” or concealer sprinkler in the 1970s. The Star Unspoilier, introduced in 1971, was an architectural favorite that has since evolved to suit demands such as the quick-response feature and residential applications. Cover plates for concealers can be shop-painted virtually any pattern or color to match new ceiling decor. The “LD-2” Star Eclipse model has a 3 1/2” diameter cover plate attached to the sprinkler by two spring-loaded clips. The clips release (usually at 135 F.) when the eutectic alloy melts, exposing the in-place sprinkler which is designed to operate at 165 °F. Star’s subsequent concealer model, the Phantom “PH-1”, is listed with an adjustable feature that allows the
cover plate to be situated 3/8" below the finished ceiling, and the plate itself has a diameter of just 2-3/4".  

As per the requirement noted in the 1996 NFPA #13 edition, only quick-response type fire sprinklers are permissible for new high-hazard installations. The glass bulb capsules (3 mm) used for these sprinklers is a much thinner version of the original. The economic advantage inherent with the use of these heads is evident when reviewing Figure 7-2.3.2.4 in NFPA #13, which allows a generous design area reduction for hydraulically calculated systems when using sprinklers listed as quick-response.

In the early 1980s, following an outbreak of suicides in a California prison in which inmates fashioned a “noose” from towels or clothing hung from die cast brass sprinkler frame arms, Star and other manufacturers developed tamper-resistant sprinklers for use in institutional settings. These also spoil efforts to deliberately discharge sprinklers. Institutional heads come in pendant and sidewall versions, insuring that piping can be confined to corridors, plumbing walls, or service areas. These are also used in detention or mental healthcare facilities. Escutcheons are flat, or 2–3 inches long, and are available in stainless steel finishes.

Central Sprinkler has developed the new Attic Sprinklers so well, I cannot envision any contractor sprinkler an attic exceeding 3000 square feet today by conventional methods. They are probably the most innovative of the newer heads. Attic Sprinklers aren’t cheap, but the representative labor savings is so considerable that a contractor bidding a job by the old method simply will not be competitive. Approximately 80% less pipe needs to be installed. Devised in 1994, it is an example of technology answering a specific need within the fire protection community. It used to be that the peaked roof of steep attics gave a fire its own head-start by venting the heat before the appropriate sprinklers could react. The steeper the roof, the greater the response problem. The newly developed heads have very specific flow/pressure requirements, because the placement and coverage of Attic Sprinklers will conform to the configuration of attics by means of the directional flow of their discharge. Quick coverage is guaranteed due to the large number of heads located where they will be the first to fuse. Certain heads situated at the attic peak cover an area 6 feet wide by 60 feet long. And the entire attic, including corners, can have blanket coverage with a maximum of three different nozzle/deflector types.

Innovations often come about due to needs created by other advancements. No one ever really heard of a skyscraper before elevators were invented, and before structural steel became extensively sophisticated. The idea of sprinkler systems wasn’t really conceived until 1870, because prior to that you didn’t have a multitude of buildings containing electrical wiring, appliances, heating equipment, stoves, microwave ovens, electric blankets, curling irons, hot water heaters, etc. When all you had to worry about was fireplaces, smokers, and arsonists, there weren’t as many fires starting. Consider the fact that in recent years, there have been numerous advancements made in automated storage warehouses. Computerized stacking and retrieval systems are in place around the world, with products stacked 40 feet high and even higher in some instances. The demand from warehouse managers is for a ceiling sprinkler that will be so effective that it will eliminate the need for in-rack sprinklers, which are looked at as a nuisance and a “time-bomb” in terms of the potential for accidental discharge. So, with a virtual bonfire of flammables to protect, sprinkler product design experts have been faced with one of the most challenging environments for fire protection.

The extra-large orifice sprinkler has been around for a long time, beginning with the GEM “Jumbo.” While later ELOs were developed to reduce the number of sprinklers required, they are now used for installation in rack warehouses. In certain commodity and racking arrangements, the ELO and the very extra large orifice sprinkler can eliminate the need for in-rack sprinklers. These sprinklers are specifically made for instances where high flows at low pressures are needed. Discharge rates are twice that of standard 1/2″ sprinklers. The Viking Model A Large-Drop sprinkler has a K-factor of 11.2 and produces larger water droplets designed to penetrate the fierce fire plume of high-piled storage fires. The large drops cool the atmosphere to improve high-challenge fire control. The sprinkler is equipped with a quick response fusible link, and this fast response feature will propel the large drops to the burning fuel at an earlier stage of fire growth. Specific requirements for large-drop heads appear in Chapter 5-10 of NFPA #113.

The new wave of storage-specific sprinklers include the K-17 and K-25. These heads have a very large orifice, designed to protect products piled vertically to 40 feet. The K-17 is a standard response head, and the K-25 has a fast response operating element. Tests conducted at Factory Mutual and Underwriters Laboratories demonstrated that these high-performing sprinklers require less discharge pressure and can control fires with fewer activating sprinklers than previous standard sprinkler and large-drop models. At the same time, they provided a deeper plume penetration without the necessity for in-rack heads, which can interfere with storage operations. The savings represented by these heads is substantial. The K-25 sprinkler has a 1.0 inch orifice and has had great success in laboratory testing. It is highly recommended for ceiling-only protection where flammable liquids are stored, and has provided effective fire safety characteristics while maintaining pressures as low as 25 psi, which will eliminate the need for fire pumps in many instances. It is a poorly kept industry secret that funding for development and testing of many of the new warehouse storage fire sprinklers has come from the manufacturers and their clients, as opposed to research agencies. A firm that stores a specific product to a certain height in a particular way can realize greater facility savings if a sprinkler is tailored specifically to their needs. As a result, the sprinklers are being manufactured with these specific uses in mind. The new heads are better, but primarily when they are tailored to a particular storage scenario. Each type of sprinkler has its own published manufacturer’s data sheet.

Architects are less likely to go with a design/build approach due to all the new technology. They are way ahead of the game if they outline specifics and contract out for a preliminary design from day one, a preliminary design concerned with economics. Designers have to be careful to specify the right sprinklers for various occupancies. The plan reviewers begin the review of any large warehouse sprinkler system by reviewing the data sheet of the fire sprinkler that is to be put to use, and then check for appropriate code conformance. In short, the new warehouse sprinklers make design more complex due to numerous options, but they answer the needs of the market with more suitable economic solutions.

The Factory Mutual Research Corporation developed the concept of the Early Suppression-Fast Response sprinkler in the 1980s to address the hazard presented by plastics storage. The ESFR sprinklers are a very popular head for many warehouse applications. It is a fast-response pendant sprinkler that must be installed in strict compliance with applicable NFPA regulations. It has a high K-factor (usually 14.2) and is also best suited for high-piled storage situations.
Sprinkler spacing must exceed 80 square feet but not exceed 100 square feet. There must be a minimum separation of 3 feet between the top of stored product and the ESFR deflector. The ESFR head responds quickly to a developing fire, delivering a high-momentum heavy water stream designed to suppress fires directly beneath the operating sprinkler.

In a relatively short window of time, many storage sprinklers have been tested, passing with flying colors. But are they realistically sensible? The new sprinklers have performed extremely well up until now, but some skeptical in the industry point to the fact that the parameters for testing have been too “clean.” For example, no tests are done with factory doors and windows open, with storage stacked sporadically, or stored too high in spots. The testing is done under ideal conditions, with all aisles clear. What about the very real possibility that these sprinklers are not replaced with identical matches? Or the possibility that the occupancy changes within the building? The biggest foe to the sprinkler system in these high storage buildings is solid shelving. That’s a scary real-life picture. If just a few solid shelves are implemented into the storage racks down the road, the entire sprinkler design is invalidated, and the whole concept of new sprinkler advancement goes for naught. Will quick-response heads be replaced with sprinklers that have quick-response bulbs or standard bulbs? It’s easy for the uninformed to make a mistake. The building engineers and the fire marshals will need to be highly qualified, with a continuous and sharp eye on the lookout.

The fire sprinkler has been called the silent sentry, on watch to provide the first strike against fire. In a culture constantly fascinated by whatever’s new, it’s no surprise that the new heads are all the rage. But it’s not the newness of these sprinklers, it is the engineering advantage they provide that fuels their successful marketability. With advancement comes additional work for the engineer. It used to be that a few sets of rules applied. Now technology is advancing so rapidly that newly developed products and installation requirements don’t necessarily coincide with existing standards. The NFPA #13 requirements that have long been recognized as industry norms now contain italicized “exceptions” that read something like “except when specified otherwise in the listing of the sprinkler.” Research and development efforts continue. What must be stepped up on the user end is inspection and maintenance efforts. A study by the National Institute of Standards and Technology in 1993 estimated that sprinkler systems do not operate effectively 8 percent of the time, as a direct result of poor installation or maintenance. This bleak forecast can only be worsened by the existence of new sprinklers that must comply with strict guidelines to meet their objectives. The challenge presented by successful testing in the laboratory must be met by a knowledgeable public, engineering community, and a higher level of expertise by inspectors.
In-House Engineer Training

Let's start with the definitions:

**Type “A” Engineer Trainee**—An individual who perceives that the onus is on him to seek out answers to his own questions. A self-motivator who feels responsible for his own acquisition of knowledge and is anxious to learn as much as he can, as quickly as he can.

**Type “B” Engineer Trainee**—Someone who will ultimately be a finger-pointer. An employee who feels that it is 100% someone else’s responsibility to teach him everything that he needs to do his job, and if he is ignorant of any knowledge vital to his job description, then someone else or the company is to blame.

This is not to imply that each and every company employee is of either one or the other persuasion, of course. It is much healthier to look at these definitions noted above as recurring examples of personal habit, as opposed to permanent character traits. But nonetheless, these are good models to use for the sake of discussion. It is no secret that the Type “A” self-learner will go fast and far in his career and will always be the type of employee who is respected, needed, counted on, desired in the job market, and most likely someone who is inherently satisfied with his professional life.

But let’s look at this from the perspective of the engineering or contracting firm. Regardless of the type of employee the firm hires, it is in the contracting firm’s best interest to train employees for various duties as thoroughly as possible. And that task requires time that no one readily has. But the better the training, the better the employee, the better the teamwork, the fewer the headaches, the heartier the company morale, and the higher the profit margin. The best contracting and engineering firms are those in which everyone involved maintains a philosophy that they should strive to give more than they take. That formula bodes well for training the new employees. With any training exercise, good communication leads to teamwork, and the resulting higher productivity leads to a successful business.

