PRIVATE FIRE SERVICE MAINS AND CONNECTIONS

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1.0 SCOPE

This property loss prevention data sheet provides recommendations for the installation, arrangement and location of private fire service mains and cross connections. In addition, it covers combined water mains (also known as combined service mains) that carry water for both fire protection purposes and industrial use.

This data sheet also includes guidance for the installation arrangement and location of components associated with fire service mains, including but not limited to manually operated valves, hydrants, meters and backflow prevention assemblies of both the reduced pressure principle and double check valve types.

Guidance is also provided on the hydrostatic testing of fire service water mains at installation.

This data sheet does not include the following:

- Guidance for the piping between the system inlet of a pump (fire or booster) and the check valve on the discharge side of a fire pump. Refer to FM Data Sheet 3-7, *Fire Pumps*.
- Guidance for the inspection, testing and maintenance of valves (including control valves) hydrants and backflow prevention devices on cross connections. Refer to FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.
- Guidance on fire hoses, nozzles and equipment for private hydrants. Refer to FM Data Sheet 10-1, *Pre-incident and Emergency Response Planning*.

For guidance on the flushing of obstructions from existing fire service mains. Refer to FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

Information on the hydraulics of fire service water mains, including hydrant and other orifice discharge coefficients and Hazen-Williams pipe coefficients, refer to FM Data Sheet 3-0, *Hydraulics of Fire Protection Systems*.

1.1 Hazards

Underground mains are a critical component of a fire protection system, connecting the water source with above-ground components such as sprinklers, hydrants and hoses, and are designed to get water to the attached fire protection systems and equipment where it can be used. A lack of water to the fire protections systems can lead to a large and devastating loss. Proper design, installation and maintenance of underground mains reduces the potential of any disruption to this water supply, allowing water to reach sprinklers and other equipment in the areas where it is needed.

1.2 Changes

April 2025. Full revision. The following significant changes were made:

A. Changed the name of the Operating Standard to “*Private Fire Service Mains and Connections*”.

B. Improved the definition of private fire service water mains.

C. Updated installation guidance for positioning underground mains beneath railroad tracks.

D. Updated thrust block guidance for fully restrained pipes.

E. Added new guidance for thrust blocks used with plastic piping.

F. Added new guidance for the installation of above-ground mains.

G. Added freeze protection guidance for above-ground mains.

H. Added UV protection guidance for plastic water mains.

I. Added new impact protection guidance for underground mains exiting within buildings.

J. Added cross connection and backflow preventer guidance from FM Data Sheet 3-3, *Cross Connections*. Data Sheet 3-3 was then made obsolete.

K. Updated guidance on leak detection and acceptable leakage rate guidance for water mains.

L. Updated guidance on flushing of water mains.

M. Relocated general inspection, testing and maintenance guidance to FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

N. Relocated guidance on fire hoses, nozzles and equipment for private hydrants to FM Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*.

O. Rearranged the guidance in this data sheet to ensure consistency with other FM data sheets.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 Use FM Approved equipment, materials, and services whenever they are applicable and available. For a list of FM Approved products and services, see the *Approval Guide*, an online resource of FM Approvals.

2.2 Construction and Location

2.2.1 Fire Service Mains

2.2.1.1 Construct water mains using pipes, joints and fittings of materials that are suitable for the ground conditions and the internal and external pressures expected.

2.2.1.2 In areas subject to spillage of aromatic hydrocarbons, polyvinyl chloride (PVC) pipe should not be used. Aromatic hydrocarbons such as benzene and toluene will dissolve and/or weaken polyvinyl chloride piping.

2.2.1.2.1 Test the soil if PVC piping is to be installed in an area where past spillage of aromatic hydrocarbons has occurred. If testing shows residual hydrocarbons are still present in the soil, consider alternative pipe materials.

2.2.1.3 Where looped mains are present, provide divisional valves so that sections of the loop may be isolated.

2.2.1.4 Provide valves on pipes that supply hydrants, so that one hydrant can be repaired without impairing the rest of the system.

2.2.1.5 Limit the maximum number of risers served by one divisional valve to six (6).

2.2.1.6 Provide access to pipe joints on mains for inspection and repair.

2.2.1.7 Run fire service mains outside of buildings.

2.2.1.8 Provide a minimum 5 ft (1.5 m) clearance between the mains and building foundation footings.

2.2.1.9 Where placement of an underground fire service main inside a building is unavoidable, place the main in a covered trench that is accessible from within the building. Use non-combustible construction for the trench walls and base. Provide drainage to allow water to be removed from the trench when needed. For additional protection of secondary pipes and pipe connections within a building (e.g., from an underground main to the riser), see Section 2.3.6.1.

2.2.1.10 Where a fire service main passes under or through a foundation wall, provide clearance around the main so that settling of the building will not damage the main.

2.2.1.11 Where a main passes underneath a building, provide outdoor valves on each side of a building beneath which the main passes, so that an indoor break can be isolated.

2.2.1.12 Size any connections from water supplies to be a minimum of 6 in. (150 mm) in diameter, including connections between the mains and hydrants. Where cross connections are present, also see Section 2.4.4.

2.2.2 Excavation for Underground Main Pipes

2.2.2.1 When excavating in a rock subgrade, provide a clearance of at least 6 in. (152 mm) below and on each side of all pipes, valves and fittings.

2.2.2.2 When the subgrade is found to be unstable or includes ash, cinders, refuse, organic material or other unsuitable material, remove such material to a minimum level of at least 6 in. (152 mm) below the bottom of the pipe. Replace all such material with clean, stable backfill material.

2.2.2.3 When the bottom of the trench or the subgrade is found to consist of material that is unstable to such a degree that it cannot be removed, construct a foundation for the pipe and/or components that cannot deteriorate over time, thereby reintroducing unstable support for the water main.

2.2.2.4 When the substrate cannot be removed or is comprised of unsuitable material, the use of alternative piping methods (such as encasement) is acceptable. (See Section 2.3.4, Protection Against External Corrosion.) Base the selection of an appropriate alternative method on the conditions present.

2.2.2.5 Provide bell holes in the trench bottom to allow joint assembly and to ensure that the pipe barrel will lie flat on the trench bottom.

2.2.2.5.1 For asbestos cement pipe, excavate a coupling hole with sufficient length, width and depth to permit assembly; and provide a minimum clearance of 2 in. (51 mm) below the coupling.

2.2.2.6 Maintain a level trench bottom, so that the pipe is supported along its full length. Exceptions for bell holes and coupling holes are acceptable, where they are present.

2.2.3 Underground Main Pipe Installation: Trenching and Laying

2.2.3.1 When excavation is complete, place a bed of sand, crushed stone or earth that is free of stones or large clods of frozen earth, on the bottom of the trench to a minimum depth of 6 in. (152 mm). Level and tamp the bedding material.

2.2.3.2 Lower all pipe, fittings, valves and hydrants into the trench in such a manner as to prevent damage to materials, any protective coatings and/or linings.

2.2.3.3 Prevent foreign material and water from entering the pipe during installation. When pipe laying is not in progress, close the open ends of pipe by installing a watertight plug or by other means.

2.2.3.4 Prevent pipe flotation, which is possible if the trench fills with water, by backfilling as necessary.

2.2.3.5 Complete the specified laying conditions:

A. For ductile iron pipe, according to AWWA C150 and as illustrated in Section 3.0, Figure 3.3-1

B. For asbestos cement pipe, according to AWWA C603 and as illustrated in Section 3.0, Figure 3.3-2

C. For polyethylene, PVC, glass fiber-reinforced and other FM Approved pipe, according to the manufacturer’s installation guidance

2.2.3.6 Limit maximum deflection at joints to that given in the appropriate internationally recognized standard for the specific water main construction material. For example, AWWA C600 for ductile iron pipes.

2.2.3.7 Where water mains are to be laid below railway tracks, consult the applicable railroad authority for special conditions and procedures that may apply to any mains laid below their tracks.

2.2.3.7.1 Where ductile iron pipe is laid under a single railway track, install the pipe so that the center point of its full length is positioned midway between the rails. (See Figure 2.2.3.7-1.)

2.2.3.7.2 Where ductile-iron pipe is laid under multiple tracks, position the joints midway between the tracks. (See Figure 2.2.3.7-1.)

2.2.3.7.3 Where asbestos cement and glass fiber-reinforced pipe is to be laid under railroad tracks or highways, these pipe materials may need to be enclosed within a larger protective pipe, following the manufacturer’s recommendations.

2.2.4 Restraining: General

Unbalanced thrust forces occur in the water main where the piping stops or changes cross-sectional area or direction. These unbalanced forces must be overcome to prevent the joints from separating at bends, hydrants, reducers, tees, valves, wyes, dead-ends and offsets on pipe systems.

2.2.4.1 Conduct soil tests prior to installation of an underground main to determine the proper methods of restraint to be used with the underground pipe and associated appurtenances.

Selection of the method of restraint depends on the soil characteristics as well as other utilities (gas or electric) and structures (foundations) in the proposed excavation area.

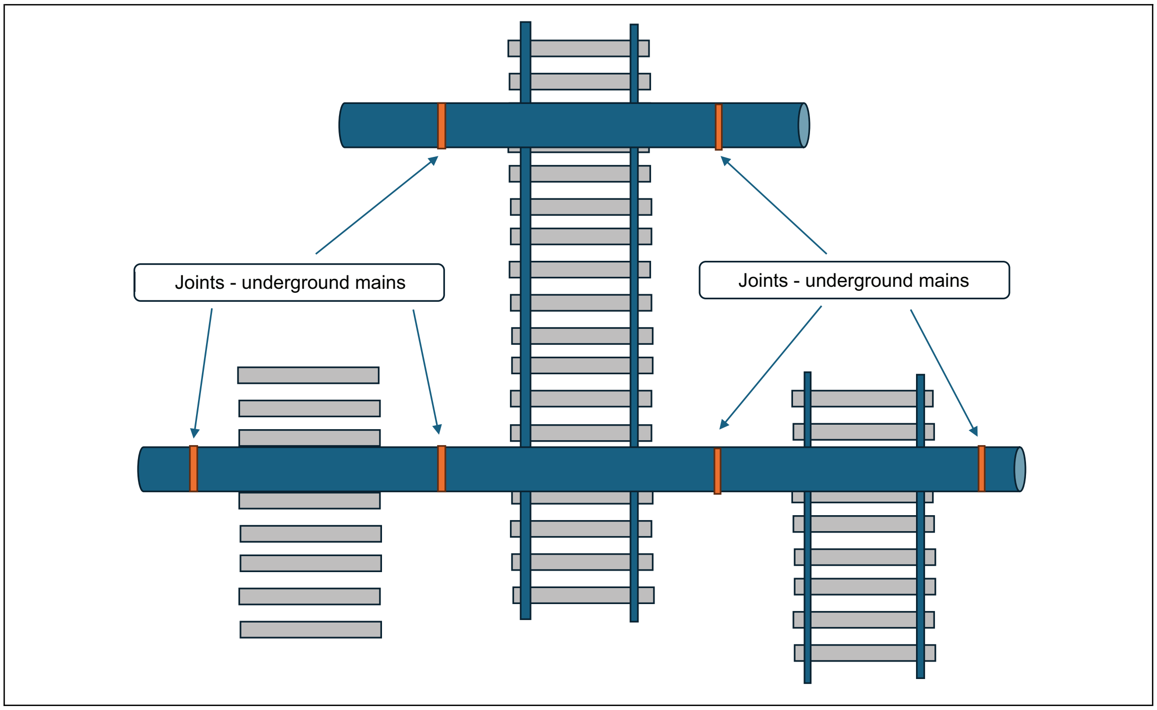

Fig. 2.2.3.7-1. Position of ductile iron pipe joins under railroad tracks

2.2.4.2 Determine the type of backfilling that will be used when installation is complete. The thickness of the pipe to be used depends on the type and degree of backfill compaction and the type of “laying condition”.

2.2.5 Restraining: Thrust Blocks

2.2.5.1 Use thrust blocks as the primary form of restraint for underground mains where the main changes diameter or direction.

2.2.5.2 Cast thrust blocks directly in the trench, ensuring that the bearing surface of the block is firmly against an area of undisturbed soil in the trench wall.

2.2.5.3 Where the bearing surface cannot be placed against undisturbed soil, the fill between the bearing surface and undisturbed soil is to be compacted to at least 90% Standard Proctor density.

