Rural Water District No. 1, Ellsworth Co., Kansas

103 N. Douglas Ellsworth, KS 67439 ♦ Phone (785) 472-4486 ♦ www.postrockrwd.com

PROCEDURAL AGREEMENT WITH CONTRACTORS

Revised – January 15, 2016

Contractor must have a minimum liability insurance of $1,000,000 including an X C & U endorsement. A certificate of insurance is to be sent to this office annually.

New Construction

When working on new construction, the contractor will be responsible for labor, backhoe work, trenching, backfill, and installation of pipe. Post Rock employees are to be present for the purpose of inspection and supervision. Post Rock personnel may help with installation; however, they may have to tend to other work of the District so the contractor should be prepared to proceed on their own. All work will be scheduled to accommodate Post Rock's normal working days unless otherwise approved by the district. Post Rock employees will make taps on main lines.

Contractor must have adequate equipment on the job to complete the work in a timely and safe manor to the Post Rock representative's satisfaction.

Contractor will be responsible for contacting, locating, and protecting all existing utilities according to all applicable laws. Contractor will be liable for any damage caused by their activities.

All pipe and material will be provided by Post Rock unless previously agreed upon by both parties. All material not provided by Post Rock will meet Post Rock specifications as set out in the *Post Rock Rural Water District Pipeline Specifications* dated: *January 12, 2016* prepared by *RMA Engineering.*

Work will begin on a project as soon as possible for all parties. Beginning and deadline dates maybe set if previously agreed upon in writing. Contractor will stay on the job until the job is completed.

Post Rock's responsibilities with a contractors work will end 4 feet beyond the meter, except in the case of a cross connection or other legal responsibilities of the district.

Work is to begin at the connection to the existing line and continue to 4-feet beyond the meter unless otherwise approved by the district representative on the job.

The District personnel will flag the tap locations, valve locations, cleanout, meter, and road and creek crossings locations. Any deviations from staking will be approved by the District personnel prior to construction. The contractor will provide stakes or flags necessary for their personnel to follow on a long run to provide for a straight line. All personnel must be aware of easement restrictions and abide by them. Any place where there is no reason for deviation; lines will be placed 20 feet into private right of way, parallel to the road right of way.

Normal procedure for road crossings will be by boring. Exception will be made only with approval of the district and the road department.

Contractor will generally provide 3.5 feet and a minimum of 3 feet of cover over the pipeline. More cover might be necessary when and where requested by a Post Rock representative.

Contractor will insure that any pipe laid in rock conditions will have adequate bedding. This will mean 6" under, 6" on each side, and 12" above the pipe. Any rock dug up by a contractor may be included in the backfill so they will not interfere with the pipe bedding or farming practices. If this is not possible, the contractor will be responsible for removal from the site and proper disposal of rock.

Private and public sewers will be crossed and paralleled so as to satisfy KDHE requirements.

Contractor will work with Post Rock employees to provide for adequate pigging, disinfection, and flushing time.

Post Rock representatives will make a pressure test on new construction where possible. Line pressure may be used where adequate at the discretion of a Post Rock RWD representative.

Contractor will dig up and make repairs of leaks on new construction at no additional cost for a period of one year, unless due to failure of material supplied by Post Rock RWD. Then contractor will be paid for time and labor at their regular rate.

Contractor will take care of ditch settlement for the first year at no additional cost, except for extraordinary hazards created by acts of God.

Any changes to this policy must be agreed upon prior to commencement of work.

This policy will remain in effect and in Post Rock's file until it is amended or rescinded by either party after completion of any current project.

Emergency Repairs and System Modifications

When a contractor is called upon for assistance in an emergency or outage situation, they will be expected to respond as quickly as possible and to render whatever assistance they are capable of to restore the safe delivery of service. Post Rock understands that contractors may have prior obligations that prohibit them from immediate response.

Contractors must understand that the nature of our service requires us to call the next closest and qualified contractor in our file.

Contractors, their subs, and their employees while working for the District are representing the District and will conduct themselves in a professional and courteous manner to both the public and the Post Rock personnel. Post Rock employees have the right to shut the job down and the contractor will cease all work at no expense to the District until differences between any parties or individuals are resolved.

The purpose of this policy statement is to make certain that all parties are aware of their responsibilities.

____(Business Name) agrees to and accepts this policy and set of specifications.

Representative:

Signature: ____

Print: ____

Date________________________

Mailing address:________________________________ E-mail: __________________

____

Contact person: _________________________ Phone: ________________________

Alternate Contact: _______________________ Phone: ________________________

After hours: ____________________________ Phone: ________________________

Post Rock Rural Water District

Pipeline Specifications

January 12, 2016

www.rmaengineer.com

1. SCOPE OF WORK: This work shall include the furnishing of all labor, materials, and equipment necessary for the clearance of right-of-way, excavating, trenching, and backfilling, the continual drainage of excavation, sheeting, bracing and shoring of sides of excavation, backfilling around structures and over water mains, and the disposal of excess excavated materials, unsuitable material and finish grade the areas disturbed by the Contractor.

2. CLASSIFICATION OF EXCAVATED MATERIALS: Excavated materials encountered during the construction of the water main trench shall be unclassified excavation. This will include all common (earth) and rock excavation including water.

3. BLASTING: The Contractor shall comply with all laws, ordinances, and applicable safety code requirements and regulations relative to the handling, storage, and use of explosives and the protection of life and property, and he shall be responsible for all damage thereto caused by his blasting operations.

The Contractor shall maintain adequate insurance coverage to protect the Owner or their representatives and employees from liability caused by the Contractor’s blasting operations.

The Contractor shall present evidence that the person in charge of blasting operations has completed an accredited course in the use of explosives such as from the U.S. Bureau of Mines or from an explosive manufacturing company.

Where necessary for adequate protection of life or property, in the opinion of the Engineer, suitable weighted plank coverings or mattresses shall be provided to confine all materials lifted by blasting within the limits of the excavation or trench. All rock which cannot be handled and compacted as earth shall be kept separate from other excavated materials and shall not be mixed with other backfill or embankment materials except as specified or directed.

4. WATER MAIN TRENCHING: The trench shall be dug to the required alignment and depth as shown on the Plans or directed by the Engineer and only so far in advance of pipe laying as the Engineer shall permit. Minimum cover on all lines shall be 42 inches unless otherwise specified. Trench width shall be a minimum of 12 inches greater than the outside diameter of the barrel of the pipe and a maximum of 24 inches greater than the outside diameter of the barrel of the pipe. The trench shall be braced and drained when necessary to ensure safe working conditions at all times. Where water is encountered, the bracing or sheeting shall be designed and placed to drain water to a sump outside the sheeting area. No water will be permitted in the trench. Bracing and/or sheeting will be left in place until the water line pipe is installed and sufficient backfill is in place so as no damage to the water line pipe may result from its removal. All trenching shall provide a uniform grade which will provide full support for the entire length of pipe. Over-depth excavation and non-uniform grades shall be backfilled with suitable material and compacted to provide uniform, continuous support for the entire length of pipe.

4.1 <u>Rock Excavation</u>: Where rock is encountered, it shall be removed to a depth of at least six (6) inches below grade. Wherever blasting is used to remove rock, the Contractor shall cover the trench with satisfactory material and take all necessary precautions to prevent damage to adjacent property and injury to the workmen. The amount of over-excavated material shall be replaced with either fine sand or earth which is free of stones. This backfill shall be placed and compacted by hand or a mechanical method approved by the Engineer prior to installation of water line pipe.

5. MECHANICAL EXCAVATION: The use of mechanical equipment will not be permitted in locations where its operation would cause damage to trees, buildings, culverts, or other

existing property, utilities, or structures above or below ground; in all such locations, hand excavating tools and methods shall be used.

Mechanical equipment used for trench excavation shall be of a type, design, and construction and shall be so operated that the control of the rough trench excavation bottom elevation is accurate and positive at all times, that uniform trench widths and vertical side walls are obtained at least from an elevation one foot above the top of the installed pipe to the bottom of the trench and that the trench alignment is such that the pipe when accurately laid to specified alignment will be centered in the trench with adequate clearance between the pipe and side walls of the trench as excavated at all points. Undercutting of the side wall to obtain such clearance will not be permitted.

All mechanical trenching equipment, its operating condition and the manner of its operations, shall be subject at all times to the approval of the Engineer.

6. WATER MAIN TRENCH BACKFILL: The kinds of backfill materials to be used and the methods of placing and compaction therefore shall conform to the requirements shown on the Plans. Inundated backfill shall not be permitted without special consideration and approval of the Engineer.

6.1 Granular Fill: Granular material for pipe embedment or replacement of rock or unsuitable foundation material removed from trench bottoms shall consist of finely graded native soils and shall be free from clay, and other materials which would cause the materials to crack or cake. The material shall be well graded to help prevent soil migrations from the trench walls.

All granular fill material beneath the pipe shall be compacted no more than necessary, in order to insure a slightly yielding support for the pipe placed thereon. Such material shall be loosely poured or scattered into the trench, to a maximum depth of 12 inches at any point, before spreading or leveling. When deposited in the trench, granular fill material beneath the pipe shall be spread and graded to provide a uniform and continuous support for the installed pipe at all points between bell holes or pipe joints, except that it will be permissible to disturb or otherwise damage the finished subgrade surface by the withdrawal of pipe slings or other lifting tackle. No blocking of the pipe to achieve proper grade will be allowed.

All granular fill material above the bottom of the pipe shall be placed in not to exceed 6-inch layers and compacted by adequate tamping, vibration, slicing with a shovel, rodding, or by a combination thereof. All backfill compaction equipment, and the results obtained thereby, shall be subject at all times to the approval of the Engineer.

6.2 Pipe Embedment: All pipe embedment material including bedding material below the bottom of the pipe shall be placed as shown on the Plans. Pipe embedment material shall extend upward to an elevation not less than 1/8 of the total trench backfill cover depth over the pipe or a minimum distance of 12 inches above the top of the pipe, whichever is greater, as shown on the Plans. Classes of pipe embedment to be used shall be as hereinafter specified.

6.2.1 Class A Arch Encasement for pipe shall be used where required by the Plans and also where conditions are such as to dictate the use thereof as determined by the Engineer.

6.2.2 Class B Bedding shall be used for all polyvinyl chloride pipe.

6.2.3 Class C Bedding shall be used for all ductile iron pipe and concrete pipe.

If compacted backfill is required for the full depth of trench above the required granular fill, tamped bedding, or arch concrete encasement material, then tamped backfill shall be used in all cases unless permitted otherwise by the Engineer.

After each pipe has been graded, aligned and placed in final position on the bedding material and shoved home, sufficient pipe embedment material shall be deposited and compacted under and around each side of the pipe and back of the bell or end thereof to firmly hold and maintain the pipe in proper position and alignment during subsequent pipe jointing, embedment backfilling operations.

Pipe embedment material, in each case, shall be deposited in the trench in such a manner that it is scattered along the sides of the pipe and not dropped in compacted masses. In addition, such material shall be deposited and compacted where required, uniformly and simultaneously on each side of the pipe in order to prevent lateral displacement of the pipe.

Under no circumstances shall the pipe embedment be disturbed or displaced after it has been adequately compacted by the moving or removal of trench boxes, or other equipment or personnel. If the pipe embedment is displaced, the contractor shall re-install those portions of the pipe laid which were disturbed.

7. BACKFILLING ABOVE PIPE EMBEDMENT: Except as otherwise permitted, trench backfill above previously compacted pipe embedment material shall conform to the material and placing requirements as follows.

7.1 Compacted Backfill: Compacted backfill material shall have a moisture content such that the required density can be obtained by the compaction method used in each case. The limits of Compacted Backfill shall be as shown on the Construction Plans, or as stipulated below or as directed by the Engineer.

7.1.1 95% of Maximum Density: Under pavements, surfacings, driveways, curbs, gutters, walks or other surface construction, structures, under road or roadway shoulders and locations which are within four feet of any structure. Compacted backfill shall be completed immediately after pipe placement.

7.1.2 90% of Maximum Density: Under established lawns or areas to be sodded or seeded. Compacted backfill shall be completed within two days of pipe placement unless the moisture content exceeds the optimum.

The top portion of backfill beneath established sodded or cultivated areas shall be furnished with not less than 12 inches of topsoil.

The material shall be placed in layers and compacted by means of suitable equipment, or by tamping with mechanical tampers or hand tampers. Each layer shall be compacted to a density equal to or greater than the percentage of maximum density indicated. Each successive layer shall contain only that amount of material which will insure proper compaction, but in no case shall any layer be greater than eight (8) inches (loose measurement) for 95% density or twelve (12) inches (loose measurement) for 90% density. The moisture content of the soil to be used for backfill shall be uniform and shall be within plus or minus two percentage points of optimum moisture for the soil.

7.2 Standard Backfill: Standard Backfill material above pipe embedment may be placed by any method or combination of methods, approved by the Engineer, which will cause the density of the backfill material to be approximately equal to the adjacent undisturbed material, which will not subsequently settle and cause a depression in the trench area and which will not impose excessive concentrated or unbalanced loads, shock or impact on, and which will not result in displacement of the installed pipe. Minimum acceptable density is 85% of maximum. Standard backfill shall be completed within two days of pipe placement.

Standard earth backfill material which is to be placed above embedment shall be free of brush, roots more than 2 inches in diameter, debris and junk, but may contain rubble and detritus from rock excavation, stones, and boulders, in certain portions of the trench depth as hereinafter provided.

Compact masses of stiff, mucky clay, or gumbo, or other consolidated material more than one cubic foot in volume shall not be permitted to fall more than five feet into the trench unless cushioned by at least 2 feet of loose backfill above the specified pipe embedment.

No standard trench backfill material containing rock, or rock excavation detritus, shall be placed in the upper 12 inches of the trench except with the specific permission of the Engineer in each case, nor shall any hard rock, or stone or boulder larger than 8 inches in its greatest dimension be placed within 2 feet of the top of pipe having a cover depth less than 10 feet, or within 3 feet of the top of pipe laid in deeper trenches. Large stones not exceeding 12 inches may be placed in the remainder of the trench backfill only if well separated and so arranged that no interference with backfill settlement will result.