At its most basic, the training formula for an entry-level technician goes like so: tell the engineering candidate what he is expected to do, why he should do it, how to do it, and how long the exercises or projects should take to complete. An engineer hired from the outside has already received these instructions, albeit from some other source. This is why problems may occur and little concord may be reached on initial projects assigned to the “outside” engineer. Successful in-house training is the simplest means to keep everyone on the same page. It may not guarantee universal happiness, but it certainly goes a long way towards better control of the firm’s engineering agenda. The most frequent argument that I’ve heard from consulting engineering firms, service companies, contracting firms, and design-build firms opposing the practice of in-house training is that this practice represents a time-consuming investment that the firm has made in one individual, who then leaves the firm anyway after a couple of years, only to be subsequently hired by a competing firm. While this scenario has no doubt happened many times, it’s important to recognize that leaving a firm is one individual’s decision, based unfortunately on factors that are often out of your control, and his mind has been made up. Someone hired from the outside may also leave the firm after a couple of years. If an employee leaves, he was going to leave sometime anyway, and there is no way to forecast that or usually, to prevent it from happening.

Many firms will appoint one or more individuals to mentor the training of a new employee. The mentor, of course, needs to be an encouraging coach who is amenable to interruptions in his own work to answer questions from the trainee at various unpredictable times of the day. The mentor must always strive to get the trainee to understand why he is expected to do certain tasks—many of his questions will be of this nature. The goals and objectives set for the training process should be specifically written down, structured on a timeline, monitored by the mentor(s), and oriented towards the core business needs of the firm. The new engineer should be supplied with all necessary resources for his job, especially the relevant codes he needs to learn, and the mentor needs to set aside specific dates and times (usually monthly) to sit down and review progress. Continuous progress is important, because stagnation in training benefits no one.
There will be more than one in-house trainee in any company’s future, so recognizing that the development of a training program is an organization’s responsibility is paramount. After that, the company gives the trainee the necessary knowledge, and it is up to the employee to implement and apply that knowledge. Because there is so much knowledge to absorb in any engineering field, the goal-setting involved in the training procedure is a vital, “building-block” approach towards this end.

There are several training schools for sprinkler designers throughout the United States, provided by various associations and universities. Many firms will utilize these, and I think wisely, to augment their own in-house training. These can also be utilized by more seasoned employees as “refresher” courses. There has been obvious progress made by all of these educational programs over the past decade. Any instructor of one of these week- or month-long schools will naturally be very interested in the student’s level of prior knowledge. One course, offered by the American Fire Sprinkler Association, has gone so far as to ask for the following minimum requirements for prospective design engineers:

- one week of experience in a fire sprinkler fabrication shop
- one week of experience in field installation
- “some proficiency” in drafting room procedures
- a working knowledge of simple algebra and geometry
- a working knowledge of blueprint reading

This prerequisite, of course, lay a solid foundation for anyone who desires to grasp a clear understanding of NFPA #13, which initially is not an easy chore to accomplish alone. While none of the training schools or universities will claim that they are churning out the equivalent of top-notch seasoned designers, their endeavor is more or less the same as that of an in-house training program, which is to prepare the engineer for his job regimen as completely as possible. Familiarizing the trainee with the numerous codes, engineering methods, rules of thumb, and fundamentals, creates the opportunity for that individual to be competent and thrive in the business.

Many contracting firms will hand a new engineer a project to design as soon as possible. What they are really doing is attempting to reduce their own engineering backlog, but proponents of this method will claim that their belief is that you cannot learn to swim until you are thrown in the pool. This theory probably slows down the learning process in the long run, but at least it forces the engineer to constantly ask questions on his own in order to finish his task. Eventually, all of his questions are answered by the following question, “what does the book say?” This forces the designer to become familiar with the relevant NFPA codes, although completely on his own. Keeping all the codes handy for him is essential, but so is providing him with some kind of handbook on sprinkler design. Many are available. No one learns design by researching codes.

Learning engineering is best undertaken step-by-step. Prior to the assignment of his first job, there are numerous other assignments to be given to the engineer that will assist him in learning not only the bread-and-butter business interests of the firm, but also in acquiring engineering skills in realistic timely fashion. Little will be missed when extra time is taken in the educational process. Most sales representatives of the engineering firm are former engineers, so don’t forget that while training an entry-level employee, you may also be training a future sales rep for the company. The following are some suggestions for a contracting firm engineer’s initial assignments:

- **Block out a job for design:** this exercise will familiarize him/her with drafting or CADD preparation for buildings of differing framework and scheme.
- **Place the engineer in charge of all resubmittals:** this will get the engineer used to the regulatory process, specific code requirements, and hopefully the many different types of projects of which the firm is engaged (i.e., high-rise, residential, high-piled storage, HPR, etc.).
- **Field-check a job for another engineer:** this exercise is good for survey experience: the checking of water supply placement, hanger locations, the reliability of structural drawings, and for potential mechanical obstructions in the field. Anytime an engineer visits a jobsite, he will learn something new, and he should be encouraged to spend a lot of time on the project site.
- **Inventory the shop:** you are supposed to do this for accounting purposes at some point anyway, and this work will get the designer very familiar with all the materials in the shop used for fire sprinkler system installations.
- **“Cut” hanger lengths on another designer’s plan:** this exercise will get the engineer thinking in three dimensions and familiarize him with architectural and structural drawings.
- **Complete a “relocate” job:** not only will this give the designer a feel for his “first” job, it will necessitate learning the rules of sprinkler spacing and positioning, requirements of (Chapter 5) NFPA #13, and the notes, sections, and details necessary for completion of the shop drawing.
- **Prepare a stocklist on another design engineer’s job:** this is an important task that will naturally instruct the engineer to become familiar with materials used for installation, while being painstakingly accurate.

Making these tasks meaningful, as opposed to just putting him in charge of the sack-race at the company picnic, is valuable for his own cross-training. He’s got to get his feet wet. He or she could also be asked to drive a small truck to deliver material or ship-off a job (once), tag-along on an inspection, take gauge readings on a fire pump test, or witness a hydrostatic test on both wet and dry systems. Something extremely informative and helpful is for the trainee to go along with a seasoned engineer on a retrofit job. While this takes hours, it is the best way to get inside an experienced head. If the senior design engineer will continue talking as he is working, the new designer will pick up a multitude of information as they move about the building. This is irreplaceable “lab” time. On the same note, the new engineer has to be prodded to continue asking questions of anyone who will respond, and this includes salesmen, engineers, fabricators, and (especially) field installers.

Ultimately, it’s still time to tackle a simple project. This is still on-the-job training, and Step one is a “plan” job (new construction). An engineer must master plan reading, design mechanics, acquire a basic feel for system layout, and finish his own job. The application of code requirements will be reflected on his own plan. He must dimension clearly and delineate all necessary valves, alarms, and system components. Someone else can calculate the first job, but the new engineer must be responsible for everything else, including the creation of a cost-effective system layout. Step two should encompass an entire start-to-finish design of a retrofit job. It will be a challenge. But, this is an excellent means by which to train a fire sprinkler engineer. Usually, this requires the engineer to formulate his own
architectural background. It also requires envisioning mechanical configurations in the field, and in doing so, this becomes instrumental in acquiring “trick of the trade” pipe routing techniques that would not ordinarily be learned off a two-dimensional project plan.

The fourth dimension known as \textit{time} should not be of critical concern to the supervisor for the first several design projects. The engineer can only learn if he is allotted plenty of time as he is designing. If a certain number of presupposed engineering hours have been estimated for a certain contract, allow double the hours for the trainee’s work on that same project. That is typical.

After he or she has mastered several projects, someone sharp must be placed in charge of teaching this trainee how to hydraulically calculate a project. I say someone sharp because, not only is there an art to teaching hydraulics, but the teacher has to be a patient communicator while being able to monitor whether or not the student is catching on. It’s not the simplest concept to learn or to teach, but it is imperative that it be done within the first six months of training. The goal, after all, is that the engineer become a productive member of a qualified workforce.

Now I’m going to digress briefly. One of my passions in life is muskie fishing. I know that this is a passion because why else would I drive north for hours towards the Canadian border, to spend days floating around casting for one of the most elusive gamefish known? A muskie will strike a lure maybe once in every 2000 casts, or about once every twenty hours. I was in a bait shop once when an angler asked a local what it took to catch one of these muskies. The local replied, “time on the lake.” The reason I bring this up is that it reminds me of what it takes to develop and learn as an engineer. It takes time on the job. \textit{But in order to develop, it takes “Type A” time on the job.} It has to be quality time, not necessarily a prodigious amount of time each day, but time well spent. Time spent asking questions, time spent listening, time spent reading. Time spent building on what you already know. You can’t fake it because if you do, you’re not fooling anybody. It’s just as easy to improve on good habits as it is for bad habits to worsen, so as always the choice is up to you. The company that takes the time to train an employee in the basics of fire protection engineering and a thorough understanding of the codes, reaps its own benefits.
A question commonly proposed to fire protection engineers called on to design a fire protection system for a new facility goes like this: “What type of fire protection is appropriate for our computer rooms and data storage areas?” Yesterday’s answer was halon. The answer to this question depends on many factors and, in fact, leads to practical and viable answers given today that may very well be quite different from the answer given five or ten years from now. Today, there are agencies worldwide testing and evaluating new alternative extinguishing agents to halons with due respect to concerns about environmental safety and global warming potential. The determining factors being tested with regard to these inert gas agents include their level of fire suppression effectiveness, their effect on the environment, their potential for over-pressurization of an enclosure, whether or not they produce gaseous by-products, and how quickly they activate after the origin of a fire.

It wasn’t too long ago that computer rooms around the globe represented an immense market for Halon 1301 systems. Halon 1301 was once recognized as the most effective chemical fire suppression agent developed. But today, halogenized agents (newly produced ones) are not a protection option because we now know that all halons are ozone depleters. The bromine atom in Halon 1301 reacts readily to destroy ozone molecules. Certain halocarbon agents that do not contain the bromine atom are considered by some to be short-term “band-aid” substitutes because they have global warming potential, and they will be further federally regulated. The production of halon itself has essentially ended as of January 1, 1994.

Another non-option for protection (in the computer room itself) is carbon dioxide extinguishing systems. Since CO₂ displaces oxygen, its discharge would cause asphyxiation or suffocation to any occupants present. A low-pressure carbon dioxide system, which would cost about double what a halon system would to install, could realistically be installed in the computer room subfloor space only. This is environmentally acceptable, and would require no clean-up whatsoever.

