# METHODS TO CONTROL LEAKS IN SEWER COLLECTION SYSTEMS

## White Paper


Prepared by

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# Methods to Control Leaks in Sewer Collection Systems

## Introduction

In recent years, federal and state regulations and mandates to reduce the sanitary sewer overflows (SSOs) have resulted in requiring better maintenance and operating practices for wastewater utilities. The EPA, in conjunction with municipal and industry representatives, has developed a framework for a dynamic management approach to collection systems called the Capacity, Management, Operation, and Maintenance (CMOM) Program. Under the new rules, owners must properly manage systems at all times by:

- Providing adequate capacity for peak flows in all parts of the system;
- Taking all feasible steps to mitigate SSOs;
- Providing 24-hour reporting of SSOs;
- Keeping extensive records on SSOs;
- Preparing follow-up records;
- Reporting on discharge monitoring reports (DMRs);
- Preparing an annual report;
- Providing public notification of SSOs or backups; and
- Developing a CMOM and audit program and making it available for public review.

Sewer collection system utilities experiencing SSOs or contributing to peak flow violations at wastewater treatment plants should begin implementing CMOM as soon as possible. Also, the Governmental Accounting Standards Board (GASB) Statement 34 (GASB 34) requires that the collection system utilities report the asset value of the wastewater system on a regular basis, which emphasizes the need for condition assessment and maintenance of the system.

## What is Infiltration/Inflow?

Infiltration is groundwater which enters the sewer collection system (pipelines and manholes) through defects in the sewer system. Inflow is defined as surface water entering the sewer via manholes, flooded sewer vents, leaky manholes, storm drains, basement drains and by means other than groundwater. Inflow is usually the result of rain and/or snowmelt events.

According to the EPA estimates, infiltration and inflow represent almost half of all flow at treatment plants nationwide. Infiltration and inflow (I/I) is a huge problem, and it only worsens over time if it is not addressed.[1]

### *How to Identify Infiltration/Inflow*

Sanitary Sewer Evaluation Surveys (SSES) are utilized to detect infiltration and inflow. Among the most commonly used methodologies are smoke testing, dye testing, closed circuit TV inspection and flow monitoring. Also, most cities have records of sewer maintenance problems, including citizen complaints. The problem areas are likely already known, and some detailed inspection can then be used in the worst areas to achieve results quickly and cost-effectively.

### *Common Causes of Infiltration*

The most common defects which might cause infiltration are as follows:

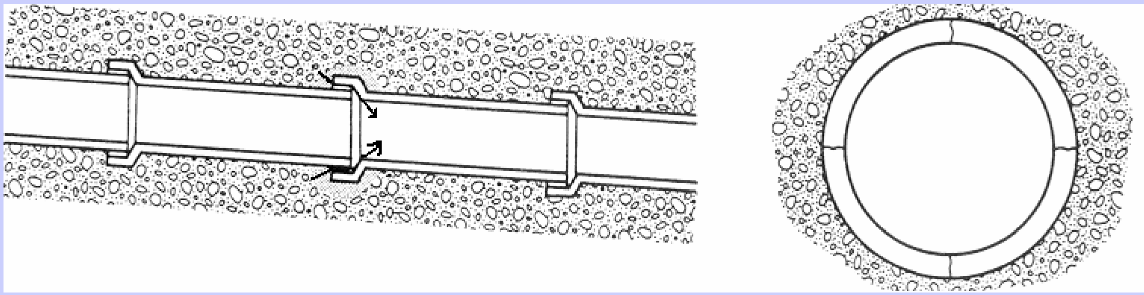
- Cracks, fractures
- Joint displacement
- Root intrusion
- Deformation
- Collapse
- Poorly constructed connections
- Abandoned laterals left unsealed

For any incident of infiltration, a number of these defects may be present, arising from a single cause or several causes in sequence. Also, infiltration itself causes the erosion of soil, washing the fine soil particles into the sewer system. This soil erosion produces the problems of sinkholes, undermining the pipe supports. As a result, the structural integrity of the pipe is endangered due to the washout of backfilling material.

