Design and Installation of Fire Sprinklers in Historic Structures

Presented by Jesse R Pfeifer

Introduction

- **Jesse Pfeifer**
  - Nicet Certified Fire Sprinkler designer
  - Nicet Certified in Inspection Testing and Maintenance of Fire Sprinkler Systems
  - 25 years of contracting experience of fire protection systems

Seminar Outline

Part 1: Design of Fire Sprinkler Systems in Historic Structures

Part 2: Installation of Fire Sprinkler Systems in Historic Structures

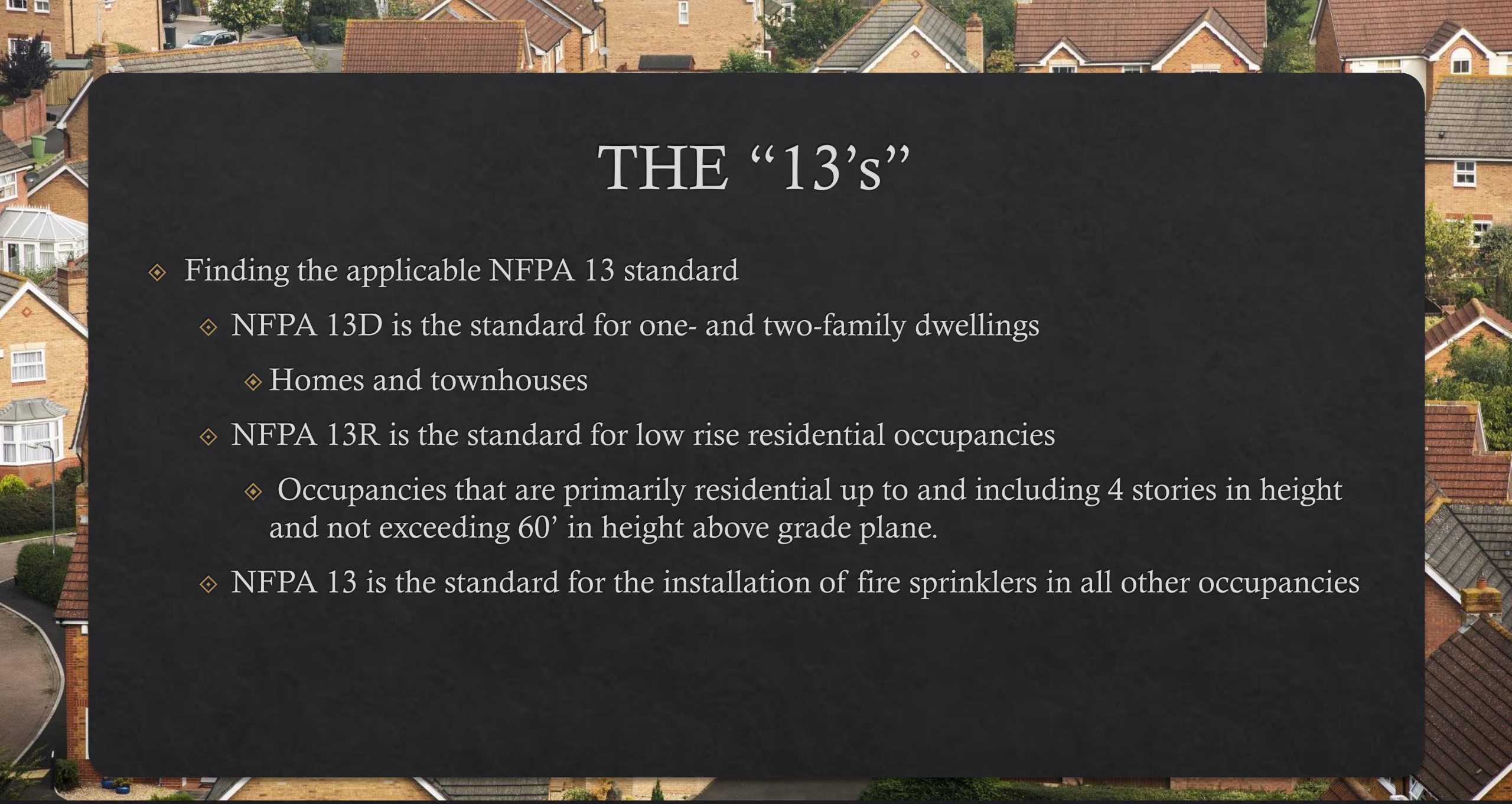
Part 3: Inspection and System Acceptance of Fire Sprinkler Systems

Part 1: Design of Fire Sprinkler Systems in Historic Structures

1. Code Overview; finding applicable design requirements
2. Choosing the correct design approach and code approved material
3. Choosing a water supply
4. Design and layout of system
5. Hydraulic Calculations of system
6. Approval Process

Code Overview; Finding Applicable Design Requirements

- Building Code VS NFPA (National Fire Prevention Association)
  - Building code requirements generally dictate the appropriate NFPA standard to use.
    - There are instances where the IBC varies from NFPA. Since the IBC is the code and NFPA is a standard the "code" will always supersede the "standard"
    - Example; IBC 901.6.1 states "automatic sprinkler systems shall be monitored by an approved supervising station" Where as NFPA 13 8.16.1.1.1 allows for valves to be locked in the open position and 8.17.1 allows for a local sprinkler alarm
  - Overview of NFPA standards
    - NFPA 13
    - NFPA 13R
    - NFPA 13D
    - NFPA 24 Installation of Private Fire Service Mains
    - NFPA 14 Installation of Standpipes
    - NFPA 20 Installation of Fire Pumps



THE “13’s”

- Finding the applicable NFPA 13 standard
  - NFPA 13D is the standard for one- and two-family dwellings
    - Homes and townhouses
  - NFPA 13R is the standard for low rise residential occupancies
    - Occupancies that are primarily residential up to and including 4 stories in height and not exceeding 60’ in height above grade plane.
  - NFPA 13 is the standard for the installation of fire sprinklers in all other occupancies

Substantial differences between NFPA 13D, 13R &13

- NFPA 13D:
  - Sprinklers not required in closets less than 24 SQ.FT. & bathrooms under 55 SQ.FT.
  - Concealed combustible spaces do not require sprinklers
  - Monitoring and alarms are not required
  - 2 sprinkler hydraulic calculation
  - 10-minute water supply capacity in most cases
  - Pumps do not need to be UL listed for fire service
  - Fire Dept Connection is not required
  - Alternative piping systems are allowed (PEX type tubing and multi service domestic water and fire sprinkler piping is allowed)

Residential 13D tank and pump package

- NFPA 13R:
  - Sprinklers not required in closets less than 24 SQ.FT.
  - Sprinklers not required in bathrooms less than 55 SQ.FT.
  - Sprinklers not required in concealed combustible spaces (note; this can be superseded by the IBC based on certain conditions)
  - Water supply duration for 30 minutes
  - 4 sprinkler hydraulic calculation (in most instances)

- NFPA 13:
  - Generally, all areas are to have sprinklers, including bathrooms, closets and concealed combustible spaces. Some residential occupancies have exemptions for closets and bathrooms.
  - 60-minute minimum water supply for light hazard occupancies. Water supply durations will increase as the hazard increases.
  - Hydraulic calculation areas are increased based on hazards.
  - Protection of life and property.

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Choosing the Correct Design Approach

Code

- Determine appropriate code(s)

Water Supply

- Determine water supply criteria
  - If a new underground water supply is being installed, use NFPA 24.