2.2.5.4 Construct thrust blocks of a concrete mix comprised of one part cement, two and one-half parts sand, and five parts stone or washed gravel.

2.2.5.5 Install thrust blocks with the bearing surface area as shown in Table 2.2.5.5-1.

Table 2.2.5.5-1. Area of Bearing Surface of Concrete Thrust Blocks

Pipe Size in. (mm)	*90° Bend or 1⁄4 Bend ft² (m²)*	*45° Bend or 1⁄8 Bend ft² (m²)*	*Tees, Hydrants, Caps, Plugs ft² (m²)*
4 (100)	3 (0.3)	2 (0.2)	3 (0.3)
6 (150)	6 (0.6)	4 (0.4)	5 (0.5)
8 (200)	11 (1.0)	6 (0.6)	8 (0.7)
10 (250)	16 (1.5)	9 (0.8)	11 (1.0)
12 (300)	22 (2.0)	12 (1.1)	16 (1.5)
14 (350)	30 (2.8)	16 (1.5)	21 (2.0)
16 (400)	38 (3.5)	21 (2.0)	27 (2.5)

Areas in this table were derived using 225 psi (1551 kPa, 15.5 bar) water pressure and 2000 lb/ft² (96 kPa, 1 bar) soil resistance, which is typical of sand and gravel with clay. For other soils, multiply the table values by the following factors:
- Soft clay: 4
- Sand and gravel cemented with clay: 0.5
- Sand: 2
- Shale, hardpan: 0.4
- Sand and gravel: 1.3

Note: Wide variations of bearing load capacity may be encountered within each soil type.

2.2.5.6 Provide thrust blocking under any hydrant or valve where the stem joins the main to prevent movement from water flow forces.

2.2.5.7 Position any thrust blocks placed under hydrants to allow for unobstructed drainage from the hydrant barrel. Small stones placed alongside the thrust block can assist in allowing water from the hydrant barrel to drain without washing away bearing surfaces.

2.2.5.8 Where concrete thrust blocks cannot be installed (e.g., due to space limitations), the use of joints and fittings per the guidance in Section 2.2.6 is acceptable.

2.2.6 Restraining: Pipe and Joint Restraints

2.2.6.1 Where thrust blocks are not used, provide joint and fitting restraints per Table 2.2.6.1-1 at every pipe joint and fitting connection.

Table 2.2.6.1-1. Applicable Pipe and Joint Restraint

	Pipe Material					
	Cast and Ductile Iron[1]	Steel	Asbestos Cement	Plastic		
				Polyethylene and HDPE	Polyvinyl Chloride (PVC)	Fiber-Reinforced Composite
Joint / fitting restraint type	Cast iron: Approved push-on, standardized mechanical, ball and socket, poured lead bell and spigot Ductile iron: ball and socket, poured lead bell and spigot; tie rod and clamps	Welded, Threaded, Flagged, Approved, Grooved couplings	Approved push-on cast iron	Butt fusion or Approved adapters	Push-on, bell and spigot, cast iron or Approved materials	Approved using solvent cement, push-oncast iron

Note 1. Push-on and mechanical joints do not provide adequate restraint against longitudinal forces for ductile iron.

2.2.6.2 Install joints according to the individual manufacturer's specifications for the specific joint used.

2.2.6.3 When using mechanical joints, full consideration of frictional and lateral soil resistance should be engineered into the system design.

2.2.6.3.1 Where pipe and joint restraints are fitted per Section 2.2.6.1, such piping is considered fully restrained.

2.2.6.3.2 Where piping is fully restrained, thrust blocks are only required at hydrants and valve connections to resist the unbalanced thrust forces at those locations.

2.2.6.4 Where rod and clamps are used for anchorage, install them per Table 2.2.6.4-1. For pipes over 12 in. (300 mm) in diameter, the use of rods alone is not adequate. Additional methods will be required to provide adequate restraint.

Table 2.2.6.4-1. Rod and Clamp Anchorage

Pipe Size in. (mm)	*Clamp Size in. (mm)*	*Bolt Size in. (mm)*	*Washers in. (mm)*		*Number of Rods and Rod Size (in. [mm]) for Rod and Clamp Anchorage*					
					Mechanical Joint			*Push-on Joint*		
			Cast Iron	*Steel*	*90° ¼ bend*	*45° ⅛ bend*	*Tee, hydrant cap, plug*	*90° ¼ bend*	*45° ⅛ bend*	*Tee, hydrant cap, plug*
4 (100)	½×2 (13×50)	⅝ (16)	⅝×3 (16×80)	½×3 (13×80)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)
6 (150)					2 ¾ (20)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)	2 ¾ (20)
8 (200)	⅝×2-½ (16×65)				4 ¾ (20)	2 ¾ (20)	4 ¾ (20)	4 ¾ (20)	2 ¾ (20)	4 ¾ (20)
10 (250)		7/8 (22)			6 ¾ (20)	4 ¾ (20)	4 ¾ (20)	4 7/8 (22)	4 7/8 (20)	4 7/8 (22)
12 (300)	⅝×3 (16×80)	1 (25)	¾×3-½ (18×90)	½×3-½ (13×90)	8 ¾ (20)	6 ¾ (20)	6 ¾ (20)	4 1 (25)	4 1 (25)	4 1 (25)

Note 1. After installation, protect tie rods, bolts, nuts, washers and clamps against corrosion with a heavy coat of asphalt material.
Note 2. The length of the rod required will vary with the pipe fitting and must be determined by field measurement. If the distance between the joints is less than 12 ft (3.7 m), extend the anchorage to the second bell.
Note 3. Specify lugs if tie rods and clamps are to be used.
Note 4. Bolt holes 1/16 in. (1.6 mm) larger than bolts. Rod holes 1.8 in. (3.2 mm) larger than rods.
Note 5. Washers may be round or square.

2.2.6.5 Conduct a visual examination and verification of all mechanical joints and rod and clamp anchorages. Where issues are identified (e.g., bolt heads that shear and break off when a predetermined torque is achieved), they are to be corrected before backfilling.

2.2.7 Backfilling

2.2.7.1 Use only backfill that is free of cinders, ash, refuse, vegetable or organic material, boulders, rocks or stones, frozen soil, and other unsuitable material.

2.2.7.2 Use clean, well-compacted sand for backfill when using plastic pipe.

2.2.7.3 Minimize the thermal effects on plastic piping during backfilling operations. Prior to laying, calculate the actual length of pipe needed, accounting for thermal expansion during laying and the subsequent pipe contraction after backfilling. This will ensure the correct length of pipe is present.

The following are acceptable strategies for mitigating thermal effects:

A. “Snaking” the pipe in the trench. Snaking involves laying extra pipe to allow for the thermal contraction upon backfilling. It also enhances soil-to-pipe friction development, preventing pipe movement during backfilling and once the pipe is buried and placed in service.

B. Filling the pipe with water prior to backfilling.

C. Conduct backfilling early in the morning when pipe and soil temperatures are nearly the same.

The high coefficient of expansion of plastic pipes means even ambient air and/or ground temperatures cause them to expand at a greater degree compared to other pipe materials. When backfilling occurs, the expanded plastic piping then contracts rapidly, potentially causing leaks or cracks.

2.2.7.4 When backfilling plastic piping, follow the manufacturer's instructions for the backfilling operation. Where instructions are not clear or not provided, the following backfilling guidance is acceptable for plastic piping:

A. Deposit selected backfill material on both sides of the pipe for the full width of the trench.

B. Tamp the backfill in thin layers not exceeding 3 in. (76 mm) in depth until the crown of the pipe is covered by 12 in. (300 mm) of tamped earth.

C. Compact thoroughly to provide solid backing against the external surface of the pipe.

2.2.8 Setting Valves, Fittings, Indicator Posts and Hydrants

2.2.8.1 Join valves and pipe fittings to the pipe in the manner required for the type of pipe being used.

2.2.8.2 Set valves so that the attached indicator posts are vertical and inspect to ensure that they operate properly.

2.2.8.3 Set hydrants plumb after dirt or other foreign material has been cleaned out.

2.2.8.4 Locate the center line of the hydrant butts at least 18 in. (450 mm), but not more than 36 in. (1.2 m), above the ground (final grade) to allow ready access for attaching hoses.

2.2.8.5 Provide dry-barrel hydrants with drainage. In permeable soil, provide coarse gravel or crushed stone for at least 1 ft (0.3 m) around the base of the hydrant and at least 6 in. (152 mm) above the drain port. In clay or other impervious soil, dig a drainage pit a minimum of 2 ft (0.6 m) below the hydrant; and fill with compacted, crushed stone and coarse sand around the hydrant elbow and 6 in. (152 mm) above the drain port. Do not connect hydrant drainage systems to sewers.

2.2.9 Above-Ground Fire Service Mains

2.2.9.1 Avoid overhead runs (e.g., elevated at ceiling level) of above-ground fire service mains.

2.2.9.2 Construct above-ground water mains of materials capable of resisting the internal and external forces they will be subject to during use.

2.2.9.3 Use non-permeable gaskets (including joint gaskets) to resist organic contamination where it may be encountered.

2.2.9.4 Design and construct supports capable of holding the combined weight of the piping and the water within.

2.2.9.5 In areas where high vehicular traffic is present, protect above-ground water mains (including any overhead runs if present) from mechanical damage, by providing bollards or other barriers.

2.2.9.6 Verify an underground fire service main installed in a trench within a building per Section 2.2.1.9 is also protected against freezing (see Section 2.3.1.3), mechanical damage, has adequate drainage and is accessible for maintenance.

2.3 Protection

2.3.1 Protection Against Freezing: Underground Mains

2.3.1.1 For underground water mains, determine the required depth of cover over the water mains by considering the maximum depth of frost penetration. Local soil conditions and elevation will affect the depth of frost cover. Consult local officials for recommended frost depth levels. For areas where frost is a factor, bury fire service mains so the crown of the pipe is a minimum of 12 in. (300 mm) below the frost line for the locality.

2.3.1.2 Where an underground main section transitions to above-ground, for example to cross a bridge, raceway or near an embankment, protect the exposed section from freezing using the guidance in Section 2.3.2.

2.3.1.3 Where underground mains have transitioned to above-ground within a building (as per Section 2.2.1.9), protect the above-ground section from freezing by providing sufficient building heat or by following the guidance in Sections 2.3.2.4 through 2.3.2.12.

2.3.1.4 Provide protection for backflow preventers where they are installed in areas subject to freezing conditions.

2.3.1.5 Where dry-barrel hydrant drain ports are required, pump the hydrant barrel dry after each use and before the drain port plugs are installed. Mark such hydrants to indicate the need for pumping after usage.

2.3.2 Protection Against Freezing: Above-Ground Mains

2.3.2.1 Avoid the use of above-ground mains in areas where freeze is likely to occur.

2.3.2.2 If used in areas where freezing may occur, provide protection from freezing per the guidance listed below in Sections 2.3.2.4 through 2.3.2.12.

2.3.2.3 Base the need for protection from freezing of above-ground mains on regional data for the 100-year return period daily minimum temperature (100-year DMT) as shown in the FM Worldwide Freeze Map, available online at www.fm.com. Also consider the thresholds in the recommendations below. Use local data where known conditions are more severe than the regional data indicates (e.g., in mountainous areas). See also FM Data Sheet 9-18, *Prevention of Freeze-Ups*, for additional guidance.

2.3.2.4 Protect above-ground water mains and their connections from freeze, when located in areas where a freezing hazard exists. Protection can include insulating coverings, insulated and/or heated enclosures, steam tracing, steam jacketing, frost proof casings, flowing the water within the pipe or heat tracing.

The chosen protection should maintain a minimum water temperature within the main that is greater than 40oF (4oC). Multiple protection measures can be combined to achieve the required protection.

2.3.2.5 Where insulation is used at locations where the 100-year DMT is 20°F [-6.7°C] or less, provide insulation with R-values as follows:

- 100-year DMT zone is 20°F (-6.7°C) to -5°F (-20.6°C), inclusive: R ≥ 3.5 hr-ft^2-°F/Btu (0.62 m^2-°C/W)
- 100-year DMT zone is -10°F (-23.3°C) to -20°F (-28.9°C), inclusive: R ≥ 5.5 hr-ft^2-°F/Btu (0.97 m^2-°C/W)
- 100-year DMT zone is -25°F (-31.7°C) or colder: R ≥ 7 hr-ft^2-°F/Btu (1.23 m^2-°C/W)

2.3.2.6 When using insulation to protect piping inside unheated buildings where freezing may occur, provide insulation with a minimum R-value of 3.5 hr-ft^2-°F/Btu (0.62 m^2-°C/W).