7.3 Hand-Placed Backfill: All hand placed backfill shall be deposited and spread with tools in uniform layers not more than 12 inches in thickness on each side of the pipe and for the full width of the trench where above the pipe.

7.4 Inundated Sand Backfill: Inundated Sand Backfill shall only be used with express permission from the Engineer. Sand used for inundated sand backfill shall be free of lumps, rubbish, roots, cinders and other objectionable material. Backfill sand shall contain not more than 10 percent by weight of clay and loam combined, not more than 5 percent shall be retained on a No. 4 sieve, and not more than 20 percent shall pass a No. 100 sieve.

The general procedure to be employed in the inundation of sand backfill with water shall be submitted by the Contractor to and approved by the Engineer prior to starting operations thereunder. Operational details in connection therewith shall be acceptable to the Engineer at all times.

Unless otherwise authorized by the Engineer, an adequate supply of water shall be available at the site of each water-settled sand fill to completely inundate the sand to the top of the trench, or structure subgrade, in one uninterrupted operation. However, in order to reduce the loss of water by seepage into a porous subsoil, the Engineer may permit stage inundation of successive layers of sand in the trench.

No compacted backfill shall be installed in freezing weather except by permission of the Engineer, and in no case shall backfilling be done with frozen material or on material already frozen in the trench.

Backfill meeting the above requirements may be done prior to specified pipe line testing at the Contractor’s option. This will be allowed to prevent displacement of the pipe during testing operations. Should the pipe not withstand the hydrostatic testing as outlined in these Specifications, the Contractor shall be required to uncover, correct and backfill the pipe without cost to the Owner.

8. DEWATERING AND DRAINAGE MAINTENANCE OF TRENCHES: Such grading shall be done as may be necessary to prevent surface water from flowing into trenches or other excavations, and to maintain the flow of water in natural water courses on or adjacent to the site. Any water accumulating in trenches or other excavations shall be removed by pumping or by other approved methods. Pipe trenches shall be kept free from water during excavation, fine grading, pipe laying and jointing. Where the trench bottom is mucky or otherwise unstable because of the presence of groundwater, and in all cases where the static water elevation is above the bottom of any trench, the groundwater shall be lowered by means of well points and pumps or by other means acceptable to the Engineer, to the extent necessary to keep the trench free from water and the trench bottom stable at all times when work within the trench is in progress. The disposal of waste water from trench dewatering operations shall be subject to the approval of the Engineer.

9. TRENCH BOTTOM STABILIZATION: Trench bottoms which become soft and mucky during construction operations shall be stabilized, by and at the expense of the Contractor, with one or more layers or aggregate bedding material or other approved material, where and as necessary to provide a firm and stable base.

10. DISPOSAL OF EXCESS EXCAVATED MATERIALS: Except as otherwise permitted, all excess excavated materials shall be disposed of away from the project site or as approved by the Engineer.

Broken concrete and other coarse debris resulting from pavement or sidewalk removal, excavated rock in excess of the amount permitted, debris encountered in excavation work, and other similar waste materials shall be disposed of away from the site of the work or as approved by the Engineer.

The excess suitable material, and unsuitable material, shall be disposed of at locations approved by the Engineer and/or as indicated on the Plans. The material disposed of shall be spread in a neat appearance, and smooth enough as not to constitute a hazard to humans and animals. The final appearance shall be subject to the approval of the Engineer. If disposal is on private property, the Contractor shall obtain written permission of the property owner on whose property the material is to be placed. Copies of all agreements with property owners are to be furnished to the Engineer.

11. CUTTING PAVEMENT AND WALKS: Concrete pavement, asphalt pavement, bituminous sealed surfaces, paved sidewalks and all other types of base pavement, shall be cut and removed only where, in the manner, and to the extent specified herein or authorized by the Engineer. Cuts shall be no larger or wider than necessary to provide adequate working space for proper installation of pipe and pipe line appurtenances. The cutting of concrete pavements along each side of trenches and at structures shall be made with a concrete saw. A clean groove at least 1-1/2 inches deep shall be cut and/or deeper when directed by the Engineer. The cutting of asphalt pavement shall be made with a saw or cutter wheel and shall be full depth of the pavement.

Concrete pavement, asphaltic pavement, bituminous sealed surfaces an all other type of base pavement over trenches excavated for pipe line shall be removed to a width not less than 12 inches wider than the width of the trench at the pavement subgrade, or as detailed in the construction plans, which trench width shall not exceed the minimum permissible trench width for the size and type of pipe which is to be installed in the trench by more than 12 inches. The trench width at the trench bottom shall not be greater than at the top and no under-cutting will be permitted. A shoulder not less than 12 inches in width at any point shall be left between the cut edge of the pavement and the top edge of the trench. Pavement cuts shall be made to and between straight line which, unless otherwise required, shall be parallel to the center line of the trench.

The Contractor shall provide adequate temporary aggregate surfacing over the traveled way during the construction to the satisfaction of the Owner. The pavement reconstruction shall be at least the depth and quality of material equivalent to the existing pavement or as required in the construction Plans and set forth in these specifications.

12. STREET AND ROADWAY CROSSINGS: Street and roadways or driveways may be crossed by trenching unless otherwise noted on the Plans. The Contractor shall install suitable barricades and lights at open trenches and take any precautions necessary to protect the public from damage as a result of the construction operations. The Contractor shall comply with the Manual on Uniform Traffic Control Devices for Streets and Highways when controlling the traffic at these locations as set forth in SECTION: SUPPLEMENTARY CONDITIONS.

All backfill for driveways, streets and roadways shall be tamped backfill for the full depth of excavation in a manner as stated herein and as approved by the Engineer and the temporary surfacing replaced to permit prompt opening to traffic. The Contractor shall arrange his work to ensure that all driveways, streets and roadways be closed no longer than necessary for construction operations. Surfacing of unpaved roadways, alleys, streets, driveways and other traveled ways shall be surfaced to match existing material. The pavement restoration of concrete and asphalt streets, roadways, driveways and other traveled ways shall be in accordance with the Construction Plans, Details and these Specifications. Where necessary to satisfy a safe and convenient temporary traffic condition, or as directed by the Engineer, the Contractor shall place aggregate type surfacing to a depth as directed by the Engineer. This temporary all-weather surfacing will be provided as temporary surfacing only during the construction operations until the permanent surfacing material is placed.

13. DRAINAGE MAINTENANCE: Backfilling of trenches for water main installed beneath and/or across roadways, driveways, walks and other traffic ways adjacent to drainage ditches and water courses shall not be done prior to the completion of backfilling to the original ground surface of the trench on the upstream side of such traffic way in order to prevent the impounding of water at any point after the water main has been laid, and all necessary bridges and other temporary structures required to maintain traffic across such unfilled trenches shall be constructed and maintained. Backfilling shall be done in such a manner that water will not accumulate in unfilled or partially filled trenches. All material deposited in roadway ditches or other water courses shall be removed immediately after pipe placement is completed and the section, grades and contours of such ditches or water courses restored to their original condition, in order that surface drainage will not be obstructed. Where trenches are constructed in or across roadway ditches or other water courses, the backfill shall be protected from surface erosion by adequate means.

14. PROTECTION OF TREES AND SHRUBBERY: No trees shall be removed on the right-of-way except where their removal is shown on the Plans or is authorized by the Owner.

Main tree roots shall not be cut except where they fall within the area to be occupied by the water main. Excavation may be done by hand where necessary to prevent injury to roots or trees. Trees which are left standing shall be adequately protected from permanent damage by reason of construction operations. Trimming of standing trees where required shall be subject to approval by the Engineer. All shrubbery outside of the right-of-way which is damaged or removed by the Contractor shall be replaced under the direction of and to the satisfaction of the Owner, by and at the expense of the Contractor.

15. BORE AND BORE WITH ENCASEMENT: Water mains constructed under existing State Highways and major streets at specific locations as designated on the Plans shall be bored and/or installed inside of pipe encasements which shall be placed by directional boring, or a combination of boring and jacking. if required, the pipe encasements shall be of the size and length as indicated on the Plans and installed accurately to line and grade, and the minimum cover specified on the Plans shall be maintained. Working pits shall be excavated at each end of the encasement pipe and the open face adjacent to the roadway shall be adequately shored to prevent slipping or raveling of the embankment.

After installation of the pipe encasement, the water main shall be properly aligned, graded and installed, with the pipe supports and spacers if indicated on the Plans.

Installation of the water main in the pipe encasement and material for the pipe encasements shall meet the requirements specified in the SECTION: WATER LINE CONSTRUCTION.

16. INTERRUPTION OF TRAFFIC: It shall be understood that no interruption of traffic will be permitted at the locations where water lines are installed in an encasement pipe and bored. Work pits for the steel pipe encasement shall be positioned so as not to interrupt traffic during their excavation or while these pits are open for construction purposes.

End of Section 02220

WATER PIPING
PART 1 – GENERAL

1.01 SCOPE OF WORK

A. This work shall consist of the construction, installation and testing of water line improvements, water transmission piping and all other appurtenances as are necessary to complete the work in accordance with the Drawings and the specifications.

1.02 SECTION INCLUDES

A. Water distribution and transmission piping, fittings and accessories
B. Execution

1.03 RELATED WORK

A. Section 02530 C900 Restrained-Joint PVC Pipe
B. Section 02220 Excavating, Trenching and Backfilling for Utilities

PART 2 – PRODUCTS

2.01 PIPE MATERIALS

A. Carbon Steel Pipe and Fittings
1. Carbon steel pipe and fittings shall conform to AWWA C200 Steel Water Pipe.
2. Dimensions for carbon steel fittings shall conform to AWWA C110, unless otherwise specified.
3. Wall thickness for carbon steel pipe and fittings shall be specified by Schedule conforming to ANSI B36.10-1985.
4. All butt welds shall be fully penetrated with gas shielding to the interior and exterior of the joint.
5. Welded cross-sections shall have a thickness equal to or greater than the welded material.
6. All welded joints shall be free of sharp edges and burrs.
7. Vertical Pipe Supports (Non-Adjustable)
    a. Non-adjustable vertical pipe supports consist of a piece of 3/8” thick flat steel to be welded between the riser and tank shell. Alternatively, two carbon steel angle irons welded between the vertical riser and the tank shell.
    b. The angle irons shall be field cut and welded in place at 45 ° angles on each side of the vertical pipe centerline. The included angle between the angle irons shall be 90 °.

c. The location of the pipe supports (flat steel or angle irons) shall avoid welded joints in the tank shell.

8. Linings and Coatings

All exposed steel pipe and fittings repairs shall be exterior coated with Tnemec Series coatings as specified below or with an approved equal.

a. Primer: 94-H2O Hyrdozinc
b. First Coat: N140-1255 Beige Pota-Pox
c. Finish Coat: N140-15BL Pota-Pox

Pipe support welds on the tank shell shall be cleaned and coated with the coatings shown above.

B. Polyvinyl Chloride (PVC) C-900 Pressure Pipe and Fittings

1. PVC piping shall have ductile iron pipe (DIP) outside diameter. This pipe is intended for use in pressure-rated potable water delivery systems.

2. The materials of the pipe shall be uniformly blended with unplasticized polyvinyl chloride. Nothing used in its manufacture shall be injurious to humans or animals, nor shall it impart taste or odor to domestic water or in any manner alter the chemical content of waters flowing through the pipe. It shall consist of all new materials, and the manufacturer shall furnish a sworn statement that no reused materials were used in the manufacture of the pipe or fittings. All pipes shall have superior high tensile strength. Pipe shall conform to all requirements of commercial standards, ANSI, and the following minimum pressure class or *as specified in the Drawings:*

a. AWWA C-900, Class 165, DR 25

b. AWWA C-905, Class 235, DR 18

c. AWWA C-905, Class 305, DR 14

3. All plastic pipe shall be approved by and bear the National Sanitation Foundation seal of approval and will comply with the requirements for Class 1245-A or Class 1245-B virgin components as defined in ASTM D1784 with an estimated hydrostatic design basis (HDB) rating of 4000 psi (27.58 Mpa) for liquid at 73.40F (230C). Pipe and fittings with elastomeric seal joints shall meet the requirements of ASTM D3139.

4. Joints

   a. Shall be push-on type with integral bell and spigot and elastomeric gaskets meeting the requirements of ASTM D-2122. Rubber gasket rings shall be neoprene or other synthetic material and conform to ASTM F-477. Natural rubber gaskets will not be acceptable.

   b. The gasketed joint shall meet the laboratory performance requirements specified in ASTM D3139 to verify a leak-free design of the joint.

5. Fittings

   a. Fittings shall be ductile iron and shall conform to ANSI/AWWA C11O/A21.10 or ANSI/AWWA C153/A21.53-88.

   b. Standard joint restraint for fittings shall have thrust blocking as per the standard details provided in the Drawings.

   c. When specified in the Drawings or Approved by the Engineer, joint restraint shall be provided by restrained mechanical joints or be a restrained fitting in lieu of concrete thrust blocks.

   d. Provide all specials, taps, and plugs as specified or indicated.

6. Gaskets and Bolting Material

   a. Rubber gasket rings shall be neoprene or other synthetic material and conform to ASTM F-477. Natural rubber gaskets will not be acceptable.

   b. Gaskets shall be part of a complete pipe section and purchased as such.

   c. Provide all gaskets, bolts, lubricants, and other accessories required to install pipe and fittings complete and ready for service.

   d. Bolts for flanged joints shall conform to ASTM A307 Grade B.

2.02 RESTRAINED JOINT PVC

A. When specified in the Drawings restrained joint PVC materials shall be as specified in Section 02530 C900 Restrained-Joint PVC pipe.

2.04 PIPE ACCESSORIES

A. Mechanical Couplings: Mechanical Couplings shall be gasketed, sleeve-type, sized to properly fit the pipes to be joined, with steel or ductile iron middle ring, steel or ductile iron follower rings, and synthetic rubber gaskets. All ferrous metal surfaces shall be shop coated with an epoxy coating for corrosion resistance. All hardware shall be 300 series stainless steel. Mechanical couplings shall be Ford Meter Box Style FC3, FC4 or FC23, Dresser Style 38 or 162 or approved equal.