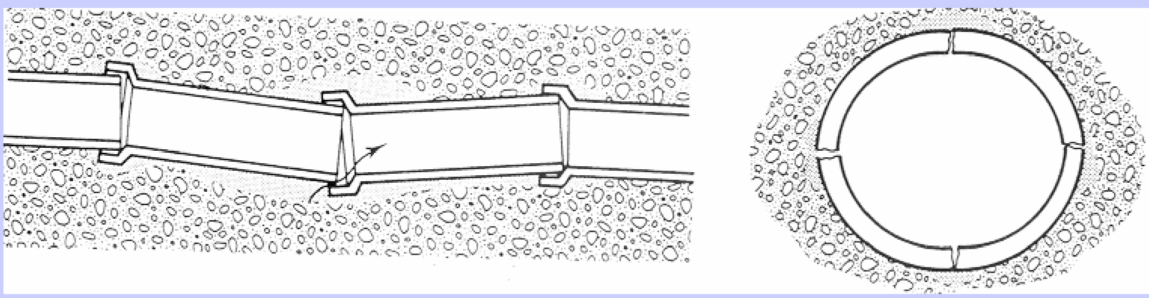
A number of the defects listed above can be considered as stages in the collapse of a sewer. These stages of sewer collapse due to ground loss are shown in Figure 1 on the following page.

While storm events are not considered a cause of infiltration, they can trigger a rise in groundwater levels and increase infiltration flows. The highest infiltration flows are observed following significant storm events or following prolonged periods of precipitation.

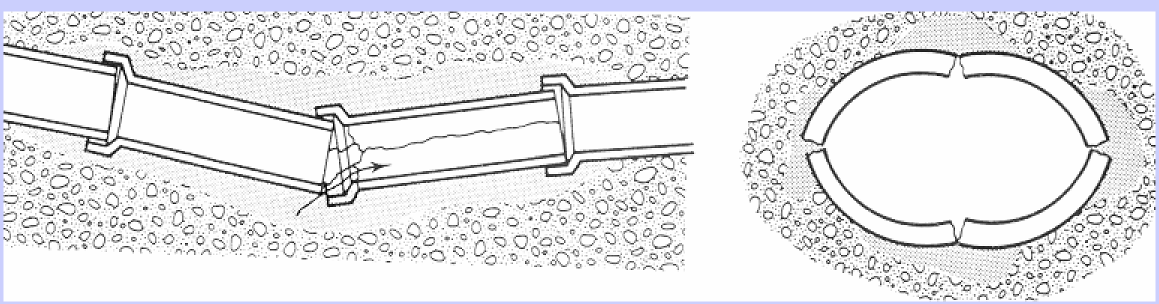
[1] **United States Environmental Protection Agency; Office of Research and Development, Washington DC 20460 EPA/625/R-961007 September 1996**



**Stage 1** Initial defect, but sewer remains held in position by the surrounding soil.



**Stage 2** Development of zones of loose ground or voids caused by the loss of ground into the sewer.



**Stage 3** Failure of the sewer pipe.

**Figure 1 The Process of Sewer Failure**

***The Effects of Infiltration***

The effects of excessive infiltration of water into the sewer collection system are as follows:

- Flooding of local sewer lines, streets, and roadways;
- Back-flooding of connected properties;
- Increased cost of pumping and sewage treatment;
- Reduced life of pumping and treatment units;
- Increased risk of SSOs resulting in fines;
- Excessive overflows from combined sewer systems.
- Depositing of fine soils resulting in reduced capacity

Maintenance and rehabilitation of an existing wastewater system are necessary for proper functioning of the collection system and dependable transfer of wastewater through the collection system to the treatment plants. As a sewer system deteriorates, external water (infiltration) enters the wastewater collection system through pipe joints, cracks in the pipeline, manhole covers and manhole joints. This infiltration consumes capacity in the collection system and treatment facilities, resulting in increased capital requirements and operation/maintenance costs. Increased costs are passed on to the businesses and individual residents in the rates they pay for the operation and maintenance of the collection systems and treatment plants.