Fire Pump

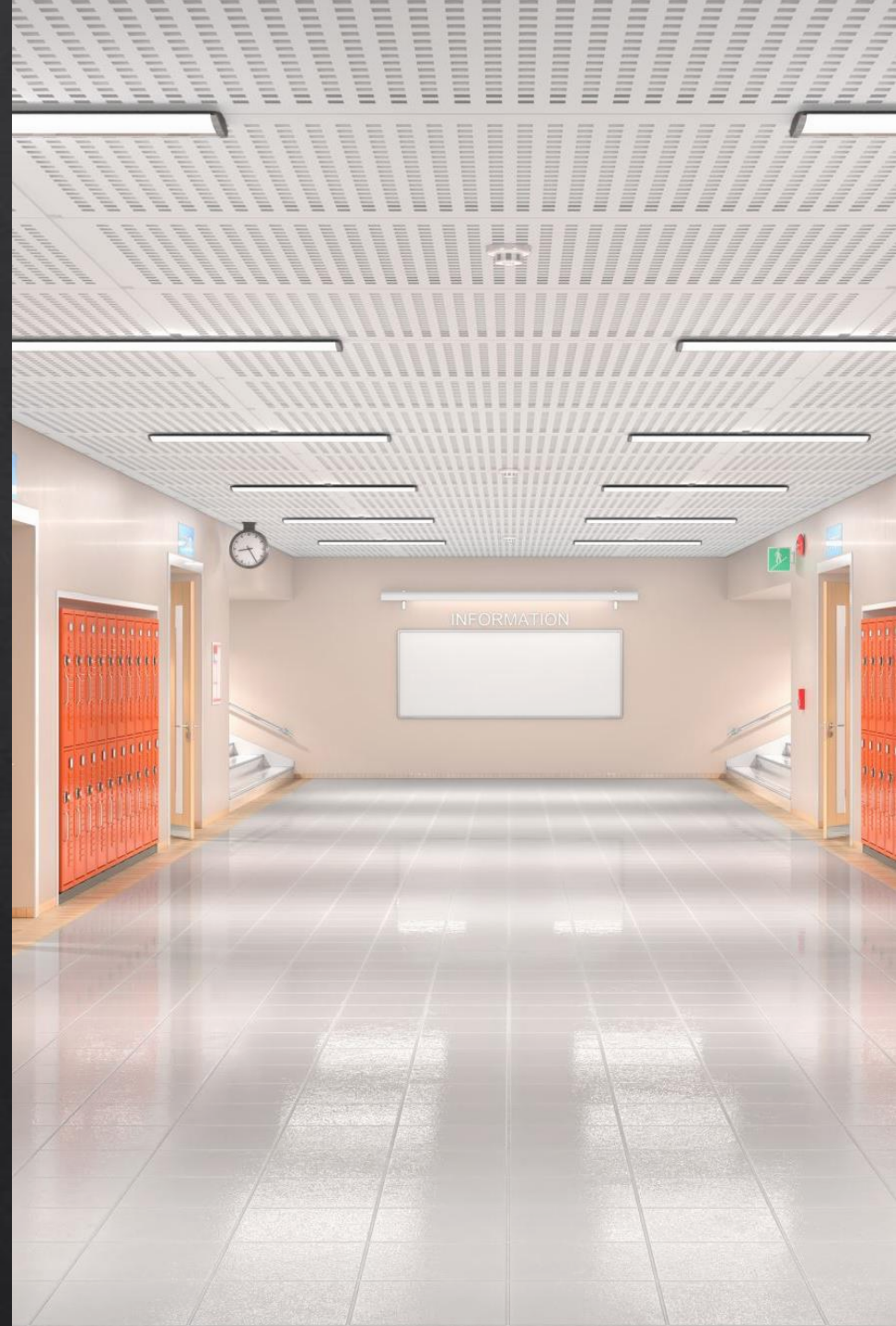
- Determine if a fire pump is required (NFPA 20)
  - Pump sizing to be based on hydraulic calculations

Standpipe

- Determine if a standpipe is required (IBC & NFPA 14)
  - Determine which class standpipe is needed
  - Determine which type of standpipe is needed

NFPA 13 Design

- **Layout of sprinklers**
  - Determine occupancy for sprinkler spacing and water demands
    - Light hazard occupancies examples
      - Meeting / classrooms / educational
      - Churches
      - Clubs
      - Museums
      - Restaurant Seating areas
      - Theaters / Auditoriums (NOT including stages)
      - Unused attic spaces



NFPA 13 Design (contd.)

- Ordinary Hazard Group I & II examples
  - Restaurant service areas
  - Automobile parking and showrooms
  - Distilleries
  - Large stack libraries
  - Wood machining / production areas

Choosing the Correct Sprinkler Systems

Wet System

- A wet system is a type of sprinkler system that contains water throughout the piping network that is attached to an automatic water supply

Dry System

- A dry sprinkler system does not contain water. The piping network is filled with compressed air. The system is attached to a "dry pipe valve." When a sprinkler head is activated, the air is released from the system, and the dry pipe valve then opens sending water into the piping network. Dry systems are generally used in areas subject to freezing.

Pre-Action Systems

- Pre-Action systems are similar to dry systems. Pre-action systems however rely on the activation of another device such as a heat detector for the pre-action valve to introduce water into the piping network. These types of systems are generally used in areas where water damage is a concern, such as computer and data rooms, museums or other areas containing sensitive or valuable equipment or supplies.

Determine areas that need to be sprinklered

- Rooms based on applicable code or standard
- Concealed combustible spaces
  - Areas above ceilings that are wood construction (NFPA 13 8.15.1)
  - Attic and roof truss areas
  - Crawl spaces

Sprinkler Spacing

- Light Hazard spacing
  - Standard spray pendents and uprights can cover a 225 sq.ft. area with a maximum spacing of 15’, in a hydraulically calculated system noncombustible space. Concealed combustible spaces are generally limited to 130 sq.ft. depending on the type construction.
  - Standard spray sidewalls can cover a 196 sq.ft. areas with a maximum spacing of 14’
- Ordinary Hazard Spacing
  - Most ordinary hazard spacing is limited to 130 sq.ft. with a maximum sprinkler spacing of 15’
- Specific Application Sprinklers
  - NFPA allows for the use of “specific application sprinklers” this means that a manufacturer developed, tested and received either UL and or FM approval to use a specific head for alterative applications and spacing. These types of sprinklers generally have their own criteria listed on the manufacturers data sheets. Examples of these sprinklers are, extended coverage sprinklers, residential sprinklers, concealed combustible space sprinklers and attic sprinklers.

Maximum Spacing of Standard Pendent and Upright Spray Sprinklers for Light Hazard

Table 8.6.2.2.1(a) Protection Areas and Maximum Spacing of Standard Pendent and Upright Spray Sprinklers for Light Hazard

		Maximum Protection Area		Maximum Spacing	
Construction Type	**System Type**	**ft²**	**m²**	**ft**	**m**
Noncombustible unobstructed	Hydraulically calculated	225	20.9	15	4.6
Noncombustible unobstructed	Pipe schedule	200	18.6	15	4.6
Noncombustible obstructed	Hydraulically calculated	225	20.9	15	4.6
Noncombustible obstructed	Pipe schedule	200	18.6	15	4.6
Combustible unobstructed with no exposed members	Hydraulically calculated	225	20.9	15	4.6
Combustible unobstructed with no exposed members	Pipe schedule	200	18.6	15	4.6
Combustible unobstructed with exposed members 3 ft (910 mm) or more on center	Hydraulically calculated	225	20.9	15	4.6
Combustible unobstructed with exposed members 3 ft (910 mm) or more on center	Pipe schedule	200	18.6	15	4.6
Combustible unobstructed with members less than 3 ft (910 mm) on center	All	130	12.1	15	4.6
Combustible obstructed with exposed members 3 ft (910 mm) or more on center	All	168	15.6	15	4.6
Combustible obstructed with members less than 3 ft (910 mm) on center	All	130	12.1	15	4.6
Combustible concealed spaces in accordance with 8.6.4.1.4	All	120	11.1	15 parallel to the slope 10 perpendicular to the slope*	4.6 parallel to the slope 3.0 perpendicular to the slope*

*See 8.6.4.1.4.4.