With the phase-out of Halon 1301 (and 1211), several chemical companies set out to find suitable alternate replacement agents. No one has ever really come up with a “drop-in” pound-for-pound mimic of halon. The first qualification to be realized is U.S. EPA approval, particularly from their Atmospheric Protection Division. The Clean Air Act requires the U.S. EPA to research and report to the public the status of potential halon substitutes. The U.S. EPA discloses their findings in the Significant New Alternatives Policy (SNAP) publication. The EPA designates agents as either acceptable, unacceptable, or pending. Along with this, the NFPA has established a new technical committee. In 1991, the committee’s task was to prepare a design standard to be ready for the commercialization of the agents. Now known as NFPA 2001, “Standard on Clean-Agent Extinguishing Systems,” this internationally accepted standard shows which agents are acceptable for occupied space protection. This determination is made by comparing the minimum design concentration for the agent with the highest acceptable toxicity exposure. NFPA 2001 requires that inert gas systems be designed with an agent concentration of 43% or less and an oxygen concentration of 12% or more if personnel are not able to evacuate the area within one minute.

Currently, NFPA 2001 (and SNAP) has recognized eleven Halon replacement agents. Two that are in wide use today are IG-541 (better known as inergen) and HFC-227 (commonly called FM-200). Both are used for the protection of sensitive electronic equipment and other highly critical environments not suitable for water-based extinguishment. Each agent has its pros and cons with respect to chemical composition, equipment hardware, installation restrictions, and system recharge cost—just to mention a few of the characteristics to be considered.

The question that you need to put to the business owner is, what value do you place on the operation of the computer room? Does your business depend on uninterrupted 24-hour operation of the computer room in order to survive? Typically, the suppression system desired must be comprised, in part, of the following essential features:

- an agent that is nontoxic
- a fast-responding system
- a system that does not bring about a major clean-up problem
- an electrically nonconductive medium

In computer rooms, the potential losses to take into account include not only the loss of computer hardware, but the loss of...
computer downtime. If continued operation of the computer room is imperative, then you will want to investigate the (fairly costly) installation of quick-responding chemical agent systems. Once more, two of the more popular gases that are both habitable (people-safe) and environmentally friendly are FM200 (produced by Great Lakes Chemical) and Inergen (made by Ansul). If systems do activate, the downtime when using either system is very short.

Inergen is a very clean agent, which makes it a popular choice (at least) for the sub-floor space (also for switchgear rooms, vaults, tape storage, process equipment, and any electronic area containing irreplaceable equipment). It is also widely used for computer rooms, and its discharge time is anywhere from 45 seconds to a full minute. It is an inert gas with superior flow characteristics. It is a mixture of three naturally occurring atmospheric gases: (52%) nitrogen, (40%) argon, and (8%) CO₂. The inergen gas curtails and extinguishes fire by lowering the oxygen content beneath the level that supports combustion. But, it should be noted that due to the CO₂ present in inergen, the brain continues to receive the same amount of oxygen in an inergen atmosphere as it would in a normal atmosphere, for reasonable periods of time. Also, the agent does not produce a fog, so visibility in a compartment remains adequate for evacuation purposes.

Designed for versatility, inergen cylinder valves can be opened electrically, pneumatically, or manually. Inergen has zero Ozone Depletion Potential (ODP), zero Global Warming Potential (GWP), and zero atmospheric lifetime. When inergen is released, its components simply resume their normal role in the earth’s life cycle. Its installation requires the presence of one or more large alloy steel components, which hold the gas at vapor pressures in excess of 2000 psi at 70°F. The amount of agent required is calculated in cubic feet rather than pounds. Pressure reducers in the cylinder manifold are a necessary system component, as is the use of Schedule 80 steel pipe up to the union orifice where pressure is reduced. Because inergen is required to reach 95% of its design concentration within 45 seconds, coupled with its higher vapor pressure, the inergen fire suppressant cylinders can be stored a fairly long distance from the protected hazard utilizing smaller diameter discharge piping. The major advantage of an inergen system is its quick response and the larger extent to which it can be reliably effective.

FM200 is a chemical blend (heptafluoropropane), stored as a liquid within the agent cylinder similar to that of Halon-type cylinders. FM200 has zero ODP, a GWP of 0.3 to 0.6, and an atmospheric lifetime of 31–42 years. This is in strict compliance with environmental regulations. It is thermally stable and on the SNAP list. The FM-200 discharge piping utilizes Schedule 40 pipe. FM200 requires less of a footprint to hold agent in a cylinder. The supply tank will be proportionately smaller. It lays in pipe at approximately 60 psi, and discharges quickly for a duration of about ten seconds to achieve a 7% concentration. Due to the typical 7–10% concentration design, the agent storage requires minimal space. But, due to the relatively low (59–60 psi) vapor pressure, the FM-200 cylinders are required to be within close proximity of the hazard. Actually, the physical properties of FM200 considered along with its traditional extinguishing requirements, allow its use in the same type of equipment that would be used for Halon 1301, requiring minimal hardware alteration for retrofit situations. Usually, the same detection and control panels can be used.

Installation of the first commercial FM-200 system began in December of 1992. In addition to computer rooms, typical applications for this clean, gaseous agent include telecommunication equipment facilities, data processing libraries, emergency power facilities, flammable liquids storage rooms, museums, clean rooms, process control centers, and so on. It creates hydrogen chloride as a by-product, which may attack existing documents or other “archive” materials. It will not, however, corrode sensitive electronic equipment, and it contains no particulates or oily residues. In fact, it leaves very little residue and is a quite popular extinguishing agent in use today for the protection of computer rooms. Proponents of FM-200 boast code-compliant, cost-effective system configurations.

If you are working with tight budget considerations, then you may want to investigate the installation of a Preaction system in the computer areas. BOCA defines a Preaction system as a fire sprinkler system employing automatic sprinklers attached to a piping system containing air with supplemental fire detection that is installed in the same area as the sprinklers. Actuation of the fire detection or smoke detection system automatically opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any open sprinklers. Preaction systems historically have had limited use in electronics-intensive applications, where the mere mention of the word “water” is probably dangerous. Some modifications are advisable. As an example, a time delay can be built into the preaction control panel, creating a time lapse before water commences to fill the system. This delay provides the building staff with a chance to investigate the incident prior to the introduction of water at the scene. As additional safety measures, on/off sprinkler heads and floor drains may be installed. Also, smoke detectors can be cross-zoned, so that two detectors must go into alarm before the preaction system is charged with water.

A Preaction system, while a less expensive option, is really insurance for protection of the building structure itself. The loss of the entire building will be protected effectively by a properly installed Preaction system, although the degree of water damage may sacrifice the equipment data center in the process. The loss of downtime may be considerable. However, the Preaction system will not activate until there surely is fire present. The question presented to the business owner is always: what type of protection do you want?

Again, the type of protection generally desired for a computer room is total flooding fire extinguishment and suppression that occurs quickly before any damaging smoke is generated and without wetting equipment and contents of the enclosed room. The desired qualities of gaseous agents present near the fire origin must include quick-response time, near-zero ozone depletion, short atmospheric life, and low toxicity. If fire suppression is accomplished within ten seconds of system activation, the release of toxic and/or corrosive gases (acidic products of decomposition under fire conditions) will be minimized.

When you need to guard absolutely against water damage to sensitive electronic gear or high-value areas, a gaseous agent is a wise choice for fire protection. The question of which agent is best suited is not simply this one or that one. Neither is the “better” gas. It should be obvious to any discerning mind that neither agent, nor any of the 11 recognized by NFPA 2001, is optimum for all possible applications. Many issues with respect to hazard definition, size of hazard, agent cylinder storage size, locations, installation cost, and agent recharge cost must be addressed. As an example, while the FM-200 gas may cost 8–10% less up front, it has a higher replacement cost. When choosing between FM200 and Inergen, you have to look at the total situation, talk to a professional, and make a choice.
The effectiveness of clean-agent systems is always dependent on the integrity of system interaction with process controls. And, the designer must determine an adequate amount of agent to supply, in accordance with recommended design concentrations for the cubic-foot volume of the computer room. With regard to clean-agent system design, there are several “red-flags” that the engineer must strive to avoid:

- Room smoke detectors must not be placed within close proximity of air diffusers
- Doors must be self-closing and never “blocked open”
- Inadequate pressure venting may result in overpressurization of the enclosure
- Too much air-handling equipment may result in loss of agent during discharge
- Cable and ventilation openings must be minimized
- Incomplete fire separations will allow exposure from external fires
- Concentration levels (especially for flammable-liquids hazards) must be adequate to combat skin fires
- Deficient fire barriers at the ceiling will fail to contain the gaseous agent

One final option for computer room protection currently available is water mist systems. The efficiency of these systems is well documented, and they may be economically advantageous as halon alternatives in many applications. Their fine water spray absorbs heat, cools flame by diluting oxygen with steam, and reduces overall heat intensity. The water-cooling effect is enhanced as a result of the division of water into small drops, which also maximizes evaporation. The creation of fine droplets increases the surface area available for heat absorption. Similar to the result firefighters obtain with fog streams, the mist allows a fuller interaction with air currents, which will scatter the droplets over a larger area, blocking the transfer of radiant heat to nearby combustibles. This process will extinguish fire without causing unacceptable levels of water damage.

A National Fire Protection Association technical committee on Water-Mist Fire Protection Systems (NFPA #750) is developing performance criteria and will also evaluate adaptability of mist systems to various applications. Strainers are used liberally within these systems to guard against potential nozzle clogging problems because of the small orifices used in the spray nozzles. The piping system must also possess a very high corrosion-resistance for the same reason. Water-mist systems are a beneficial fire protection tool for applications where neither gaseous agents nor standard conventional sprinkler systems are a satisfactory answer. The evolution of fine spray technology has continued to show significant progress in successful fire testing, making this another viable alternative.