B. Pipe Insulation: Insulation shall be Manville Micro-Lok with AP-T jacket, or equal. Metal jacketing shall be 0.016-inch aluminum with continuous moisture barrier and smooth finish. Insulation shall have composite (insulation, facing and adhesive used to adhere the facing or jacket to the insulation) fire and smoke hazard ratings not to exceed flame spread 25 and smoke developed 50, as tested by procedure ASTM E 84, NFPA 255 and UL 723. Accessories, such as adhesives, mastics, cements, tapes and fiberglass inserts for the fittings shall have the same component rating as listed above. All products, or their shipping cartons, shall bear a label indicating that flame and smoke ratings do not exceed the above requirements. Treatment to facings shall be permanently fire and smoke resistant. Chemicals used for treatment shall be unaffected by water and humidity. Certification in writing shall be provided, prior to installation, that all products meet the above criteria.

C. Buried Utility Warning and Identification Tape: Warning Tape shall be detectable aluminum foil plastic backed tape or detectable magnetic plastic tape manufactured specifically for warning and identification of buried piping. Tape shall be detectable by an electronic detection instrument. Tape shall be 6" wide and colored per industry standard with warning and identification imprinted in big black letters continuously and repeatedly over entire tape length. Warning and identification shall denote the proposed utility and read "CAUTION BURIED WATER PIPING BELOW" or similar wording. Use permanent code and letter coloring unaffected by moisture and other substances contained in trench backfill material.

2.06 BACKFILL

A. Backfill materials shall be as specified in Section 02220 Excavating, Trenching, and Backfilling for Utilities.

2.07 VALVES

A. Water main gate valves shall conform to AWWA C500 as modified herein. All gate valves shall be resilient seat, non-rising stem type with O-ring stem seals. All gate valves shall have Stainless Steel grade 304, or greater, packing bolts, bonnet bolts, nuts, washers, etc. Gate valves shall be open left. Gate valves shall be American Flow Control Series 2500 or approved equal.

SECTION 3 – EXECUTION

3.01 EXAMINATION

A. Verify that existing conditions are as shown on the Drawings.

3.02 PREPARATION

A. The Contractor shall verify the location and depth of all utilities a minimum of 24 hours prior to construction. The Contractor may utilize the toll free number for the "Kansas One Call System, Inc." at 1-800-344-7233. This number is applicable anywhere within the state of Kansas. Prior to commencement of work, the Contractor shall notify all those companies which have facilities in the vicinity of the construction.

3.03 PROTECTION

A. Locate, identify, and protect utilities that are not to be removed or replaced from damage. The Contractor shall make every reasonable effort to protect all existing utilities from damage. If any utility is damaged through the carelessness or neglectful actions of the Contractor, the utility shall be repaired by its owner at the Contractor's expense.

B. Any private facilities damaged or disturbed by the Contractor's work shall be repaired by the Contractor prior to close of the working day. Repairs shall be made in a manner sufficient to restore utility service to that property.

C. Protect trees, plant growth, and features designated to remain as final landscaping.

D. Protect all property or lot corner pins and stakes from damage or displacement. All property pins removed or damaged are to be reset by a Registered Land Surveyor at the Contractor's expense.

E. Protect from damage or displacement all project benchmarks and existing structures within or adjacent to the construction limits that are not to be removed or demolished.

3.04 SEPARATION OF WATER AND SEWER UTILITIES

A. Gravity Sewer Lines Laid Parallel to Water Lines: When potable water pipes and gravity sewers are laid parallel to each other, the horizontal distance between them shall be not less than 10 feet (3.0 m). The distance shall be measured from edge to edge. The laying of water pipes and sanitary sewers shall be in separate trenches with undisturbed earth between them. In cases where it is not practical to maintain a 10 foot (3.0 m) separation, the engineer will consult with KDHE to consider equivalent protection by other methods.

B. Gravity Sewer Lines Crossing Water Lines: When a water pipe and a sanitary sewer cross and the sewer is 2 feet (0.6 m) or more (clear space) below the water pipe, no special requirements or limitations are provided herein. At all other crossings, the Engineer will consult with KDHE to consider equivalent protection by other methods.

C. Pressure Sewer Lines: When sewer force mains run parallel to water lines, the separation distance shall be as far as practical, but at least a 10 foot (3.0 m) horizontal separation shall be maintained. There shall be at least a 2 foot (0.6m) vertical separation at crossings with water main crossing above the sewer force main. In cases where it is not practical to maintain the required vertical or horizontal separation distance between a water line and a sanitary sewer force main, the Engineer will consult with KDHE to consider equivalent protection by other methods.

D. Sewer Connections: There are to be no physical connections between any parts of the potable water system with building sewers, sanitary sewers, or wastewater treatment facilities by means of which it would be possible for sewage, even under exceptional circumstances, to reach the wells, storage reservoirs, or distribution systems.

E. Sewer Manholes: No water pipe shall pass through or come in contact with any part of a sewer manhole.

F. Storm Sewers: The separation distance between a storm sewer (which is not a combined storm/sanitary sewer) and a water main should be based on geotechnical considerations. Required separation distances between water mains and combined storm/sanitary sewers are equivalent to those for water mains and gravity sanitary sewers.

G. Drains: Underground drains from fire hydrants or valve pits should not be directly connected to sanitary or storm drains.

H. Other Pollution Sources: It is of the utmost importance that potable water lines be protected from any source of pollution. The following shall pertain to instances where septic tanks, absorption fields, waste stabilization ponds, feedlots, or other sources of pollution are encountered.

1. A minimum distance of 25 feet shall be maintained between all potable water lines and all septic tanks or waste stabilization ponds.

2. Under no circumstances shall a water line extend through a septic tank absorption field or feedlot. All water lines shall be located a minimum of 25 feet from the furthest known extent of any sewage contamination. Under no condition will it be considered that encasement of the water main through an area of real or potential pollution would provide the protection needed to the water supply.

3.05 EMBEDMENT

A. Trenching and backfilling shall be performed in accordance with Section 02220 Excavating, Trenching, and Backfilling for Utilities. Blasting will not be allowed unless approval by the Owner and Engineer is given.

B. Granular Bedding: Bottom of trench shall be over excavated and the pipe shall be bedded with compacted granular material placed on a flat trench bottom and extending to an elevation 6" to 12" inches above the top of the pipe. The granular bedding shall have a minimum thickness of 4 inches under the barrel. Embedment over rock shall include an additional 2 inches below the pipe.

C. Place embedment material at the trench bottom with proper allowance for bell joints. Level materials in continuous layers not exceeding 4 inches in compacted depth. Shovel slicing of embedment shall be performed along the sides of the pipe as embedment is placed to consolidate the bedding and haunching below the pipe.

D. Consolidate granular embedment by rodding, spading and compacting as necessary to provide uniform pipe support.

E. Each lift of granular embedment material shall be compacted to a minimum 90% of maximum density as determined by ASTM D-698.

F. Low permeability Trench Plugs shall be installed at 400' intervals along the waterline trench to prevent water leak migration.

G. Where shown on the Drawings, concrete encasement shall be provided instead of pipe embedment.

3.06 PIPE INSTALLATION

A. All pipes shall be protected during transport, storage and installation from shock and free fall. Pipes shall be installed without cracking, chipping, breaking, bending or damaging the materials. Damaged pipe shall be replaced with new materials except when repairs are permitted by the Engineer. Use slings, lifting lugs, hooks and other protection devices during handling. A double sling shall be required when handling plastic pipe 10 feet or longer.

B. Install pipe of the size, material, strength class, and joint type as specified or indicated on the Drawings. Clean the interior of all pipe fittings and joints prior to installation.

C. Install water pipelines with the bell ends facing the direction of laying, except when reverse laying is specifically authorized by the Engineer.

D. Laying of Pipe: All pipes shall be laid true to the alignment and grade indicated on the Drawings as staked by the Contractor. Laser Beam equipment is preferred for construction with checks on grade by survey equipment, when required. Each pipe section shall be carefully inspected before it is laid and any section not conforming in all respects to the specifications shall be rejected. Any defective pipe inadvertently laid, shall on discovery at any time, be immediately removed and replaced at the Contractor's expense.

E. Pipe installation shall be in accordance with applicable standards, such as ANSI/AWWA C600 and ANSI/AWWA C605, except where conflicts with this section occur, in which case this section shall govern.

F. Clean the interior of all pipe fittings and joints prior to installation. Protect pipe against the entrance of debris and foreign matter during discontinuance of installation and at the close of the working day by installing a close fitting plug at the open end. Plugs shall be water tight against heads up to 20 feet of water.

G. The Contractor shall take whatever means necessary to keep the trenches free of water and as dry as possible during pipe installation, bedding and jointing operations. No pipe shall be laid in water or under unsuitable trench conditions. Should unsuitable trench conditions be encountered, the Contractor shall halt work until the Engineer approves continuation of the work or alternate methods for continuation of the work.

H. Dewatering of Trench and Other Excavations: The Contractor shall provide and maintain adequate dewatering equipment to remove and dispose of all surface and ground water entering excavation, trenches and all other parts of the work. Each excavation shall be kept dry during subgrade preparation and continually thereafter until the structure is to be built, or the pipeline to be installed is completed to the extent that no damage from hydrostatic pressure, flotation or other causes will result. Water main in place shall not be used as drainage lines.

I. After each pipe has been brought to grade, aligned and placed in final position, place sufficient embedment material under the haunches and on each side of the pipe to hold the pipe in proper position during subsequent pipe jointing, bedding and backfilling operations. Compact embedment material to 90 percent maximum density by rodding, spading, or using suitable compaction equipment. Place embedment material uniformly and simultaneously on each side of the pipe to prevent lateral displacement.

J. Pipe cutting shall be performed in a neat and workmanlike manner without damage to the pipe. Main taps for service saddles shall be made with a tapping tool specifically designed for that purpose. Cut edges shall be smoothed by power grinding to remove burrs and shape edges.

3.07 PIPE JOINTING

A. Locate joints to provide for differential movement at changes in type of embedment, concrete collars and encasement and structures. Water main jointing shall be according to the following specifications:

1. Clean and lubricate all joint and gasket surfaces as recommended by the manufacturer.

2. Examine all materials prior to installation for soundness and compliance with specifications.

3. Check joint position and condition after assembly prior to installing additional pipe sections.

4. Check joint opening and deflection for specification limits.

B. Threaded: Pipe threads shall conform to ANSI/ASME B1.20.1, NPT, and shall be full and cleanly cut with sharp dies. Not more than three threads at each pipe connection shall remain exposed after installation. Ends of pipe shall be reamed, after threading and before assembly, to remove all burrs.

1. Threaded joints, in plastic piping, shall be made up with Teflon thread tape applied to all male threads. At the option of the Contractor, threaded joints in other piping may be made up with Teflon thread tape, thread sealer or a suitable joint compound.

C. Flanged: Flange bolts shall be tightened sufficiently to slightly compress the gasket and affect a seal, but not so tight as to fracture to distort the flanges. Anti-seize thread lubricant shall be applied to the threaded portion of all bolts during assembly. Connecting flanges shall have similar facings, i.e., flat or raised face.

D. Push-on: Gasket installation and other jointing operations shall be in accordance with the recommendations of the manufacturer. Each spigot end shall be suitably beveled to facilitate assembly. All joint surfaces shall be lubricated with a material that meets manufacturer requirements and conforms to NSF 61 immediately before the joint is completed. The interior surface of the bell and the exterior surface of the spigot shall be free of dust, dirt, gravel and other foreign material, both before and after the application of the lubricant sealer. The joint shall be connected by first brushing upon the matting surface the proper lubricant sealer as recommended by the pipe manufacturer, the spigot end shall then be centered on grade into the bell end of the last downstream pipe length and shoved home and properly seated.

3.08 JOINT RESTRAINT FOR WATER MAIN

A. Joint restraint shall be provided for pressure piping. Joint restraint may be provided by concrete thrust blocking or by mechanically restrained joints as detailed in the Drawings.

3.09 ASSOCIATED WATER MAIN WORK

A. Sheeting and Bracing or Trench Boxes shall be provided in all trenches where required to insure maximum safety of workman. Sheeting may be wood or metal. Sheeting shall be driven to a depth of at least two feet below the pipe. Following installation of the pipe and backfill to at least two feet over the pipe, shoring shall be removed as backfilling procedures progress, but only when banks are stable and safe from caving or collapse. With Engineers approval, wooden sheeting shall be cut off at least two feet below ground level and the remainder left in place.

3.12 DISINFECTION

A. Before being placed in service, all new potable water mains, including fittings, valves and service lines, shall be chlorinated using a method specified in AWWA C651 or as specified in Appendix D of KDHE's Policies, General Considerations and Design Requirements for Public Water Supply systems in Kansas. The Owner or Engineer shall approve the procedure in advance.

B. Before being placed in service, the standpipe shall be disinfected using Method 2 as specified in AWWA C652.

SECTION 02530
C900 RESTRAINED-JOINT PVC PIPE

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. This Specification covers thrust-restrained Polyvinyl Chloride (PVC) Pipe with Ductile Iron Pipe (D.l.P.) outside diameters. This pipe is intended for use in pressure-rated potable water delivery systems.

1.02 RELATED WORK

A. Section 02510 Water Distribution Piping

1.03 REFERENCE DOCUMENTS

A. American Society for Testing and Materials (ASTM).

1. ASTM D1784, Standard Specification for Rigid PVC Compounds and Chlorinated PVC Compounds

2. ASTM D2837, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials

3. ASTM D3139, Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

4. ASTM F477, Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

B. American Water Works Association (AWWA).

1. AWWA C900, Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4" through 12" for water distribution.

2. NSF14 - Plastic Piping System Components and Related Materials.

C. National Sanitation Foundation (NSF).

1. NSF61 - Drinking Water System Components-Health Effects.

PART 2 PRODUCTS

2.01 GENERAL

A. Products delivered under this specification shall be manufactured only from water distribution pipe and couplings conforming to AWWA C900. The restrained joint pipe system shall also meet all short and long term pressure test requirements of AWWA C900. Pipe, couplings, and locking splines shall be completely nonmetallic to eliminate corrosion problems.