The volume of infiltration is directly related to the lengths and diameters of the sewer pipe and manholes in the collection system. The EPA recommended maximum infiltration rate is not to exceed 200 gallons/inch-diameter/mile/day.[2]

## Why Control Infiltration?

It is imperative to control leaks and infiltration for the following reasons:

(1) To meet federal and state regulations and avoid sanitary sewer overflows (SSOs);

(2) To reduce the operation and maintenance (O&M) costs;

(3) To avoid man-made sinkholes and damage to transportation infrastructure;

(4) To reduce wastewater treatment costs; and

(5) To extend the life of the collection system.

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[2] EPA Report 11022 EFF12/70 NDIS No. TD-200827

Regular maintenance and rehabilitation of the collection system will reduce the infiltration/inflow into the system, which results in lower capital expenditures and reduced costs for operation and maintenance of the sewer system and treatment facilities. Reducing infiltration flows also increases the longevity of the treatment facilities and minimizes the risks of both sewer and ground-level infrastructure collapse. In a case study presented at the NASTT NO-DIG 2004 conference in March of this year, the following conclusion was presented as a lesson learned: "Infiltration should not be considered as a minor additional operating cost at the pump station. Rather, it could lead to more expensive repair of the roadway and other structures above the pipe, and must be addressed through regular maintenance."[3] And, finally, reducing infiltration reduces the risk of SSOs which might jeopardize compliance with state and federal regulations, resulting in fines.

### *The Cost of Not Controlling Infiltration*

Controlling infiltration is an important aspect of sanitary sewer system management. Since 1972, when Congress passed the Water Pollution Control Act, the significance of infiltration/inflow to the costliness of sewage treatment service has been recognized in the EPA's funding process. The U.S. Environmental Protection Agency requires applicants for water treatment facility funding to demonstrate that their collection systems are not subject to "excessive" infiltration/inflow. "Excessive" is defined as infiltration/inflow that can be eliminated from the system at cost lower than the cost of treatment.[4]

The cost impact of infiltration can be explained using a simple example of a sewer system with 5-foot joint spacing. Assuming each joint leaks at a very low rate of 0.25 gallon/minute, the total ground water infiltration into the system would be 138.75 million gallons per year per mile of sewer system. The total annual treatment cost would be $138,750 per mile of sewer system, assuming a reasonable treatment cost of $1.00/ thousand gallons of water. Nationally, treatment costs run from a dollar to $2.00 per thousand gallons of water.

## Methods Employed for Sewer System Rehabilitation

In choosing a method for rehabilitating sewer collection systems, it is important to understand where and why the leaks and infiltration are occurring. There is no "silver bullet" that is all encompassing. Cost-effective and reliable solutions will vary depending on whether the leak is at a manhole, in a joint, in a lateral pipe or in a large mainline pipe.

[3] 84" STORM SEWER REHABILITATION USING GROUT TO REDUCE INFILTRATION, Salam A. Khan, and Joseph H. Barnes, NASTT NO-DIG 2004, New Orleans, Louisiana, March 22-24, 2004
[4] Public Works, November 1984

### *Deficiencies Considered for Rehabilitation*

The following collection system deficiencies are usually considered when rehabilitation decisions are made. Causes of deficiencies can range from inadequate design or construction to old age:

- Broken or crushed pipe
- Deteriorated pipe
- Deteriorated or cracked pipe or mortar joints in brick sewers and manholes
- Cracked pipe
- Leaking pipe joints in mainline sewers
- Leaking building sewers
- Leaking manhole external drops
- Leaking laterals
- Improperly supported pipe
- Deteriorated or leaking manhole walls, bases or troughs
- Leaking or deteriorated wet wells and lift stations, regulator structures and tide gate chambers.

