Packer Injection Grouting for the Long-Term – An Engineering Perspective

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ABSTRACT

Packing injection grouting, or also known as testing and sealing of pipe joints, has often been the victim of a poor reputation. A number of utility owners have had bad experiences in attempting to stop or impede the infiltration of clean water into their sewer lines by grouting the pipe joints and laterals. The goal of any sewer rehabilitation is to ensure the proper longevity of the work. Failures that occur within months or even a couple of years after completion of the rehabilitation work are not an acceptable option.

Grouting, in theory, has been a cost-effective method of sealing pipe joints and can be a very viable technology for structurally-sound pipes. Grouting has been unsuccessfully attempted in the past by numerous municipalities. However, past failures of grouting are generally attributable to technical issues, some of which are largely unknown by even the contractors who perform the grouting work.

Grouting failure is caused by a number of issues. One of the primary causes of failure is related to the control of the grout mixture rather than actual grout injection procedure. One of the critical issues is gel time – the time it takes for the grout to catalyze from liquid form to gelatinous form. Gel times are often set to ensure that the grout moves through the open pipe joint and into the surrounding soil before hardening, thus forming a soil-grout matrix around the pipe joint and sealing it from future groundwater infiltration. However, gel times can vary dramatically with changes in temperature. For typical grout used in sewer pipe joint sealing, manufacturers state that gel times can be doubled (or halved) for every 10°F change in temperature. Operators, engineers, and inspectors who are unaware of this nuance may think that a pipe joint has been successfully sealed because it passes a subsequent air test, but in reality the surrounding soil has very little grout and the joint has been simply “veneered”.

This cause of failure and others failures will be discussed in this paper. Some of the other topics will include:

- The critical details of the grout mixture and grouting techniques
- Highlighting the types of grout available for sewer pipe joint sealing
- Specifying the correct gel time based on pipe size, pumping rates, and project goals
- Methods to ensure gel times meet the contract documents
- Discussing the additives that can be used to increase grout strength and performance in sewer pipe joint sealing applications
- Using step-grouting as a technique to pack large voids or soils
- Recommended contract requirements to help ensure successful grouting jobs.
- Importance of observing the work by a qualified Resident Project Representative
KEYWORDS
Sanitary Sewers, Infiltration, Inflow, Grouting, Sewer Rehabilitation, Infiltration, Pipe Joint Testing and Sealing

INTRODUCTION
Chemical grouts have been in use for over 50 years. For sewer systems, the intent of chemical grouting in sewer systems is to seal leaks and stop infiltration and exfiltration. Most leaks in structurally sound sewer systems are through pipe joints, manholes, service connections, and service laterals. Grouting does not simply fill existing defects and open pipe joints; grout is pumped under pressure through the defects and joints and into the surround soil/pipe bedding where they gel with the soil and for a gel-soil matrix that provides a waterstop around the pipe defect or joint. In addition, this gel-soil matrix can provide the added benefit of stabilizing the soil, preventing further loss of pipe bedding into the pipe, and providing longer-lasting support.

Figure 1 – Grout-Soil Ring

The basic principle of grouting pipe lines is to test the joints by hydraulically applying a positive pressure to the joints, monitoring the pressure in the void and monitoring the test medium flow rate. The test medium is usually air. The intent of joint testing is to identify those sewer pipe joints that are not watertight and that can be successfully sealed by packer injection grouting.

Packer injection grouting shall be accomplished by pressure injection of chemical grout into the soils encompassing the pipe joint. Chemical grouts are designed to be injected into the soil surrounding the pipe. Catalyzation is supposed take place at the point of injection/repair. Adequate volumes of grout must be injected to form an effective watertight seal.

