Appendix F
Pipeline Rehabilitation Techniques

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There are a number of possible solutions to problems arising from internal scaling, corrosion and deposition in water distribution pipes. These range from simple periodic cleaning to replacement of the pipe using "trenchless" techniques. Installation of a replacement pipe along a new route by open trench laying, directional drilling, and microtunneling, may also be viable in certain circumstances. The aim of the selection process is to consider all the following factors to arrive at the most cost-effective, technically viable solution:

1. The nature of the problem(s) to be solved (scale, corrosion, structural deterioration, inadequate capacity, etc.)
2. The hydraulic and operating pressure requirements for the rehabilitated main
3. The materials, dimensions, and geometry of the water main
4. The types and locations of valves, fittings, and service connections
5. The length of time in which the main can be taken out of service
6. Site-specific factors (traffic, slope/terrain, soil/rock excavation, water table, etc.)

Cleaning Techniques

Although cleaning a water pipe may not be the best solution for water quality or flow and pressure problems, cleaning may offer the lowest-cost, immediate solution to some of these problems. However, cleaning is more frequently used as a necessary preliminary step before carrying out one of the lining processes described later.

Flushing

While improving water quality is the primary purpose of flushing, careful observation of the system hydraulics during the process may indicate problems in mains, such as inadequate capacity, undiscovered restrictions, or closed or partially closed valves.

Cable-Attached Devices

Systems that use cable-attached devices for cleaning distribution mains include drag cleaning, hydraulic-jet cleaning, and electric scraper cleaning. In each case, the length of hose or cable determines the length of the pipe section that can be cleaned.

- **Drag Cleaning**: The process in which a cable-and-winch pulls a mechanical cleaner, composed of a series of steel scraper blades and rubber squeegees, through the pipe. This cleansing method is appropriate when water pressure or volume is insufficient to propel a hydraulically driven device, or when excessive pressure would be required for hydraulic cleaning, especially with small-diameter mains.

- **Hydraulic-Jet Cleaning**: A pipe-cleaning method in which a special nozzle attached to a hose emits a jet of water at high velocity and pressure that removes debris and

deposits from the interior of the pipe. The principal advantage of hydraulic-jet cleaning is removal of very tough deposits.

- **Electric Scrapers**: Electric scrapers are used to clean large-diameter lines by incorporating revolving brushes or rotating arms. The principal advantage of this method is the ability of the operator to evaluate the effectiveness of the cleaning process as it proceeds through the line.

Fluid-Propelled Cleaning Devices

Fluid-propelled cleaning devices such as foam pigs and mechanical metal scrapers are used and not constrained by the cable length to advance them along the main (i.e., they use water pressure).

- **Foam Pigs**: Foam pigs are flexible, bullet-shaped cleaning tools manufactured of low-density polyurethane foam. Pigs are propelled down water mains by the pressure and volume of water in the distribution system. Cleaning is accomplished by the frictional drag and flexible characteristics of the foam pig, which removes foreign objects, iron tuberculation, and other matter as it passes through the pipes.

- **Metal Scrapers**: A metal cleaning scraper consists of a steel frame shaped like a piston. The cleaner is propelled through the water main by means of water pressure and often accomplishes cleaning with a single pass in a continuous operation. An opening must be provided at each end of the section to be cleaned for entry and exit of the cleaning tool. The principal advantage of this method is the ability to clean long stretches of heavily deposited pipe at 2 to 10 ft/sec in a single, continuous operation with minimal excavation points.

Interior Lining Techniques

Lining a pipeline can minimize the need for frequent flushing and/or cleaning. Linings have also been installed to reduce or eliminate leaks through corroded areas of pipe or bad joints. A smooth lining in a corroding pipe helps to maximize hydraulic carrying capacity and to minimize pumping costs. Additionally, some lining systems can correct structural failures, bridge breaks, and missing sections in corroded pipe, thus restoring service through a continuous pipeline.

In-place lining of water mains can be accomplished by one or more of the following general methods: Cement-mortar lining, epoxy lining, slip lining with an inner lining pipe or tube, and cured-in-place lining.

Cement-Mortar Lining

Pipe that is lined with cement mortar is protected from oxidation because of the composition of the portland cement. Today, cement mortar is applied to new ductile-iron pipes and most new steel pipes before installation, making this method a standard in the water industry.

The lining machine is placed in the pipe at 300 to 1,500 ft intervals, depending on pipe diameter, valve locations, bends, profile, and alignment. The lining machine applies the pumped mortar and is equipped with rotating trowels or a conical drag trowel positioned just behind the dispensing head. As the machine moves through the pipe, it leaves a smooth, troweled (non-structural) finish. A reinforced cement-mortar lining may also provide structural improvement.

Epoxy Lining

The process for in-situ epoxy resin lining (ERL) of iron and steel has been performed in North America since the early 1990s to rehabilitate old, unlined water mains. The epoxy materials approved for use were first certified by ANSI/NSF Standard 61 in 1995.