2.3.2.6.1 For above-ground mains located inside unheated manned buildings the use of insulation only is acceptable. If unmanned, heat tracing should be installed in addition to the insulation.

2.3.2.7 Inspect insulation regularly to ensure any deterioration is identified and corrected promptly. Determine inspection frequencies based on site specific conditions, but not less than annually.

2.3.2.8 For all above-ground mains located in areas subject to freeze, provide low-water-temperature monitoring with alarms when temperatures fall below 40°F (4°C). Connect monitoring to a central supervisory service or a constantly attended and monitored location (such as a manned local control room). Design the system to also alarm if the heat tracing fails.

2.3.2.9 Provide backup power to heat tracing where it is used. Backup power systems can include, but are not limited to, generators and batteries. Refer to FM Data Sheet 5-23, *Design and Protection for Emergency Standby Power Systems*, for additional guidance.

2.3.2.10 Inspect insulation and heat tracing whenever temperatures are 32°F (0°C) or lower. Formalize and document these inspections in a Freeze Response Plan.

2.3.3 Protection Against Earthquake: Above-Ground Mains

2.3.3.1 Where located in areas subject to earthquake, provide adequately sized and configured bracing for above-ground mains per the guidance in FM Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*.

2.3.4 Protection Against External Corrosion

2.3.4.1 Avoid installing iron or steel pipe under coal piles, in cinder fill, or wherever acids, alkalis, pickling liquors, etc., can penetrate the soil.

2.3.4.2 When using polyethylene encasement as a method of protection against external corrosion, apply the following guidelines:

1. Install polyethylene encasement in accordance with ANSI/AWWA C105/A21.5.
2. Use polyethylene film of minimum 0.008 in. (0.20 mm) thickness.
3. Use polyethylene tubes or polyethylene sheets.
4. Install polyethylene encasement to prevent contact between the pipe and the surrounding backfill and bedding material. Complete air tightness and water tightness are not necessary.
5. Encase fittings, valves and other appurtenances to iron fire service mains.
6. Avoid prolonged exposure of the polyethylene film to sunlight. Such exposure will eventually deteriorate the polyethylene film.
7. Use the same backfill material as that specified for pipe without polyethylene wrapping. Use care to prevent damage to the polyethylene wrapping when placing backfill.

2.3.4.3 Do not use underground mains as the grounding electrodes for electrical distribution systems.

2.3.4.4 Stray electric currents can cause or accelerate electrolytic corrosion in water mains. When stray electric currents are suspected, determine their extent and origin using professional ground surveys.

2.3.4.5 Where stray currents cannot be eliminated or diverted and the main is not yet seriously corroded, protect the main by providing bonding at all the joints and low-resistance metallic direct-to-ground connections.

2.3.4.6 Where piping of dissimilar metals is joined together, insulate the joint to prevent the passage of electric current.

2.3.4.7 Where insulation is used to protect above-ground water mains, valves or appurtenances, ensure these areas are inspected at least annually for any potential corrosion under the insulation.

2.3.4.8 Apply protective coatings to exposed nuts, bolts, etc., prior to backfilling to protect against corrosion.

2.3.5 Protection Against UV Exposure

2.3.5.1 Where above-ground water mains are constructed of PVC or plastic piping and UV degradation is expected, provide protection from UV exposure. UV-resistant paints or other opaque materials are acceptable, provided their application does not degrade or weaken the construction of the PVC pipe.

2.3.6 Protection Against Impact Damage Inside Buildings

2.3.6.1 Protect from mechanical (impact) damage connections from the underground main (e.g., connections from the main to the riser) that transition from underground to above-ground within buildings. A concrete collar or steel pipe at the transition point from underground to above-ground are acceptable.

2.4 Equipment and Processes

2.4.1 Manually Operated Valves on Fire Service Mains

2.4.1.1 Install valves that open in a counterclockwise direction.

2.4.1.2 Where all valves open clockwise or a mixture of opening directions are present, clearly identify the direction of opening at both the valve itself, and on any sketches or piping and instrument diagrams (P&IDs) where the valves are depicted.

2.4.1.3 Where an indicator post cannot be used, such as in a road, use an indicating valve (such as an indicating butterfly valve or an outside screw and yoke gate valve) installed in a watertight, frost-proof, concrete or masonry pit (see FM Data Sheet 3-2, *Water Tanks for Fire Protection*).

2.4.2 Single Check Valves on Water Mains

2.4.2.1 If a single check valve is required to prevent water from the private fire protection main system from being lost through the tanks and pump supply, install the valve at the discharge from fire pumps and at gravity tank and pressure tank connections.

2.4.2.2 When check valves are installed in a vertical pipe, flow must be in the upward direction.

2.4.2.3 Install check valves on water mains so that they are accessible for inspection, testing and maintenance purposes.

2.4.2.4 Provide ample clearance for valves with side mounted covers to permit clapper removal. Check valves without covers (e.g., wafer check valves) must be removed from the system for clapper replacement or repair.

2.4.2.5 When located underground, install check valves in watertight, frost-proof concrete or masonry pits.

2.4.2.6 Where the main passes through the wall of the underground pit, provide clearance around the main where it passes through the pit wall; and pack the annulus with a sealant.

2.4.2.7 Provide manually operated valves on both sides of the check valve to allow isolation for maintenance or repair.

At the connection to the public main, the curb box valve can serve as the upstream valve for the purpose of isolation during maintenance/repair operations. Indicating type valves are preferred when installed to isolate the check valve for maintenance/repair. Other valve types may be suitable depending on the situation and application.

2.4.3 Anti-Water Hammer Check Valves and Surge Arresters

2.4.3.1 Install single swing check valves at the discharge of the fire pump.

2.4.3.2 Where the single swing check valve may cause severe water hammer, use a special anti-water hammer check valve instead.

2.4.3.3 Where a special anti-water hammer check valve is used in any design of a private fire service system, the friction loss through the anti-water hammer check valve should be accounted for to ensure system adequacy prior to the installation of the valve. Changes to the system design will be needed if the system is shown to be inadequate.

For FM Approved anti-water hammer valves, consult the *Approval Guide* for the individual valve friction loss.

2.4.3.4 When direct bolting anti-water hammer check valves to the body of butterfly valves, ensure adequate clearance exists between the butterfly check vane and the check valve clapper. Where clearance is inadequate, selection of a different anti-water hammer check valve may be required.

2.4.3.5 Use a surge arrester or damper if an anti-water hammer check valve alone proves inadequate to control the problem.

2.4.3.6 Install surge arresters on the system side of the fire pump discharge check valve. The surge arrestor should be installed as close to the check valve as possible.

2.4.4 Cross Connections and Backflow Preventers

2.4.4.1 Avoid cross connections between potable and non-potable water supplies.

2.4.4.2 Where back flow preventers are required, calculate the frictional loss effect on fire protection system water pressures due to the preventer. Complete this calculation prior to installation of the preventer. Where fire protection is found to be inadequate, changes to the system design will be needed to ensure adequate protection exists.

2.4.4.3 Where backflow preventers are required, flush all mains to remove foreign material prior to installing the backflow preventer.

State or local authorities may require backflow preventers when connecting to the public supply.

2.4.4.4 Provide backflow preventers with indicating-type control valves (i.e., OS&Y valves or gate valves with indicator posts).

2.4.4.5 Install backflow preventers with ample space to ensure accessibility for inspection, testing and maintenance.

2.4.5 Fire Service Connections

2.4.5.1 Install a single check valve at each fire service connection, located as near as possible to the point where it joins the system.

2.4.5.2 Do not provide a shutoff valve in the piping between the fire service connection and the fire service mains.

2.4.5.3 Provide an automatic drip valve (ball drip) at a low point in the pipe between the check valve and the outside hose coupling of the fire service connection. Arrange the automatic drip system so that it discharges to a proper frost-free location.

2.4.5.4 For guidance on the installation of fire service connections on sprinkler systems, refer to FM Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2.4.6 Hydrants

2.4.6.1 Provide hydrant protection for yard storage per the guidance in Data Sheet 1-20, *Protection Against Exterior Exposure*.

2.4.6.2 Where hose connections at standpipes are used to reduce the total number of hydrants, include the water demand requirements for these connections when determining the total water supply demand.

2.4.6.3 Provide hydrants spaced approximately 300 ft (90 m) apart.

2.4.6.4 Where needed, provide roof hydrants for the protection of conveyors passing over buildings, for fires in duct work and for applying hose streams through roof monitors and skylights.

2.4.6.5 Where a wall hydrant is supplied from oversized (4 in. [100 mm] minimum) sprinkler system piping, this substitute is acceptable as a yard hydrant.

2.4.7 Connections from Water Supplies

2.4.7.1 Size connections to a water supply or hydrant to ensure sufficient water supply for all fire protection needs. Take into account future water supply needs and hose stream allowances when determining the size of the main required.

2.5 Operation and Maintenance

2.5.1 Hydrostatic Leakage Testing

2.5.1.1 Hydrostatically test all new mains and mains that have been relined at not less than 200 psi (1380 kPa, 13.8 bar) pressure for two hours, or at 50 psi (345 kPa, 3.4 bar) over the maximum static pressure when the maximum static pressure is above 150 psi (1034 kPa, 10.3 bar). This testing will determine the tightness of joints and ensure that no linings or fittings are defective. If a booster pump is present, consider the pump shut-off (churn) pressure when determining the maximum static pressure. See Appendix F for additional information.

2.5.1.2 Ensure the pipe being hydrostatically tested is restrained appropriately during the testing to prevent deformation, bending or movement. For underground mains, also check the soil around the pipe used for restraint purposes.

2.5.1.3 Ensure the pipe or pipe segment being tested is exposed during hydrostatic testing to confirm any leaks in the pipes or joints, or any deformation or bending that results from testing can be seen.

2.5.1.4 Measure the amount of leakage at the joints. The maximum allowable leakage rates for various diameters of water mains when conducting hydrostatic testing are provided in Table 2.5.1.4-1.

Leakage rate calculations for diameters not shown can be determined using the equations in Appendix F of this data sheet.

Table 2.5.1.4-1. Maximum Rate of Leakage – Hydrostatic Testing
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Nominal Pipe diameter		*Max. allowable leakage rate*	
in.	mm	gal/hr/100 ft	L/hr/100 m
2	50	0.019	0.236
4	100	0.03	0.472
6	150	0.057	0.708
8	200	0.076	0.944
10	250	0.096	1.19
12	300	0.115	1.43
14	350	0.134	1.66
16	400	0.153	1.9
18	450	0.172	2.14
20	500	0.191	2.37
24	600	0.229	2.84

Note 1. For other lengths, diameters and pressures, use the equations in Appendix F to determine the appropriate testing allowance.
Note 2. For sections that contain various sizes of pipe, the testing allowance is the sum of the testing allowances for each size and section.

2.5.1.5 Upon completion of the hydrostatic testing and prior to backfilling, conduct an inspection of the main, joints and associated components

2.5.1.6 Complete a signed "Contractor's Material and Test Certificate" as shown in FM Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*. One copy is to be kept by management, one by the contractor and one sent to the FM office serving the area in which the installation is located.

2.5.1.7 Upon completion of the hydrostatic test, open all control and hydrant valves. All hydrant valves should then to be closed at the normal operating rate.

2.5.2 Leak Detection in Underground Water Mains

Corrosion, freeze damage, impact damage or other types of damage can create or lead to a main break. Often, the first sign of a potential issue is a detectable leak in the main. Promptly locating and repairing these leaks can prevent a main break from occurring.