### *Methods for Controlling Leaks and Infiltration*

Rehabilitation methods to control infiltration in the sewer collection system can be summarized as follows:

- Chemical grouting: A soil sealing process which employs a two-part liquid chemical grout that solidifies after curing. The grout is remotely applied under pressure to leaking joints or laterals and small cracks in sewers and manholes to seal the voids within the soil surrounding the exterior of the pipe at the point of leakage.
- CIPP (cured-in-place) lining: An internal liner is formed by inserting a resin-impregnated felt tube through the manhole into the sewer. The liner is then expanded against the inner wall of the existing pipe and allowed to cure.
- Fold and form liner: A folded thermoplastic pipe is pulled into place through a manhole and then rounded, using heat, steam and air pressure to conform to the internal diameter of the existing pipe.
- Slip lining: An access pit is excavated adjacent to an existing sewer and a liner pipe of slightly smaller diameter is slid into the existing pipe to create a continuous, watertight liner between the two manholes.
- Pipe bursting: An access pit is excavated adjacent to an existing sewer and the pipe is broken outward by means of an expansion tool.

A flexible liner pipe of equal or larger diameter is pulled behind the bursting device as a replacement sewer.

A strong misconception exists about how to stop infiltration. While liners, when properly designed and constructed, will stabilize the structural integrity of the host pipe, even close-fit liners will not eliminate the problem of infiltration and will not stabilize the soil surrounding the pipes. Tests have shown that infiltration from joints and cracks will enter in the annular space between the liner and the host pipe and migrate through this space until an opening is found for it to join the sewage flow. Such openings are regularly found in collection lines where holes are cut into the liner to permit reconnection of the house services to the mainline sewer. These tests reveal the exact flow along the annulus of the close-fit liner will vary, depending on the location and magnitude of the defect in the host pipe, with respect to the location and continuity of that space.[5]

The use of various types of liners also presents a problem when it is necessary to connect, or adhere, a lateral liner to the mainline. The greasy surface of the mainline makes it virtually impossible to obtain a tight, leak-proof seal at the lateral connection. The only method of sealing these openings is to grout the service line connection after lining or to grout the mainline. This stops the infiltration around and through the connection to the lateral. When lining is used, grouting the connection also prevents water movement in the annular space between the liner and the old pipe.

The most effective repair technique to eliminate infiltration uses chemical grout and an inflatable packer guided by a CCTV. (See Illustrations on next page.) Chemical grouting has been used successfully for more than 40 years. This method to control leaks reduces the permeability of the soil outside the leaking joints, but does not reduce the capacity of the system. It provides a long-term solution to the leaking problem, while stabilizing the soil outside the joint.

Rehabilitation methods used to control leaks in the sewer collection system are summarized in Table 1.

[5] Examining Close-Fit Liner Annulus by B. Jay Schrock, P.E., Underground Construction, September 2001