Concealed Combustible Spaces

- One of the more difficult challenges in older and historic buildings is identifying and properly protecting concealed combustible spaces. Many older building are wood construction or contain combustible materials in floor / ceiling spaces. NFPA 13 (2016 ed) section 8.15.1 identifies these areas, as well as gives the protection criteria. Generally speaking, if an area above a ceiling has unprotected wood truss, or solid wood members with a space larger than 6" from the bottom of the member to the ceiling, will require sprinkler protection. All combustible attic spaces in a NFPA 13 building and some 13R buildings do require sprinkler protection.
- Noncombustible construction areas that also contain a large amount of combustible material, such as insulation, wiring and piping may also need sprinkler protection.

Approved Materials

- All products and materials used in NFPA 13, R and D must be “listed and approved” or otherwise approved for use in the “standards.” Most items are marked with the UL and/or FM symbol. There are exceptions in NFPA 13D for alternate materials. The listing and approvals can also be found on the manufacturers data sheets.
- Use of CPVC pipe in historic buildings. CPVC pipe and fittings are used in many retrofit applications due to its flexibility of installation and less pre and onsite fabrication compared to metal piping. It’s important to note that although CPVC is a great option for older and historic buildings it does have its limitations:
  - CPVC piping is limited to light hazard areas or small ordinary hazard rooms.
  - CPVC piping can be installed “exposed” but has many limitations on how this can be done.
  - CPVC piping can be installed in concealed combustible spaces, but specific application sprinklers must be used in conjunction with it to properly meet it’s “listing and approval”

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Water Supply

- Generally, in an NFPA 13 design, a municipal water supply is the most economical means for a fire sprinkler system. Obtain water supply information with a fire hydrant flow test *USE VIDEO* *https://www.youtube.com/watch?v=akTzGvdLQL8*
- If a municipal water supply is not available, an alternative water supply is needed such as a water storage tank or pond that a fire pump will take suction from. Water storage requirements are based on the GPM requirement of the sprinkler system X the duration needed. i.e., sprinkler demand = 350 GPM / light hazard duration required = 30 minutes: 350 x 30 = 10,500 minimum gallons required.
- The gallons per minute and pressure needed for a sprinkler system is determined by hydraulic calculations of the system. If the water supply does not have adequate pressure, the use of a fire pump is generally needed. If the flow of the water supply is not adequate, alternative means of water storage must be used, such as a water storage tank.

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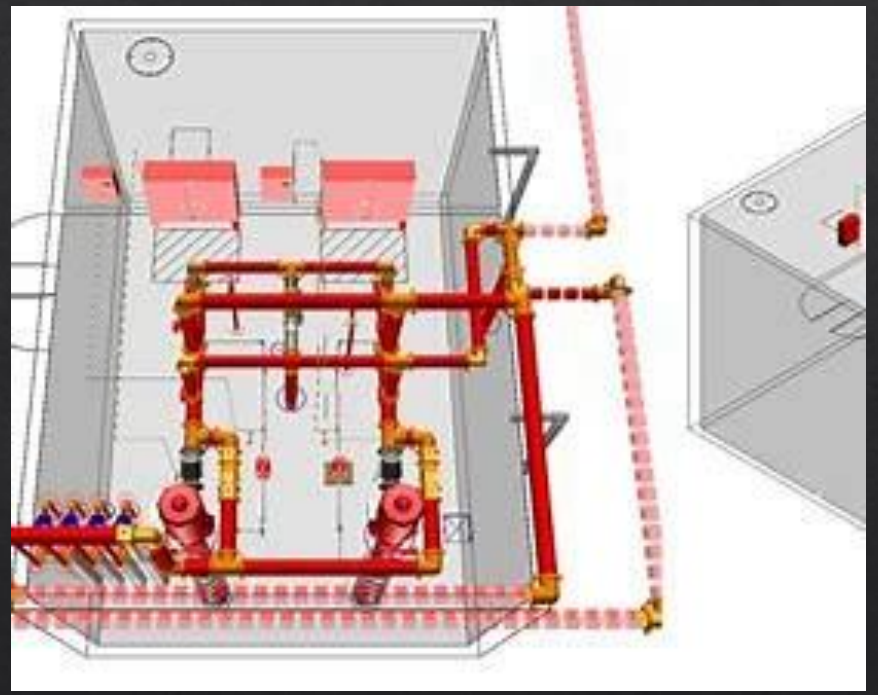
Design and Layout

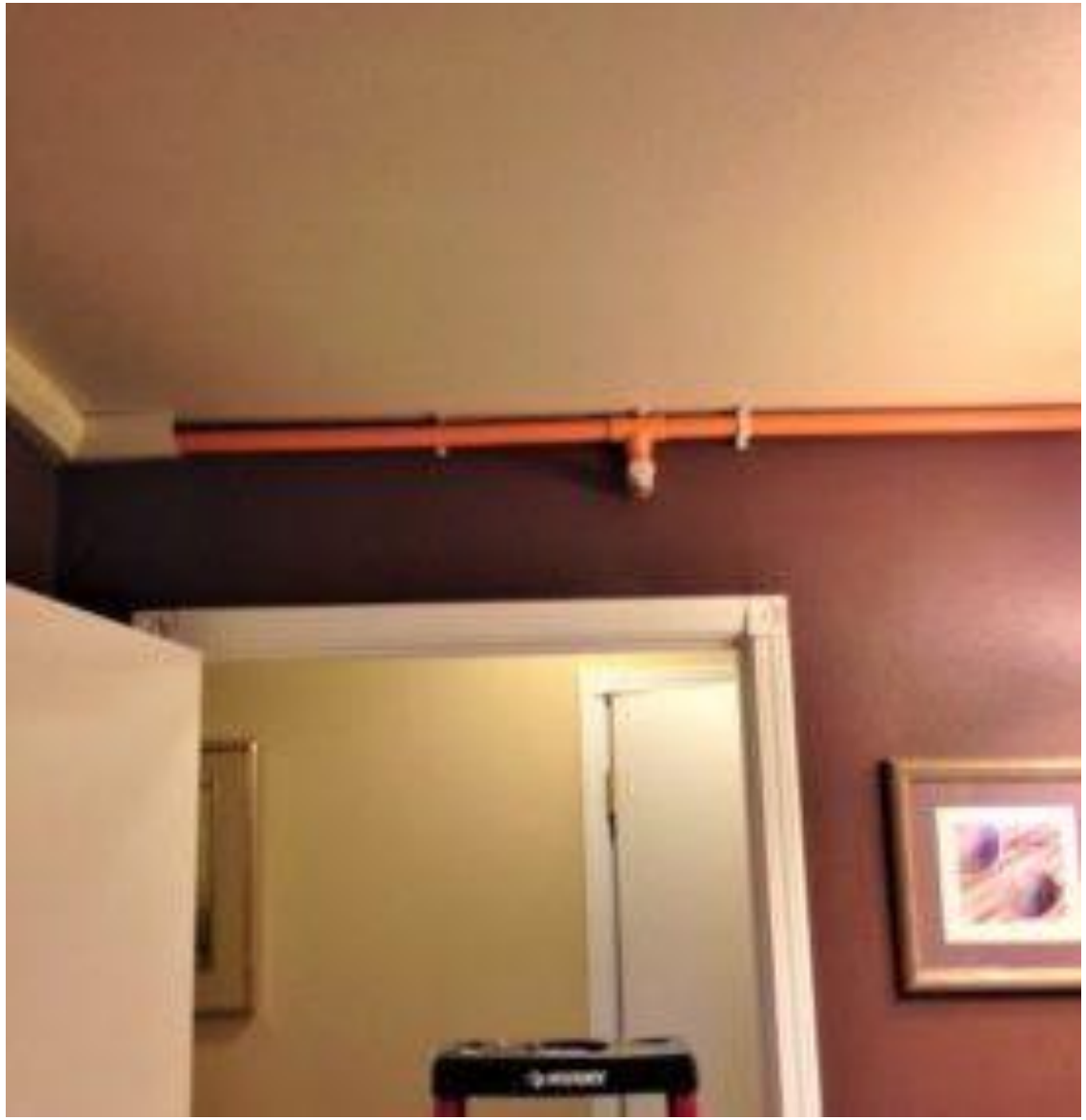
Once the appropriate design requirements have been established, the sprinkler designer will work with the architect, engineer, or building owner to accomplish the desired sprinkler layout, pipe routings, etc.