The following are common indicators of a potential leak within a water main:

A. Noticeable persistent pools or wet spots

B. Areas where grass/vegetation grows higher than surrounding vegetation

C. Leaks present at pipe joins (above-ground pipes)

D. Cracked areas or bulges in pavement

E. Formation of sinkholes or depressions

F. Increase in water usage or water costs

G. Persistent, unpleasant smells

H. Low water supply pressure/decrease in flow

I. Dirty or discolored water

J. Sounds (splashing, hissing, clinking)

K. Constant running of the jockey pump

2.5.2.1 Where signs of leakage are present, isolate and test individual sections of the water main to identify the location and magnitude of the leak. Use one or more of the following methods:

A. Acoustic detection

B. Endoscopic examination – via cameras

C. Hydrostatic testing

2.5.2.2 Repair the leak with a leakage rate greater than that given in Table 2.5.1.5-1.

2.5.2.3 Where pressure drop is used instead of leakage rate, the following equation can be used to estimate the leakage rate:

$Q = (V * PD) / (t * C_d)$

Where:

Q = Leakage rate
V = Volume of the pipe section being tested
PD = Pressure drop over the measured time period
t = Time elapsed (the time over which the pressure drop occurs)
C_d = Coefficient of discharge

Coefficients of discharge (C_d) can range from 0.45 to 0.95 depending on the shape of the hole associated with the leak. An average value of 0.65 will suffice for most applications.

2.5.3 Flushing Water Mains

2.5.3.1 Prior to making connection to the sprinkler system(s) or other equipment such as tanks and fire pumps, completely flush all piping until the water runs clear. Depending on the layout of the system, include all piping from the water supply to the system riser, lead-in connections to the system and any hydrants.

Flushing can be accomplished through hydrants at dead ends of the system or through accessible above-ground flushing outlets (see Section 3.6.3). If water is supplied from more than one source, close divisional valves as needed to produce a high-velocity flow through all parts of the main to facilitate flushing. Acceptable minimum flushing rates are as follows:

A. The hydraulically calculated water demand rate of the system, including any hose requirements

B. The flow necessary to produce a velocity of 10 ft per second (3 m/sec) as indicated in Table 2.5.3.1-1

C. The maximum flow rate available to the system under fire conditions

Table 2.5.3.1-1. Flow Required to Produce a Waterflow Velocity of 10 ft/sec (3 m/sec) Through Water Mains

Pipe Diameter, in. (mm)	*Flow Rate, gpm*	*Flow Rate, L/min*
6 (150)	880	3330
8 (200)	1560	5905
10 (250)	2440	9235
12 (300)	3520	13325
14 (350)	4790	18133

2.5.3.2 When the water supply cannot produce the high velocity flow for flushing in a pipe-schedule system, use the maximum flow rate available.

2.5.3.3 Conduct regular flushing of underground mains in accordance with FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance* to remove obstructions.

2.5.3.4 For new mains or where a main has been replaced, a full flush of the main or of the replaced segment should be completed per Section 2.5.3.1.

2.5.4 Pipe Tapping

2.5.4.1 Ensure the disk is removed after the cutting operation is complete. Typically, operation of the tapping machine cutter will remove the disk cut from the mains. If the disk is not removed by the machine, shutdown the tapping process until the disk can be recovered by hand.

2.5.4.2 Confirm the scope of work to be conducted as part of any pipe relining/rehabilitation operation before commencing any work. Include, at a minimum, the following:

A. Soil conditions. Polyethylene pipe or pipes externally coated with polyethylene can degrade under certain soil conditions. See additional guidance in Section 2.2.1.2.

B. The suitability of the pipe rehabilitation system for correcting the type and size of the defect in the existing pipe.

C. The suitability of the material used in the pipe rehabilitation for use in the existing pipe.

D. The method of cleaning to be used. Certain cleaning methods can negatively impact existing pipe joints. See Section 3.6 for further information. Cleaning underground piping is essential before relining.

2.5.4.3 Analyze the impact of changes made as part of pipe relining to ensure the relined pipe is still adequate. This analysis can be completed via a flow test. Certain pipe properties (internal diameter, C-factor, etc.) will change during the relining process.

2.5.4.4 Conduct hydrostatic testing on relined mains in accordance with Section 2.5.1.

2.5.5 Inspection, Testing and Maintenance of System Components

2.5.5.1 Supervise and maintain system components in accordance with FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance* and the guidance in this data sheet.

2.5.6 Inspection, Testing and Maintenance of Backflow Preventers

2.5.6.1 Maintain inspection, testing and repair records for each backflow prevention device.

2.5.6.2 Where multiple fire-service connections from public mains exist, overhaul and clean the valves and backflow preventer assemblies one at a time, leaving the others in service.

2.5.6.3 When only one connection from a public main exists and the secondary supply is from a fire pump, operate the pump to maintain pressure at the sprinklers while the public water connection is shut off.

2.5.6.4 If the secondary supply is from a tank, confirm the tank is full and all tank control valves are open prior to and upon completion of testing.

2.5.6.5 When opening check valves on a backflow preventer during testing, open one check valve at a time. Doing so will ensure protection can be restored quickly in the event of a fire during maintenance operations.

2.5.7 Inspection, Testing and Maintenance of Single Check and Manual Valves

2.5.7.1 Inspect, test and maintain single check and manual valves per the guidance in this data sheet and FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

2.5.7.2 If several check-valve fire service connections from public mains exist, overhaul and clean one check valve at a time, leaving the others in service.

2.5.7.3. When only one fire service connection from the public main exists, observe the following precautions:

A. If the secondary supply is from a fire pump or a tank, ensure the secondary source will maintain pressure on the sprinklers while the public water connection is shut off.

B. If other supplies cannot be maintained in service or if no other supply exists, overhaul the check valve while the plant is not in operation.

2.5.7.4 Remove any roughness or corrosion on the clapper face or seat ring that would prevent the clapper from seating tightly. Do not use a file or coarse scraper on the clapper face or seat ring. Scrape any incrustation formed by hard water from interior bronze parts.

2.5.7.5 Clean and lubricate valves (including stems and threads as needed) and indicator post mechanisms to ensure continued, suitable operation. Lubrication frequencies will depend on the conditions in which the valve or mechanism is situated/operates and the manufacturer's guidance for the specific piece of equipment. Shorter periods between cleaning and lubrication may be required, depending on conditions in which the valve or indicator post mechanism is situated.

2.5.7.6 Make sure the side plugs that hold the hinge pin in place are tightly screwed without binding the clapper arm. Ensure the clapper is free to open wide and seat positively.

2.5.7.7 Repack valves when excessive tightening of stuffing box glands is required. Excessive tightening of these glands can score the valve stem and make the valves difficult to operate.

2.5.8 Inspection and Testing of Double Check Valves and Reduced-Pressure Backflow Preventers

2.5.8.1 Maintain reduced pressure backflow preventers per the manufacturer's instructions. See also guidance in FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

2.5.8.2 Conduct full internal inspections and cleaning of reduced pressure and double check valve assemblies at least once every five (5) years. More frequent internal inspections may be necessary at locations with highly mineralized or corrosive water or where required by health or water authorities. Consult manufacturer's instructions for details on maintenance and cleaning procedures.

2.5.9 Maintenance of Hydrants - General

2.5.9.1 Inspect hydrants at the frequency stated in FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*. Where hydrants are located in freezing climates, more frequent inspections may be necessary.

2.5.9.2 Inspect and maintain the outlets and caps as follows:

A. Outlets should be tight.

B. Outlets are accessible to allow the attachment of hoses when needed.

C. Outlet threads and caps should be lubricated to allow easy removal when needed. The method of lubrication will depend on the hydrant type.

D. The frequency of lubrication will depend on conditions where the valve is located and should be set by the site personnel and/or the manufacturer's guidelines as applicable.

2.5.9.3. Inspect the hydrant barrels to ensure no cracks are present.

2.5.10 Maintenance of Dry Barrel Hydrants

2.5.10.1 Where water or ice is present within the barrel stem, drain the hydrant and eliminate the cause.

2.5.10.2 For hydrants that drain improperly, clear the drain hole by opening the hydrant one or two turns with the hose outlets closed. Where is this approach is not successful, the hydrant should be dug up or disassembled and the drain hole cleared with a rod.

2.5.10.3 Where a hydrant leaks at the valve, attempt to remove any obstruction by opening the valve wide and flowing water from the hydrant outlet. If this approach is not successful, disassemble the hydrant and remove the obstruction.

2.5.10.4 When hydrants leak at the packing, replace the packing or tighten the packing gland.

2.5.10.5 Where repair or replacement of a valve facing or seat ring is required, dig up or disassemble the hydrant. For certain compression type hydrants, use the special socket-key wrench supplied by the manufacturer to remove the retainer ring or the seat ring before the hydrant's valve mechanism can be removed.

2.5.11 Maintenance of Wet-Barrel Hydrants

2.5.11.1 When a wet-barrel hydrants is leaking at the valve, an obstruction or a defective valve facing is the likely cause. Attempt to remove any obstruction first by opening the valve and flowing water from the outlet. If not successful, disassemble the hydrant and remove the obstruction. Replace the valve seat if found to be defective.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Fire Service Mains: Types of Material

FM Approved fittings, pipes and joints should be selected when installing or repairing a fire service main. Materials and fittings selected should be appropriate for installation conditions and the working pressures expected. They should fall within the same range of working pressures and installation conditions as those present for the pipe on which they are to be installed.

Acceptance of pipe, joints and fittings that are not FM Approved is based on satisfactory experience and conformity to specifications of recognized engineering bodies.

Certain pipes may be lined to offset the corrosive action of water. Linings can include, but are not limited to cement-mortar, coal-tar or polymers.

Steel pipe is particularly suitable for use where it may be exposed to earthquake shock, or to the impact from vehicle loads on railroad tracks, highways and similar locations. Its greater strength is also advantageous in unstable soil or on steep slopes.

Asbestos-cement pipe is suitable for locations where ferrous pipes, without special protective linings or coverings, would be obstructed or weakened by actively corrosive waters, soil conditions or electrolysis. Where asbestos-cement pipe is to be buried in highly acid or alkaline soils, the pipe manufacturer should be consulted as to its suitability.

Plastic pipes of various materials are available, including polyethylene, polyvinyl chloride and glass, fiber-reinforced plastic. All are lightweight and corrosion resistant, but some plastic pipes are subject to chemical attack under certain conditions. For example, PVC can be degraded by aromatic hydrocarbons. In these cases, selection of the appropriate plastic piping may require consultation with the manufacturer.

3.2 Fire Service Mains: Arrangement and Location

As plant layouts vary widely, establishing firm rules for the arrangement and location of fire service mains and their components (such as divisional valves) can be difficult. Protection requirements are often balanced with economic considerations, as underground mains are costly to install. The following considerations can assist in these situations:

1. As far as practical, the arrangement of mains and divisional valves should be so to minimize or eliminate the impact of impairments on the fire protection system.

2. Where multiple water sources are present, arrange the underground mains so an impairment is unlikely to impair all sources.

3. Where multiple water sources are provided, they need not all remain in service in the event of an impairment. Only those (or that one) necessary to meet the total water demand need be available.

4. Where loops are provided so that multiple paths are available for water flow to a single point, the mains forming the legs of the loop need only be sized to carry that portion of the flow occurring under no-impairment conditions. Where the hazard is such that a deluge system is provided, sizing the legs of the loop to carry the total water flow may be advisable.

5. Manifolded riser arrangements, though generally undesirable (see FM Data Sheet 2-8), decrease the need for looped mains.

6. Where looped mains are present, divisional valves allow sections of the loop to be isolated for purposes such as maintenance. The maximum number of risers to be impaired simultaneously depends on the values exposed to loss by the impairment, the possibility of temporary water supply connections to the impaired risers from in-service hydrants or other sources, the expected frequency of fires (this may be deduced from the occupancy), and the ease with which the area may be patrolled.

   A general guideline is to limit the number of risers served by one divisional valve to approximately six. Base the identification of needed valves on the combination of the above guideline and good judgment. For example: If 13 risers are served by two divisional valves, an additional valve may not be needed after careful review and consideration.

7. Large, multi-riser, multi-source, multi-building plants usually benefit from looped main arrangements. In such plants, extensive main installations are usually necessary; so completing loops does not add significantly to the cost.

8. Looped main arrangements can be economically advantageous, especially for large buildings. The cost of several long runs of feed main indoors may exceed the cost of providing a looped main to directly feed the risers on the far side of the building.

9. The cost of excavation in the installation of underground mains is a major factor. Rock formations that require blasting increase cost; while clay soils, which do not require shoring, may be more economically excavated.

10. An underground main is rarely necessary solely to supply hydrants. Wall hydrants can be fed from indoor sprinkler system piping, providing an acceptable hose stream supply in cases where no underground main exists in the vicinity of the needed hydrants.