New solutions take time: consider the fact that it took the industry twenty years to get halons developed and out into the marketplace. An aggressive research and development program is being conducted by the U.S. Department of Defense. Their goal is to demonstrate environmentally friendly and user-safe processes, techniques, fluids, and agents by the year 2005 that meet their own operational requirements (once satisfied by halon systems) for their aircrafts, ships, combat vehicles, and critical-mission support facilities. National Fire Protection Association Standard #75, “Standard for Protection of Electronic/Data Processing Equipment,” outlines the basic regulations governing computer room protection. An informed choice for the selection of the most appropriate fire detection and suppression system for computer rooms is a critical step for the fire protection engineer. And, regardless of the system selected, containment of the protected space and separation of it from the rest of the building is equally important.
Figures and Photos

Following are the figures and photographs pertinent to Chapters 2–21.
Figure A-4

- **Spare-Head Cabinet**
- **2 4" 0-1-4 Control Valves - Electrically Supervised**
- **3" Flow Switch**
- **Water Pressure Ga.**
- **1/2" Main Drain**
- **4" Out to F.D.C.**
- **4" Check Valve and 1/2" Ball-Drip Assembly**
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<th>Temp</th>
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| Beam Upright  | F.G. | Z    | 1/2"  | 155°    |      |        | 34       | 26                     | COLOR CODE: #11000 |}
| Nodic. Sidewall| F.G. | Z    | 1/2"  | 155°    |      |        | 1        | 1                     | MANUFACTR. J-1 TO J-3 |}
| Chrome Pendant | F.G. | Z    | 1/2"  | 155°    |      |        | 7        | 2                     | FIRE WAKE SCHEDULE   |}

TOTAL SPRINKLERS THIS DRAWING: 34

Figure A-7
HEADER COMPONENTS

1. 4" Flanged 90° Elbow
2. 4" O, S, & Y Control Valve
3. 4 X 4 X 3 Flanged Tee
4. 4" Detector Check Valve, 1" meter by-pass
5. 1" pipe stanchion
6. ½" Pressure Gauge assembly
7. 3" Waterflow Indicator
8. 4" X 12" Flanged Spool
9. 4" Wafer Check Valve, with ½" Ball-drip
10. 3" Grooved Elbow
11. 1½" Angle Valve for Main System Drain
12. Spare-head Cabinet
CROSSMAINS & BULKMAINS

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Figure A-11
CROSS-SECTION

Figure B-1

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BAR JOIST DIMENSIONS

Figure B-2
## Welded Pipe-O-Lets - Take-Out Sheet

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### Branch-Line Pipe-O-Let Outlet Size

Figure B-3

© 2001 by CRC Press LLC
RISER NIPPLE DETAIL
ROOM NO. 180
N.T.S.

Figure B-4
Components

1. 3" O, S, y control valve & tamper sw.
2. 3" Viking "E-2" fl-gr dry valve & trim
3. 1" groved elbow
4. 1" pipe staunchion
5. 3" groved elbow, 4-3 vic 75o groved red coupling and 3" vic flange
6. Air compressor

Note: Volume capacity of 3" dry system is 199.2 gallons

Section "A"

1/4" = 1'-0"
MAIN HEADER COMPONENTS

1. 6 X 4 Reducing Flanged Elbow
2. 4" O,S, & Y Control Valve
3. 4" Viking "D-5" Deluge Valve & Trim for Double-Interlocked Preaction System
4. 4" Ames No. 3000-ss Double-Detector Check Valve Assembly
5. 1" Pipe Stanchion
6. 4" Grooved Elbow
7. 4" Flow Switch
8. Viking "D-1" Maintenance Air Compressor
9. 2" Outlet to 2" Angle Valve for Main Drain
10. Spare-Head Cabinet
11. 4 X 4 X 4 Flanged Tee
12. 1¼" Water Pressure Gauge
13. 4" Flanged 90° Elbow
14. 4" Central "B" Water Check Valve

Note: Affix Hydr. Placard to Base of Riser

SECTION "A"
3/8" = 1 - 0

Figure B-6
### Cutting Dimensions for Short Turn Fittings

**Size of Pipe Being Cut**

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© 2001 by CRC Press LLC
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C - Cast Malleable or Ductile Iron.
Figure C-3

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Size of largest outlet determines dimensions of all outlets.
# Valve Take-Outs

(Total)

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Figure C-4
Figure C-5

2½" control valve

1" rise to A.S.
beneath landing

2½" flow switch

UL, cUL listed
Test & Drain
kit - ½"

½" express drain

4" sprinkler riser

At stair
NTS
Figure C-6

1. 6" x 6" x 6" Flanged Tee
2. 6" 90° Flanged Elbow (Relocate Existing)
3. 6" 0.5" Control Valve & Tamper Switch
4. 6" x 1" Flanged Spool w/ 1/4" P.O.C.
5. 4" N/C No. 710 Grooved Check Valve
6. 6" Reliable Model "B" Fl-G-R Dry-Pipe Valve with Basic Trim, 19" Long
7. 4" Grooved Tee
8. 1" Pipe Stand

New Components
- Add to Existing Header

Riser Isometric
No Scale

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SOUTH ELEVATION
AT COLUMN "B"
N.T.S.

Figure C-8
HYDRAULIC SYSTEM

This Building is Protected by a
Hydraulically Designed
Automatic Sprinkler System.

Location

No. of Sprinklers

Basis of Design
1. DENSITY ____________gpm/sf

2. DESIGNED AREA OF DISCHARGE

System Demand
1. WATER FLOW RATE ____________GPM

2. RESIDUAL PRESSURE AT THE
   BASE OF THE RISER ____________PSI

Figure D-1
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DETAIL NO. 1 - LOOKING NORTH

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Figure D-3
Figure D-4

UNDERGROUND FEED

NO SCALE
Figure D-5

STORAGE RM./OFFICE - 1ST FLR.

SCALE: 3" = 1'-0"
EXIST. MOULDING TO REMAIN

NEW HEAD MOUNTED ON FLAT BANDING OF MOLDING

SECRETARIAL OFFICE

MANAGERS OFFICE

OFFICES - 2ND FLR. (WALL SECTION LOOKING NORTH)

SCALE: 3/8" = 1'-0"

Figure D-7
TOGGLE BOLT NEW 0.06"
CALV. MT. 2-HOLE PIPE
STRAP INTO EXIST. T.C.
STRUCT. FLOORSLAB & T.C.
GIRDER FIRE-PROOFING
AS INDICATED.

NEW CONICAL-SHAPED
RAISED MT. ESCUTCHEON
PLATE INTEGRATED W/ PLASTER MOULDING.
PAINT.

SPRINKLER HD. MOUNTED
ALONG CREEK KEY BANDING.

EXIST. PLASTER

EXISTING
4" T.C. TILE

THIRD FLOOR STAIR LOBBY
SPECIAL: 3:" = 1'-0"

Figure D-8
RISER NIPPLE DETAIL - TYPICAL

1/2" = 1'-0"

Figure D-9
SECTION "B"

3/16" = 1'-0"

Figure D-11

EXISTING
BRANCH LINE

CUT 1" ARM IN
6 FIELD TO FIT

PANEL CEILING

SPRINKLER RELOCATION DETAIL

SCALE 1-0

Figure D-12
Figure D-13

1" DROP 5.40

1" BCI 90° ELBOW

1/4"-2 NIPPLE

1/2" RED. COUPLING

135°F. RATED COVER PLATE

SPRINKLER HEADLINE

MUTUAL DETAIL

N.T.S.
NORTH ELEVATION

1/4" = 1'-0"

Figure E-2
Figure E-3
Figure E-6

SITE PLAN

1" = 60'

NEW 31,720 SQ FT, NON-COMBUSTIBLE STRUCTURE

FIRE DEPT. CONNECTION

ALL NEW 8" WDG. PIPE IS DUCTILE IRON

E HAYES ST.

CWM

HYDR.

E EDGEWOOD AVE.

1/2" INLET

NEW 12" CITY TAP 12" CUM
Figure E-7

LOCATION PLAN

N. RUSH ST.

CHESTNUT
PEARSON
CHICAGO AVE.

ST. CLAIR
N. MICHIGAN
S. SUPERIOR
HURON
ERIE

NTS
HEADER COMPONENTS

1. 8 x 6 x 6 Flanged Tee by Plumber
2. 6" O,S,& Y Control Valve
3. 6 x 6 x 4 Flanged Tee
4. 6" Flanged 90° Elbow
5. 6" Wall-Post Indicator Valve
6. 4" Reliable "DW" Swing Check Valve
7. 6 x 2-9½ Flanged Spool
8. 1" Pipestand
9. 4" Stockham Fig. 125 FL-T Elbow
10. 12-sprinkler Spare-Head Box
11. 6" Waterflow Indicator - 110v.
12. ¼" Water Pressure Gauge
13. 2" Angle Valve for Main Drain
14. ¼" Ball Drip Assembly
15. 6" Reliable "C" Wafer Check Valve
Figure E-11
**GENERAL NOTES**

This system has been hydraulically calculated to provide a density of 1.203 gpm/sf over the most remote 2000 sq. ft.

Hangers shall consist of 3/8" JR. TOP-BEAM CLAMPS, 3/8" ALL-THREAD ROD, and swivel ring. (1/2" for 6" pipe)

All cross main piping shall be hung at centerline 15'-1" elevation, and shall consist of schedule 10 black steel pipe

All branch line piping shall be hung at centerline 16'-9" elevation (unless noted) and shall consist of schedule 40 black steel pipe

Installed system shall be hydrostatically tested at 200 psi for a period of two hours

Total head count for job is 329.

All materials used shall be U.L. listed and F.M. approved

A placard, detailing hydraulic information, shall be affixed to riser.

Both system controlling valves shall be equipped with tamper switches

Elevation of suspended ceilings is 8'-0"

Elevation for dry heads shall be 16'-11" (swing arm if necessary)

Figure E-13
GENERAL NOTES

This system has been hydraulically designed to provide a density of .10 gpm/sf over the most hydraulically remote 1,500 square feet.

Hangers for job shall consist of 3/8" Jr. top beam clamp, 3/8" all-thread rod, and swivel ring.

Risers for mutuals shall be 1 x 0.2 schedule 40 black steel nipples (see detail on Sheet No. 2). Swing arms shall be utilized to locate sprinkler drops within 1/8" of acoustical ceiling panel centers.

All materials for this job shall be U.L. listed and F.M. approved.

The total head count for this job is 754.

Occupancy for this noncombustible structure is school - light hazard.

Concealer "phantom" sprinklers shall be installed in all corridors, washrooms, and locker rooms.

No on-site welding will be necessary for this installation.

Pipe sizing and spacing shall be in strict compliance with regulations set forth in N.F.P.A. pamphlet No. 13 governing light hazard occupancies.

This building shall be completely sprinklered.

Pipe color code for all piping on this sheet is orange.

[Symbol] = denotes hydraulic reference point.

[Symbol] denotes 1/2" dry pendent sprinkler (2 needed this sheet).

[Symbol] denotes 1/2" 1/8" chrome recessed pendent sprinkler (147 this sheet).

[Symbol] denotes 1/2" 1/8" phantom "concealer" sprinkler (39 needed this sheet).

See sheet No. 2 for additional notes.