- Designing systems in historic buildings can be particularly challenging due to the existing conditions and lack of space and access.
- Most designers will start out with a comprehensive field survey of the structure.
- Often CAD backgrounds of the building are available but, in some cases, they are not, and the structure must be surveyed and drawn as well as the sprinkler system.



Design and Layout (contd.)

- Some options in historic buildings are using exposed piping, or piping that can possibly be run in soffits or additional dropped ceilings. There are also fabricated soffit systems that are engineered for fire sprinkler systems



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Hydraulic Calculations

Once the system is drawn the next step is to perform hydraulic calculations. Calculations are performed to "prove" the system will supply adequate water in the event of a fire.

Calculations are based on the following:

- Water supply, flow and pressure
- Sprinkler demands, based on hazard, sprinkler spacing and the size of the most hydraulically demanding area(s)
- Friction loss throughout the system
- In mid-rise and high-rise building standpipe(s), also require hydraulic calculations
- Calculations will determine the type and size of sprinkler needed, above and below ground pipe sizing and pump sizing.

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Approval Process

After design and calculations are complete the drawings are submitted for approvals. Review and approvals are generally completed by:

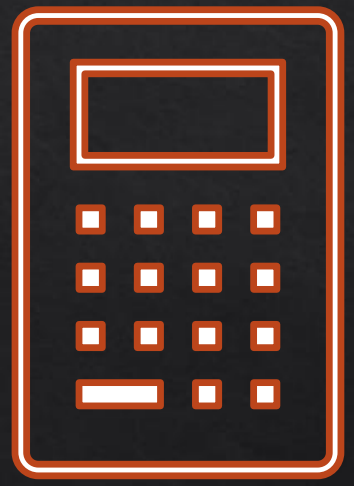
The project Architect and/or Engineer

The Code Official or third-party reviewer.

The Insurance Underwriter

NFPA 13 lists criteria for what fire sprinkler shop drawings and calculations should encompass.

Chapter 23 Plans and Calculations



Chapter 23 Plans and Calculations

23.1* Working Plans.

23.1.1* Working plans shall be submitted for approval to the authority having jurisdiction before any equipment is installed or remodeled.

23.1.2 Deviation from approved plans shall require permission of the authority having jurisdiction.

23.1.3 Working plans shall be drawn to an indicated scale, on sheets of uniform size, with a plan of each floor, and shall show those items from the following list that pertain to the design of the system:

(1) Name of owner and occupant.
(2) Location, including street address.
(3) Point of compass.
(4) Full height cross section or schematic diagram, including structural member information if required for clarity and including ceiling construction and method of protection for nonmetallic piping.
(5) Location of partitions.
(6) Location of fire walls.
(7) Occupancy class of each area or room.
(8) Location and size of concealed spaces, closets, attics, and bathrooms.
(9) Any small enclosures in which no sprinklers are to be installed.
(10) Size of city main in street and whether dead end or circulating; if dead end, direction and distance to nearest circulating main; and city main test results and system elevation relative to test hydrant.

Chapter 23 Plans and Calculations (contd.)

(11) Other sources of water supply, with pressure or elevation.
(12) Make, type, model, and nominal K-factor of sprinklers, including sprinkler identification number.
(13) Temperature rating and location of high-temperature sprinklers.
(14) Total area protected by each system on each floor.
(15) Number of sprinklers on each riser per floor.
(16) Total number of sprinklers on each dry pipe system, preaction system, combined dry pipe–preaction system, or deluge system.
(17) Approximate capacity in gallons of each dry pipe system.
(18) Pipe type and schedule of wall thickness.
(19) Nominal pipe size and cutting lengths of pipe (or center-to-center dimensions). Where typical branch lines prevail, it shall be necessary to size only one typical line.
(20) Location and size of riser nipples.
(21) Type of fittings and joints and location of all welds and bends. The contractor shall specify on drawing any sections to be shop welded and the type of fittings or formations to be used.
(22) Type and locations of hangers, sleeves, braces, and methods of securing sprinklers when applicable.
(23) All control valves, check valves, drain pipes, and test connections.
(24) Make, type, model, and size of alarm or dry pipe valve.
(25) Make, type, model, and size of preaction or deluge valve.
(26) Kind and location of alarm bells.
(27) Size and location of standpipe risers, hose outlets, hand hose, monitor nozzles, and related equipment.
(28) Private fire service main sizes, lengths, locations, weights, materials, point of connection to city main; the sizes, types and locations of valves, valve indicators, regulators, meters, and valve pits; and the depth that the top of the pipe is laid below grade.
(29) Piping provisions for flushing.
(30) Where the equipment is to be installed as an addition to an existing system, enough of the existing system indicated on the plans to make all conditions clear.
(31) For hydraulically designed systems, the information on the hydraulic data nameplate.
(32) A graphic representation of the scale used on all plans.
(33) Name and address of contractor.
(34) Hydraulic reference points shown on the plan that correspond with comparable reference points on the hydraulic calculation sheets.
(35) The minimum rate of water application (density or flow or discharge pressure), the design area of water application, in-rack sprinkler demand, and the water required for hose streams both inside and outside.
(36) The total quantity of water and the pressure required noted at a common reference point for each system.
(37) Relative elevations of sprinklers, junction points, and supply or reference points.
(38) If room design method is used, all unprotected wall openings throughout the floor protected.
(39) Calculation of loads for sizing and details of sway bracing.
(40) The setting for pressure-reducing valves.
(41) Information about backflow preventers (manufacturer, size, type).
(42) Information about listed antifreeze solution used (type and amount).
(43) Size and location of hydrants showing size and number of outlets and if outlets are to be equipped with independent gate valves. Whether hose houses and equipment are to be provided, and by whom, shall be indicated. Static and residual hydrants that were used in flow tests shall be shown.
(44) Size, location, and piping arrangement of fire department connections.
(45) Ceiling/roof heights and slopes not shown in the full height cross section.
(46) Edition year of NFPA 13 to which the sprinkler system is designed.

23.1.4* A signed copy of the owner's certificate and the working plan submittal shall include the manufacturer's installation instructions for any specially listed equipment, including descriptions, applications, and limitations for any sprinklers, devices, piping, or fittings.

23.1.5* Working Plans for Automatic Sprinkler Systems with Non–Fire Protection Connections.

23.1.5.1 Special symbols shall be used and explained for auxiliary piping, pumps, heat exchangers, valves, strainers, and the like, clearly distinguishing these devices and piping runs from those of the sprinkler system.

23.1.5.2 Model number, type, and manufacturer's name shall be identified for each piece of auxiliary equipment.

23.2 Water Supply Information.

23.2.1 Water Supply Capacity Information. The following information shall be included:

(1) Location and elevation of static and residual test gauge with relation to the riser reference point
(2) Flow location
(3) Static pressure, psi (bar)
(4) Residual pressure, psi (bar)
(5) Flow, gpm (L/min)
(6) Date
(7) Time
(8) Name of person who conducted the test or supplied the information
(9) Other sources of water supply, with pressure or elevation

23.2.1.1* Where a waterflow test is used for the purposes of system design, the test shall be conducted no more than 12 months prior to working plan submittal unless otherwise approved by the authority having jurisdiction.