2.02 MATERIALS

A. Pipe and couplings shall be made from unplasticized PVC compounds having a minimum cell classification of 12454-B, as defined in ASTM D1784. The compound shall qualify for a Hydrostatic Design Basis (HDB) of 4000 psi for water at 73.40F, in accordance with the requirements of ASTM D2837.

2.03 APPROVALS

A. Restrained joint PVC pipe products shall have been tested and approved by Underwriters Laboratories and Factory Mutual Research for continuous use at rate pressures as follows:

1. DR18 (235 psi)

2. DR14 (305 psi)

B. Copies of agency approval reports or product listings shall be provided to the Engineer. Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with NSF 61 by an acceptable certifying organization.

2.04 DIMENSIONS

A. Nominal outside diameters and wall thicknesses of thrust-restrained pipe shall conform to the requirements of AWWA C900. Thrust-restrained pipe shall be furnished in 4", 6", 8", 10" and 12" sizes, Class 235 (DR18) and Class 305 (DR14). Pipe shall be furnished in standard lengths of 20 feet.

2.05 JOINTS

A. Pipe shall be joined using non-metallic couplings to form an integral system for maximum reliability and interchangeability. High-strength, flexible thermoplastic splines shall be inserted into mating, precision-machined grooves in the pipe and coupling to provide full 360 restraint with evenly distributed loading.

B. Couplings shall be designed for use at or above the rated pressures of the pipe with which they are utilized, and shall incorporate twin elastomeric sealing gaskets meeting the requirements of ASTM F477. Joints shall be designed to meet the leakage test requirements of ASTM D3139.

PART 3 EXECUTION

3.01 WORKMANSHIP

A. Pipe and couplings shall be homogeneous throughout and free from voids, cracks, inclusions and other defects, and shall be as uniform as commercially practicable in color, density and other physical characteristics.

3.02 QUALITY CONTROL

A. Every pipe and machined coupling shall pass the AWWA C900 hydrostatic proof test requirement of 4 times the pressure class for 5 seconds.

3.03 MARKING

A. Pipe and couplings shall be legibly and permanently marked in ink with the following minimum information:

1. Nominal size (for example, 4 In.)
2. PVC
3. Dimension Ratio (for example, DR18)
4. AWWA Pressure Class (for example Class 235)
5. Manufacturer's name or trademark and production record code.
6. Seal (mark) of the testing agency verifying the suitability of the pipe material for potable water service.
7. Seal (mark) of the certifying agencies which have tested and approved the pipe for us in fire protection systems.

3.04 APPROVED MANUFACTURERS

A. C900/RJTM PVC restrained-joint pipe from CertainTeed Corporation or approved equal.

END OF SECTION

APPENDIX D

PROCEDURES FOR THE DISINFECTION OF WATER MAINS

All new or repaired potable water lines in a public water supply system must be disinfected with free chlorine before they are put into service (KAR 28-15-18(d)). These disinfection procedures are based on the AWWA Standard for Disinfecting Water Mains, AWWA C651. The most recent revision of the standard shall apply. A copy of the complete standard is available for review at the KDHE office, Curtis State Office Building, 1000 Jackson St., Suite 420, Topeka, KS. A copy of the standard may be obtained from the American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado, 80235.

NON-EMERGENCY PROCEDURES FOR THE DISINFECTION OF WATER MAINS

There are five basic steps for the non-emergency disinfection of water mains. The first step is to protect the water main's sanitary condition. It is always best to prevent the introduction of contaminated material into water main pipe, especially during its installation. However, whenever this is not possible, any contamination that does occur must be either flushed from the water main or removed by other more direct methods prior to disinfection. When the water main has been adequately cleared, it may then be disinfected by either the tablet, continuous or slug method of disinfection. These methods disinfect by maintaining a minimum period of contact between the water main and the disinfecting solution prepared and delivered as prescribed below for each method. In addition, each method requires flushing of the heavily chlorinated disinfecting solution followed by its proper disposal in a manner that does not adversely impact the environment. The final step consists of collecting samples from the water main for bacteriological testing as a means to confirm the effectiveness of the disinfection procedure. While this method of confirmation is not required, KDHE strongly recommends that this final step be completed.

Step 1: Preventative Measures During Construction

During construction, the interior as well as all sealing surfaces of pipes, fittings, and accessories should be kept clean as possible. Inspect the interior of all pipes prior to installation. If dirt enters the pipe, it should be removed and the affected interior of the pipe swabbed with a 1 percent free available chlorine solution. All openings in pipelines should be closed with watertight plugs whenever the trench is unattended. Sealing, lubricating, or gasket materials used in pipe installation should be stored and handled in a manner that avoids contamination and keeps them suitable for use with potable water.

Step 2: Preliminary Flushing of Mains

Before being chlorinated, the main should be completely filled with water to eliminate air pockets and then flushed to purge the line of dirt and debris. This is typically done after the completion of the leakage and pressure tests. Incomplete removal of dirt and debris from lines prior to disinfection often leads to failed bacteriological tests, requiring repeated disinfection. Preliminary flushing should be accomplished at a rate of at least 2.5 ft/sec. Fittings and valves should be thoroughly cleaned before applying chlorine to a main. Special attention should be given to mechanical joints, fittings, and valves that may contain spaces that are difficult to chlorinate once they become filled with water.

Table 1 shows the required flow rate to obtain a velocity of 2.5 ft/sec in commonly used sizes of pipe. Flushing can be enhanced by the use of soft pigs to remove dirt, debris, and air from the main prior to disinfection. The use of pigs can also conserve water and is particularly useful when there is insufficient water supply to attain a 2.5 ft/sec minimum flushing velocity.

TABLE 1 - FLOWS REQUIRED FOR VARIOUS FLUSHING VELOCITIES

Pipe Size (in)	Pipe Area (sq ft)	Flow Required (gpm) for Given Velocity		
		1 ft/sec	2.5 ft/sec	5 ft/sec
2	0.02	10	25	50
4	0.09	40	100	200
6	0.20	90	220	440
8	0.35	155	390	780
10	0.55	245	610	1,220
12	0.79	350	880	1,760
14	1.07	480	1,200	1,400
16	1.40	625	1,570	3,140

Preliminary flushing, however, should not be conducted if tablets or granules of calcium hypochlorite have been placed in the pipe during installation. In this case, special care must be exercised in ensuring that the main does not become contaminated with dirt or other materials during construction.

Step 3: Chlorination of Mains

Disinfection of mains should be done only by crews who have had experience with chlorinating agents, who are aware of the potential health hazards associated with these chemicals, and who are trained to carefully observe proper construction and disinfection practices.

Chemical Forms of Chlorine

Chlorine is generally available in three chemical forms: gaseous (elemental) chlorine (shipped as a liquefied gas); in solution (sodium hypochlorite); and as a solid (calcium hypochlorite tablets or granules). The gaseous form may only be applied with feed systems that operate under vacuum, the solution form is generally diluted, and the solid form must be dissolved.

A. Gaseous Chlorine

Gaseous chlorine is generated from the controlled vaporization of liquid chlorine supplied in 100 or 150-lb steel cylinders through a vacuum-operated chlorinator with a booster pump. The vacuum-operated chlorinator injects chlorine gas into water to form a solution; the booster pump introduces the solution into the main to be disinfected. Direct-feed chlorinators, which operate solely from gas pressure in the chlorine cylinder, are not approved for use due to the danger of chlorine release. Gaseous chlorine application should only be conducted under the direct supervision of a trained operator and in accordance with the safety standards and practices described in Chapter IX of KDHE's "Policies, General Considerations and Design Requirements for Public Water Supply Systems in Kansas."

B. Sodium Hypochlorite

Sodium hypochlorite is available as a liquid in 1 quart to 5 gallon containers and contains approximately 5 to 15 percent available chlorine. ANSI/NSF 60 certified household bleaches typically contain approximately 5.25 percent available chlorine. The availability of household bleaches having NSF International's ANSI/NSF 60 certification varies from market to market. Special precautions must be taken to minimize deterioration of sodium hypochlorite solutions in storage.

C. Calcium Hypochlorite (HTH)

Calcium hypochlorite (HTH) is available in granular and tablet forms typically containing approximately 65 percent available chlorine. The granules dissolve readily in water; however, the tablets can be more difficult to dissolve. In contrast to sodium hypochlorite, calcium hypochlorite can be stored for extended periods of time without significant deterioration. Contact with organic material or high temperatures must be avoided due to the danger of fire or explosion.

Methods of Chlorination

AWWA Standard C651 provides for three methods of chlorination for water mains: tablet, continuous, and slug. The chlorine dose and minimum contact time for each AWWA method are summarized in Table 2. Recommendations for disinfection of small sections of mains under emergency repair are also included in Table 2. Methods for measurement of free chlorine residual are summarized in Attachment A. Before any disinfection method is utilized, valves must be positioned so that the highly chlorinated water in the main being treated does not flow into water mains that are in active service.

TABLE 2 - CHLORINATION METHODS FOR DISINFECTING WATER MAINS

Chlorination Method Used	Initial Chlorine Dose (mg/L)	Minimum Contact Time (hours)	Minimum Chlorine Resid. (mg/L)
Nonemergency Procedures			
Tablet	25	24	10
Continuous	25	24	10
Slug	100	3	50
Emergency Procedures			
Premixed Solution or Hypochlorite Injection	300	0.25	100
Swabbing	10,000 (1% sol)	---	Swab throughly the interior of pipes and fittings used in repairs.

Factors to consider when choosing a method of chlorination include length and diameter of the main, types of joints present, equipment and materials necessary for disinfection, skills and training of personnel, safety concerns, and if the main must be quickly put into service. The continuous and slug methods require the use of appropriate chlorine feed equipment and the determination of the necessary chlorine feed rate for the chlorine solution. In long, large-diameter mains, the slug method has the potential for reducing the volume of water and amount of chemicals needed as compared to the continuous method.

The tablet method is convenient to use for mains with diameters less than 24 inches and does not require special chlorine feed equipment. There are, however, important limitations with this method. The tablet method precludes preliminary flushing which is often necessary to remove dirt and debris and assist in the removal of air from the lines. Calcium hypochlorite granules or tablets may be dislodged from the lines during filling and accumulate at points of restriction leaving portions of the line without disinfectant. The tablet method should not be used in large diameter mains, where a worker might enter the main for inspection, due to the potential for tablets to release toxic fumes.

A. Tablet Method

The tablet method consists of pre-placing calcium hypochlorite granules or tablets in the main during pipe installation in sufficient amounts so as to obtain a 25 mg/L available chlorine dose. For calcium hypochlorite granules, they should be placed at the upstream end of the first section of pipe, at the upstream end of each branch main, and at 500 ft.

intervals. Additionally, one tablet should be placed in each hydrant, hydrant branch, and other appurtenances. For 65 percent available chlorine, the quantities of granules necessary for a 25 mg/L chlorine dose are listed in Table 3 as a function of pipe diameter.

TABLE 3 - AMOUNTS OF CALCIUM HYPOCHLORITE GRANULES TO BE PLACED AT 500-ft INTERVALS FOR 25 mg/L FREE CHLORINE DOSE

Pipe Diameter	Calcium Hypochlorite Granules (65% available)	
(in)	(ounces)	(grams)
2	0.4	12
4	1.7	47
6	3.8	107
8	6.7	190
10	10.5	297
12	15.1	427
16	26.8	760

Adapted from AWWA Standard C651-05

Calcium hypochlorite granules should not be placed in the pipe so as to come in contact with exposed joint compounds, such as those used on solvent-welded plastic pipe, because of the danger of fire or explosion from the reaction of the joint compound with the calcium hypochlorite.

Instead of granules, calcium hypochlorite 5-g tablets can be attached with a food-grade adhesive to the top inside surface of each section of the main's pipe. Table 4 shows the number of 5-g tablets required for commonly used pipe sizes.

After installation is complete, the main should be filled with potable water at a velocity no greater than 1 ft/sec (See Table 1 for flow rates corresponding to 1 ft/sec velocity for standard pipe sizes.). The chlorinated water must be maintained in the main for at least 24 hours. If the water temperature is less than 41 °F (5 °C), the water should remain in the pipe for at least 48 hours. At the end of the minimum contact period, the treated water in all portions of the main must have a residual of not less than 10 mg/L free chlorine as confirmed by measurement of the chlorine residual. Methods utilized to measure free chlorine residual are discussed in Attachment A.

TABLE 4 - NUMBER OF 5-g CALCIUM HYPOCHLORITE TABLETS REQUIRED FOR DOSE OF 25 mg/L*

Pipe Diameter (in)	Length of Pipe Section, ft: 13 or less	18	20	30	40
	Number of 5-g Calcium Hypochlorite Tablets				
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1	2	2
8	1	2	2	3	4
10	2	3	3	4	5
12	3	4	4	6	7
16	4	6	7	10	13

*Based on 3.25-g available chlorine per tablet; any portion of tablet rounded to the next highest interger. (Adapted from AWWA Standard C651-05)

B. Continuous Method

Though this method is referred to as "continuous," it does not require continuous feeding of chlorine into the main over a 24 hour period. The key feature is that the main is "continuously" in contact with at least 10 mg/L free chlorine concentration over 24 hours with an initial dose of 25 mg/L. Two procedures will be outlined below.

Procedure 1: Addition of Pre-mixed Chlorinated Water

In this procedure, hypochlorite is added to potable water in a tanker truck or other large container in sufficient volume to completely fill the main with a chlorine residual of 25 mg/L. The chlorinated water from the tanker truck or large container is then pumped into the main until full as indicated by a discharge through a terminal outlet such as a hydrant. The addition of premixed chlorinated water to the main does not require the feeding of a concentrated chlorine solution or the measurement and control of the filling rate and the chlorine solution injection rate.

The minimum amount of calcium hypochlorite (HTH) required for a 25 mg/L chlorine dose can be calculated from the known volume of the main that is to be disinfected:

$$\frac{Vol_{main,}gal * \frac{1\ MG}{1 \times 10^{6} gal} * 8.34 \frac{lb}{gal} * 25 \frac{mg}{L}}{\frac{(\%\ available\ Cl_2)}{100}} = \text{minimum lbs of HTH available} \quad \text{(Eq. 1)}$$

where,

Vol_{main} = volume of main, gal
= length(ft) * π[dia(ft)]^2/4 * 7.48 gal/ft^3

Please note that the units in the above equation (Eq. 1) will correctly cancel provided one recognizes that there are one million mg in one liter (10^6 mg/liter) and that % available Cl_2/100 is equal to lbs of chlorine per lb of HTH (lb Cl_2/lb HTH).