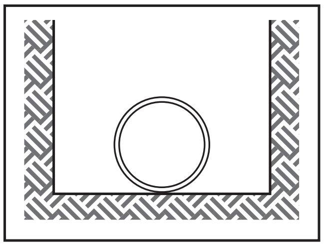
    An exception to this situation is in single-building plants where wall hydrants are used to supply water for fighting fires indoors. In this case, wall hydrants cannot be relied upon to be in service for use with hose streams on a fire inside the building. The risk that the sprinkler system (and, therefore, the water supply to the wall hydrant) will be shut off at a critical moment is too great. Thus, hydrants fed from underground mains may be necessary to avoid this condition.

    A second exception is where hydrant protection is necessary for yard storage remote from buildings. In this case, an underground main system used solely to supply the yard hydrants may be necessary.

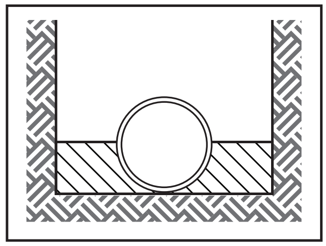
3.3 Trenching and Laying (Installation)of Underground Mains

The installation of underground mains piping should be in accordance with the relevant ANSI/AWWA standard for the piping material used (i.e., ANSI/AWWA C600 for ductile iron piping and ANSI/AWWA 603 for asbestos cement pipe). These AWWA standards were written for water utility piping, but the same principles and procedures apply to fire service mains. Figures 3.3-1 and 3.3-2 show the pipe laying conditions for ductile-iron and asbestos-cement pipe, respectively.

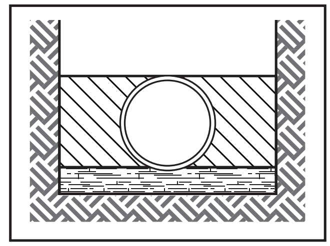
Bell holes are provided in the trench bottom to allow joint assembly, and to ensure that the pipe barrel will lie flat on the trench bottom. Except for bell holes and coupling holes, a level trench bottom is maintained; so that the pipe is supported along its full length.



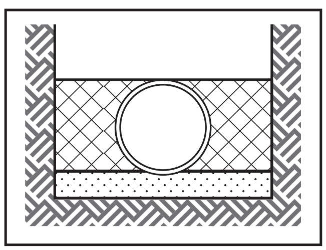
Type 1*
Flat-bottom trench.† Loose backfill.



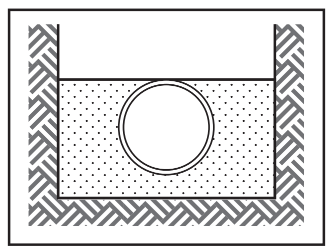
Type 2
Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.



Type 3
Pipe bedded in 4 in. (100 mm) minimum of loose soil.‡
Backfill lightly consolidated to top of pipe.



Type 4
Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter, 4 in. (100 mm) minimum.
Backfill compacted to top of pipe.

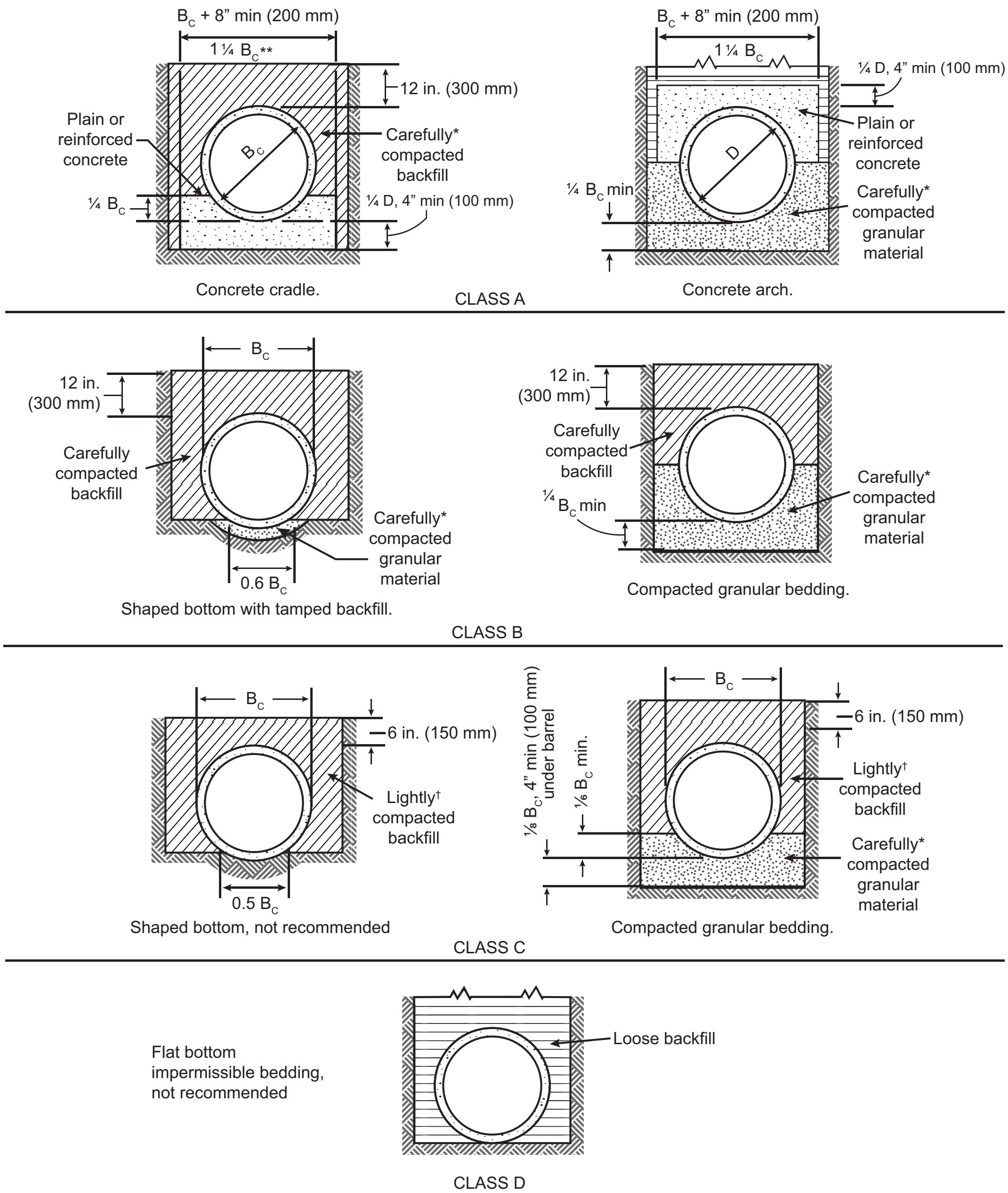


Type 5
Pipe bedded in compacted granular material to centerline of pipe. Compacted granular or select ‡ material to top of pipe.

NOTE:

*For 14 in. and larger pipe, consideration should be given to the use of laying conditions other than type 1.
† "Flat-bottom" is defined as undisturbed earth.
‡ "Loose soil" or "select material" is defined as native soil excavated from the trench, free of rocks, foreign materials, and frozen earth.

Fig. 3.3-1. Laying conditions for ductile-iron pipe



NOTE: In rock trench, excavate at least 6 in. (150 mm) below the coupling of the pipe except where concrete cradle is used.
*Carefully compacted backfill or granular material
† Lightly compacted backfill
** B_C = Outside Diameter of Pipe

Fig. 3.3-2. Laying conditions for asbestos-cement pipe

3.4 Restraining

Unbalanced thrust forces occur in the water main where the piping stops or changes cross-sectional area or direction. At bends, hydrants, reducers, tees, valves, wyes, dead-ends and offsets on pipe systems, these unbalanced forces must be overcome to prevent the joints from separating. For example, a resultant force of 43,500 lbs (193,500 N) can act on a 90° bend on a 12 in. (305 mm) pipe at a water pressure of 225 psi (1550 kPa). In addition to the guidance in Section 2.2.5, technical information on thrust restraint can be found in AWWA Manual M11, Steel Pipe—A Guide for Design and Installation and AWWA Manual M23, *PVC Pipe-Design and Installation*. Figure 3.4-1 shows examples of joint restraint.

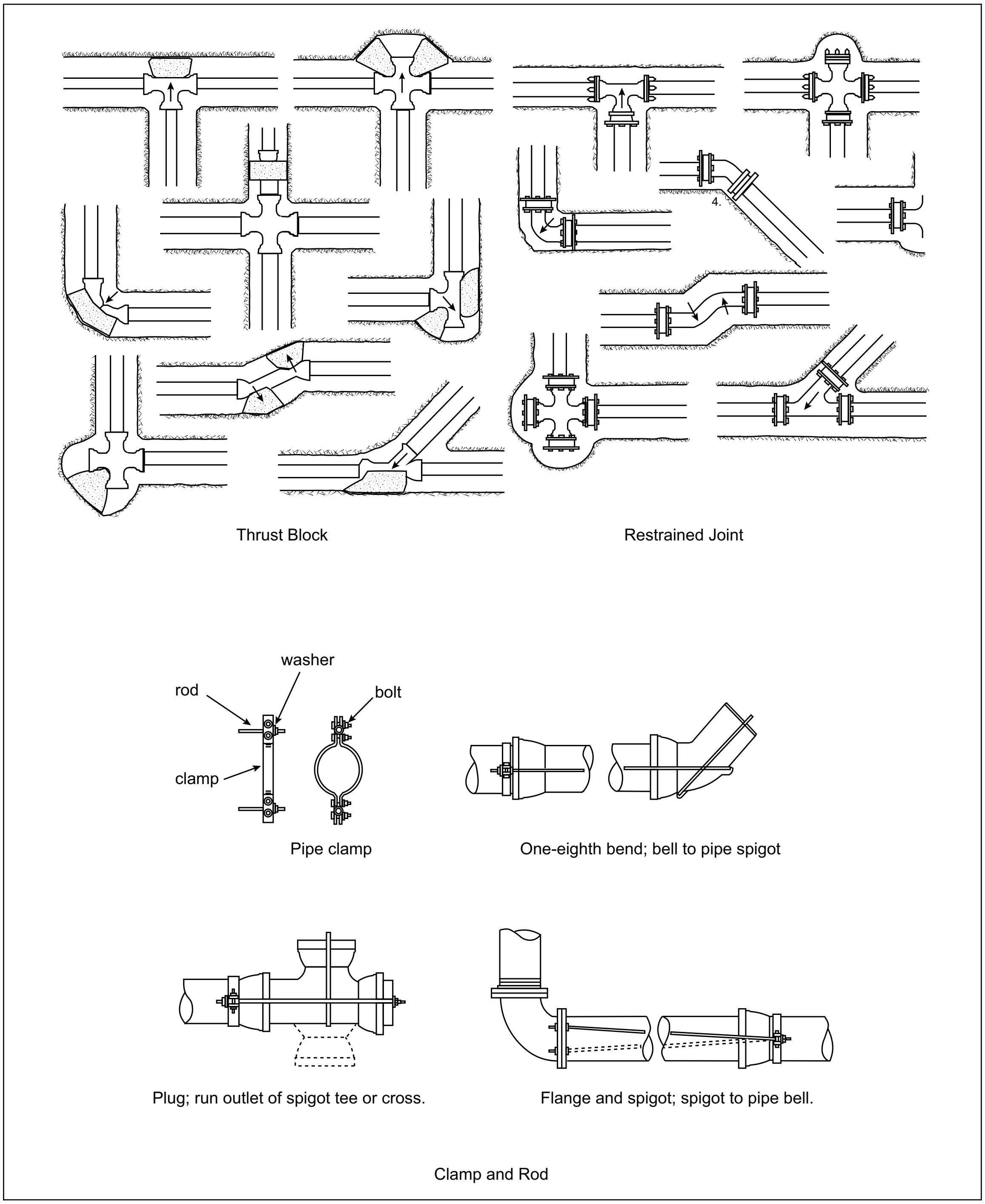


Fig. 3.4-1. Various methods of joint restraint

3.5 Protection Against Freezing

Local officials should be consulted for recommended frost depth levels. Generalized maps of a location may not be specific enough to provide the necessary details to supply adequate freeze protection. The additional depth of cover as stated in Section 2.3.1 is necessary due to the lack of water circulation in fire service mains.

3.6 Protection Against External Corrosion

External corrosion occurs when metallic salts, acids or other substances in the soil combine with moisture, resulting in an electrochemical reaction. Common situations where this occurs include iron or steel pipe installed under coal piles, in cinder fill, or wherever acids, alkalis, pickling liquors, etc., can penetrate the soil.