23.2.2 Water Supply Treatment Information. The following information shall be included when water supply treatment is provided in accordance with 24.1.5:

(1) Type of condition that requires treatment
(2) Type of treatment needed to address the problem
(3) Details of treatment plan

23.3 Hydraulic Calculation Forms.

23.3.1 General. Hydraulic calculations shall be prepared on form sheets that include a summary sheet, detailed worksheets, and a graph sheet. *[See Figure A.23.3.2(a), Figure A.23.3.3, and Figure A.23.3.4 for copies of typical forms.]*

23.3.2* Summary Sheet. The summary sheet shall contain the following information, where applicable:

(1) Date
(2) Location
(3) Name of owner and occupant
(4) Building number or other identification

Questions & Break

Part II: Installation of Fire Sprinklers in Historic Structures

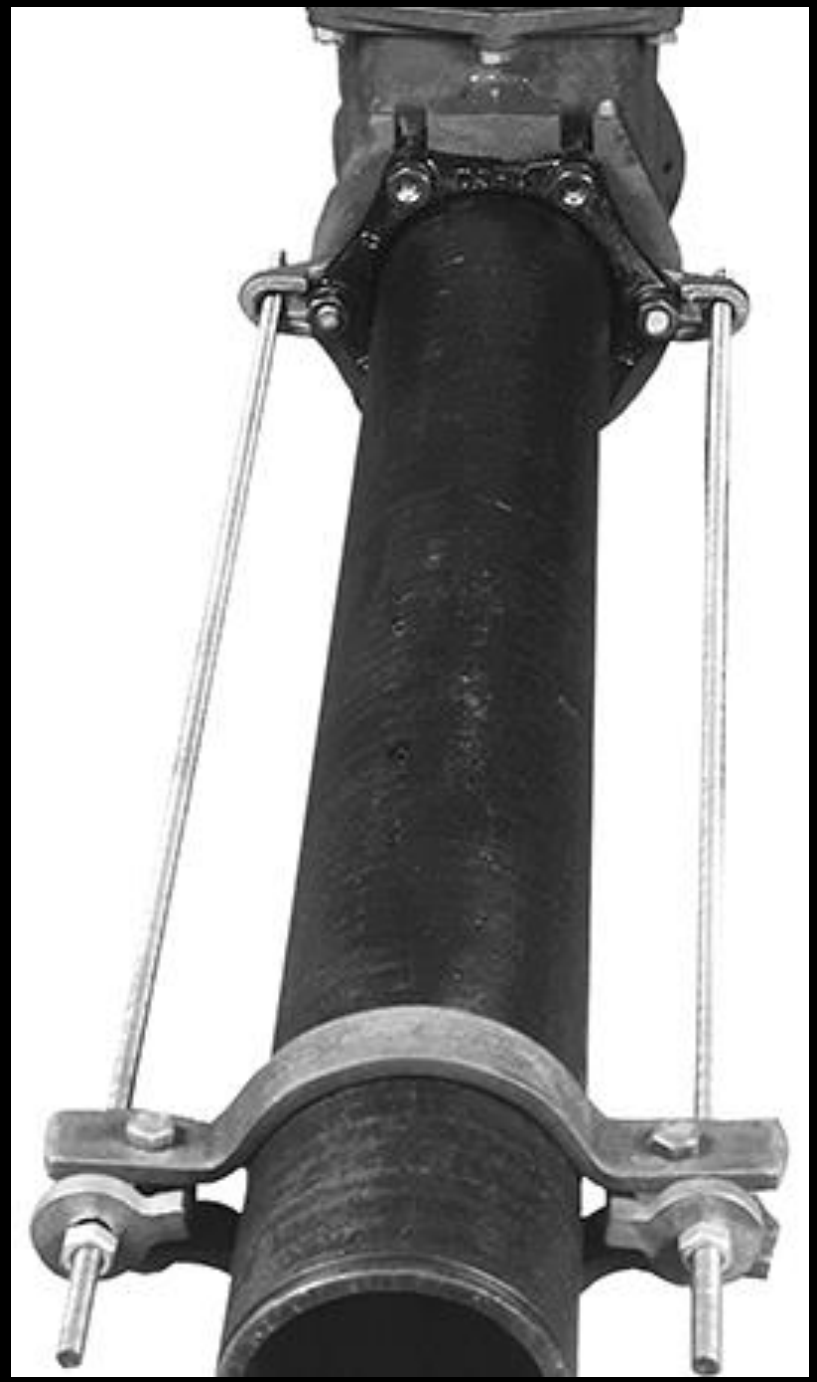
1. Water Service and Underground Piping
2. Above Ground Installation
3. Field Layout
4. Keeping Safety in Mind
5. Field Checking Installation

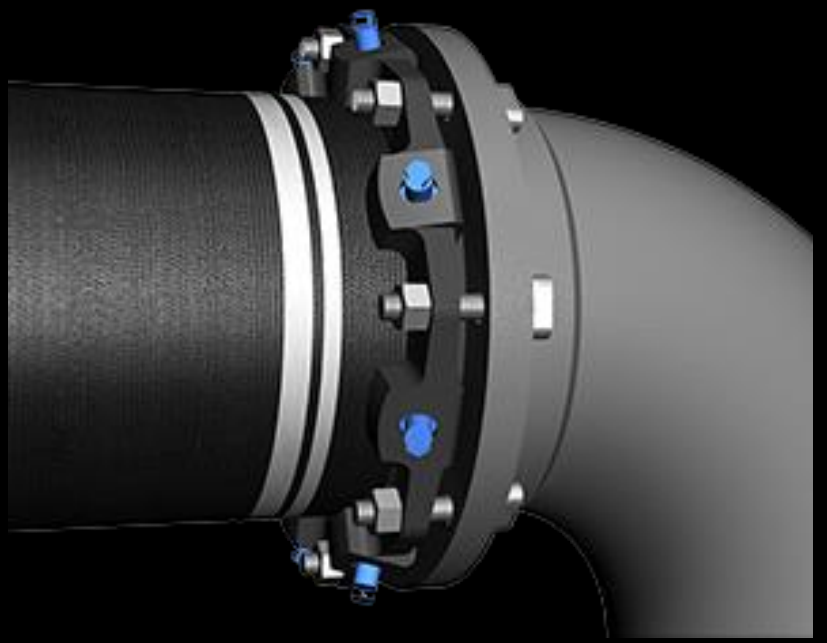
Water Service and Underground Piping

- Public Water Service
  - Typical installations are with the following materials:
    - Ductile Iron piping
    - C-900 “Blue Brute”
    - Copper and plastic piping for smaller services

Ductile Iron

- Ductile iron and C-900 plastic piping is the most common installation for larger pipe sizes
  - Ductile iron pipe has “mechanical joint” push in style fittings. Often “mega-lug” style restraints are used but joints with change of directions must also be “restrained.” This can be accomplished with threaded rods and or thrust blocks.