The following equation determines the necessary amount of sodium hypochlorite to achieve a 25 mg/L chlorine dose in a given main:

$$\frac{Vol_{main} * 25 \frac{mg}{L}}{Conc_{soln} \frac{mg}{L}} = Vol_{soln} \quad \text{(Eq. 2)}$$

where,

Vol_{main} = volume of main, gal
$Conc_{soln}$ = concentration of chlorine in sodium hypochlorite solution, mg/L as Cl_2
Vol_{soln} = volume of sodium hypochlorite solution, gal

The quantities of 15 percent available chlorine sodium hypochlorite or 65 percent available chlorine calcium hypochlorite (HTH) required to produce a 25 mg/L concentration in water filling a section of main with a length of 100 ft. in common diameters are shown in Table 5.

Procedure 2: Injection of Concentrated Chlorine Solution

An alternate approach is to inject a concentrated chlorine solution into the main while it is being filled. The contractor or operator maintains a desired water flow rate while filling the main through an inlet valve on a temporary connection to the existing distribution system or other approved source. At a point no more than 10 ft. downstream from the inlet to the main, the concentrated chlorine solution is pumped into the main at a uniform feed rate until the desired chlorine residual (at least 25 mg/L) is measured in the flushed water at the terminal outlet (Figure 1). The main is then shut down and the chlorinated water allowed to stand in the pipe for a 24 hour period. At the end of this time period, the treated water in the main should have a chlorine residual of not less than 10 mg/L free chorine in all portions of the main as confirmed by the measurement of the chlorine residual in samples collected from the main. Methods utilized to measure free chlorine residual are discussed in Attachment A.

TABLE 5 - HYPOCHLORITE REQUIRED TO PRODUCE 25-mg/L DOSE IN 100 ft OF PIPE

		Hypochlorite Solution				Granules
	Total	Percent Available Chlorine				
Pipe Size (in)	Pipe Volume (gal)	1-percent (gal)	5-percent (gal)	10-percent (gal)	15-percent (gal)	65-percent (ounces)
2	16.3	0.041	0.0082	0.0041	0.0027	0.084
4	65.3	0.16	0.033	0.016	0.011	0.34
6	147	0.37	0.073	0.037	0.024	0.75
8	261	0.65	0.13	0.065	0.044	1.3
10	408	1.02	0.20	0.10	0.068	2.1
12	587	1.47	0.29	0.15	0.098	3.0
16	1044	2.61	0.52	0.26	0.17	5.4

Note: 1-percent chlorine solution = 10,000 ppm or mg/L free chlorine.

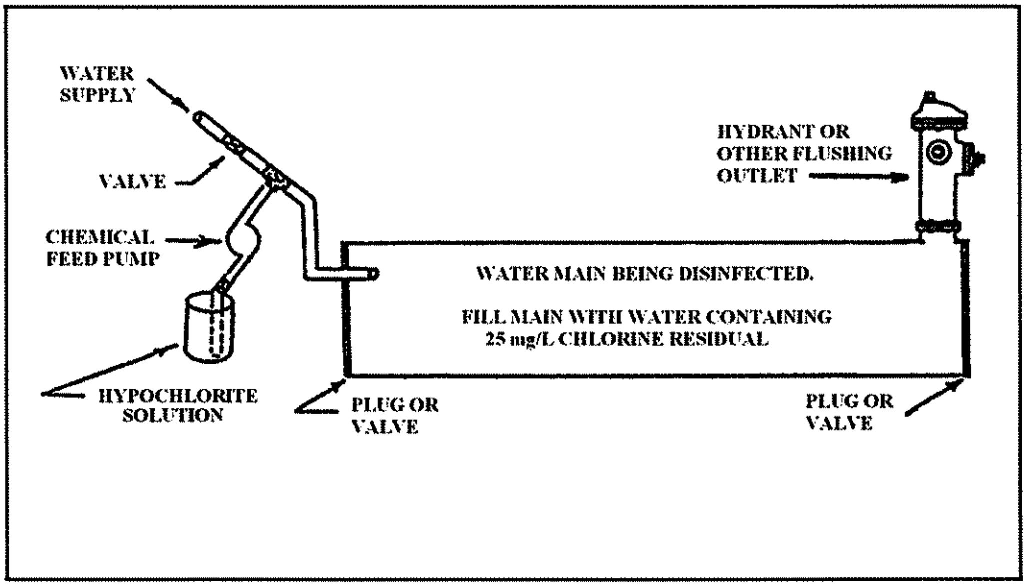

Figure 1 - TYPICAL HYPOCHLORITE INJECTION SYSTEM

The concentrated chlorine solution may be prepared from calcium or sodium hypochlorite and injected into the main with a chemical feed pump designed for chlorine solutions. While this is readily accomplished with sodium hypochlorite because it is purchased as a liquid, calcium hypochlorite in the form of HTH granules or tablets must first be dissolved in water. It is important to remember that the HTH granules or tablets should be added to the correct volume of water in order to adequately disperse the heat generated during dissolution, rather than adding water to the HTH granules or tablets. Feed lines and connections should be of such material and strength as to safely withstand the corrosive effect of the concentrated chlorine solution and the pressure of the pump. The flows of both the water filling the main and the concentrated chlorine solution being injected must be proportioned so that the resulting chlorine concentration in the main is uniform and at least 25 mg/L (Figure 2).

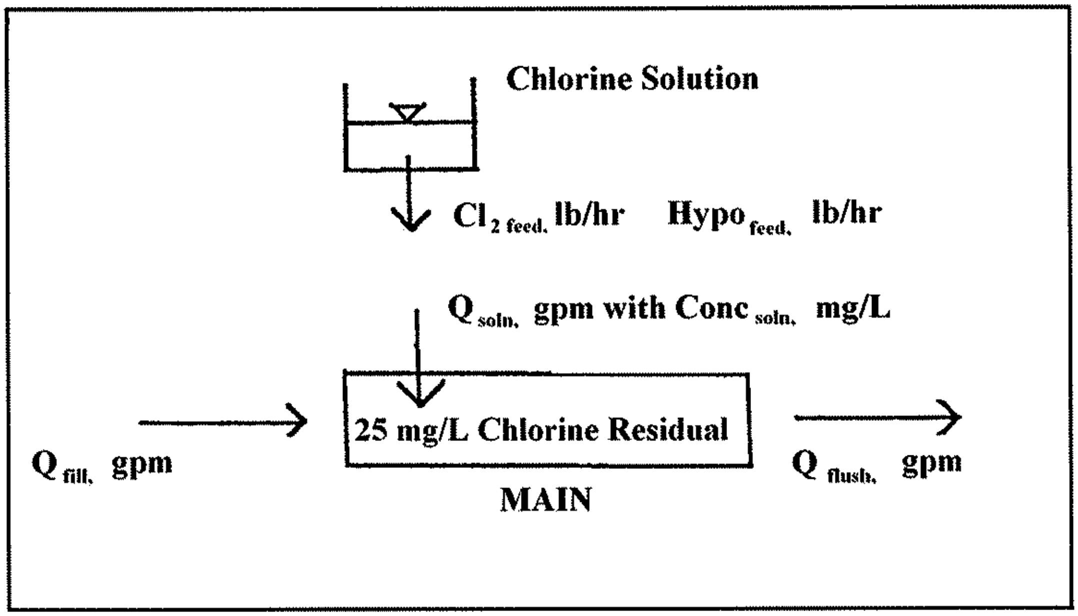

Figure 2 - MASS BALANCE DIAGRAM FOR Cl_2 SOLUTION INJECTION

In most cases, the chlorine solution injection rate, Q_{soln}, will be significantly less than the rate of filling the main, Q_{fill}. When this is true, Q_{fill} may be considered essentially equivalent to the rate of water exiting the main, Q_{flush}. After startup of the chlorine solution injection, the chlorine residual should be checked at the first available outlet, and the hypochlorite injection rate adjusted to obtain a residual of at least 25 mg/L.

This approach, the injection of a concentrated chlorine solution into a flowing main, is consistent with the typical chlorination procedure used by operators in disinfecting a continuous flow of water from a well using a hypochlorite feed system. It does, however, require maintaining a specific main filling rate (or flushing rate from the outlet of the pipe) as well as a uniform chlorine solution injection rate. Flow rates may be difficult to measure accurately under field conditions that typically involve temporary connections. In addition to the use of flow meters, methods for estimating flow rates include measuring the time to fill a container of known volume or measuring the trajectory of the discharge from a hydrant and using the formula in Figure 3 to determine the flow rate.

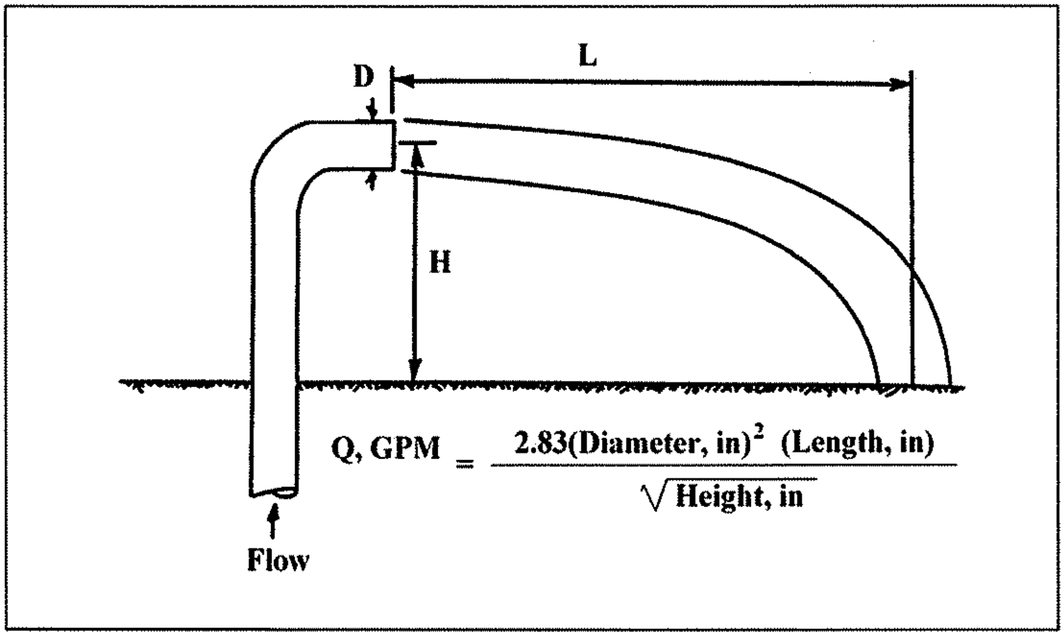

Figure 3 - FORMULA FOR ESTIMATING RATE OF DISCHARGE
Reproduced from *Water Distribution System Operation and Maintenance: A Field Study Training Program*, 5th ed. (2005), with permission. Copyright by the California State University, Sacramento Foundation.

The chlorine feed rate into the main, $Cl_{2\ feed}$, for a 25 mg/L dose (assuming 100 percent available chlorine such as supplied by chlorine gas) may be calculated with the following equation:

$$Q_{fill}, \frac{gal}{min} * 1440\frac{min}{day} * \frac{1\ day}{24\ hr} * \frac{1\ MG}{1 \times 10^6 gal} * 8.34\frac{lb}{gal} * 25\frac{mg}{L} = Cl_{2\ feed}, \frac{lb}{hr} \qquad \text{(Eq. 3)}$$

where,

Q_{fill} = flow rate of water filling main, gpm
$Cl_{2\ feed}$ = chlorine feed rate into main, lbs of Cl_2 as 100% available chlorine /hr

In chlorine feed rate problems, the chlorine solution injection rate, Q_{soln}, and the filling rate of the main, Q_{fill}, are typically assumed and fixed. Where the chlorine solution is applied uniformly to the main while it is filling, the time of filling of the main, T_{fill}, is essentially equivalent to the time of chlorine solution injection, $T_{injection}$:

$$\frac{Vol_{main}, gal}{Q_{fill}, \frac{gal}{min}} = T_{fill}, min = T_{injection}, min \quad \text{(Eq. 4)}$$

where,

Vol_{main} = volume of main, gal
Q_{fill} = main filling rate, gpm
T_{fill} = time to fill main, min
$T_{injection}$ = time of chlorine solution injection, min

The minimum volume of chlorine solution, prepared from either sodium or calcium hypochlorite, may be determined by multiplying the chlorine solution injection rate by the time of chlorine solution injection:

$$Q_{soln}, \frac{gal}{min} * T_{injection}, min = Vol_{soln}, gal \quad \text{(Eq. 5)}$$

where,

Q_{soln} = rate of chlorine solution injection, gpm
$T_{injection}$ = time of chlorine solution injection, min
Vol_{soln} = volume of chlorine solution, gal

Utilization of Calcium Hypochlorite (HTH)

When calcium hypochlorite is utilized to prepare a concentrated chlorine solution for this second procedure, the chlorine solution feed rate, $Cl_{2\ feed}$ (lb/hr) (Eq. 3), can be converted to a calcium hypochlorite feed rate (HTH), HTH_{feed} (lb/hr) by use of the following equation:

$$\frac{Cl_{2\ feed}, \frac{lb}{hr}}{\frac{(\%\ available\ Cl_2)}{100}} = HTH_{feed}, \frac{lb}{hr} \quad \text{(Eq. 6)}$$

The total lbs of calcium hypochlorite required for disinfecting a given main are determined by multiplying HTH_{feed}, (lb/hr) by the injection time, $T_{injection}$, expressed in units of hours or by solving Eq. 1 above:

$$HTH_{feed}, \frac{lb}{hr} * T_{injection}, hr = \text{minimum required HTH, lbs} \quad \text{(Eq.7)}$$

where,

HTH_{feed} = calcium hypochlorite feed rate, lb/hr
$T_{injection}$ = time of chlorine solution injection, hr