Figure E-14
NOTES: (WET PIPE SPRINKLER SYSTEM)
- Building Const. Non-Combustible. Steel Beams, C.M., Floors & Walls
- System design, materials, and installation methods per NFPA 13
- System hydraulically calculated per light hazard criteria
- 10 GPM/25 Ft. Density
- Waterflow Test: 3/4 Ps static, 31 Ps residual, flowing
- 1500 psi, at point of connection
- Pipe: 2" F.D., Super 40 Blue, 3/4" Allow, Thinwall Black
- Fittings: Black Cast Iron Screwed/Grooved
- Underground lead-in and flushing by others
- Electrical Wiring and painting of pipe by others
- System to be hydraulically tested at 1000 psi for 2 hours
- Local Authorities to be notified in advance 24 hrs prior to tests
- Sprinklers should be not necessary positioned in geometric centers or suspended ceiling panels

LEGEND

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<td>Pipe below top of steel</td>
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<td>Pipe above finished floor</td>
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<td>1/2&quot; 155&quot; chrome recessed recessed sprinkler (42 req'd)</td>
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<td>1/2&quot; 155&quot; brass horizontal sidewall sprinkler (3 req'd)</td>
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<td>1/2&quot; 155&quot; brass vertical sprinkler (2 req'd)</td>
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<td>1&quot;</td>
<td>Galvanized plug</td>
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<tr>
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<td>1/2&quot; 212&quot; dry horizontal sidewall sprinkler (48 req'd)</td>
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Figure E-15

SECTION "C"

3/8" = 1'-0"
**ANTI-FREEZE LOOP COMPONENTS**

1. 2½" Grooved P.O.L. in 4" Main
2. 2½" Vie No. 10 DR Grooved Drain Elbow
3. 3½" Fill Cup
4. (2) ⅜ x 0-2 Nipples, 3½" Gate Valve
5. (2) ⅛ x 0-3 Nipples, Cap, 1" Gate Valve
6. 2½" Central "BFV" Grooved Butterfly Valve
7. 2½" Grooved 90º Elbow
8. (2) ⅜ x 0-2 Nipples, Cap, ½" Gate Valve
9. ⅛ x 0-4 Nipple and Cap
10. 2½" Central "No. 90" Grooved Check Valve

**Note:** Set Hydrometer to -22°F. Freezing Pt.

* Fill system with 21 Gallons Glycerine and approx. 14 Gallons Water

---

**SECTION "B"**

\[\frac{3}{A} = 1.0\]
Figure F-5

Horiz. Sidewall Sprinkler Deflector Typically Positioned 10" DN from CLG.
Figure F-8

TYPICAL - WELDED P.O.L. OUTLETS FOR
3/4" SPRINKLER HEADS - NO ON-SITE
WELDING IS NECESSARY FOR THIS JOB.
SECTION AT COLUMN 22

LOOK NORTH

1" = 1'-0"

Figure F-9
Figure F-10

NEW 3 x 2 GROOVED - OUTLET MECHANICAL TEE

1 1/2” ELBOW

2 x 2 GR. RED. CPLG. - Vic. #750

DRILL 1” HOLE IN EXISTING MAIN FOR NEW 3 x 2 GR. OUTLET MEC. TEE

3” MAIN

2 1/2” GRVD. ELBOW

2” GRVD. ELBOW

FLOW

NEW 2” MAIN

1/4” = 1 - 0

CUT-IN DETAIL
SECTION - ROOM 534

3/8″ = 1-0

Figure F-11
ENLARGED PLAN VIEW

ROOM 434

1/2" = 1'-0"

Figure F-12
Figure G-1

Figure G-2

*Figure rod length as "X" minus 8", minus take-out for ring*
**HANGER DETAIL**

**NOT TO SCALE**

Figure G-3

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1. **Concrete**
2. **Concrete Insert**
3. **Hanger Rod**
4. **Adj. Swivel Ring**

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**Figure G-4**

- (2) 1/2" x 2 1/4" Bolts
- (2) Phillips Screws
- (2) 1/2" Washers

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**Unistrut P5500 (1/8 Length)**

**Unistrut P6344 Fitting with Two Unistrut Nuts**

**Unistrut P5500 Slotted (1/0 Length)**

---

**Detail ~ Hanger "G-4"**

**No Scale**
Figure G-5

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Figure G-6

[Diagrams showing the dimensions and components of a safety system, including a pipe ring, coach screw rod, and optional ceiling button.]
DETAIL - HANGER "B"

CONC. BEAM

3/8" EYE SOCKET (2) WASHERS
3/8" HILTI STUD & NUT

3/8" ROD
23" long

SWIVEL RING

PIPE

3/4" = 1 - 0

Figure G-9

TOGGLE NUT

ALL-THREAD ROD

SWIVEL RING

SPRINKLER PIPE

Figure G-10
Figure H-1

LINE OF HYDRAULICALLY
"REMOTE" AREA NEEDS
TO EXPAND BY 30%
IF SYSTEM IS DRY

SHADED AREA REPRESENTS
THE 1500 SQ. FT. AREA NEEDED
FOR WET SYSTEM CALCULATION!

LINE OF HYDR.
MOST DEMANDING
SPECIFIED AREA
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Figure H-2
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Figure H-3
## EQUIVALENT PIPE LENGTH CHART [expressed in feet]

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Figure H-4
LINE C  C-FACTOR IS 120  K-FACTOR IS 5.50  END HEAD PRESSURE IS 12.00 PSI

HEAD ADD TOTAL PIPE EFF PSF/FT PSI TOTAL VELOCITY NORMAL
GPM GPM SIZE LENGTH GPM PSI PRESSURE PSI PRESSURE
1 19.05 19.05 1.380 10.50 0.031 0.33 12.33

K FACTOR OF LINE C IS 5.43

LINE G  C-FACTOR IS 120  K-FACTOR IS 5.50  END HEAD PRESSURE IS 12.10 PSI

HEAD ADD TOTAL PIPE EFF PSF/FT PSI TOTAL VELOCITY NORMAL
GPM GPM SIZE LENGTH GPM PSI PRESSURE PSI PRESSURE
1 19.13 19.13 1.049 10.58 0.120 1.27 13.37 1.36 12.91
2 19.06 38.19 1.049 10.58 0.431 4.56 17.93 1.15 16.78
3 22.53 60.72 1.380 10.58 0.267 2.83 20.76 1.21 19.55
4 24.32 85.04 1.610 14.00 0.235 3.29 24.05

K FACTOR OF LINE G IS 17.34

RISER NIPPLE FOR LINES C-G  C-FACTOR OF PIPE IS 120
PRESSURE AT TOP OF RISER NIPPLE IS 24.05 PSI

GPM PIPE EFF PSF/FT PSI TOTAL
SIZE LENGTH PSI
111.70 2.067 11.67 0.115 1.34 25.39

K-FACTOR AT BOTTOM OF RISER NIPPLE FOR LINES C-G IS 22.17

CROSS MAIN AND FEED MAIN  C-FACTOR OF PIPE IS 120
STARTING PRESSURE AT END OF CROSS MAIN IS 26.79 PSI

LINE LINE HDS HEADS GPM GPM SIZE LEN EFF PSI/FT PSI TOTAL VEL NORMAL
ADD K OF ADD TOTAL ADD TOTAL PIPES EFF PSF/FT PSI TOTAL VEL NORMAL
LINE LINE HDS HEADS GPM GPM SIZE LEN
D-H 22.17 5 5 114.75 114.75 3.260 12.00 0.0132 0.16 26.95 0.52 26.43
C-G 22.17 5 10 113.98 228.73 3.260 11.00 0.0472 0.52 27.47 0.75 26.72
P 8.69 2 12 44.92 273.65 3.260 23.58 0.0658 1.55 29.02

STATIC PRESSURE FOR 14,458 FEET IS 6.26 PSI

DEMAND AT RISER BASE IS 273.65 GPM AT 37.57 PSI
FEED MAIN  C-FACTOR OF PIPE IS 120
PRESSURE AT START OF FEED MAIN IS 37.58 PSI

GPM PIPE EFF PSF/FT TOTAL PRESSURE
SIZE LENGTH PSI
273.66 4.026 30.00 0.0235 0.70 38.28

UNDERGROUND  C-FACTOR OF PIPE IS 140

PRESSURE AT START OF UNDERGROUND IS 38.28 PSI

GPM PIPE EFF PSF/FT TOTAL PRESSURE
SIZE LENGTH PSI
273.66 3.980 145.20 0.0187 2.72 41.00

Adding the 250 GPM outside hose allotment, the total system demand becomes 523.66 G.P.M. at 41.0 psi.

Figure H-5
### Friction Loss Table
For Water Flowing in **AW** Sprinkler Pipe and Schedule 40 Steel Pipe.

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Figure H-7
Friction Loss Table for Water Flowing
In 3" Light Weight Steel Pipe

Expressed in PSI Per Lineal Foot of Pipe

I.D. = 3.260

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Figure H-8

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safetymessage.com
LINE C  C-FACTOR IS 100  K-FACTOR IS 5.50  END HEAD PRESSURE IS 11.98 PSI

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K FACTOR OF LINE C IS 10.03

LINE D  C-FACTOR IS 100  K-FACTOR IS 5.50  END HEAD PRESSURE IS 11.98 PSI

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K FACTOR OF LINE D IS 10.03

LINE F  C-FACTOR IS 100  K-FACTOR IS 5.50  END HEAD PRESSURE IS 11.98 PSI

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K FACTOR OF LINE F IS 16.36

LINE G  C-FACTOR IS 100  K-FACTOR IS 5.50  END HEAD PRESSURE IS 11.98 PSI

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K FACTOR OF LINE G IS 16.62

RISE NIPPLE FOR LINES C-G  C-FACTOR OF PIPE IS 100

PRESSURE AT TOP OF RISER NIPPLE IS 28.51 PSI

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K-FACTOR AT BOTTOM OF RISER NIPPLE FOR LINES C-G IS 25.67

Figure H-9

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CROSS MAIN AND FEED MAIN C-FACTOR OF PIPE IS 100

STARTING PRESSURE AT END OF CROSS MAIN IS 30.74 PSI

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STATIC PRESSURE FOR 14.458 FEET IS 6.26 PSI

DEMAND AT RISER BASE IS 374.29 GPM AT 48.14 PSI

FEED MAIN C-FACTOR OF PIPE IS 120

PRESSURE AT START OF FEED MAIN IS 48.14 PSI

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UNDERGROUND C-FACTOR OF PIPE IS 140

PRESSURE AT START OF UNDERGROUND IS 49.40 PSI

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Adding the 250 GPM outside hose allotment, the total system demand becomes 624.29 G.P.M. at 54.25 psi.