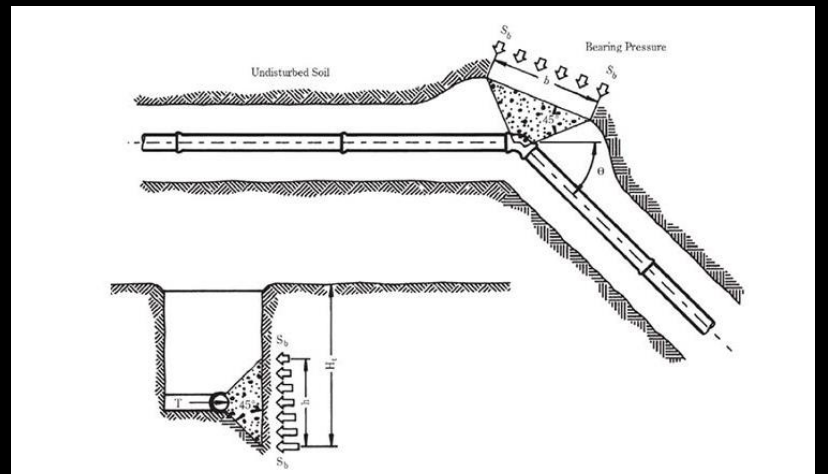
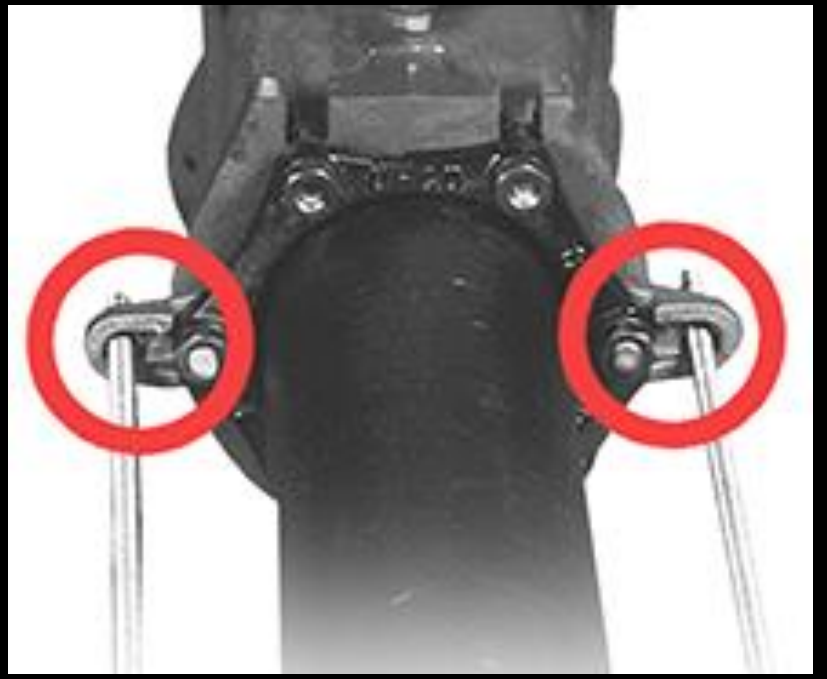


Figure 4 - Thrust Block Showing Bearing Area Against Undistrubed Soil
Source: Thrust Restraint Design for Ductile Iron Pipe, Seventh Edition - 2016, published by the Ductile Iron Pipe Research Association.



Under Ground Pipe flushing and testing

- Underground piping is subject to the following acceptance procedures according to NFPA 24
  - Flushing – Underground piping shall be flushed as per NFPA 24 Table 10.10.2.1.3
- Underground piping shall also be hydrostatically tested as per NFPA 24 at 200 psi or 50 psi in excess of working pressure. Underground piping is permitted to have 5psi of loss if there is no visual leakage.

Table 10.10.2.1.3 Flow Required to Produce Velocity of 10 ft/sec (3.0 m/sec) in Pipes

Nominal Pipe Size (in.)	Flow Rate (gpm)	Nominal Pipe Size (mm)	Flow Rate (L/min)
2	100	50	380
2½	150	65	570
3	220	75	833
4	390	100	1,500
5	610	125	2,300
6	880	150	3,350
8	1,560	200	5,900
10	2,440	250	9,250
12	3,520	300	13,300

Part II: Installation of Fire Sprinklers in Historic Structures

1. Water Service and Underground Piping
2. Above Ground Installation
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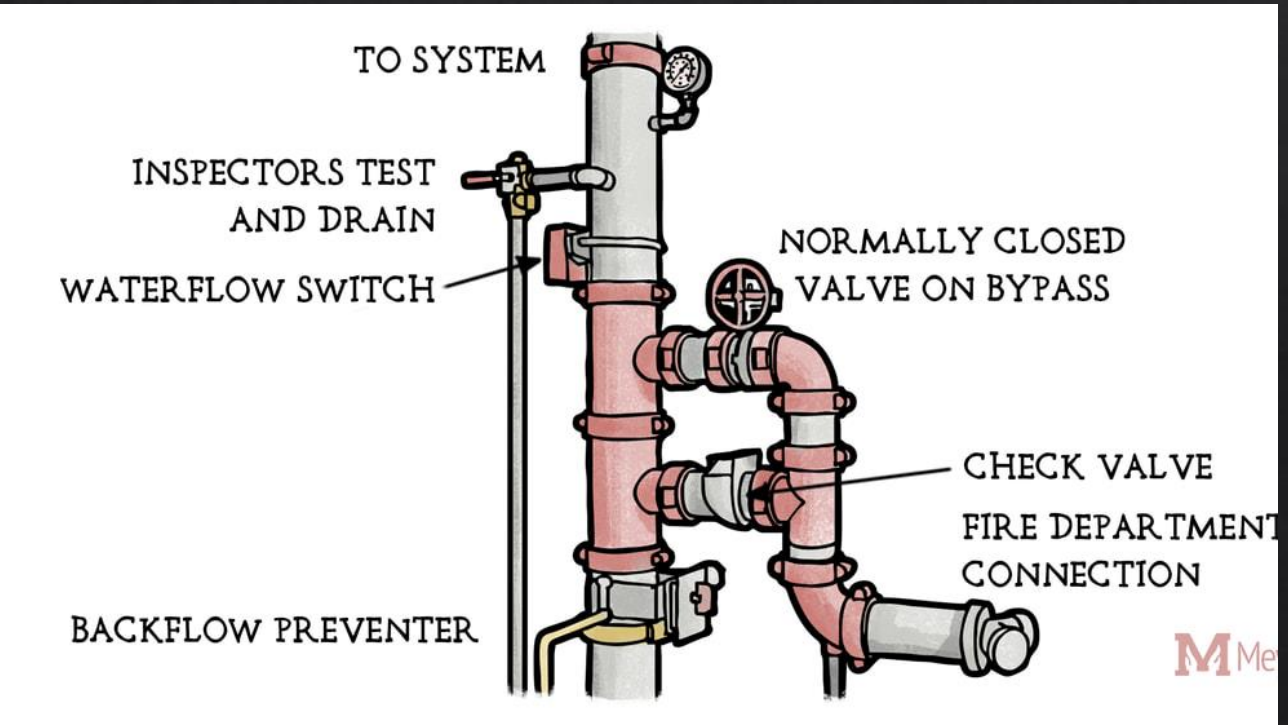
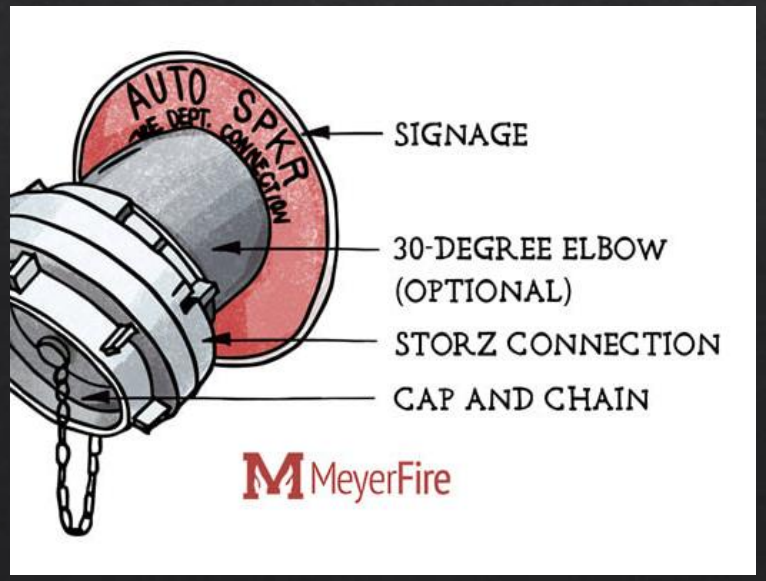
4. Keeping Safety in Mind
5. Field Checking Installation