The concentration of the chlorine solution, prepared by the addition of the required lbs of HTH to the necessary volume of water, Vol_{soln} (Eq. 5), may be calculated by use of the following equation:

$$\frac{\text{lbs of HTH}}{Vol_{soln}, gal} * \frac{(\%\ \text{available } Cl_2)}{100} * \frac{1 \times 10^6}{1\ MG} * \frac{1\frac{mg}{L}}{8.34\frac{lb}{MG}} = Conc_{soln}, \frac{mg}{L} \quad \text{(Eq. 8)}$$

where,

Vol_{soln} = volume of chlorine solution, gal
$Conc_{soln}$ = chlorine concentration in injected solution, mg/L as Cl_2

Utilization of Sodium Hypochlorite Solution

A concentrated sodium hypochlorite solution may also be utilized for this second procedure. Sodium hypochlorite is available in liquid form as a concentrated chlorine solution expressed typically in percent available chlorine where 1 percent available chlorine is approximately equivalent to 10,000 mg/L chlorine. Strong solutions of sodium hypochlorite, such as 15 percent, may be injected directly into a flowing main with a chemical feed pump without the necessity of dilution. In such cases, the concentration of chlorine in the injected solution is known. For an assumed sodium hypochlorite solution injection rate, Q_{soln}, the filling rate of the main, Q_{fill}, can be determined from the following equation:

$$\frac{Q_{soln} * Conc_{soln}, \frac{mg}{L}}{25\frac{mg}{L}} - Q_{soln} = Q_{fill} \quad \text{(Eq. 9)}$$

where,

Q_{soln} = rate of sodium hypochlorite solution injection, gpm
$Conc_{soln}$ = chlorine concentration in injected solution, mg/L as Cl_2
Q_{fill} = main filling rate, gpm

Table 5 includes the minimum volumes of various sodium hypochlorite solutions (1%, 5%, 10%, and 15%) for direct injection into a 100 ft. main to prepare a 25 mg/L chlorine dose. Eq. 2 above may also be used to calculate the required volume of chlorine solution as sodium hypochlorite for a given Vol_{main}, Q_{fill}, and Q_{soln}. For a given Q_{fill}, Eq. 3 above may be utilized to calculate the necessary chlorine feed rate into the main, which is converted to a sodium hypochlorite feed rate by the following equation:

$$\frac{Cl_{2\,feed}, \frac{lb}{hr}}{\frac{(\%\ available\ Cl_2)}{100}} = Na - hypo_{feed}, \frac{lb}{hr} \qquad \text{(Eq. 10)}$$

where,

$Cl_{2\ feed}$ = chlorine feed rate into main, lbs of Cl_2 as 100% available chlorine /hr
Na-$hypo_{feed}$ = rate of sodium hypochlorite solution injection, lb/hr

If a flow rate in gal/hr is more convenient, then the sodium hypochlorite feed rate can be determined by the following equation:

$$\frac{Cl_{2\,feed}, \frac{lb}{hr}}{\frac{(\%\ available\ Cl_2)}{100} * 8.34\frac{lb}{gal}} = Na - hypo_{feed}, \frac{gal}{hr} \qquad \text{(Eq. 11)}$$

where,

$Cl_{2\ feed}$ = chlorine feed rate into main, lbs of Cl_2 as 100% available chlorine /hr
Na-$hypo_{feed}$ = rate of sodium hypochlorite solution injection, gal/hr

If a sodium hypochlorite solution must be diluted with water to prepare for injection into a main a given volume of a solution having a lower chlorine concentration (e.g., diluting a 15 percent available chlorine solution to form a 5 percent available chlorine solution), then the following equation may be used to determine the volume of concentrated sodium hypochlorite required:

$$\frac{(gal\ dilute\ soln) * (\%\ available\ Cl_2\ dilute\ soln)}{(\%\ available\ Cl_2\ concentrated\ soln)} = gal\ concentrated\ soln \qquad \text{(Eq.12)}$$

C. Slug Method

The slug method consists of the formation of a slug of chlorinated water in the main with a free chlorine concentration of at least 100 mg/L. The slug of highly chlorinated water must flow through the main at a slow enough rate so that all parts of the main and its appurtenances will be exposed to the highly chlorinated water for a period of at least 3 hours. As the slug moves through the main, all valves must be fully operated to ensure complete disinfection. This method would be appropriate for long, large diameter mains where the continuous feed method would be impractical. It could also be used for smaller mains of limited length where the continuous method's requirement of 24 hours of contact time cannot be satisfied. By application of a solution having a higher initial chlorine dose, 100 mg/L, the required minimum contact time may be reduced from 24 hours to 3 hours.

The slug of chlorinated water is typically formed through the application of gaseous chlorine, although hypochlorite solutions, purchased as premixed or mixed on site, could also be employed. For relatively small mains, hypochlorite could be added to potable water in a tanker truck or a large container such that the chlorinated water would have an initial concentration of at least 100 mg/L free chlorine. The chlorinated water from the tanker truck or large container could then be pumped into a section of the main until full as indicated by a discharge from the outlet at the other end of the section of main being repaired.

The free chlorine residual must be regularly measured in the slug during the required minimum 3 hours of contact time. If at any time, the free chlorine residual in the slug drops below 50 mg/L, additional chlorine must be applied to the head of the slug in order to reestablish the level of free chlorine in the slug to be at least 100 mg/L.

Step 4: Final Flushing of Mains

After the appropriate minimum retention period, highly chlorinated water should be flushed from the main until chlorine residual measurements show that the chlorine concentration of the water leaving the repaired section of main is no higher than that generally prevailing in the distribution system. Care must be exercised when disposing of water with excessive chlorine residuals. Chlorine is toxic to fish and other aquatic life. Disposal of chlorinated water into storm sewers without prior neutralization of the chlorine residual should be avoided if residual chlorine will still be present when the water directly or indirectly reaches a stream, river, or lake.

Neutralization of the chlorine residual remaining in the water can be accomplished by application of a de-chlorination chemical to the highly chlorinated water in a temporary retention pond, container, or tanker truck. Typical de-chlorination chemicals employed are sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$), sodium sulfite (Na_2SO_3), and sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$). The amounts of these chemicals required to neutralize various residual chlorine concentrations in 100,000 gallons of water are listed in Table 6. While the application of de-chlorination chemicals to highly chlorinated waters quickly reduces the level of free available chlorine, significant reductions can also be achieved by exposure of these waters to sunlight in open ponds or in containers. Note that over-feeding a de-chlorination chemical can deoxygenate the receiving water, so the de-chlorination process must be carefully controlled.

TABLE 6 - AMOUNTS OF CHEMICALS REQUIRED TO NEUTRALIZE VARIOUS RESIDUAL CHLORINE CONCENTRATIONS IN 100,000 GALLONS OF WATER

Residual Chlorine Concentration (mg/L)	Chemical Required			
	Sulfur Dioxide (lb)	Sodium Bisulfite (lb)	Sodium Sulfite (lb)	Sodium Thiosulfate (lb)
1	0.8	1.2	1.4	1.2
10	8.3	12.5	14.6	12.0
25	20.9	31.3	36.5	30.0
50	41.7	62.6	73.0	60.0

Adapted from AWWA Standard C651-05.

Step 5: Bacteriological Testing (Optional)

AWWA Standard C651 requires that after the final flushing two consecutive sets of bacteriological samples within a 24 hour period be collected from the new main. At least one set of samples shall be collected from every 1200 ft. of the new main, one set from the end of the line and at least one set from each branch. The samples are tested for the presence of coliform organisms in accordance with *Standard Methods for the Examination of Water and Wastewater* (APHA *et al.*, 2005). KDHE does not require bacteriological testing of new mains but recommends such tests to confirm the effectiveness of the disinfection procedure. It is not uncommon for a public water supply system to require bacteriological testing of mains as part of their standard specifications for the installation of water mains. Unless the provisions of AWWA Standard C651 are incorporated by reference in the system's specifications, the specifications for bacteriological testing should provide: the type, number, and frequency of samples for bacteriological tests; the method of initial sample collection to include repeat sample collection; the party or parties responsible for testing; and the laboratory selection requirements.

Attachment B to this appendix provides a brief summary of bacteriological sampling procedures and analytical methods; however, the most current procedures and methods as outlined in the drinking water regulations should always be employed.

EMERGENCY WATER MAIN DISINFECTION PROCEDURES

When repairs require that mains be opened and depressurized under emergency conditions such as a break or other physical failure of the pipeline, the necessity of restoring water service as soon as possible prevents complete compliance with the routine main disinfection procedures of AWWA Standard C651. Alternate disinfection procedures under such conditions are described in more detail in an article published by Scoot R. Yoo in OPFLOW (Yoo, 1986). The following recommended disinfection procedure is based in part on the article.

The entry of contaminants into the repaired main should be minimized. When feasible, employ clamps, sleeves or other devices to avoid having to take the main out of service and to depressurize it to make the necessary repairs. If the main must be taken out of service and depressurized while repairs are being made it is important that excavated areas be dewatered to the extent practical to prevent dirty water from contacting or entering the pipe. When a pipe is cut and a section removed, the inside of the remaining pipe ends must be examined and pieces of pipe, scale, or other debris removed. Temporary plugs for all open ends of pipes must be provided.

If the main must be depressurized and opened, then the pipe should be disinfected by swabbing it with a concentrated chlorine solution and then thoroughly flushed upon completion of repairs. Alternatively, a high chlorine residual should be maintained in the repaired section of the main for an appropriate period of time. The swabbing method is quick and is generally effective under repair conditions that do not pose a threat of significant contamination. The swabbing method, however, should not be utilized where there is a potential for significant contamination of the main, e.g., when sewage is detected in the trench during repairs.

Swabbing Method

All new pieces of pipe, couplings, clamps, sleeves, and other materials used in the repair must be thoroughly swabbed with a concentrated (1 percent available chlorine or greater) chlorine solution to disinfect all surfaces which will come in contact with potable water. The concentrated chlorine solution may be prepared by adding 2 oz of calcium hypochlorite (65 percent available chlorine) or 26 fl oz of household bleach (5 percent available chlorine) to 1 gallon of water. Clean rags or a sprayer are typically employed to apply the concentrated chlorine solution. Longer pieces of pipe may be disinfected using a clean mop. Proper personal protection such as rubber gloves and goggles should be worn. Respiratory protection equipment should also be worn when ventilation is inadequate.

Hypochlorite Injection or Addition of Pre-mixed Solution

In both of these methods of disinfection, the repaired section of main is briefly contacted with chlorinated water that will have high chlorine residual.

Preliminary Steps

Both methods require the repaired section of main to be isolated from the distribution system. This will require that all service connections along the section of main to be disinfected be shut off. Temporary connections for filling the main with water as well as a method of flushing the main through a hydrant or other temporary outlet must be provided. The isolated section of main must be initially flushed to remove dirty water, debris, and air.

Hypochlorite Injection

In the hypochlorite injection method, liquid sodium hypochlorite is injected into the flowing main by means of a chemical feed pump to establish a high chlorine residual in the repaired section of the main (Figure 1). The initial required chlorine dose is 300 mg/L, verified by measuring the chlorine residual in the water flushed out through an outlet in the other end of the repaired section. The minimum amount of hypochlorite solution required to treat one pipe volume with an initial chlorine dose of 300 mg/L can be calculated using the following equation:

$$\frac{300\frac{\text{mg}}{\text{L}}}{\text{Conc}_{\text{soln}}} * \text{Vol}_{\text{main}} = \text{Vol}_{\text{soln}} \quad \text{(Eq. 13)}$$

where,

$\text{Conc}_{\text{soln}}$ = concentration of chlorine in a sodium hypochlorite solution, in mg/L as Cl_2, where 1 percent available chlorine solution is approximately equal to 10,000 mg/L.
Vol_{main} = volume of main, gal
Vol_{soln} = volume of sodium hypochlorite as chlorine solution, gal

Table 7 includes the minimum volumes of sodium hypochlorite solution (5 and 12.5 percent available chlorine) necessary to achieve an initial chlorine dosage of 300 mg/L in 100 ft. of main. Volumes in excess of the table values will be necessary because pumping must continue until the minimum chlorine dose is verified at the flushing outlet.

TABLE 7 - HYPOCHLORITE REQUIRED PER 100 FT OF MAIN

		Hypochlorite Solution				**Hypochlorite Granules**	
	Total	**gal of 5-percent**		**gal of 12.5-percent**		**ounces of 65-percent**	
Pipe Size (in)	**Pipe Volume (gal)**	**Dose 100 mg/L**	**Dose 300 mg/L**	**Dose 100 mg/L**	**Dose 300 mg/L**	**Dose 100 mg/L**	**Dose 300 mg/L**
2	16.3	0.03	0.10	0.013	0.039	0.33	1.0
4	65.3	0.13	0.39	0.052	0.16	1.3	4.0
6	147	0.29	0.88	0.12	0.35	3.0	9.0
8	261	0.52	1.6	0.21	0.63	5.4	16.1
10	408	0.82	2.4	0.33	0.98	8.4	25.1
12	587	1.2	3.5	0.47	1.4	12.1	36.2
16	1044	2.1	6.3	0.84	2.5	21.4	64.3

Note: 5-percent chlorine solution = 50,000 ppm or mg/L free chlorine.

Addition of Premixed Solution

An alternate method is the preparation of a premixed chlorine solution in sufficient volume to completely fill the repaired section of main. A hypochlorite compound is added to potable water in a tanker truck or other large container in the proportions indicated in Table 7 to form a thoroughly mixed solution having a chlorine concentration of at least 300 mg/L. The chlorine solution from the tanker truck or large container is then pumped into the repaired section of the water main until the water main is full as indicated by a discharge through a hydrant or other outlet device at the other end of the section of water main being tested.

Minimum Contact Period

The minimum contact period for an initial chlorine dose of 300 mg/L is 15 minutes. After the minimum 15 minute contact period, a chlorine residual of at least 100 mg/L should be verified. Lower initial chlorine doses may be used for longer contact periods (e.g., 100 mg/L initial chlorine dose with a 3 hour contact time).