Figure H-10
Contract Name: Jones Glass
No. Residual PSI = 42 at 605 GPM Flow

Static PSI = 50

Adjusted Demand Point
IF SYSTEM CONVERTED
TO A DRY SYSTEM

Total System
Demand = 524.2 GPM
At 40.16 PSI

Figure H-11
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Figure H-12
### FELPAUSCH FOOD CENTER

#### 31-MAY-89

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**FEED MAIN**  
*C-FACTOR OF PIPE IS 120*

**PRESSURE AT START OF FEED MAIN IS 36.11 PSI**

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<th>PSI/FT</th>
<th>TOTAL PRESSURE</th>
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**STATIC PRESSURE FOR 22,583 FEET IS 9.78 PSI**

**DEMAND AT RISER BASE IS 309.44 GPM AT 47.47 PSI**

---

**FEED MAIN**  
*C-FACTOR OF PIPE IS 140*

**PRESSURE AT START OF FEED MAIN IS 47.47 PSI**

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<th>PSI/FT</th>
<th>TOTAL PRESSURE</th>
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**ADDING 500.00 GPM FOR OUTSIDE HOSE STREAMS, THE TOTAL SYSTEM DEMAND IS 809.44 G.P.M. @ 47.77 PSI**

---

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FELPAUSCH FOOD CENTER, MINGS BROOK MALL
GRID SCHEMATIC

1  
4
7
10
13
16
19
22
25
28
31
34
37
40*
43*
46*
49*
52*
55*
56*
57*
58*

*presupposed grid location

Figure H-14
Sprinkler system design curves — 20-ft (6.1-m) high rack storage — Class IV nonencapsulated commodities — conventional pallets.

Figure J-4
<table>
<thead>
<tr>
<th>Height</th>
<th>Commodity Class</th>
<th>Encapsulated</th>
<th>Sprinklers Mandatory In-Racks</th>
<th>Ceiling Sprinkler Water Demand</th>
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<td>m</td>
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Figure J-5
# Adjustment to Ceiling Sprinkler Density for Storage Height and In-Rack Sprinklers

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<th>Storage Height (ft)</th>
<th>In-Rack Sprinklers</th>
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<th>Permitted Ceiling Sprinklers Density Adjustments</th>
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<td>Over 12 ft (3.7 m) through 25 ft (7.6 m)</td>
<td>None</td>
<td>Yes</td>
<td>None</td>
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<tr>
<td>Over 12 ft (3.7 m) through 20 ft (6.1 m)</td>
<td>Minimum required</td>
<td>Yes</td>
<td>None</td>
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<tr>
<td></td>
<td>More than minimum but not in every tier</td>
<td>Yes</td>
<td>Reduce density 20% from that of minimum in-rack sprinklers</td>
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<td>In every tier</td>
<td>Yes</td>
<td>Reduce density 40% from that of minimum in-rack sprinklers</td>
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<td>Over 20 ft (6.1 m) through 25 ft (7.6 m)</td>
<td>Minimum required</td>
<td>No</td>
<td>None</td>
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<tr>
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<td>More than minimum but not in every tier</td>
<td>No</td>
<td>Reduce density 20% from that of minimum in-rack sprinklers</td>
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<td>In every tier</td>
<td>No</td>
<td>Reduce density 40% from that of minimum in-rack sprinklers</td>
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*Figure J-6*
Ceiling sprinkler density vs storage height.

Figure J-7
### Table 7-4.2.1.2.1 In-Rack Sprinkler Spacing

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<th>Commodity Class</th>
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<td>III</td>
<td>IV</td>
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For SI units: 1 ft = 0.3048 m

**Figure J-8**

![Graph showing sprinkler density and design area operation](image)

**Curve Legend**

- **A** — 8-ft (2.44-m) aisles with 266°F (129°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
- **B** — 8-ft (2.44-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
- **C** — 4-ft (1.22-m) aisles with 266°F (129°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.
- **D** — 4-ft (1.22-m) aisles with 165°F (74°C) ceiling sprinklers and 165°F (74°C) in-rack sprinklers.

**Figure J-9**

Figure 7.4.2.1.1(g) Single- or double-row racks — 20-ft (6.1-m) high rack storage — sprinkler system design curves — Class IV encapsulated commodities — conventional pallets.
Figure K-2
Figure K-4
FIRST FLOOR FIRE PUMP ROOM

Figure K-7
# Table 2-19  Summary of Fire Pump Data

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<th>Suction in.*</th>
<th>Discharge in.*</th>
<th>Relief Valve in.</th>
<th>Relief Valve Discharge in.</th>
<th>Meter Device in.</th>
<th>Number and Size of Hose Valves in.</th>
<th>Hose Header Supply in.</th>
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<td>50 (180)</td>
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*Actual pump flange may be less than pipe size.

1990 Edition
Figure K-9

South Pump Room Elevation
FIRE PUMP ROOM COMPONENTS

1. 8 x 3 x 6 Flanged Tee By Others
2. 6" Flanged Elbow
3. 6" O.S.& Y Control Valve
4. 6 x 6 x 6 Flanged Tee
5. 6" Febco #806YD Double-Detector Check Valve
6. 750 GPM @ 65 Psi Horizontal Electric Fire Pump
7. 6" Swing Check Valve
8. 6 x 4 Flanged Reducer
9. 6 x 5 Flanged Reducer
10. 6 x 1-4½ Flanged Spool
11. 8½" Concrete Pad
12. 12-sprinkler Spare Head Cabinet
13. 2" Main Drain Valve & Assembly
14. Junction Box & Mercoid Switch
15. 6 x 3'4" FL-GR Spool

Note: Affix Placard, Detailing Pertinent Hydraulic Information, Near System Riser

Figure K-10
Figure K-12
Figure K-13

1. 8" UNDERGROUND, ABT. 140' TO 10" CITY CONNECTION
2. 8" FLGD. 90° ELBOW
3. 8x8x8 FLGD. TEE
4. 8" FLGD. 45° ELBOW
5. 8" FLGD. O, 5, 1/2 VALVE, AND NOTIFIER SGV TAMPER SWITCH
6. 8" SWING CHECK VALVE
7. 4" FLGD. SUPERVISED O, 5, 1/2 VALVE
8. 6" FLGD. SUPERVISED O, 5, 1/2 VALVE
9. 8x8x4 FLGD. TEE
10. 8x8x6 FLGD. TEE
11. 8x6 FLGD. ECCENTRIC REDUCER BY PUMP MFGR.
12. 6" FLGD. 90° ELBOW
13. 8x1-11 SPOOL - FL-FL
14. 8x7-1/2 SPOOL FL-FL
15. 8x0-5 SPOOL FL-FL
16. 8" FLGD. SIDE-OUTLET 90° ELBOW
17. POTTER FIG. 5864 FLUSH FIRE PUMP TEST CONNECTION
18. 6° 90° GRVD. ELBOW AND (2) ZERO-FLEX COUPLINGS
19. 1" PIPES TANDS
20. 6" x 1-11 SPOOL FL-FL
21. 6 x 12-8 FL-G SCH. 40 PIPE
22. 6 x 0-7 T-G SCH. 40 PIPE
23. 4" BLIND FLANGE
24. 2" MAIN DRAIN TO FLOOR DRAIN
25. 1/4" PRESSURE GAUGE
Figure K-15
Figure K-16

SECTION "A"
NORTH ELEVATION

NEW 8" PUMP BYPASS

DISCONNECT  REMOVE OLD 4" F.D.C. SUPPLY

NEW LOCATION FOR F.D.C. SUPPLY

10'

To LOOP
# Diesel Fire Pump Bypass and Fittings Arrangement

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<td>2. 8&quot; x 20&quot; Flanged Spool</td>
<td>5. 8&quot; Flanged Spool</td>
<td>2. 8&quot; Detector Check Valve, 1/2&quot; Trim + Meter</td>
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<td>3. 8 x 8 x 8 Flanged Tee</td>
<td>6. 8&quot; Wafer Check Valve</td>
<td>4. 8&quot; 90° Flanged Elbow</td>
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<tr>
<td>4. 4&quot; Check Valve, 1/8&quot; Ball-Trim</td>
<td>7. 8 x 8 x 8 Flanged Tee</td>
<td>6. 8&quot; 0.5 + y Control Valve and Tamper Switch</td>
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<tr>
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<td>8. 8&quot; Flanged 90° Elbow</td>
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<td>6. Fire Stanchion</td>
<td>9. 8&quot; 0.5 + y Control Valve and Tamper Switch</td>
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<td>7. 5&quot; x 21&quot; Flanged Spool</td>
<td>10. 4&quot; Blind Flange</td>
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<td>8. 8 x 8 x 8 Flanged Tee</td>
<td>11. 8 x 8 x 8 Flanged Tee</td>
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<td>12. 8 x 8 x 8 Flanged Tee</td>
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Figure K-17

© 2001 by CRC Press LLC
Figure K-18

FIRE PUMP AND BYPASS - FLOOR PLAN

scale: 1/2" = 1'0"

© 2001 by CRC Press LLC
SYSTEM &2 PUMP & BYPASS
AT COLUMN LINE P-G

\[ \frac{1}{2}'' = 1 - 0 \]

Figure K-19
WEST ELEVATION AT RISER

$\frac{1}{2}'' = 1\text{-}0$

Figure L-1
Figure L-5

© 2001 by CRC Press LLC
Figure L-6
### SUMMARY SHEET

**Date:** 1-16-95

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**Figure L-8**
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/Ft. surcharge (2" and under - LW) 351

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Figure L-13
# Fire Protection Estimate

**Contract No.:**

**Date:**

**Estimate For:**

**Individual Negotiating and Title:**

**Street and Number:**

**City:**

**State:**

**Occupied by Owner or Tenant:**

**Kind of Business:**

**Name of Arch't. or Eng'r:**

**Does Estimate Cover:**

- New Equipment
- Water Supplies—Single-City-Tank-Pump
- Plans and Equipment to be Approved by
- Extension to Present System

**Special Instructions:**

---

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![Figure L-14](https://safetymessage.com)
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Figure L-14 (continued)
Figure L-15

**EAST ELEVATION AT RISER**

\[ 3/8" = 1-0 \]

- 1. G x 3 FLG. REDUCER
- 2. 3 x 0-6 FLG. SPOOL
- 3. 3" O.S. "Y" CONTROL VALVE
- 4. 3" FLANGED TEE
- 5. 3" AMES NO. 3000-55
- 6. 3" GRVD. CHECK VALVE
- 7. "AMERICAN STAR" - 10" LONG
- 8. 1/2" BALL-DRIP ASSEMBLY
- 9. SPARE-HEAD CABINET
- 10. 3" FLOW SWITCH
- 11. 1/4" PRESSURE GAUGE
- 12. 3 x 2-1/2 GR. REDUCING CPLG.
- 13. 2-1/2 GR. ELBOW
- 14. 1/4" OUTLET FOR MAIN DRAIN
- 15. 3" VIC FLANGE

*NOTE: AFFIX HYDR. PLACARD TO BASE OF RISER*
Photo 1 The end of the carpenters rule is flush to the end of the 1 1/2" nipple. This illustrates the 1" take-out, measured on the interior of the broken fitting, of a 1 1/2" × 1 1/2" × 1" cast-iron tee.