Protection from external corrosion can be achieved with polyethylene encasement or using an alternative pipe material for the specific conditions.

For example, asbestos-cement pipe is particularly suitable for locations where ferrous pipe would be subjected to attack by actively corrosive water, soil conditions or electrolysis.

Cathodic protection is one option to shield against corrosive soils. It imposes direct electric current from a galvanic anode to the buried main. It is rarely used in fire protection installations due to the costs involved.

3.7 Cleaning of Fire Service Mains

The carrying capacity of unlined, cast iron, ductile iron and steel water mains decreases with age as tubercles or rusting affect the inside of the pipe. The effective diameter also may be reduced by chemical deposits, silt or organic growths. Cleaning is normally performed when a significant decrease in hydraulic performance (degradation of the C-factor or capacity) is seen that affects the performance of downstream protection systems. Cost of cleaning a buried water main is usually significantly less than replacement with new pipe of the same size.

Impairment of sprinklers or other protective equipment during these operations should be handled according to recommended procedures. Piping connected to a public water system must usually be disinfected after the work is completed and before service is restored. Finally, the results of the cleaning should be verified by waterflow testing.

3.7.1 Flushing

Flushing of water mains removes any debris from the pipes that may prevent the flow of water from reaching the fire protection systems. Water is passed through the pipes at a given velocity, to dislodge any material in the flow path. The dislodged debris is then collected and removed. Figures 3.7.1-1 to 3.7.1-3 shows a typical flushing connection arrangement on a sprinkler riser manifold.

Fig. 3.7.1-1. Interior view of flushing connection on sprinkler riser manifold. The pipe discharges out through the wall on the right.

Fig. 3.7.1-2. Flushing hose connections for a flushing chamber

Fig. 3.7.1-3. Flushing chamber

Hydrants located at the dead ends of the system are also often used to flow the water and collect the debris from the flushing.

3.8 Lining and Relining of Fire Service Mains

Pipe lining may be installed on pipes or other materials during their original installation as a protective measure. However, lining of pipes is generally used as a method to rehabilitate existing pipes and underground mains that have small breaks or leaks, provided the host pipe is repairable. If the host pipe has completely burst or is compromised, then pipe lining may not be an option for repair. The affected pipe may need to be fully replaced. The most common methods of pipe rehabilitation are:

- Centrifugally cast concrete pipe (CCCP)
- Cured-in-place pipe (CIPP)
- High-density polyethylene sliplining (HDPE)

For all methods, prior to starting any pipe rehabilitation or relining, the existing pipe is measured using a small camera to map the interior of the piping and the locations of any branch or tap lines.

The piping is then cleaned to remove any deposits or material before the relining operation commences.

Centrifugally cast concrete pipe (CCCP) is a type of spin-in-place pipe lining that uses a spinning head to apply thin coats of a cementitious material (e.g., Portland cement or Permacast mortar) to the inside of the pipe. These thin coasts may also contain other material such as fiber reinforcement and rust inhibitors to increase erosion resistance and prevent corrosion. The number of applied coats governs the thickness of the lining as determined during the initial examination phase. This type of lining is typically seen in large concrete pipes and culverts.

Cure-In-Place Pipe (CIPP) uses an epoxy resin to line existing pipe and is the most common type of pipe rehabilitation seen today. After inspection, cleaning and measurement of the existing pipe, a special liner is prepared and soaked with epoxy resin. The resin-impregnated liner is then inserted or pulled into the existing pipe in an inverted condition, positioning the resin between the liner and the existing internal pipe wall. A special bladder is then inserted into the liner and inflated, using air or water, pressing the epoxy resin against the internal surface of the existing pipe. The resin is then dried and cured using UV light. Heat or steam branch lines and taps can also be coated using this method. The lining is thin and smooth; therefore, the flow in the newly relined pipe is not noticeably reduced. This method can be applied to pipes with a wide range of diameters.

High-density polyethylene sliplining does not involve adding a new liner but instead, involves pulling a new polyethylene pipe inside the old existing pipe. Sections of pipe are grouted together prior to being pulled into the existing piping. One disadvantage of this method is that the flow capacity of the pipe is noticeably reduced due to the addition of the HDPE pipe.

Because any relining operation will impact the internal properties of the pipe, a calculation of these impacts should be conducted. An example of this is seen when a pipe is relined using the CIPP epoxy resin. The resin lining does reduce the internal diameter of the pipe, thereby reducing the flow slightly. However, the new epoxy lining is smoother, thereby increasing the C-factor. This change in C-factor reduces frictional losses, with the overall effect being no real reduction in flows through the relined pipe.

Cure-in-place pipe (CIPP) and high-density polyethylene (HDPE) sliplining pipe rehabilitation systems are covered under FM Approval Standard 1616, *Underground Pipe Rehabilitation Systems*.

Re-lining of the host pipe with an Approved product per FM Approval Standard 1616 will reduce the internal diameter of the host pipe and improve the C-factor. For a 6 in. (150 mm) diameter pipe, a 0.35 in. (9 mm) reduction in internal diameter will be seen after relining; and for a 24 in. (610 mm) diameter main, a 0.94 in. (24 mm) reduction in internal diameter will be seen. After re-lining, the C-factor will be in the range of 140-150. Together, these effects have a minimal impact on downstream water demands.

3.9 Failure (Breakage) of Underground Fire Service Mains

Underground water mains may fail because of corrosion, external loading or water pressure surges (water hammer). Joints may separate as a result of inadequate anchorage at bends and tees. Manufacturing defects are rarely responsible. Defective pipes are usually identified by inspection prior to installation.

Excessive stresses in piping are caused by uneven movement or settlement in unstable soil, or by external loading from above. Such loading can be due to building walls and foundations, heavy floor loads, and vehicle or rail traffic. Where underground mains run beneath floors of buildings, floor settlement is a major factor. Repair of main breaks below the floor can be a lengthy and costly procedure. In addition, the break can cause much damage, both to the structure (by washouts) and to the building contents.

Hydrostatic tests are frequently used to determine the condition of underground piping. Such tests merely indicate whether the system of water mains and pipes present will withstand that pressure and do not necessarily indicate the system’s true condition.

3.9.1 Hydrostatic Failure

”Hydro breaks” (hydrostatic failures) occur when a complete section of pipe wall is blown off by internal pressure. Hydro breaks are of two types, low pressure and high pressure.

In a low-pressure hydro break, a section of pipe, starting at or near a coupling, is lifted out of the pipe wall.

The cause of failure is probably a crack in the pipe end caused by rough handling after hydrostatic testing at the pipe manufacturing plant. Invariably, the pipe will be cracked through to the end, yet the crack is usually not severe enough to show up as a leak. When pressure is increased or water hammer is encountered in the system, the weakened section blows out.

In a high-pressure hydro break the break occurs in the center of the pipe and has the appearance of resulting from an explosion – with the affected section of the break lifting out of alignment from the main pipe. A crack to the end of the pipe is possible.

Cause of failure is probably water hammer from air present in the pipe, combined with high water pressure.

3.9.2 Crush Failure

Crush failure is characterized by a crack along the horizontal axis of the pipe usually down both sides. It is due to loads applied above the crush limits of the pipe. The excess loads can result from excessive depth of bury and/or live loads.

3.9.3 Shear Failure

Shear failure has the appearance of having been cut straight across the pipe diameter, but pipe ends are usually substantially offset in profile. Pipe ends, although straight, have rough and irregular surfaces and can have a small lip and companion cavity.

The failure is caused by shear conditions that exceed the pipe strength. It is often caused by pipe being laid on a trench bottom that changes from one type of soil to another, e.g., hard, stable trench bottom to a soft, yielding type of soil conditions. It also can be caused by hillside movement or slipping, as when a pipe section enters a structure without adequate flexibility provisions.

3.9.4 Flex Failure

Flex failure has the general appearance of having been cut straight across the pipe diameter similar to a shear failure, except that the pipe ends are not offset. The failure is caused by the pipe having been forced to bend to the breaking point.

Pipe ends are opened up on the top or bottom, thus indicating how the pipe was bent. For example, if the bending was caused by a rock under the crack location, this would result in the top section of the pipe (away from the rock) being split open more than the section of the pipe closest to the rock’s location.

3.9.5 Corrosion

Corrosion of pipes is the deterioration of pipe material due to a reaction with the environment. This deterioration can be external to the pipe or internal. Three general types of corrosion are recognized: galvanic, electrolytic and biological. Soil corrosion or metallurgical investigations may be required to determine the cause and type of corrosion. Section 3.6 provides additional guidance for external corrosion of mains.

3.9.6 Investigation and Repair of Breaks

When investigating breaks, the class and the type of pipe should be determined first along with the condition(s) that caused the break. Where corrosion is a factor in the main break, determining the extent of the corrosion by uncovering parts of the underground mains system should be a key factor. In cases where the corrosion has not advanced to a dangerous degree, protection of the pipe may be achieved by coating and wrapping.

Cinder fill is one of the most common causes of pipe corrosion. Wherever this is present, it should be removed and replaced with clean soil; or the main should be relocated.

In cases of excessive corrosion, other steps may be needed to discover and correct the issue.

If hydrostatic tests are needed as part of the investigation process, individual sections of the main should be isolated using the divisional valves and individually tested. If a failure should occur when testing a particular section, only minor discharge will result; and the damage that could have resulted if fire pump pressures were applied to the system will be prevented.

When mains are located under buildings, particular care should be taken when testing them. If replacement is required, the new pipes should either be located in the yard away from foundations and other structures, or indoors in a trench—not re-run under the building.

If excessive pressure surging (water hammer) is suspected as the reason for the breaks, the cause of the water hammer should also be examined to either eliminate or minimize the water hammer effects. The installation of anti-water hammer check valves or suitable pressure relief valves, or ridding the system of air by flowing water, may reduce the occurrence of water hammer.

Breaks in underground mains may be repaired quickly with bolting split sleeves. Long breaks, however, may require replacement of the pipe. For short or circumferential breaks, special saddles and clamps are available.

3.9.7 Leakage from Existing Underground Fire Service Mains

Leaks in underground mains can occur for a variety of reasons and are often indicators of more serious problems. Excessive leaks or large volume leaks can mean a main break may be imminent or may have already occurred.

Common indications a leak could be present within an underground main include frequent fire pump start-ups, loss of water from a gravity tank, and even unusually large water bills. When investigating the source of leaks, eliminate obvious sources such as sprinkler drain valves or hydrants, tank overflows or backup through the pump suction lines. Also confirm that any unaccounted-for water from the fire pump system is not being used for industrial purposes.

3.9.7.1 Leak Location and Detection

When attempting to locate leaks, the original plans are valuable in determining the location and arrangement of the underground mains.

Signs a leak may be present include surface depressions in driveways or railroad sidings above where mains cross, and even clumps of grass that are higher than the surrounding vegetation. Areas where unusual surface loadings or heavy vehicle traffic are present should also be checked; as these occasionally cause yard mains to settle, resulting in joint leakage or cracks. Inadequate anchorage at dead ends and blow-off connections are also sources of leaks. Constant surface moisture above mains that pass under or through building foundations could also indicate an issue.

A good strategy to determine if a leak is present is to systematically close the divisional and sprinkler-riser control valves, and note whether the pressure at sprinkler-riser gauges or hydrants remains constant. Any unusual pressure drops indicate that the leak is within the closed-off section of the yard main.

If the rate of leakage is abnormal (see Section 2.5.1.4), a listening device can help locate the leak. When escaping through a pipe wall, all leaks lose energy to the wall and the surrounding area; and the energy is then converted to audible sound waves. These sound waves can be picked up by sensitive instruments and amplified so the user can hear them. In the hands of an experienced operator, these instruments can help locate a leak with remarkable accuracy.

The listening device should preferably be used when the plant is shut down and all is quiet. Leaks are common in hydrants and stuffing boxes of indicator post gate valves, so listen at these points first. Leaks are difficult to locate with listening devices when underground pipes are located in swampy or porous fill, or where sewers or other pipes run nearby.

Other methods of leak detection include driving rods through the soil along the run of main where the leak is suspected, and then listening at the exposed end of the rods. The sound of escaping water will increase as the point of leakage is approached. Noting whether the rod is wet when withdrawn and whether it drives easily when nearing pipe depth are further indications a leak may be present.