Final Steps

The heavily chlorinated water is flushed from the main until the chlorine residual is reduced to the level normally present in water supplied to the area. Consideration should be given to the collection of bacteriological samples after the disinfection procedure has been completed to provide a record of the effectiveness of the disinfection procedures where repairs were made under conditions that posed a threat of contamination.

Bibliography

APHA, AWWA, and WEF, 2005. *Standard Methods for the Examination of Water and Wastewater, 21st ed.* American Public Health Association, Washington, D.C.

AWWA, 1990. *AWWA's Pocket Guide to Water Sampling, Vol 1. Microbiological Contamination.* Denver, CO.

AWWA, 2003. *Basic Science Concepts and Applications, Principles and Practices of Water Supply Operations, 3rd ed.* Denver, CO.

AWWA, 2005. *Disinfecting Water Mains.* AWWA Standard C651. Denver, CO.

California Department of Health Services, Sanitary Engineering Branch, and USEPA, Office of Drinking Water, 2004. *Water Treatment Plant Operation, A Field Study Training Program, Volume 1, 5th ed.* Hornet Foundation, Inc. California State University, Sacramento, CA.

California Department of Health Services, Sanitary Engineering Branch, and USEPA, Office of Drinking Water, 2005. *Water Distribution System Operation and Maintenance, A Field Study Training Program, 5th ed.* Hornet Foundation, Inc. California State University, Sacramento, CA.

KDHE, Bureau of Water, 2004. *Public Water Supply Survival Guide for the Total Coliform Rule.* KDHE, Bureau of Water, Topeka, KS

Lisle, J., 1993. *An Operator's Guide to Bacteriological Testing.* American Water Works Association, Denver, CO.

Stevens, R. L., and J. C. Dice, 1981. Chlorination – A Proven Means of Disinfecting Mains, *Opflow, 7* (10) (October).

Stevens, R. L. and J. C. Dice, 1987. Chlorination – Pills for Pipe and Techniques for Tanks, *Opflow, 7* (11) (November).

White, G. C., 1999. *Handbook of Chlorination and Alternative Disinfectants, 4th ed.* John Wiley & Sons, Inc., New York, NY.

Yoo, S. R., 1986. Procedures for Emergency Disinfection of Mains, *Opflow, 12* (1) (January).

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ATTACHMENT A

METHODS FOR MEASURING FREE CHLORINE RESIDUAL

Standard Methods for the Examination of Water and Wastewater (APHA *et al.*, 2005) describes eight methods for measuring residual chlorine concentration. Of the eight, the amperometric titration, DPD colorimetric, DPD ferrous titrimetric, and iodometric titration methods are the most commonly practiced. The amperometric titration method is the most common method of measurement practiced in the laboratory and the DPD colorimetric method is the most common and simplest method of measurement practiced in the field.

DPD colorimetric methods used in the field typically involve collecting a water sample in the sample tube of a DPD test kit; adding the DPD color reagent (N,N-diethyl-p-phenylenediamine) provided in the kit to the water sample; and then matching the resulting color of the sample with a color on the comparator wheel to estimate the free chlorine residual in mg/L. The magenta or red coloring of the sample can be observed as the DPD is oxidized by the free chlorine in the sample. The intensity of the color is directly proportional to the free chlorine concentration in the sample. DPD colorimetric field test kits for a variety of ranges of free chlorine are widely available.

Each DPD colorimetric chlorine test kit is designed to measure a specified range of free chlorine concentration. Low range test kits typically measure free chlorine concentrations as high as 3.5 to 5 mg/L. Some manufacturers have produced high range test kits that are capable of measuring free chlorine concentrations at the level of doses required for disinfection of water mains, e.g. 25 mg/L. A low range test kit can, however, be used to measure a free chlorine concentration higher than the kit's range by diluting the sample to reduce the free concentration to be within range of the test kit. Samples can be diluted using the graduated cylinder dilution method or the DPD drop dilution method.

It is important to note that if the concentration of chlorine in the sample exceeds the highest concentration for which a DPD test kit is valid, or if the reagents are not added in the proper order, the results are likely to be erroneous.

Graduated Cylinder Dilution Method

Collect a 2 mL sample of highly chlorinated water and pour the sample into an empty 50 mL or larger graduated cylinder. Add distilled water for a total of 50 mL and gently mix. Distilled water can be purchased in most grocery and convenience stores in gallon containers.

Transfer from the graduated cylinder the volume of diluted chlorinated water specified by the test kit to the test kit's sample tube. Add DPD reagent, mix, and then estimate the free chlorine concentration based on a comparison of the color of the diluted sample with the kit's standards according to the kit's instructions.

Multiply the estimated free chlorine concentration by the dilution factor, which is calculated as follows:

$$\frac{\text{(Volume of distilled water + Volume of chlorinated sample)}}{\text{(Volume of chlorinated sample)}} = \text{Dilution Factor} \quad \text{(Eq. A1)}$$

When 2 mL of sample are combined with 48 mL of distilled water in a graduated cylinder, the dilution factor is 25 as determined below:

$$\frac{\textbf{(48 mL of distilled water + 2mL of sample)}}{\textbf{(2mL of chlorinated sample)}} = \textbf{Dil. Factor of 25}$$

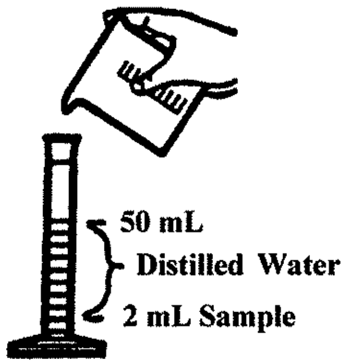

Figure A-1 Dilution of Sample in Graduated Cylinder.

For example, if it is determined that the diluted sample from the graduated cylinder has a chlorine residual of 1 mg/L, the undiluted sample from the disinfected main would have a residual of 25 x 1 mg/L or 25 mg/L. If it is not possible to accurately determine the chlorine residual of the undiluted sample, it may be necessary to apply a different dilution to the sample. For example, if the anticipated level of chlorine residual is around 100 mg/L, as it might be in for the slug method, a more appropriate dilution factor would be 50. This level of dilution could be obtained by diluting 1 mL of sample with 49 mL of distilled water.

DPD Drop Dilution Method

Add 10 mL of distilled water and one premeasured packet or powder pillow of DPD reagent (or 0.5 mL of DPD solution) to the DPD test kit's sample tube.

Using an eye dropper, add a sample of the highly chlorinated water on a drop-by-drop basis to the kit's sample tube until a color is produced.

Record the number of drops added to the sample tube. Assume one drop equals 0.05 mL.

Determine the free chlorine concentration in the kit's sample tube that contains the drops of sample, 10 mL of distilled water, and the DPD reagent by means of a colorimetric comparison with the standard according to the test kit's instructions.

Estimate the chlorine residual in the chlorinated sample from the disinfected main with the following equation:

$$\frac{(Cl_2 \text{ Residual}_{\text{sample-tube}}, \frac{\text{mg}}{\text{L}}) * (\text{Vol}_{\text{distilled-water,}} \text{mL})}{(\text{Vol}_{\text{sample,}} \text{drops}) * (0.05 \frac{\text{mL}}{\text{drop}})} = Cl_{2\ \text{residual-sample}}, \frac{\text{mg}}{\text{L}} \qquad \text{(Eq. A2)}$$

For example, assume three drops of chlorinated water from the disinfected main determined a free chlorine concentration of 0.6 mg/L in 10 mL of distilled water in the kit's sample tube. Determine the free chlorine concentration in the sample of chlorinated water from the disinfected main with Eq. A2:

$$\frac{(0.6 \text{ mg/L}) * (10 \text{ mL})}{(3 \text{ drops}) * (0.05 \text{ mL/drop})} = 40 \text{ mg/L}$$

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ATTACHMENT B

BACTERIOLOGICAL SAMPLING AND ANALYSIS

AWWA C651-05 requires that two consecutive sets of samples, taken at least 24 hours apart, be collected from the main and examined for bacteriological contamination after the final flushing and prior to connecting the new main to the distribution system. If the results of the examination of the initial bacteriological samples are unsatisfactory, the new main should be flushed and additional samples collected and examined. According to AWWA C651-05, if the results of the examination of any of the additional samples are also unsatisfactory, the main must be re-chlorinated, flushed, and resampled until satisfactory results are obtained. KDHE recommends bacteriological testing of newly installed or repaired mains.

Analytical Methods

AWWA Standard C651-05 requires that the samples be examined for bacteriological quality in accordance with AWWA's *Standard Methods for the Examination of Water and Wastewater* (APHA *et al.*, 2005). Coliforms are the indicator organisms used in monitoring the bacteriological quality of drinking water. The maximum contaminant level for total coliforms under the Safe Drinking Water Act is based on the presence or absence of the indicator bacteria, not on density or direct count. Four commonly utilized laboratory methods of examination for coliforms are described in *Standard Methods for the Examination of Water and Wastewater*: MMO-MUG, multiple tube fermentation (MTF), presence-absence (PA), and membrane filtration (MF).

Several private laboratories located within the state of Kansas are certified for microbiological examination of drinking water samples. A current list can be obtained from the Public Water Supply Section of KDHE at (785) 296-5514, KDHE's Laboratory Improvement Program Office at (785) 296-3811 or http://www.kdheks.gov/lipo/index.html, or the KDHE district offices. The laboratory that is chosen to perform the analysis will typically provide the sampler with instructions and appropriate containers for sample collection. The KDHE microbiology laboratory is also available for examination of bacteriological samples. Scheduling for sample bottles and their examination by the KDHE microbiology laboratory may be requested from the Public Water Supply Section of KDHE at (785) 296-5514. Public Water Supply Systems that currently receive monthly sample bottles for monitoring distribution system samples for compliance with the Total Coliform Rule must not utilize their regular monthly bottle allotment for assessing the effectiveness of disinfection procedures on mains. Additional sample bottles requested for this sampling effort must be requested as a special project.

Number of Samples

AWWA Standard C651-05 provides that at least one set of samples for bacteriological examination be collected from every 1,200 ft of the new water main, plus one set from the end of the line, and at least one set from each branch. If trench water or excessive quantities of dirt entered the new main during construction, samples should be taken at intervals of approximately 200 ft and identified by location.

Sample Collection Procedures

Use only sterile bottles furnished by the laboratory. Keep the bottles sealed until used. Each sample bottle should contain a de-chlorinating agent (typically, sodium thiosulfate) in sufficient amount to neutralize any residual chlorine in the water sample. Do not rinse the bottle prior to taking the sample as such rinsing will remove the de-chlorinating agent and render the subsequent sample invalid. Samples are not to be taken from a sampling fixture that has an aerator attached or from a sampling fixture attached to pipe or pipe/hydrant combination having a weep hole.

C651-05 prohibits collection of samples from hoses or fire hydrants. Experience has shown that the examination of samples collected from these types of sampling locations may result in a false presence of coliforms due to contamination of the sample. AWWA Standard C651-05 recommends the use of a specially installed sampling tap consisting of a smooth, unthreaded, 0.5-inch hose bib. Alternatively, a corporation stop installed in the main equipped with a copper-tube gooseneck assembly may be utilized as a sampling tap. After the samples have been collected, the gooseneck assembly may be removed and retained for future use.

Be sure that the heavily chlorinated water has been thoroughly flushed from the main before sampling. Run water through the sampling tap at a steady rate 3 to 5 minutes before beginning sampling procedure.

Wash hands thoroughly. Remove the bottle lid just before filling, holding the lid in your free hand. Do not contaminate the inner surface of the cap of the bottle with your hands. Fill the bottle to the shoulder or fill line. Do not overflow the bottle or splash water into or out of the bottle or onto the outside rim of the bottle. Replace the lid and tighten securely.

Complete the appropriate sample documentation provided by the laboratory. This will typically include a sample label and chain of custody form. If the KDHE laboratory is being utilized, a KDHE Sampling Data Card must be completed instead of a chain of custody form. The KDHE Sampling Data Card requires completion of the following information: collection date, collector's last name and first initial, time of collection, collection location, and chlorine residual.

Sample Delivery to Laboratory

Deliver the samples to the laboratory promptly after collection. There are strict time limits on the amount of time that may elapse between sample collection and analysis before the sample is considered too old to analyze. Check with your laboratory on sample holding time requirements. The EPA requires that samples reach the laboratory within 30 hours of collection. Unless special arrangements are made, schedule the collection of samples so that they do not arrive at the laboratory on weekends or holidays. Samples should be held at a temperature of 40 °F (4°C). If practicable, place samples in an iced cooler for storage during transport if transport time will exceed one hour. At no time, however, should the sample container be allowed to become immersed or submerged in the ice or melted ice water. Check with the laboratory for specific packaging and transport recommendations.

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ATTACHMENT C

EXAMPLE CALCULATIONS FOR THE DISINFECTION OF WATER MAINS WITH CHLORINE

1. FLUSHING RATE – Calculate the flushing rate for a given velocity (Table 1).

Example:

Calculate the flushing rate for a 6-inch diameter pipe which would provide a velocity of 2.5 ft/sec within the main.

Formulas:

$Area_{main}$, $ft^2 = \pi[(dia, ft)^2/4]$ = cross-sectional area of main

Flushing rate, gpm
$= (Area_{main}, ft^2)*(Velocity, ft/sec)*(7.48 gal/ft^3)*(60 sec/min)$

Solution:

$Area_{main}$, $ft^2 = \pi[(6 in)*(1 ft/12 in)]^2/4 = 0.196 ft^2$

Flushing rate, gpm
$= (0.196 ft^2)*(2.5 ft/sec)*(7.48 gal/ft^3)*(60 sec/min)$
= 220 gpm

2. PREPLACEMENT OF HTH GRANULES IN MAIN – Calculation of the amount of calcium hypochlorite (HTH) granules required for disinfection of a water main with a chlorine dose of 25 mg/L (Table 3).

Example:

Calculate the quantity of calcium hypochlorite granules required to disinfect 1,000 feet of a 4-inch diameter PVC pipe. Assume granules contain 65 percent available chlorine by weight.