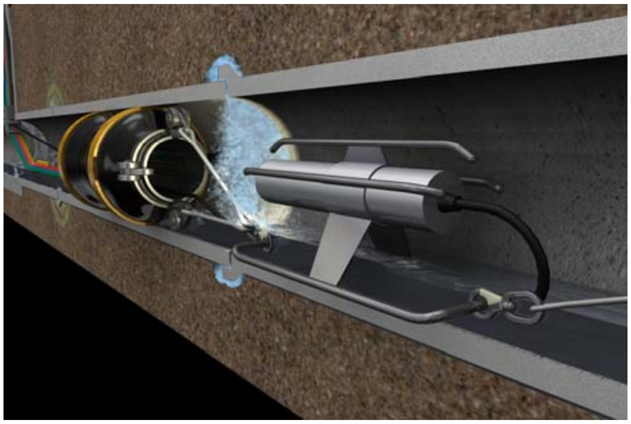

**Figure 2: Leaking sewer line joint with camera assisting the packer as it moves into position**

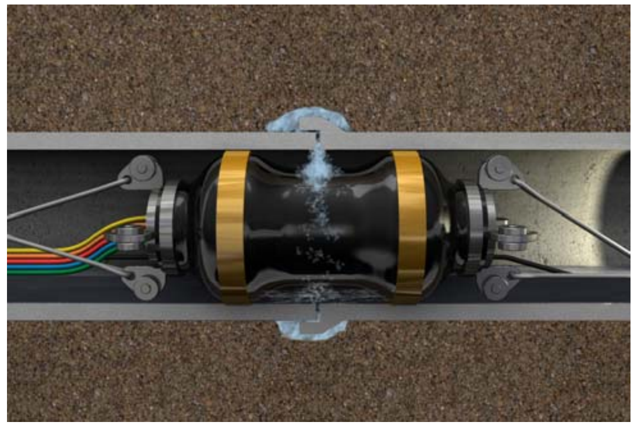

**Figure 3: Packer with joint positioned between two rubber elements and ready to inflate**

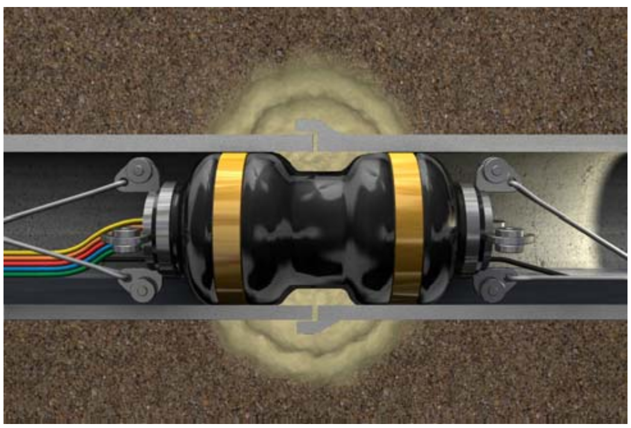

**Figure 4: Chemical Grout injected through joint into void and surrounding soil**

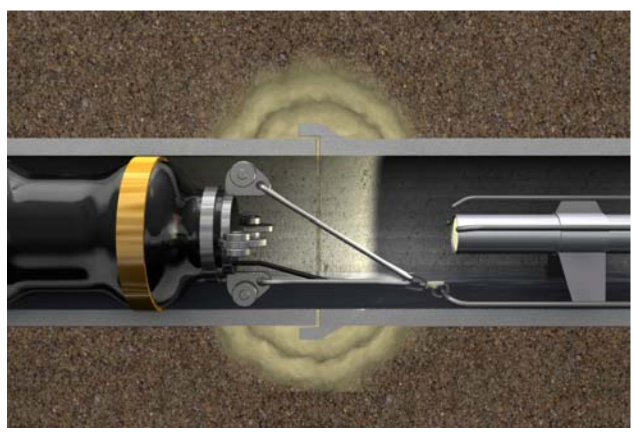

**Figure 5: Packer deflates, removes grout ring and is ready to move to next joint**

## Table 1. Trenchless Rehabilitation Methods in Sewer Collection Systems and Underground Structures

| Options | Type/Description | Advantages | Disadvantages | Areas of Application |
|---|---|---|---|---|
| Chemical Grout | Impregnation of the soil surrounding the pipe with a curable compound, thus effectively sealing the soil. Chemical grout can be used to stop leaks in pipe joints and cracks, as well as leaks around lateral connections and leaks in manholes. | • No excavation<br>• Very flexible<br>• Repair limited to damaged area<br>• Quick<br>• Economical<br>• Longevity<br>• Stops I/I<br>• Stabilizes soil outside the pipe | • No structural repair to the pipe itself, except for stabilization of the supporting soils outside the pipe. | • Repair of sewer line joints<br>• Manhole infiltration<br>• Lateral infiltration<br>• Underground structures<br>• Tunnels<br>• Parking Structures<br>• Subways |
| CIPP Lining | Flexible tube externally coated with a polyurethane membrane and internally with resin, is inverted on site by air/water pressure. The tube turns inside out and travels down the pipe and is later cured by hot water. | • No excavation<br>• Economic compared to manhole-to-manhole replacement<br>• New pipe within old pipe | • Tightness of liner to pipe is questionable; an annular space exists.<br>• Does not stop I/I<br>• Expensive | • Repair of holes and areas of extensive cracking |
| Fold and Form Liner | A folded thermoplastic pipe is pulled into place through a manhole and then rounded, using heat or steam and pressure to conform to the internal diameter of the existing pipe. | • No excavation<br>• New pipe within old pipe | • Reduction of pipe diameter<br>• Long-term buckling strength may be an issue<br>• Does not stop I/I<br>• Expensive<br>• Limited to small diameter pipes | • Repair of holes and areas of extensive cracking |
| Slip Lining | Insertion by pulling or pushing a new pipe into the old one. The remaining annular space may be filled with granular material. | • New pipe within pipe | • Reduction of pipe diameter<br>• Full length of pipe has to be lined<br>• Lateral connection is difficult to reconnect<br>• Does not stop I/I<br>• A large annular space exists in slip lining unless the annular space is grouted<br>• Expensive | • From manhole to manhole<br>• Medium level of damage |