Finally, electronic instruments such as pipe inspection cameras or acoustic leak detection can be used, allowing the inspection of the mains without draining the water first.

Acoustic detection may involve using specialized microphones to identify the source of the leak or may use pulsed sound waves to create an acoustic picture of the internal surfaces of the pipes and/or identify any blockages.

If a leak is detected, determining the rate of leakage in existing systems can be achieved by either of the following methods:

1. Meter readings. Measure all water delivered to the section under test by reading the meter (if any) on the public water connection or by using a small domestic water meter attached to a hydrant. Any flow of mill-use water through connections to the yard system will usually be detected by an irregular meter reading. If a booster pump maintains pressure on the fire system, operate it; and use the small meter to obtain the rate of leakage.

   Figure 3.9.7.1-1 shows a water meter attached to a hydrant. The meter is used to measure all water delivered to the test section.

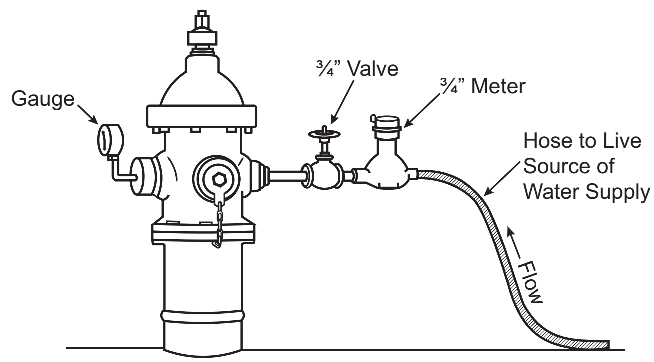


Fig. 3.9.7.1-1. Metering method of leak detection

2. Measure the drop in water level in a gravity tank. If the fire service system is also supplied by one or more connections to public water, close the control valves in these connections during measurements so that all water flowing to leakage will come from the gravity tank.

3. Hydrostatic testing. Any observed drop in pressure within a known section over a known period of time is converted to a leakage rate. Limitations on this method are related to estimating the coefficient of discharge of the hole, which may not be known until seen (e.g., in an underground situation).

3.10 Components and Equipment

3.10.1 Flow Meters

Some water utilities require the installation of flow meters in connections from public water mains to private fire service systems. Meters include both full registration meters and waterflow detector check valves. Each type experiences friction loss that should be accounted for in the design of a private fire service system. A compound type meter on the bypass line is also available as an option.

3.10.2 Anti-Water Hammer Check Valves and Surge Arresters

Water hammer is the term associated with the destructive forces, exemplified by pounding noises and vibration, which develop in a piping system when a column of noncompressible liquid flowing through a pipeline at a given pressure and velocity is stopped abruptly. When water hammer occurs, a high intensity pressure wave travels back through the piping system until it reaches a point of some relief, such as a larger diameter riser or piping main. The shock wave then surges back and forth between the point of relief and the point of impact until the destructive energy is dissipated in the piping system, sometimes in the form of broken piping. This violent action accounts for the piping noise and vibration. Water hammer can also occur without any noticeable sound.

Generally, the anti-water hammer check valve (see Figure 3.10.2-1) has a spring mechanism that automatically closes the valve disk at zero flow, before flow reversal occurs, thereby preventing surge and water hammer.

Surge arresters or dampers are used to moderate the potentially destructive effects of pressure surges or water hammer due to a pump starting and stopping and a valve opening and closing. They are used when an anti-water hammer check valve alone proves inadequate to control the problem.

These hydropneumatic devices absorb pressure surges into a precalculated volume of captive gas and return the absorbed water volume to the system in a controlled fashion. Surge arresters are installed on the system side of the fire pump discharge check valve as close to the check valve as possible. Water hammer arresters are covered in ANSI/ASME Standard A112.26.1, *Water Hammer Arresters*.

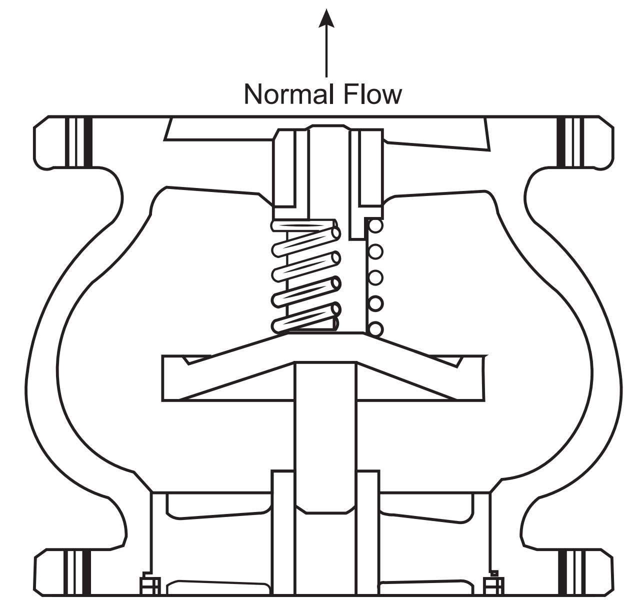


Fig. 3.10.2-1. Anti-water hammer check valve

3.10.3 Double Check Valve Assemblies (DCVAs)

Double check valve assemblies (DCVAs) are used where backflow prevention is required on cross-connections. A double check valve assembly consists of an assembly of two independently acting, internally-loaded check valves.

The prevention of backflow depends solely on the proper operation of at least one of the independently acting check valves. Finding one of the check valves in a leaky condition is unusual, and finding both check valves leaking simultaneously is highly improbable.

3.11 Cross Connections and Backflow Preventers

Potential contamination and liability resulting from contamination of public potable water supplies due to lack of or faulty cross connection control assemblies has forced local and state agencies to enact various laws and regulations. Any interconnected piping between a consumer's water system and a public potable water system requires the approval of local and/or state water or public health authorities. Backflow prevention methods are usually required when a public potable water source is interconnected to a consumer's non-potable water system.

Backflow prevention is typically achieved using one of two principles. The first is known as air gap separation and is the most commonly seen. However, air gap separation at connections to fire protection systems is not usually practical.

The second principle seen in cross connections to prevent backflow uses the principle of reduced pressure in lieu of air gap separation. Reduced pressure backflow prevention assemblies (RPBA's) have a relatively high friction loss and a recommended limit to their flow capacity. Therefore, fire protection systems using these devices must have a water supply at a pressure high enough to compensate for this loss.

Approved double check valve assemblies (DCVA) (see Figure 3.11-1), properly installed and maintained, can also provide protection against backflow. However, these devices are considered to provide only the minimum protection against backflow. As such, health authorities require significant evaluation before these are allowed to be used. Friction loss in double check valve assemblies is generally somewhat less than that in reduced pressure backflow prevention (RPBA) assemblies.

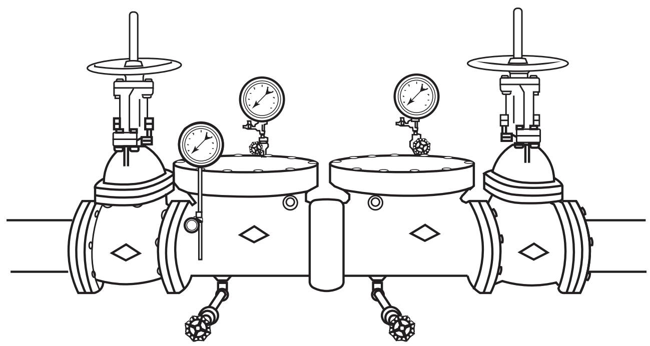


Fig. 3.11-1. Double check valve

No accepted standard practice exists for the protection of potable water supplies from non-potable supplies. The majority of local and state health agencies accept backflow prevention assemblies approved by either the Foundation for Cross-Connection Control and Hydraulic Research of the University of Southern California (FCCCHR of USC) or the American Society of Sanitary Engineering (ASSE). Some cities or states have their own plumbing testing laboratories where backflow prevention assemblies are tested and approved for use within their jurisdiction. Many local and state agencies have also adopted the AWWA Manual M14, *Backflow Prevention and Cross-Connection Control*: Recommended Practices as a means of determining the need, if any, of cross-connection control assemblies for fire protection systems.

The AWWA Manual M14 also classifies cross connections and connection control based on the water source and the arrangement of the water supplies.

3.12 Reduced Pressure Principal Assemblies

This assembly consists of two internally loaded check valves operating in series and a spring-loaded, diaphragm-actuated differential pressure relief valve connected to the zone between the check valves.

Leakage through one or both check valves or the relief valve is indicated by the discharge of water from the relief valve port. The reduced pressure assemblies operate on the principal that water will not flow from a zone of lower pressure to one of higher pressure.

4.0 REFERENCES

4.1 FM

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*
Data Sheet 3-0, *Hydraulics of Fire Protection Systems*
Data Sheet 3-2, *Water Tanks for Fire Protection*
Data Sheet 3-7, *Fire Protection Pumps*
Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*

The *Approval Guide*, a publication of FM Approvals

4.2 NFPA Standards

NFPA 24, *Installation of Private Fire Service Mains and Their Appurtenances*

NFPA 1962, *Care, Use and Service Testing of Fire Hose Including Connections and Nozzles*

4.3 Others

ANSI/AWWA C104/A21.4, American National Standard for Cement Mortar Lining for Cast Iron Pipe and Fittings for Water.

ANSI/AWWA C105/A21.5, *American National Standard for Polyethylene Encasement for Gray and Ductile Cast Iron Piping for Water and Other Liquids*

ANSI/AWWA C150/A21.50, *American National Standard for the Thickness Design of Ductile Iron Pipe*

ANSI/AWWA C600, *AWWA Standard for the Installation of Ductile-Iron Water Mains and Their Appurtenances*

ANSI/AWWA C603, *AWWA Standard for the Installation of Asbestos Cement Pressure Pipe*

AWWA Manual M17, *Installation, Field Testing and Maintenance of Fire Hydrants*

AWWA Manual M23, *PVC Pipe—Design and Installation*

ANSI/ASME A112.26.1, *Water Hammer Arresters*

APPENDIX A GLOSSARY OF TERMS

Air gap (AG): The unobstructed vertical distance through free atmosphere between the lowest opening of any pipe or faucet conveying water or waste to a tank, plumbing fixture, receptor, or other assembly, and the flood-level rim of the receptacle. These vertical, physical separations can never be less than 1 in. (25 mm). Local codes and regulations may have more stringent requirements.

Assembly: A combination of one or more Approved body components (such as check valves), including approved shutoff valves.

Backflow: The undesirable reversal of flow into a potable water distribution system, resulting from a cross connection.

Backflow preventer: An assembly or means to prohibit the backflow of water into the potable water supply.

Backpressure: A pressure higher than the supply pressure, caused by a pump, elevated tank, boiler, air/steam pressure, or any other means, which may cause backflow.

Back-siphonage: Backflow caused by negative or reduced pressure in the supply piping.

Certified backflow-prevention assembly tester: A person certified by the approving authority to test, repair and maintain backflow prevention assemblies.

Cross connection: A connection or potential connection between a potable water system and other non-potable environments or substances that could contact the potable water. Examples of non-potable environments or substances may include chemicals, water products, steam, water from other sources (potable or non-potable), solids or gases.

Bypass arrangements, jumper connections, removable sections, swivel or changeover assemblies, or any other temporary or permanent connecting arrangement through which backflow may occur are considered cross connections.

Contamination: An impairment of a potable water supply by the introduction or admission of any foreign substance that degrades the quality and creates a health hazard.

Double check valve assembly (DCVA): An assembly composed of two independently acting, Approved check valves that includes tightly closing, resilient-seated shutoff valves located at each end of the assembly and fitted with properly located, resilient-seated test cocks. This assembly shall only be used to protect against a non-health hazard).

Flood level rim: The level at which liquid in plumbing fixtures, appliances or vats could overflow onto the floor when all drain and overflow openings built into the equipment are obstructed.

FM Approved: Product and services that have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Non-health hazard: A contaminant that does not cause a serious illness or other health effect. Examples include contaminants that have a bad smell or taste.

Potable water: Water that is safe for human consumption as described by the public health authority having jurisdiction.