Photo 2 An installed brass upright sprinkler head. This sprinkler should not have been painted!
Photo 3 The sign hanging from the chain declares the 1” valve to be a (wet-pipe) inspector’s test valve; located in a remote furnace room.
Photo 4 This is the resulting installation from the plan drawing depicted in Figure L-15. The fire department connection has been moved during installation to a different location. As a precaution against freezing, the contractor installed pipe covering around all piping including the main drain line, with the exception of the valve stems, pressure gauge, and the metered backflow preventer bypass. Of course, the drain piping downstream of the drain valve is dry, and some pipe covering will have to be removed if and when the backflow preventer interior requires cleaning.
A wet-pipe system riser and a dry-pipe system riser are installed side-by-side. It was not advisable to install only a dry-pipe system in the small structure that these systems service, since there exist numerous heated areas to protect. Separate hydraulic placards are affixed to each system riser.

Photo 5
Photo 6 These sprinklers installed beneath a combustible outdoor roof section are part of an anti-freeze system.

Photo 7 This single sprinkler has been piped from the branch-line to a location beneath very wide ductwork.
Photo 8 A hanger assembly consisting of a top-beam clamp, 3/8" threaded rod, and a standard swivel ring.

Photo 9 Located near the ceiling, this system cut-in to a combination standpipe includes a butterfly valve, flow switch, and a system drain that is piped to an express drain. Note that the drain valve is correctly placed downstream of the flow switch.
Photo 10  Another system cut-in made on a combination standpipe in a high-rise building. The component shown downstream of the flow switch is a combination system drain/inspector’s test connection.

Photo 11  The system supply for this header is at the far end of the photograph. Notice that the flanged spool preceding the backflow preventer is galvanized. Both control valves are equipped with tamper switches.
Photo 12 This header is located in the basement level and has the domestic supply piped out the bottom of the flanged tee. The fire department connection for this single wet-pipe system will be piped from the grade-level floor. The supply side O, S, and Y valve is open, but we can visually establish (by its stem position) that the system side O, S, and Y valve is shut. Note that the 2″ main drain discharge is piped nowhere in particular. It will be no fun draining this system.

Photo 13 This is also a basement installation. The signs identify the control valves. Note that four hydraulic placards are neatly mounted to the right of the spare-head cabinet. The large component is a 6″ reduced-pressure backflow preventer, which is not listed for below-grade installations.
Photo 14 This shows an acceptable pressure gauge installation, which has been piped off of the riser on the 2" main drain piping upstream of the drain valve.
Photo 15 The domestic supply originates from the top of the 4" flanged tee. The system control valve is located at the base of the riser, downstream of the detector check valve. The 4" fire department connection piping was moved from its original intended location during installation, with the result being a 4" blank flange forever hanging in place, piped from a 4" pipe-o-let on the riser. This pipestand should have been properly secured to the floor.
Friction Loss Tables for Thinwall Cross-mains
Black Schedule 10 Steel Pipe C = 120
Friction Loss—PSI per lineal foot of pipe

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## Answer Key

(From Chapter 10, pp. 46–49)


(From Chapter 12, pp. 61–64)


(From Chapter 15, pp. 83–87)

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(From Chapter 19, pp. 114–118)

| 9. C | 20. A | 31. C | 42. A |
acceptable  worthy of being approved by means of conformance to the applicable published standards.

accelerator  a quick-opening device used to increase the speed of dry-pipe valve activation.

air compressor  a single piece of equipment used to reduce the volume of air and increase its pressure, to charge a dry-pipe sprinkler system.

anti-freeze system  a wet-pipe system that contains an anti-freeze solution and is connected to a larger wet-pipe system that it uses for a water supply. It supplies automatic sprinklers to protect small unheated areas.

approved  acceptable to the organization, office, fire marshal, or individual assuming the responsibility for approving equipment and installation, and procedure.

arm-over  the piece of piping that originates from a branch-line piping outlet to supply and connect to a sprinkler drop.

atrium  a covered space which extends vertically two or more stories within a building, usually at the building entrance or a centralized open area.

auditorium  the space allotted to the audience in any large room used for public gatherings of any kind.

basement  a separate level of a building that is partially or wholly below grade.

bid  any presentation of a price for a specified amount of installed labor and/or materials; or a quotation for the same which includes an hourly rate for work to be performed.

branch-line  the system piping which is fed by a cross-main, and into which automatic sprinkler-heads are fitted.

cap  a fitting for closing the end of a pipe or tube.

cavitation  the formation of partial vacuums in a liquid, which under certain circumstances can be a side-effect of the swift passage of that liquid produced by an impeller or propeller blade.

centrifugal pump  a fire pump in which the desired pressure is generated by the action of centrifugal force.

check valve  a mechanical device used to control, insure, and limit the flow of pressurized water or air to a single direction. If excess pressure is applied to the inlet side of the valve, the clapper is forced open, allowing pressure to build up downstream of the check valve. The clapper is held closed with the application of excess pressure from the outlet side.

clapper  a moving part within a check valve, usually brass, that is hinged and held in a closed position by gravity at zero pressure, until excess inlet pressure forces it open and allows waterflow.

clearance  the area above the top of stored products, measured by the linear distance from ceiling sprinkler deflectors to the actual top of storage.

code official  the designated authority in charge of the administration and enforcement of a particular code.

codes  a complete written collection of installation and safety regulations, arranged logically and with a table of contents, and periodically amended, contained in applicable statutes of general and permanent importance.

cold soldering  a condition in which running or spraying water cools the fusible elements of a fire sprinkler, preventing those elements from attaining their fusing temperature.

combustible  capable of catching fire and burning.

combustible liquid  a liquid having a flash point equal to or above 100°F.

commodity  any stored product or assemblage of product to be warehoused. By NFPA standards, this includes the items, their packaging, and containers.

controller  the metal upright cabinet containing a network of electrical control devices for the starting and the control of electric motors for fire pumps. These devices include a circuit breaker and disconnect switch.

corrosive  that which is able to wear away or eat away at materials gradually over time.
**cross-bracing** a hanger assembly whereby a sufficiently long piece of iron or steel is rigidly supported by two parallel building structural members to support a length of pipe that lays between the same two structural members.

**cross-main** the portion of piping that is fed by a riser or feed-main that subsequently connects to and feeds the branch-line piping.

**cut-in** the procedure by which a means is devised to form a new piping connection onto an existing pipe, which serves as the supply, and often involves the cutting of existing aboveground or underground pipe.

**cut sheets** the manufacturer’s published documents of technical data that contain product description, details of product operation, advice on maintenance, product safety information, guarantees, approval and listing information, and instructions for installation.

**deflector** that part of a fire sprinkler nozzle, usually brass, that deflects and turns all or part of the forward-moving water stream to form the discharge pattern.

**deluge system** a fire suppression system employing open sprinkler nozzles connected to a water supply through a valve which will open upon activation of a detection system, flowing water which discharges from all sprinklers within the system.

**design density** the presupposed amount of delivered water, measured in gallons per minute per square foot, used as a basis for the hydraulic calculation of a remote area of a sprinkler system in order to safely size all related fire sprinkler piping.

**detection** the electronic or automatic determination of the presence of a signal that automatically indicates a condition of heat, smoke, flame, or rate of temperature rise, in order to signal an alarm indicating fire.

**detector check valve** a device that serves the dual purpose of preventing backflow and metering the water used for firefighting. The clapper of the check valve is weighted to divert small flows away from the main line and through a metered by-pass. The check valve also prevents the backflow of nonpotable water.

**detection system** an electrical system designed and installed to discover the existence of fire, flame, heat, or smoke, and sometimes used to actuate a fire protection system through system interaction controls.

**domestic water** in commercial buildings, water that is carried by the plumber’s pipe, typically supplying all sinks, showers, toilets, drinking fountains, washing machines, bathtubs, dishwashers, urinals, laboratories, and garden hose connections.

**downstream** the direction in which the water is flowing, or is intended to flow.

**drop** the vertical length of (usually 1") pipe connecting the (concealed) branch-line to a reducing coupling into which the (exposed) pendent sprinkler is fitted.

**dry pendent sprinkler** a sprinkler that is secured in a vacuumed extension pipe that has a seal at the inlet to prevent the influx of water until sprinkler operation. Its use in unheated areas of a dry-pipe system is designed to prevent water from being pocketed into a drop from the branch-line above by gravity.

**dwelling unit** any structure that will be used by individual(s) to live and to sleep within it. NFPA standards recognize apartments, condominiums, dormitory rooms, hotel rooms, and sleeping rooms of nursing homes as dwelling unit examples.

**encapsulated** that which is packaged, protected, and encased in plastic wrap, often to prevent spillage of product, either partially or totally surrounded by plastic sheets or bubble wrap.

**estimate** a detailed breakdown of calculated figures that, when totaled, approximate the total cost to perform a certain amount of work which consists of the installation of known materials and related costs of engineering, fabrication, cartage, taxes, equipment rental, etc.

**escutcheon** a shielding plate or (usually metal) canopy that a pipe or fire sprinkler is routed through at a wall or ceiling.

**exhauster** a device which speeds up the expelling of air from dry-pipe systems.

**extended-coverage sprinkler** any of various large-orifice sprinklers whose performance objectives are to discharge water over a larger area than that of standard sprinklers and can provide coverage up to 400 square feet in overall floor area when installed in accordance with the manufacturer’s listing data.

**fabrication** the operation of assembling, and sometimes hanger material, on to piping that is cut and threaded to predetermined lengths.

**feed-main** the piping that is used to connect riser to riser, riser to crossmain, or cross-main to cross-main. This piping is also called the supply main or the bulk main.

**fire** any instance of uncontrolled burning.

**fire alarm system** an interrelated grouping of devices that will sound aural and/or visual warning alarms when manually or automatically activated.

**fire area** the area of any building or section of a building separated from every other building or section of a building by a fire wall, as governed by local ordinance.

**fire pump** a specially designed mechanical pumping device permanently installed and utilized for raising water and boosting liquid pressure for the safe satisfaction of the demands of a fixed fire protection system.

**fire triangle** the traditional conceptual model that demonstrates the three entities that must be present for fire origin and sustenance; those being heat, fuel (something to burn), and oxygen or the chemical process of oxidation.
fitter a sprinkler fitter is one who installs piping and equipment set up for use as an integrated functioning system to provide fire suppression and control.

flammable liquid a substance that is in liquid form at ordinary temperatures and has a flash point below 100°F.

flash point the lowest temperature at which a liquid gives off enough vapor to ignite momentarily in air.

flashover the sudden spread of fire over an area when that area becomes heated to a certain temperature.

flow switch an indicating device designed to detect either a pressure drop or a physical flow of water within an automatic sprinkler system.

flushing connection a removable fitting (and nipple) of at least 1 1/4” nominal pipe size installed at the end of a cross-main for the convenient implementation of a flushing operation.

general contractor a firm that contracts (usually for a lump sum amount) to manage and perform the complete construction of a building project from beginning to end.

gridded systems a sprinkler system piping layout in which at least four branch-lines are supplied by (and connect) parallel cross-mains, and the discharging sprinkler is thereby supplied water from two opposite directions.

head the total head of a fire pump is equal to the energy given to a fluid as it passes through the pump. Head is measured in units of feet, which is determined by dividing pressure in psi by 0.433.

header the collective manifolderd arrangement of system controlling valves situated at the water supply inlet to a fire sprinkler system or systems.

hose station a 1 1/2” valve and connecting hose line supplied by a wet-pipe sprinkler system, that is to be used in the building interior for fire purposes only.

high-piled storage by NFPA code, a commodity stored to a height exceeding 12’.

hotel a building that is designed for and used for the primary purpose of accommodating more than ten overnight guests or lodgers.