| Pipe Bursting | Technique which uses radial forces to break out and push away the pieces of the existing pipe and permit a new pipe to be simultaneously installed. | • New pipe inserted<br>• Limited surface disruption | • Excavation required<br>• Laterals reconnected by digging<br>• Expensive | • Replacement of badly damaged sewers<br>• Runs with few laterals<br>• Can result in a new, pipe with larger diameter |
| New Pipe Installation | Soil is excavated and new pipe is installed. | • Completely new pipe<br>• Longer lifetime<br>• Modification of diameter is possible<br>• Simple and well-known technology | • Large surface area disturbed<br>• Risk of damaging other pipes and cables during excavation<br>• Disturbance of traffic<br>• Expensive<br>• Time consuming | • General repair of complete structural damage<br>• Pipelines close to the surface<br>• Open areas with no obstacles |

## What is Chemical Grouting?

Chemical grout is a two-part solution that changes to a solid in a predictable period of time. ASTM F 2304 defines chemical grouting as “a soil sealing process, which seals the voids within the soil surrounding the exterior of the pipe at the point of leakage”. Grouts used in sealing of sewer pipes must have the following characteristics:

- While being injected, the chemical grout must be able to react/perform in the presence of water (groundwater);
- The cured material must withstand submergence in water without degradation and must re-hydrate after each dry-out cycle
- The resulting grouted soil formation must prevent the passage of water (infiltration) through the sewer pipe joint
- The cured grout material must be flexible as opposed to brittle
- The cured grout material must not be biodegradable
- Residual grout materials must be easily removable from the sewer line to prevent reduction or blockage of sewage flow
- The cured grout should be chemically stable and resistant to the mild concentrations of acids, alkalis and organics found in the soil and in normal sewage

### *How Does It Work?*

Chemical grouting is the injection of grout into the soil surrounding the pipe. This is the most common method of sealing leaking sewer joints. It is a type of permeation grouting in which water in the soil voids is replaced with grout to reduce the permeability of the grouted soil around the leaking joint.

The intent of grouting is to seal sewer pipe joints which fail to pass joint tests or have leakage rates of ¼ gallon per minute or more. The basic equipment consists of a closed-circuit television system and the necessary chemical sealant containers, pumps, regulators, valves, hoses and joint sealing packers for the various sizes of sewer pipes. A cylindrical packer is used to seal small and medium sewer pipes from 6 inches to 42 inches in diameter [ASTM F 2304, 2003]. Larger diameter pipes may be grouted with specialized packers or man entry methods. See Figure 6.