Private fire service main: A primary, underground water main located on the private property of the client, such as:

a) When connected to a public water system, the private fire service main begins at a point designated by the public utility, usually at a manually operated valve near the property line.

b) The primary piping between the source of water and the water supply side of the first above-ground component in a water-based fire protection system. It includes the inlet of any pump (fire/booster), the base of any hydrants or monitor nozzles where they are the only form of protection, and the inlet of any foam-making equipment for foam protection systems.

c) The primary piping between the check valve on the outlet of the fire pump and the base of the riser (BOR) of water-based fire protection systems. This includes any underground loop mains or primary piping between the check valve on the discharge of the pump and the sprinklers or hydrants/standpipes if no sprinklers are present.

d) The primary piping from a water source to a gravity or pressure tank

e) The piping from the system side of a gravity or pressure tank's discharge water control valve to the fire protection system.

Reduced-pressure backflow-prevention assembly (RPBA): This assembly consists of two independently acting approved check valves together with a hydraulically operating, mechanically independent pressure differential relief valve located between the check valves and below the level of the first check valve. These units are located as an assembly between two tightly closing, resilient-seated shutoff valves and are equipped with properly-located, resilient-seated test cocks.

Snaking: Laying of piping in a series of gentle curves (usually S-shaped) to provide extra slack in a length of piping. This technique can be used to offset the thermal expansion of plastic piping.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2025. Full revision. The following significant changes were made:

A. Changed the name of the Operating Standard to "*Private Fire Service Mains and Connections*".

B. Improved the definition of private fire service water mains.

C. Updated installation guidance for positioning underground mains beneath railroad tracks.

D. Updated thrust block guidance for fully restrained pipes.

E. Added new guidance for thrust blocks used with plastic piping.

F. Added new guidance for the installation of above-ground mains.

G. Added freeze protection guidance for above-ground mains.

H. Added UV protection guidance for plastic water mains.

I. Added new impact protection guidance for underground mains exiting within buildings.

J. Added cross connection and backflow preventer guidance from FM Data Sheet 3-3, *Cross Connections*. Data Sheet 3-3 was then made obsolete.

K. Updated guidance on leak detection and acceptable leakage rate guidance for water mains.

L. Updated guidance on flushing of water mains.

M. Relocated general inspection, testing and maintenance guidance to FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

N. Relocated guidance on fire hoses, nozzles and equipment for private hydrants to FM Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*.

O. Rearranged the guidance in this data sheet to ensure consistency with other FM data sheets.

January 2022. Interim revision. The following significant changes were made:

A. Added Section 2.1 on using FM Approved equipment and services. Removed all subsequent redundant iterations of this language in the document.

B. Added guidance for the new FM Approved pipe rehabilitation system in Section 2.0.

C. Updated explanatory text on pipe rehabilitation systems in Section 3.0 to support the new Section 2.0 guidance on FM Approved pipe rehabilitation systems.

D. Updated guidance on thrust block areas in Table 2.

E. Relocated information on leak detection methods and equipment to Section 3.0. This material contains no recommendations.

F. Replaced unreadable figures in the document.

G. Updated references and terminology to current FM Global and FM Approval brand assurance standards.

September 2000. Reorganized to provide a consistent format.

June 1992. First issued.

APPENDIX C UNDERGROUND MAIN INSTALLATION CHECKLIST

Figure C-1 provides a flowchart to be used during actual underground main installations. The items included in the flowchart are those often performed poorly, leading to underground breaks, leaks and impairments to the fire protection system. Before underground main installation begins, confirm plans have been reviewed and accepted to ensure all aspects of design and material selection are in accordance with requirements.

Once the underground main is backfilled, identification and correction of any problems are far less likely. Hence, immediate correction of any problems should occur, or work should be suspended until corrections are made.

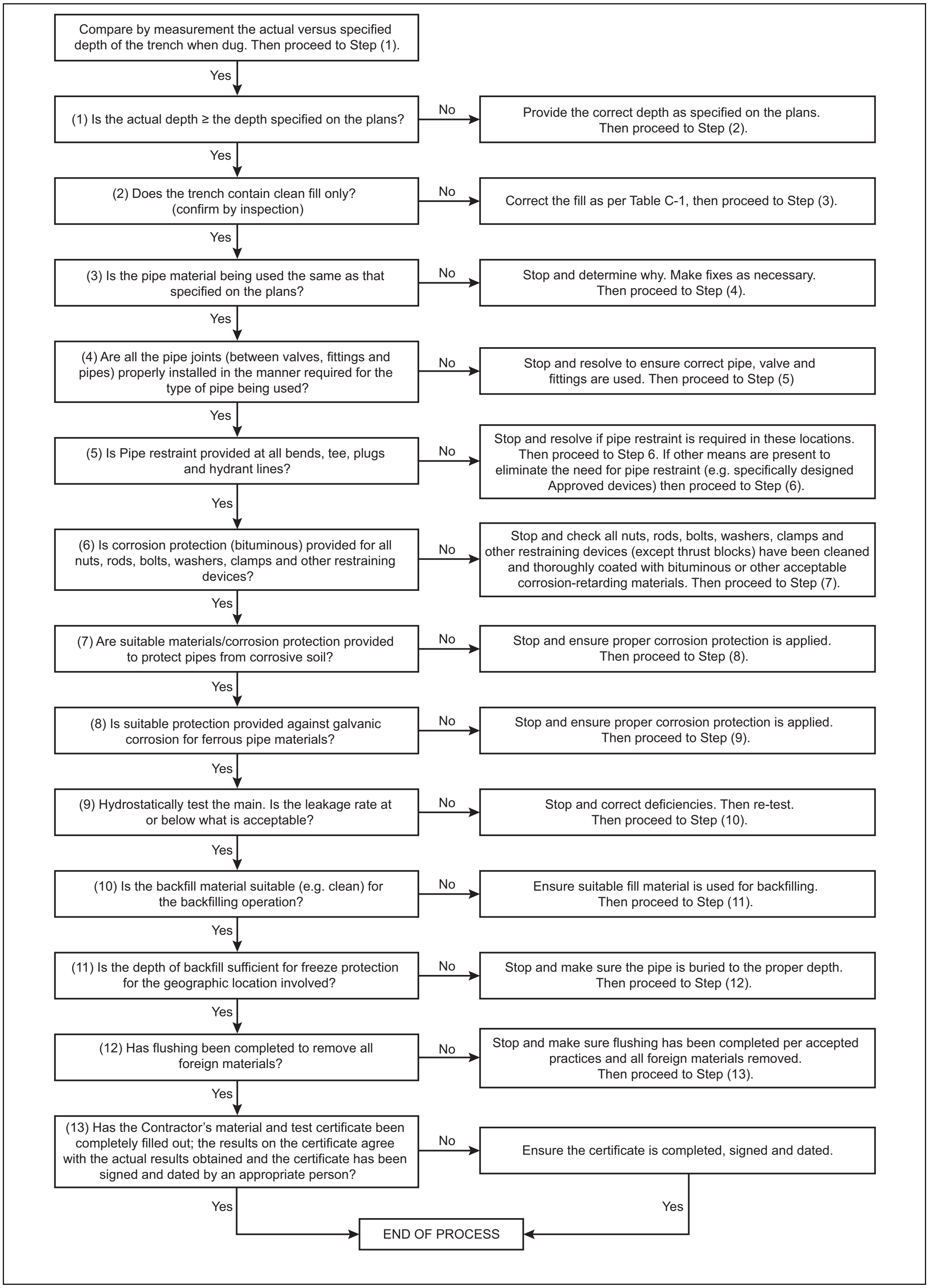


Fig. C-1. Installation flowchart for underground mains

Table C-1. Trench Bed Fill Materials

If the Trench Bed Contains	*And:*	*Then:*
Rocks, boulders or any exposed rock surface	They cannot be removed	Construct a foundation for the pipe using suitable material.
	They can be removed	Remove all rocks, etc. to provide a clearance at least 6 in. (152 mm) below and on each side of all pipe, valves and fittings. Replace removed material with a bed of sand, crushed stone or earth that is free from stones, large clods or frozen earth, on the bottom of the trench to a minimum depth of 6 in. (152 mm) level and tamp the bedding material.
Unstable material	Which cannot be removed	Construct a foundation for the pipe using suitable material
	It can be removed	Remove unstable material and replace it with clean stable backfill material.
Ash, cinders, refuse or other organic material	It cannot be removed, and it is unstable:	Construct a foundation for the pipe using suitable material, and protect the pipe against corrosion
	It can be removed	Remove material to a minimum of at least 6 in. (152 mm) belowintended pipe elevation and replace with clean, stable backfill material.

APPENDIX D JOB AID - HYDROSTATIC LEAKAGE TESTING

Hydrostatic leakage testing (hydrostatic testing) is a pressure test used to detect leaks and validate the structural integrity of a piping system. Common applications include testing during the installation of a new water main, during the relining of a water main, or as a regular integrity check per FM Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

Complete hydrostatic testing using the following steps:

A. Slowly fill with water each section of the main to be tested.

B. Expel all air by opening hydrants at the high points of the system and at both ends, or by bleeding air through the sprinkler drains.

C. Open widely the valve controlling the entry of water before shutting the hydrants or drains.

D. After the system has been filled with water and the entrapped air expelled, close the valve that controls the section being tested and begin applying pressure.

E. Increase the water pressure in 50 psi (345 kPa, 3.5 bar) increments until the specified test pressure is attained.

F. After each increase in pressure, make observations of the stability of the joints. Observe such items as protrusion or extrusion of the gasket, leakage, or other factors likely to affect the continued use of a pipe in service. Leave the joints uncovered until all the tests have been completed satisfactorily. Large installations may be tested in their entirety, or sections between valves may be tested individually. In some cases, including older pipe within the test section may be necessary.

G. Increase the pressure to the next increment only after the joint has become stable. This condition applies particularly to movement of the gasket.

H. After the pressure has been increased to the required maximum value and held for one hour, decrease the pressure to 0 psi (0 kPa, 0 bar) while watching for leakage.

I. Slowly increase the pressure again to the specified maximum, and hold the pressure for one more hour while leakage measurements are made. Do not use fire pumps to supply pressure, because a pipeline break during testing could result in damage from the large flow of escaping water. Instead, use a small hydrostatic test pump.

J. Measure the amount of leakage at the specified test pressure by pumping from a calibrated container.

The maximum rate of leakage can be calculated using the following equations:

US Units:

$$L = \frac{SD\sqrt{P}}{148,000}$$

where:

L = testing allowance (makeup water) [gph (gal/hr)]
S = length of pipe tested (ft)
D = nominal diameter of pipe (in.)
P = average test pressure during hydrostatic test (gauge psi)

Metric Units:

$$L = \frac{SD\sqrt{P}}{794,797}$$

Note:

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APPENDIX E JOB AID – WATER MAINS FLUSHING

This job aid provides general guidance for conducting a flushing investigation. It also provides a method of calculation that can be used to approximate how long a flushing will take for the water to run clear.

1. Prior to arrival on site, confirm with the contractor conducting the flushing what equipment/apparatus will be used. Rigid elbows are preferred. Soft elbows can work loose or fail under the pressure of the flowing water, and should be avoided.

2. On site, install a pressure gauge at the backflow preventer. Doing so serves two purposes:

   a. Allows verification that no valves are closed on the site side of the piping.

   b. Monitors the pressure of the water supply to help prevent the mains' pressure dropping from below 20 psi. This step is important when using a pump and a city supply for the source of the flushing water.

3. Monitor the flow rate of the flushing water to ensure the necessary flushing flow is maintained. This flow will be based on pipe size.

4. Calculate the time needed to flush a water main segment using the following steps:

   a. Take the length of the segment (pipe run) in feet (meters) and divide it by 10 ft/sec (3 m/sec).

      This calculation gives the base time (in seconds) needed to flush the entire run from the origin point to the discharge point.

   b. Multiply this base time in seconds by a factor of two. Doing so accounts for the additional time needed to clear any large debris that may be in the pipe. Larger debris tends to be pushed by the flow of water within the pipe, effectively rolling along the bottom of it. This can increase the time taken to remove such debris.

   c. Start the flow of the flushing water. When the required water flow is reached, the timer can start.

   d. Monitor the water flow to ensure it is running clear at the end of the flushing time. In rare cases additional time may be required. However, in practice, most flushing is completed within the times given.

Example: For a 2300 ft (700 m) long run of mains, a base time for flushing would be approximately four minutes. To ensure larger debris is removed, the time taken would be approximately eight minutes to complete the flushing; and the water should run clear as stated in Section 2.5.3.1.