- Steel VS CPVC for installers
  - Steel pipe has more flexibility as far as approval and listings, but the process is generally more time consuming. Most contractors opt to “pre-fabricate” steel piping. This usually requires additional field visits by designers, additional shop drawings and time.
  - CPVC is more flexible from an installation standpoint, but it is also important to note that installers should be certified from a CPVC manufacturer. There are many specific listings and installation items that installers should be aware of. Companies such as Spears and Blazemaster offer courses for certification.
  - https://www.vikinggroupinc.com/sites/default/files/documents/080712_Viking%20Plastics%20Install%20Design%20Manual_Rev%2021-1.pdf

Above Ground Installation Options



- System Risers
  - System riser or water service entrances can be configured in many ways. Most riser connected to public water systems will be required to have backflow protection.
  - In the 2002 version of NFPA 13, the standard introduced new requirements that sprinkler systems have the means to "forward flow" the sprinklers systems GPM demand through the backflow preventor on an annual basis

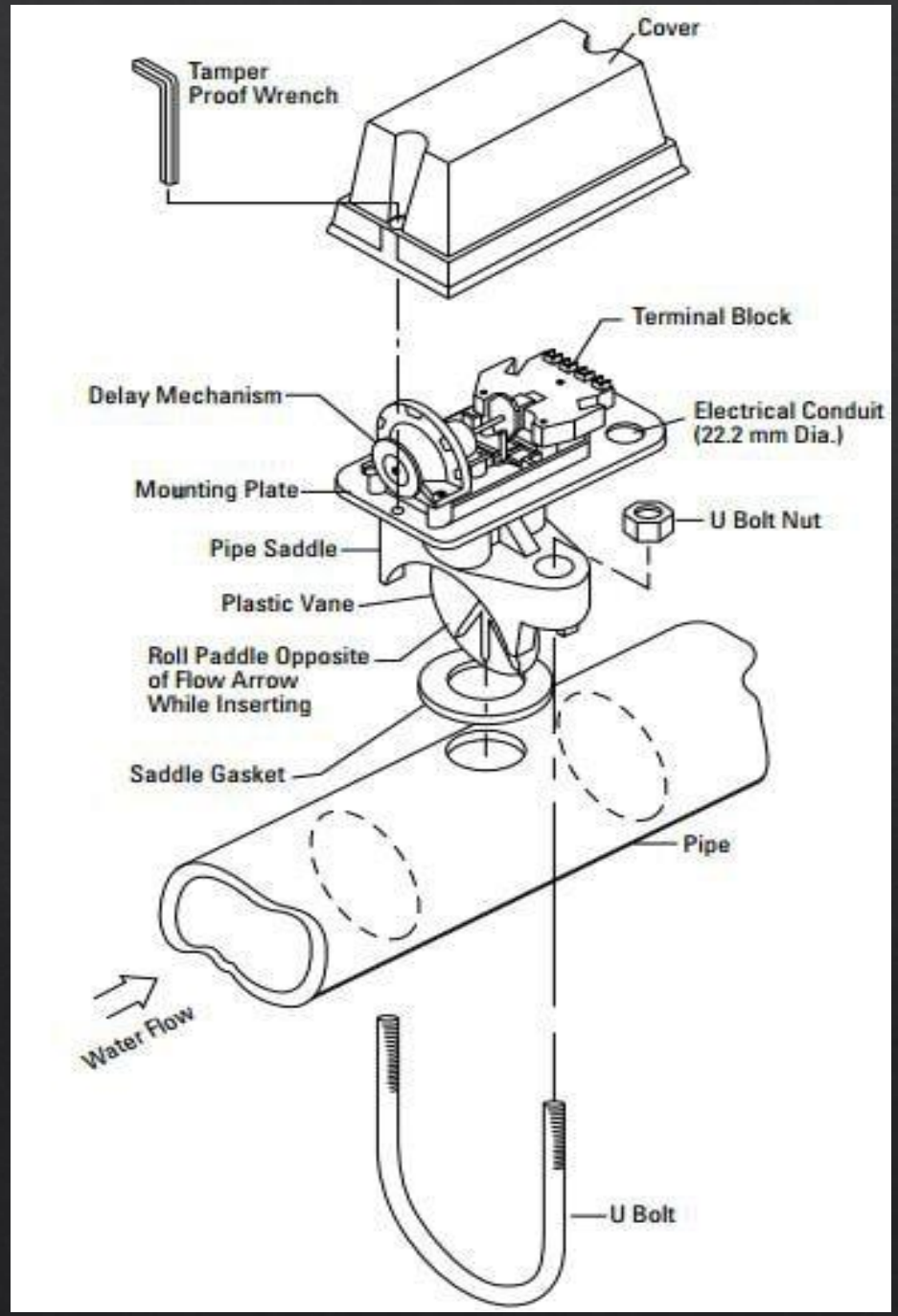


Fire Department connections are installed for the fire department to supplement the fire sprinkler system in the event of a fire. The style and connection type of the connection is governed by the local fire department.

Fire department connections should always be installed with a condensation drain to prevent freezing.

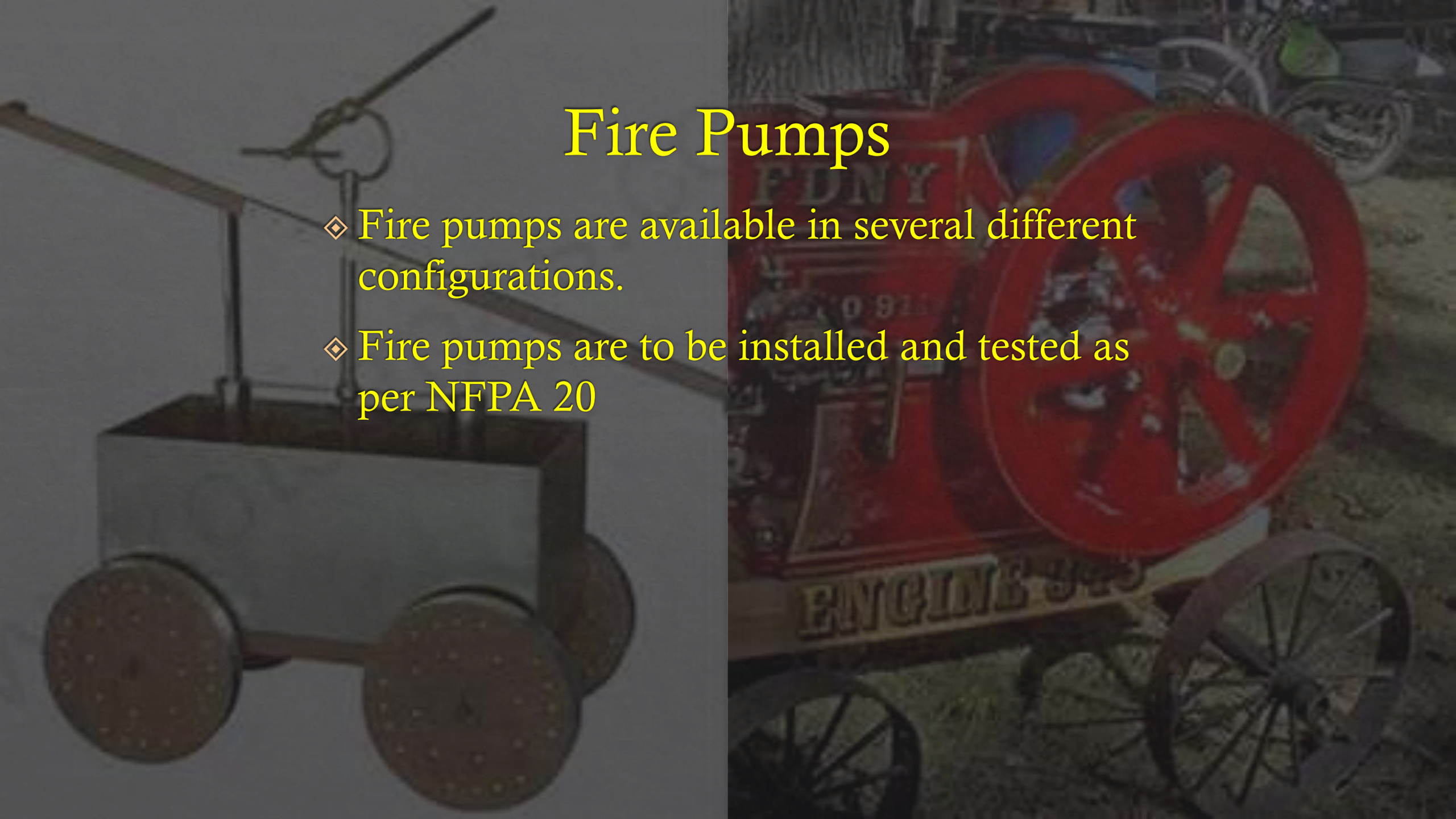
The placement of fire department connections can be challenging on historical structures and may need to be coordinated between the contractor, fire department and historical societies.