**Figure 6. Typical Grout Application Setup**

ASTM F 2304 (2003) indicates that no joint shall be considered sealed unless, while under continual pressure, an attempt is made to pump grout to "refusal" (up to ½ gallon per inch diameter pipe size). The term "refusal" means the mixed chemical grout has flowed throughout the void, through any joint failure and into the surrounding soil. It has gelled and formed a cohesive seal stopping further grout flow, thus the rise in void pressure shows a "refusal" to pumping more grout into the void area. Under pumping conditions, the void pressure will slowly rise above groundwater pressure as grout is forced into the void and out into the surrounding soil. As pumping continues past the gel set time, a point is reached at which the void pressure rapidly spikes an additional 8 to 12 psi above the prior void pressure in a short pumping period of 1 to 5 seconds. This is considered the "point of refusal", and grout pumps are stopped and the grout allowed to cure an additional 30 to 40 seconds.[6]

### *The History of Chemical Grouting*

Chemical grouting has been successfully used in stabilizing soils and stopping water leakages in sewer pipes and tunnels and since the 1950's. Some examples of these applications are summarized in Table 2. As evidence shows, chemical grout seals in sewer lines that were treated over 40 years ago are still stopping infiltration and inflow. Additionally, DOE studies have shown that Acrylamide grout has a half-life of more than 115 years.[7]

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[6] ASTM International *Standard Practice for Rehabilitation of Sewers using Chemical Grouting*; Designation: F2304 – 03; Paragraphs 12.4, 12.4.1

[7] Farmer, C. D., L. K. Hyder, S. Y. Lee, and B. P. Spalding. 1986. *Demonstration of In Situ Immobilization of Buried Transuranic Waste Using Acrylamide Grout.* Martin Marietta Energy Systems, Inc., U.S. Dept. of Energy, under contract no. DE-AC05-84OR21400, Publication no. RAP86-69, Environmental Sciences Division Oak Ridge National Laboratory, Oak Ridge, TN 37831.

## Table 2. Applications of Chemical Grout to Stop Water Leaks

| References | Grout Used | Project/Location | Properties and Variables | Remarks |
|---|---|---|---|---|
| Dahlmeyer, F. D. (1962) | Acrylamide Grout | Sewer pipe sealing in Hollywood, FL | 334-foot section of 8-inch vitrified clay pipe with hot-poured joints were sealed using internal grouting. The pipe was between 4 and 6 feet below the grade and 1 foot below the ground water table. | Infiltration was reduced from 11.3 gpm to 0.62 gpm, and exfiltration was reduced from 44.9 gph to zero. The cost of the treatment was considerable less than other repair methods. |
| Brunton, B. W. (1963) | AM-9 Chemical Grout | Sealing sewer leaks at Sudbury City, Canada | Acrylamide grout was used to solve infiltration problems. 12,972 feet of 18-inch pipe and 3,013 feet of 8-inch and 12-inch pipe were checked with CCTV. | 328 joints of 18-inch pipe and 210 joints of 8-inch and 12-inch pipes were sealed at a cost of $32,800 (US) and $12,000 (US) respectively. The repairs were reported to be 97% effective. |
| AM-9 Chemical Grout Manual (1965) | AM-9 Chemical Grout | Stopping water infiltration in sewer system at Fort Myers, FL | 28 miles of sewer system were grouted with Acrylamide grout with setting times of less than 1 minute | The inflow into the system was estimated at 6 million gallons per day, where it should have been 2.5 million gallons per day. Infiltration was reduced by 3 million gallons per day. |
| Henry, Floyd (1967) | Acrylamide Grout | Austin, TX | Acrylamide grout has been used since the mid 1960s to remedy severe I/I problems throughout the sewer system. Joints in the 8” and 12” sewer lines on Greenlawn Parkway were grouted with Acrylamide in 1967. | TV inspection and testing in 1984 and 1988 confirmed the joints had no leaks. Subsequent testing in 1997 revealed the wall of the concrete pipe was so corroded that a pressure test could not be obtained. However, there was no visible leakage at the time of the test, indicating the grout was still holding back the groundwater. |
| Harris, Rick (1999) | Acrylamide Grout | Downingtown, PA | In the early 1990s, a 5000-foot section of 10” pipe had been lined with a CIPP process at a cost of $250k, but was leaking at the lateral connections. Grout was applied at each connection and the first 6 feet of every lateral line. | Infiltration was reduced from 62k gpd to 2k gpd, and by 1995, Downing-town was able to sell 300k gallons of their treatment plant allotment to a neighboring community for $2.4million |
| Erie County, Ohio Website (2004) | Acrylamide Grout | Ruggles-Mittiwanga Sanitary Sewers | Sanitary sewers have been and are being repaired by installing liner systems in manholes and sewers and grouting the first 10 feet of sewer service laterals at the sewer main | Sewers rehabilitated in 2000… have reduced the wet weather flows to the County Ruggles-Mittiwanga Wastewater Plant by more than 50%. |