I-beam in steel construction, the solid horizontal structural member not supported everywhere along its length but resting on columns at the ends, thereby subject to the force of flexure, bearing a weight at the center, and normally in place to support a system of open web steel joists that run in a perpendicular direction.

impeller the rotating wheel in a centrifugal pump.

incipient stage the first of the four basic stages of fire; where no smoke, flame, or appreciable heat is yet present. Only invisible products of combustion are produced.

in-rack sprinkler ordinary temperature-rated upright sprinklers having either a 1/2” or 17/32” orifice size, designed for placement within storage racks, and having a metal “water shield” appliance affixed above the deflector that collects heat, protects the sprinkler head from damage, and prevents water discharging at a higher level from wetting its operating response elements.

inspector’s test a 1” connection to the sprinkler piping, controlled by a 1” valve to enable the inspector to open the valve to check for adequate water flow and alarm sounding.

interstitial space a concealed intermediate level in a building created by a floor supported above a ceiling by an interstitial framing truss. Although usually noncombustible, this area may require the installation of additional sprinklers. Examples include accessible spaces housing mechanical system equipment in hospitals; and structural means of egress, such as catwalks above theatre ceilings.

isometric drawing the representation of objects on a single plane, placed as in isometric projection but disregarding the foreshortening of the edges that are parallel to the three principal axes of the rectangular solid, and as to produce an appearance distorting the true lengths of certain lines that are parallel to the three principal axes, within a (continuous) spatial drawing framework.

kinetic the motion of material or liquid bodies, and their associated forces and energies.

landing a platform or confined floor area between two flights of stairs.

large-drop sprinkler a listed sprinkler designed to protect high-piled storage of product and capable of producing large water droplets to combat high-challenge fire hazards.

listed included in a published document of a testing agency laboratory or other recognized organization acceptable to the authority having jurisdiction.

looped system a fire sprinkler system in which multiple feed- and cross-mains are tied together so as to provide more than one path of water flow to the branch-lines.

made-on the act by which a threaded fitting of the proper size has been turned onto a male threaded pipe end, torqued as far as it can comfortably go.

markup the dollar amount, usually figured on a percentage basis, that is added to an estimated cost in order for a contractor or sub-contractor to arrive at a final selling price for quotation purposes.

mechanical tee a cross-main outlet fitting with a grooved or threaded outlet, that contains two castings that are bolted around the main. A hole must be drilled in the main piping for the new downstream flow.

mercantile refers to a commercial trade occupancy operated by merchants, dealers, marketers, or retailers.

mezzanine an intermediate floor situated in any story or level of a structure and limited in overall floor area with respect to that story or level.

miscellaneous storage storage piled less than 12’ in height that is particular to NFPA Pamphlet No. 13 occupancy
use groups, and is also subject to the specific limitations outlined in Chapter 7 of that standard.

**mutual** (see: return bend)

**nipple** a piece of piping 12” or less in overall length.

**noncombustible** that which under normal circumstances cannot burn, support combustion, be ignited, or release flammable vapors when subjected to heat or fire. Examples of non-combustible materials include steel, sand, iron, brick, tile, concrete, glass, slate, and plaster.

**occupancy** the purpose for which a building, room, or section of building is used or is intended to be used.

**owner** the individual or partnership that possesses legal title to a building.

**packaging** a commodity wrapping, cushioning, or container.

**pendent sprinkler** a fire sprinkler equipped with a notched deflector designed for a ceiling application with the understanding that the water stream will be directed by the piping layout in a downward flow towards that deflector.

**pipe schedule system** an automatic sprinkler system in which the foundation for pipe sizing is selected from one of the NFPA #13 schedules that are determined by factors such as occupancy and type of piping material, and which is based on the total number of sprinklers to be supplied.

**pneumatic** describes a device that is moved or worked by air pressure.

**potable** suitable and safe for drinking.

**preaction system** a sprinkler system containing air under pressure and employing automatic sprinklers and a supplemental fire detection system. Actuation of the detection system opens a valve that allows water to be discharged from sprinkler(s) that have fused.

**preliminary drawing** a basic fire sprinkler system layout that is diagrammatic in nature and is to be used for purposes of proposal solicitation and bid.

**pressure switch** an electrical device that will change the direction of an electric current upon sensing a rise or drop in air or water pressure.

**pressure tanks** pressurized water reservoirs used to supply a limited amount of water for building fire sprinkler systems.

**proposal** a detailed presentation in writing of a firm price to perform a certain specified amount of labor and materials and related work, for acceptance to a buyer.

**proscenium** the vertical plane of separation between an auditorium and a stage in front of the curtain, and sometimes referred to as the forestage.

**pyrolysis** the chemical decomposition of a substance when subjected to heat.

**quick-response sprinkler** a listed upright, pendent, or sidewall sprinkler that has special thermal response elements that will operate approximately 40% more rapidly than those of a listed standard sprinkler.

**rack** any combination of vertical, horizontal, and diagonal structural members assembled and erected for the purpose of supporting stored products or materials.

**recessed sprinkler** a sprinkler in which part of the body is mounted within a recessed housing. Mounted in a sidewall or pendent position, normally 1/2” to 1” of the sprinkler body upstream of the deflector is exposed outside of the housing.

**reflected ceiling plan** an architectural depiction of the suspended drop-ceiling of a room or area, which includes the ceiling grid layout and locations of all light fixtures, detectors, diffusers, air vents, speakers, and (sometimes) sprinkler heads.

**residential sprinkler** any automatic fire sprinkler that is specifically listed for use in residential occupancies.

**residual pressure** the pressure that is remaining in a system while an amount of water is being flowed from system outlet(s).

**retrofit** system installation that takes place anytime following completed building construction and after building occupancy permits are approved and granted.

**return bend** a piping configuration supplying a single pendent sprinkler and containing two 1” elbows through which fluid flow undertakes three directional changes after the branch-line outlet in this order: upwards, horizontal, and then downwards.

**riser** the vertical supply pipes in a fire suppression system installed to carry an upwards flow of water.

**roof height** the distance from the finished floor to the underside of the roof deck.

**schematic** reduced and arranged according to an intentional scheme.

**scupper** a metal component mounted in a building wall opening to permit water to drain off of a roof but disallowing any possible rodent entry.

**shaft** a narrow space enclosed with side walls and extending vertically through two or more stories in a multi-story building.

**shall** indicative of a mandatory NFPA requirement.

**shop drawing** a fire sprinkler system layout showing (among other things) pertinent dimensions and exact pipe sizes, lengths, and elevations, which is to be used as an installation direction and guide and for plan submittal purposes.

**should** indicative of a noted recommendation in NFPA standards.

**siamese** any fitting that combines the flow from two or more lines into a single stream.

**sidewall sprinkler** a sprinkler that is positioned near the wall and ceiling of a room, and having a deflector
arrangement that guarantees a water spray pattern out into that room.

skin fire  a liquid fire on a spill of less than 1” in depth of flammable liquid on a solid surface.

small room  by NFPA standards, a light hazard occupancy room of 800 square feet or less in total floor area.

smoldering fire  a fire in which smoke is visible, but no flame or appreciable heat is yet present.

solenoid  a switch using a coil of wire in the form of a cylinder that carries a current that becomes magnetized when current flows and, consequently, opens or closes a system valve.

solid shelving  solid or slatted shelving located within storage racks that will obstruct downward water penetration through the racks.

specifications  the printed detailed instructions and enumeration of particulars, prepared by an architect or engineer, that comprise a description of work to be done, and thereby becoming a legal part of the contract.

sprig  a short riser piece, normally one-inch in size, that serves to supply water to an upright or sidewall sprinkler head from a sprinkler system branch-line or cross main.

stage  the space in a theatre or assembly room, separate from the auditorium and equipped for theatrical or similar performances, that necessitates the use of curtains, lights, mechanical appliances, and portable or fixed scenery; often constructed with a raised floor.

standards  (see: codes)

stocklist  a partial or complete want list of materials to be purchased, and to be shop fabricated for a particular installation project.

subcontractor  a contracting firm that is one of many contracted out by the general contractor, that specializes in one phase of the construction of a building. Examples include an electrician, painter, plumber, steamfitter, or fire sprinkler contractor.

superintendent  an employee of the general contractor who (usually) has an on-site project office and, who is responsible to act as an owner’s representative to coordinate, schedule, and to direct the work of all personnel involved in activities related to the construction of that project.

symbol  something that stands for a real object or idea.

tamper switch  a valve position indicator that is tamper resistant and which supervises or monitors the open position of a sprinkler system control valve.

trave  the space between two beams, or a division made by beams resulting in a rectangular ceiling area or bay that is outlined by a combination of walls and solid beams that constitute possible sprinkler spray obstruction.

tree  the conventional method of piping layout for sprinkler systems in which a single cross-main supplies water flow to branch-lines that are fitted with automatic sprinklers. The water discharged from the sprinklers always flows from a single direction.

underground pipe  large-diameter nondestructible supply piping used to transport water from a supply source to a specified spot in the interior of a building to be sprinklered.

unit cost  either the dollar amount expenditure for one item to be procured by a contractor, or his one hour of direct labor cost for design, installation, trucking, or other labor activities.

upright sprinkler  a sprinkler installed in the traditional position on exposed pipe, with its deflector above the orifice.

velocity flow  the speed at which water passes a given point.

wall-post indicator valve  an aboveground, building-interior sprinkler control valve which has the actuator and indicator located on the building exterior. It is mounted horizontally, and the indicator is visible through an opening in the post, which shows whether the valve is opened or closed.

water curtain  a succession of automatic sprinklers placed six feet apart on-center in a straight line and situated in a manner to be able to create a wall of water discharge. The sprinklers are positioned 6” to 12” from the draft stop on the side away from the opening.

water hammer  the surging effect of a substantial pressure rise that accompanies a sudden change in the velocity of water flowing inside pipe.

weld  to join metals by heating the edges and applying pressure by hammering, with the addition of a fusible filler.