- Alarm Devices
  - Alarm devices are to be installed on fire sprinkler systems
    - Valve tamper switches are installed on all control valves to send notification in the event a control valve is closed
    - Flow and pressure switches are installed on sprinkler systems to send a fire alarm signal in the event water is flowing through the system, or water is introduced into a dry or pre-action system.
    - Fire Pumps are also monitored for several different points depending on the type of the fire pump.

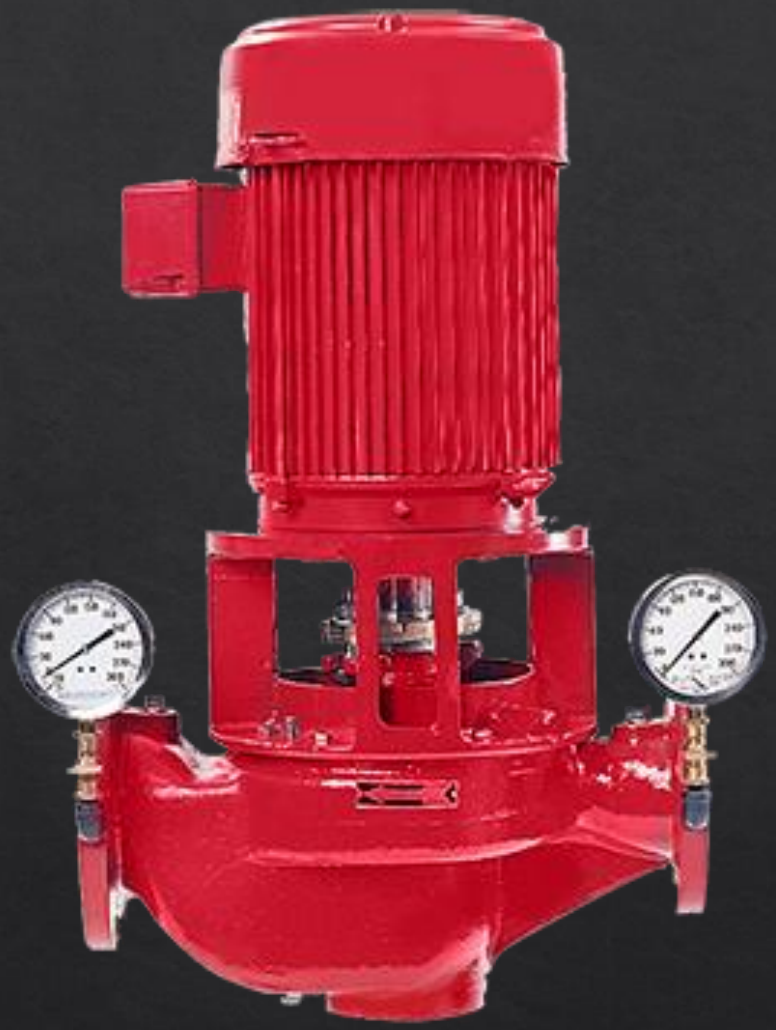


Fire Pumps

- Fire pumps are available in several different configurations.
- Fire pumps are to be installed and tested as per NFPA 20



Horizontal Split Case



Inline Vertical

Vertical Turbine

Right Angle Gear Driven Vertical Pump

Part II: Installation of Fire Sprinklers in Historic Structures

1. Water Service and Underground Piping
2. Above Ground Installation
3. Field Layout
4. Keeping Safety in Mind
5. Field Checking Installation

Field Layout

- A successful installation starts with proper field layout and planning.
  - Coordinating with existing building elements
  - Coordinating with other trades
  - Coordinating with the Fire Department and AHJ

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Safety working in historic structures

- Working in historic structures can present many safety hazards. Historic structures should always be checked for hazardous materials before work begins, such as lead and asbestos.
- Many sprinkler systems will need to be installed above existing ceilings. Workers and inspectors should always use fall protection methods above existing ceilings.
- Pressure testing sprinkler systems can also be hazardous. Anyone near a pressurized system should always have proper PPE.

Part II: Installation of Fire Sprinklers in Historic Structures

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Sprinkler installation should always be checked and verified for proper installation. Deviations from the approved drawings may require revised or additional hydraulic calculations.

Questions & Break

Part III: Inspections and System Acceptance of Fire Sprinklers in Historic Structures

1. Visual Inspection
2. Functional testing
3. Air and Hydrostatic testing of wet and dry systems
4. Fire Pump testing

Visually Inspecting Sprinkler Systems

- System should be checked against the “approved drawings”
  - Check the sprinkler spacing
  - Check the pipe routing and size
- Check that “listed and approved” material is being used
- Check that all valves are properly identified
- Check that all control valves have tamper devices
- Check that dry systems have proper pitch , are capable of draining, and have approved drains if necessary
- Piping is aligned properly
- Sprinklers are spaced properly and installed at the correct deflector distances.

Part III: Inspections and System Acceptance of Fire Sprinklers in Historic Structures

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Functional Tests

- Main drain tests shall be conducted
- Water flow devices shall be tested
- Dry and pre-action systems shall be tripped and timed, time should be as per NFPA 13 29.2.3.2.1 and the system design
- Control valves shall be tested and completed closed and opened, tamper devices shall also be tested
- Backflow devices shall be forward flow tested

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Air and Hydrostatic Testing

- Dry sprinkler systems are to be air tested at 40 psi for 24 hours. Then hydrostatically tested at 200 psi for 2 hours
- Wet Systems shall be hydrostatically tested at 200 psi for 2 hours
  - NOTE: systems that are subject to pressures over 150 psi shall be tested at 50 psi over the normal working pressure.

Part III: Inspections and System Acceptance of Fire Sprinklers in Historic Structures

1. Visual Inspection
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Fire Pump Testing

- Fire pumps shall be tested and inspected as per NFPA 20
- Suction piping shall be flushed
- Suction and discharge piping shall be hydrostatically tested at 200 psi or 50 psi over working pressure that is in excess of 150 psi
- Fire pump, controller and engine factory representatives shall be present for field acceptance tests
- Fire pumps shall be performance tested; results should be compared to the factory curve.
  - Performance tested should be recorded at churn pressure, 100% of rated capacity and 150% of rated capacity (when available or at least system demand)

Questions