Epoxy lining of potable water mains is currently classified as a non-structural renewal method. The process involves cleaning the pipe to remove existing corrosion buildup and then spraying a thin (1 mm) liquid epoxy coating onto the inner wall of the pipe. A lining machine applies the epoxy material with a centrifugal spinner applicator. The coating cures in one day and provides a smooth and durable finish, resistant to mineral deposits and future tuberculation buildup.

Prior to lining, pipes must be thoroughly cleaned to remove tuberculation and produce a clean surface to which the epoxy lining will adhere. Techniques such as drag-scraping will provide a sufficiently clean surface for ERL.

Slip-Lining

Another viable method of rehabilitating existing water pipelines is the insertion of flexible thermoplastic liners directly into the mains. The key benefit of slip-lining is that it creates a new, integral pressure pipe inside the old, deficient pipeline without a complete excavation. While slip-lining has been widely used by sewer and natural gas utilities since the early 1980s, other pipe-lining techniques have been more widespread for use in transmission and distribution systems for source water and treated, potable water.

Using a process known as thermal butt fusion, the ends of several consecutive 40-ft lengths of flexible pipe are joined at a convenient location aboveground to form a single length of pipe, usually hundreds of feet long. One end of this pipe is then pulled by cable into the entry pit and through the section of old pipe. The new pipe is then reconnected to the existing mains.

However, an inserted liner substantially reduces the effective cross-sectional area of the pipe. Consequently, the future flow requirements must be considered when deciding to slip-line. Finally, the geometry of the unlined pipe must be considered, as liners generally do not install easily through elbows exceeding 45 degrees. Regardless of these drawbacks, slip-lining is a useful lining method.

Cured-in-Place Lining

Cured-in-place pipe (CIPP) lining techniques involve inserting a polymer fiber tube or hose impregnated or coated with a thermoset resin system into the host pipe. The resin is then cured, either under ambient conditions or by application of heat using steam or water, to produce either a rigid "pipe within a pipe" or a semi-rigid liner which depends on adherence to the pipe wall for support.

Pipe Bursting

Pipe bursting is a trenchless method of replacing existing water mains by breaking and displacing existing pipe and installing a replacement pipe in the void created. The pipe-bursting process replaces the original pipe with a new pipe that is the same diameter or larger. The system consists of a pneumatic, hydraulic, or static bursting unit that splits the existing pipe while simultaneously installing a replacement pipe of the same or larger diameter and pressure rating.

The bursting action of the tool increases the external dimensions of existing pipe sufficiently to break it into pieces, which the tool compresses into the surrounding ground. In addition to breaking the pipe, this action creates the void into which the bursting unit is pulled or pushed, allowing forward progress. These systems work with existing pipe varying in diameter from 4-in to 48-in. The pipe to be replaced can be either fracturable material or material that can be sliced by cutters integrated into the bursting unit. Pipe-bursting equipment and technologies are often subject to patent protection.

A review of plans should identify service connections, valves, hydrants, and fittings, which must be excavated and disconnected before pipe-bursting operations commence. A temporary bypass system may be needed to maintain service to consumers.

Pit excavation is needed to accommodate replacement pipe sections. Pits should be centered over the existing line, and excavation sizes should be verified in the field prior to construction of the project. Polyethylene pipe is a common choice for replacement pipe. Sections should be assembled and joined on the job site by the butt-fusion method. Care must be taken not to damage the inserted pipe as it passes through the fragments of the old pipe.

Pipe-bursting technologies are subject to patent protection, so the contractor should warrant to the utility that the equipment to be used is furnished in accordance with applicable licensing or use agreements and that the prices quoted cover all applicable royalties and fees required under such agreements. The contractor should protect the utility against any costs, loss, damage, or expense arising out of any claim of infringement of patent or trademark or any violation of a licensing agreement.

Pipe bursting technology could be used if the host pipe does not have adequate structural strength and thus making it an unattractive candidate for relining. This technology could also be used when relining with a smaller diameter pipe (resulting in reduced capacity) is not a viable option.

Bypass Piping

As noted earlier, depending on the cleaning or lining method used, temporary distribution system shutdowns may occur. Some processes require relatively brief shutdowns, so work can be completed without installing bypass lines. Conversely, some cleaning techniques and all lining methods require more extensive shutdowns that may create the need to install bypass piping to maintain water service to customers for at least several days duration.

The installation of bypass lines can be the most time-consuming and labor-intensive operation of a cleaning or lining project. However, the use of bypass piping does allow fairly long shutdowns while still maintaining acceptable service to consumers.

A residential area bypass line is usually 3 to 4 inches in diameter with provisions for a 0.75-in or 1-in. hose connection to each residence or business along the main. Site conditions affect the amount of potential damage to the line, possible tripping hazards, and any obstructions to pedestrians and vehicular traffic. In a business or commercial area, bypass lines are usually 4 in. or larger in diameter.

Once bypass piping has been used to maintain service during cleaning or lining projects, care during the reconnection phase is very important to avoid further service interruptions. Upon completing the cleaning or lining, the permanent pipelines must be flushed and disinfected according to AWWA C651. Following this step, the lines are ready for service, the bypass lines can be disconnected, and customers reconnected to the permanent service lines.