### *Standards and Specifications for Grouting*

Recently, ASTM International published the standard ASTM F 2304-03 “Standard Practice for Rehabilitation of Sewers Using Chemical Grouting”, which describes the procedures for testing and sealing individual sewer pipe joints with appropriate chemical grouts using the packer method. ASTM Standard F 2304-03 gives the generic listing of chemical sealing materials currently in use and summarizes their basic properties, requirements, and characteristics.

## Conclusion

There are basically three scenarios in sewer collection systems which allow infiltration:

***Case 1: Leaking problem***
In this case, the pipe is structurally sound and leakage is due to a problem with open or leaking joints. In this condition, chemical grouting provides the only cost- effective solution to the problem. Any other repair technique would be unnecessarily expensive since the only requirement is to stop the leaks, and no other method is less expensive than chemical grouting.

***Case 2: Leaking and corrosion problem***

Corrosion is commonly encountered in wastewater systems. To be effective in this situation, the leakage should be eliminated using chemical grouting prior to any treatment of corrosion. However, grouting will not be an effective treatment to prevent further corrosion since it works outside the pipe. In this case, a combination of grouting the joints and lining, or coating, the pipe to prevent further corrosion would be the preferred engineering method of rehabilitation. If lining is chosen, the lateral reconnections should always be grouted to prevent water movement in the annulus and to seal the connection between the old pipe and the lateral.

***Case 3: Leaking and partially deteriorated structural problem***

This is the most severe condition that could be encountered in the sewer system. Structural repair of the pipe or manhole is required. However, unless the leak is stopped prior to any structural repair (lining), the water will eventually find its way into the system at openings in the liner for each service connection and at manholes. Infiltration will flow through the annular space of the existing and newly installed pipe until if finds its way into the sewer line. If possible, the water leakage should be stopped or reduced using chemical grout prior to lining in the mainline and after lining at the service connections in order for the lining to be successful in stopping infiltration.

It is expected that city sewer systems in the United State will continue to be prone to infiltration problems due to deteriorated joints even though the pipes may remain structurally sound. The American Public Works Association's *National Statistical Survey* showed that rubber rings (used in the form of plastic and compression gaskets) were historically the most widely used joining materials throughout the United States and Canada. These rubber rings were used with concrete and vitrified clay pipes which were built in short lengths, thus requiring more joints, which are subject to infiltration. The problem arises from the fact that there was no standard introduced for the rubber rings and standard composition until 1970. Recycled rubber had been widely used and, since the rubber used had no anti-bacterial agents, it is now being slowly eaten away and deteriorating with time.

To date, the only proven method of stopping infiltration is the application of chemical grout. Based on its cost-effectiveness, durability and method of leak repair for sewer pipe joints, manholes and laterals, chemical grouting has proven to be the least expensive remediation alternative for stopping leaks and infiltration. Additionally, the Department of Energy, in report number RAP86-69 estimated the microbiological half-life of Acrylamide grout to be 115 years. Thus, chemical grout will provide significant reductions in infiltration and, when combined with other methods that provide structural integrity, will prove to be an effective and reliable long-term solution for the rehabilitation of sewer collection systems.

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