Formulas:

Vol_{main}, $MG = \pi(dia, ft)^2/4*(length, ft)*(7.48 gal/ft^3)*(1 MG/1x10^6 gal)$

Cl_2 needed, lb = (Vol, MG)*(Cl_2 dose, mg/L)*(8.34 lb/gal)

Calcium hypochlorite needed, lb = (Cl_2 needed, lb)/(percent available Cl_2/100)

Solution:

Vol_{main}, MG = π[(4 in)*(1 ft/12 in)]^2/4*(1,000 ft)*(7.48 gal/ft^3)*(1 MG/1x10^6 gal)
= 0.000653 MG

Calcium hypochlorite needed for disinfection of 1,000 ft of 4-in pipe, oz
= (0.000653 MG)*(25 mg/L Cl_2)*(8.34 lb/gal)*(16 oz/lb)/(0.65)
= 3.4 oz

This answer could also be obtained from Table 3 which is expressed in terms of the ounces of calcium hypochlorite granules required each 500-foot interval. In this example, since the pipe is 1,000 feet long, the amount of granules required must be doubled so the amount needed is 2 * 1.7 oz = 3.4 oz.

3. **PREPLACEMENT OF HTH TABLETS IN MAIN – Calculation of the number of 5-g calcium hypochlorite tablets (65 percent available chlorine) for disinfection of a water main with an initial chlorine dose of 25 mg/L (Table 4).**

Example:

Calculate the number of 5-g calcium hypochlorite tablets (65 percent available chlorine) necessary to apply an initial chlorine dose of 25 mg/L to 846 feet of 8-inch diameter PVC pipe.

Formulas:

Vol_{main}, MG = π[(dia, ft)^2/4]*(length, ft)*(7.48 gal/ft^3)*(1 MG/1x10^6 gal)

Calcium hypochlorite needed, lb
= (Vol, MG)*(Cl_2 dose, mg/L)*(8.34 lb/gal)/(percent available Cl_2/100)

Solution:

Vol_{main}, MG = π[(8 in)*(1 ft/12 in)]^2/4*(846 ft)*(7.48 gal/ft^3)*(1 MG/1x10^6 gal)
= 0.00221 MG

Calcium hypochlorite needed for disinfection of 846 ft of 8-in pipe, lb
= (0.00221 MG)*(25 mg/L Cl_2)*(8.34 lb/gal)/(65%/100)
= 0.71 lb

Weight per 5-g tablet of calcium hypochlorite, lb/tablet
= (5 g/tablet)*(0.035274 oz/g)*(1 lb/16 oz)
= 0.011 lb/tablet

Number of tablets providing 0.71 lb of calcium hypochlorite, tablets
= (0.71 lb calcium hypochlorite)*(1 tablet/0.011 lb)
= 64.5 tablets

Since there are approximately 47 sections of 18-foot sections in an 846-foot length of main, the number of tablets required per 18-foot section is 64.5 tablets/47 sections = 1.37 tablets per section. Assuming partial tablets are not possible, 2 tablets should be used per section of pipe for a total of 94 tablets for the 846 ft length of pipe. As Table 4 indicates, this solution could also be obtained from 2 tablets for each 18-foot section of 8-inch pipe.

4. CONTINUOUS METHOD

Procedure 1: Addition of Premixed Chlorinated Water (Table 5)

Example:

Calculate the amount of hypochlorite (sodium or calcium) necessary for disinfection of 500 ft of 6-inch main by the addition of premixed chlorinated water. For this problem, assume calcium hypochlorite is 65 percent available chlorine and sodium hypochlorite is a 15 percent available chlorine solution.

Formulas:

Vol_{main}, MG = $\pi[(\text{dia, ft})^2/4]*(\text{Length, ft})*(7.48 \text{ gal/ft}^3)*(1 \text{ MG}/1\text{x}10^6 \text{ gal})$

Utilizing calcium hypochlorite,
lbs of HTH = (Vol_{main}, MG)*(8.34 lb/gal)*(25 mg/L Cl_2)/(percent available Cl_2/100)

Utilizing sodium hypochlorite,
minimum volume, gal = (Vol_{main})*(25 mg/L Cl_2)/($Conc_{soln}$, mg/L as Cl_2), where a 1 percent available chlorine solution as sodium hypochlorite is approximately equivalent to 10,000 mg/L as Cl_2.

Solution:

Vol_{main}, MG = $\pi[(6/12)^2/4]*(500 \text{ ft})]*(7.48 \text{ gal/ft}^3)*(1 \text{ MG}/1\text{x}10^6 \text{ gal})$
= 7.34×10^{-4} MG or 734 gal

Utilizing 65 percent available chlorine calcium hypochlorite, the required amount of HTH in lbs to be added to 734 gal:

= (7.34×10^{-4} MG)*(8.34 lb/gal)*(25 mg/L Cl_2)/(0.65)
= 0.24 lb or 3.8 oz

The volume of 15 percent available chlorine sodium hypochlorite to be added to 734 gallons:

$$= (734 \text{ gal})*(25 \text{ mg/L } Cl_2)/(150{,}000 \text{ mg/L})$$
$$= 0.12 \text{ gal}$$

This answer can also be obtained from Table 5 which indicates that for a 100-foot section of 6-inch diameter water main, 0.024 gal of 15 percent available chlorine sodium hypochlorite or 0.75 ounces of 65 percent available chlorine HTH are required for a 25 mg/L chlorine dose. Since the problem statement specifies a 500-foot main, the table entries should be multiplied by 5 yielding the minimum quantities of 0.12 gal of 15 percent available chlorine sodium hypochlorite or 3.8 oz of 65 percent available chlorine HTH.

Procedure 2: Injection of Concentrated Chlorine Solution (Table 5)

Example:

Calculate the amount of hypochlorite (sodium or calcium) necessary for disinfection of 5,250 ft of 8-inch diameter main by the continuous method. For this problem, assume calcium hypochlorite is 65 percent available chlorine and sodium hypochlorite is a 15 percent available chlorine solution.

Formulas:

Vol_{main}, MG $= \pi[(\text{dia, ft})^2/4]*(\text{length, ft})]*(7.48 \text{ gal/ft}^3)*(1 \text{ MG}/1\text{x}10^6 \text{ gal})$

Chlorine feed rate ($Cl_{2\ feed}$), lb/hr

$$= (Q_{fill}, \text{gpm})*(1440 \text{ min/day})*(1 \text{ day}/24 \text{ hr})*(1 \text{ MG}/1\text{x}10^6 \text{ gal})*(25 \text{ mg/L})$$

Calcium Hypochlorite

Calcium hypochlorite, lb/hr $= (Cl_{2\ feed}, \text{lb/hr})/(\text{percent available } Cl_2/100)$

HTH, in lb $= (Vol_{main}, \text{MG})*(8.34 \text{ lb/gal})*(25 \text{ mg/L } Cl_2)/(\text{percent available } Cl_2/100)$

Chlorine concentration in prepared chlorine solution, mg/L

$$= (\text{HTH, lb})/(Vol_{soln})* (1\text{x}10^6 \text{ gal}/1 \text{ MG})$$
$$*(1 \text{ mg/L}/8.34 \text{ lb/MG})*(\text{percent available } Cl_2/100)$$

Sodium Hypochlorite

Flow rate of water into main (Q_{fill}), gpm

$$= [(Conc_{soln}) * (Q_{soln}, \text{gpm})/25 \text{ mg/L})] - (Q_{soln}, \text{gpm})$$

Solution:

Vol_{main}, MG = π[(8 in)*(1 ft/12 in)]^2/4]*(5,250 ft)*(7.48 gal/ft^3)*(1 MG/1x10^6 gal)
= 0.0137 MG

Calcium Hypochlorite

Assume a chlorine solution injection rate of 2.5 gal/hr (0.0417 gpm) and a filling rate of 150 gpm.

Cl_2 feed rate, lb/hr
= (150 gpm)*(1440 min/24 hr)*(1 MG/1x10^6 gal)*(8.34 lb/gal)*(25 mg/L)
= 1.88 lb/hr

Calcium hypochlorite feed rate, lb/hr
= (1.88 lb/hr)/(65%/100)
= 2.89 lb/hr

Calcium hypochlorite necessary for disinfection of 5,250 ft of main, lb
= (0.0137 MG)*(25 mg/L Cl_2)*(8.34 lb/gal)/(65%/100)
= 4.4 lb

The time it takes to fill the main, T_{fill}, which may be assumed equivalent to the period of chlorine solution injection, $T_{injection}$, is determined by dividing the volume of the main by the rate of filling: 13,700 gal/150 gpm = 91 min. For a chlorine solution injection rate, Q_{soln}, of 0.0417 gpm, the required volume of chlorine solution, Vol_{soln}, is 3.8 gal. The combination of 4.4 lb of HTH in 3.8 gal of water results in a chlorine solution with a concentration estimated by the following:

Chlorine concentration in solution, mg/L as Cl_2
= (4.4 lb/3.8 gal)*(65%/100)*(1x10^6 gal/1 MG)*(1 mg/L/8.34 lb/MG)
= 90,200 mg/L or an approximately 9% solution.

Sodium Hypochlorite

In this case, assume the 15 percent available chlorine sodium hypochlorite solution will be pumped into the main without dilution at an injection rate of 2.5 gal/hr (0.0417 gpm). The required main filling rate, Q_{fill}, can be calculated as follows:

Q_{fill}, gpm = [(0.0417 gpm)*(150,000 mg/L)]/(25 mg/L) – 0.0417 = 250 gpm
The required volume of sodium hypochlorite solution is calculated from $T_{injection}$ and the assumed injection rate:

T_{fill}, min = $T_{injection}$, min = 13,700 gal/250 gpm = 55 min

Vol_{soln}, gal = (55 min)*(0.0417 gpm) = 2.3 gal

An alternative approach is to calculate the required feed rate of sodium hypochlorite. For an assumed main filling rate of 150 gpm (Q_{fill}), a 15 percent available chlorine solution, and an injection rate of 2.5 gal/hr (0.0417 gpm), the sodium hypochlorite feed rate ($Na\text{-}hypo_{feed}$) to form a 25 mg/L chlorine dose is calculated from the following equation:

Sodium hypochlorite feed rate (15 percent available chlorine), lb/hr
= [(150 gpm)*(1440 min/day)*(1 day/24 hr)*(1 MG/1x10^6 gal)
(8.34 lb/gal)(25 mg/L Cl_2)]/(15%/100)
= 12.5 lb/hr

Sodium hypochlorite feed rate (15 percent available chlorine), gal/hr
= [(150 gpm)*(1440 min/day)*(1 day/24 hr)*(1 MG/1x10^6 gal)
*(25 mg/L Cl_2)]/(15%/100)
= 1.5 gal/hr

T_{fill}, min = $T_{injection}$, min = 13,700 gal/150 gpm = 91 min

$Vol_{Na\text{-}hypo}$, gal = (91 min)*(0.0417 gpm) = 3.8 gal of sodium hypochlorite

Sodium hypochlorite, lb
= (12.5 lb/hr)*(91 min)*(1 hr/60 min)
= 18.9 lb

Sodium hypochlorite, gal
= (1.5 gal/hr)*(91 min)*(1 hr/60 min)
= 2.3 gal

5. **SLUG METHOD – Calculation of the amount of chlorine necessary to form a slug of chlorinated water in a main with an initial chlorine dose of 100 mg/L.**

Example:

Calculate the amount of chlorine gas required to create a slug of chlorinated water in 5,000 ft of a 6-inch diameter ductile iron main with an initial chlorine dose of 100 mg/L.

Formulas:

Vol, MG
= π[(dia, ft)^2/4]*(length of "slug", ft)*(7.48 gal/ft^3)*(1 MG/1x10^6 gal)

Chlorine (100 percent available chlorine) needed, lb
= (Vol, MG)*(Cl_2 dose, mg/L)*(8.34 lb/gal)

Solution:

Vol_{main}, MG
$= (\pi[(16\ in)*(1\ ft/12\ in)]^2/4)*(5{,}000\ ft)*(7.48\ gal/ft^3)*(1\ MG/1x10^6\ gal)$
$= 0.0522$ MG

Chlorine (100 percent available chlorine) needed, lb
= (0.0522 MG)*(100 mg/L)*(8.34 lb/gal)
= 43.5 lb

6. EMERGENCY MAIN DISINFECTION – Calculation of the sodium hypochlorite pumping rate and minimum volume of hypochlorite necessary to establish initial chlorine doses of 100 mg/L and 300 mg/L in a water main (Table 7).

Example:

Calculate the sodium hypochlorite pumping rate (assuming a 5 percent available chlorine solution) and the amount of sodium hypochlorite solution necessary to establish a 300 mg/L chlorine dose in a 300-foot section of a 6-inch diameter main. Assume Q_{fill} into the main is 50 gpm.

Formulas:

Sodium hypochlorite solution pumping rate, gpm
$= [(Cl_2\ dose,\ mg/L)/(Conc_{soln},\ mg/L)]*(Q_{fill},\ gpm)$

Vol_{main}, gal
$= (\pi(dia,\ ft)^2/4)*(Length,\ ft)*(7.48\ gal/ft^3)$

Volume of sodium hypochlorite solution, gal
$= [(Cl_2\ dose,\ mg/L)/(Conc_{soln},\ mg/L)]*(Vol_{main},\ gal)$

Solution:

Sodium hypochlorite solution pumping rate, gpm
$= [(300\ mg/L\ Cl_2)/(50{,}000\ mg/L\ Cl_2)]*(50\ gpm)$
= 0.3 gpm

Vol_{main}, gal
$= (\pi[(6\ in)*(1\ ft/12\ in)]^2/4)*(300\ ft)*(7.48\ gal/ft^3)$
= 441 gal

Volume of sodium hypochlorite solution, gal
$= [(300\ mg/L\ Cl_2)/(50{,}000\ mg/L)]*441$ gal
= 2.65 gal

$T_{injection}$, min = 2.65 gal/0.3 gpm = 441 gal/50 gpm = 8.8 min

The volume of sodium hypochlorite solution calculated in this problem can also be determined from Table 7. Table 7 indicates for a 6-inch pipe, 0.88 gal of 5-percent sodium hypochlorite solution is required to establish a 300 mg/L dose of Cl_2 in a 100-ft section of main. For a 300-ft section of main, the necessary volume of sodium hypochlorite from Table 7 for a 100-ft section should be multiplied by 3 to give 2.6 gal.