GROUTING BASICS
Grouting is simple, quick and relatively inexpensive compared to other rehabilitation technologies. Its main limitation is that it cannot repair broken pipes, as pipe lining and pipe busting can. It is highly effective, however, on sound pipes that are admitting groundwater through the joints. When a utility has identified leaking but otherwise generally structurally sound sewer pipes and manholes, grouting is a feasible option.
Sewer mainline packers are cylindrical devices which can be accurately positioned over joints or circular cracks by means of cables attached to either access point of the sewer (e.g., manholes). The packers have inflatable ends that expand tightly against the pipe walls, isolating a short section of pipe and creating a void into which a test medium can be pumped. A sensing unit is normally located within the void area and will accurately transmit continuous pressure readout to the control panel. If pressure drops indicate the joint does not pass, grout can be delivered into the void area and into the joint/defect.

Figure 2 – Typical Sewer Main Packer Equipment

![Figure 2](Logiball, Inc., Used by Permission)

Figure 3 – Typical Sewer Main Packer Equipment Setup

![Figure 3](Logiball, Inc., Used by Permission)
Tap and lateral service sealing is generally accomplished with a lateral packer. The objective of the lateral service packer is to seal the tap connection to the main sewer and a portion of the lateral service. Commonly used lateral packer systems are positioned in a main line so that the center section of the packer aligns with the lateral line. Then an inflatable tube is inserted into the lateral line (generally between 6 feet up to 30 feet). The free end of this tube is larger than the rest so it will press out against the lateral pipe and form a tight plug. When the two ends of the packer are inflated in the main line a T-shaped area, including part of the main and the lateral line, is effectively isolated from the rest of the sewer system and can be tested with air pressure. If a leak is found, chemical grout can be applied to seal it. After the grout has been applied, the connection is tested again.

**Figure 4 – Typical Lateral Grouting**

Sealing of lateral pipe joints for laterals connected to manholes can either be done using by either pushing smaller mainline packers or by the use of a push packer. A push packer operates in the same manner as a mainline packer except access is only required at one end. The push packer is physically placed and the pipe section between the inflatable ends is usually much longer than a mainline packer.

**Figure 5 – Example of Push Packer**
Grout materials are pumped into the void space and into the joints and potentially other defects through the hose system at controlled pressures that are in excess of groundwater pressures. The pumps should be run continuously until refusal. Refusal means that the mixed grout has flowed through any joint failure, through other defects, through any annular space, and into the surrounding soil; gelled or filled the available void space; and formed a cohesive seal stopping further grout flow, until an appropriate back pressure is achieved while pumping (per the specifications or per the ASTM standards).

**DESIGN LIFE OF GROUT**

One of the key questions in grouting revolves around the design life of grout. Excavation activities have revealed that grouting performed 25 to 30 years ago still maintain the soil-gel matrix ring around the pipe joints. However, grout is subject to drying and cracking so it is important that grout constantly stays wet or humid. For sewers that are below the water table year round, grouting may have a longer design than sewers that are only seasonally below the ground water table.

Most agree that grouting won’t last as long as a newly installed pipe. In order to perform equal life-cycle costs, many engineers and utilities have generally settled on a 10- to 15-year life cycle for grouting. However, at less than a one-sixth of the cost of replacement and one-fourth of the cost of cured-in-place pipe lining, this approach is easy more cost-effective, quickly reduces I&I flows, and stabilizes the structural condition of the pipeline. If a line has structural damage, grouting alone is not enough. If there is only one defect in a pipe segment, it is often cost-effective to install a cured-in-place point repair (CIPPR) to address the structural defect and then follow that up with a grouting approach.

On the other hand, if a line segment requires more than one CIPPR or if it has a high criticality rating (i.e., in front of a hospital, behind City Hall, etc.), cured-in-place pipe (CIPP) lining or other longer-term rehabilitation methodologies may be preferable.

From an engineering perspective, it is critical that the level of service be selected to properly determine if grouting is an appropriate rehabilitation technology. For instance, if a utility selects a life cycle of 50 years, a properly designed and installed CIPP may last 50 years with a one-time capital investment. However, grouting may be more attractive if the pipe structurally sound and if the utility is willing to come back every 10-15 years and regroup joints. This is a critical and often overlooked aspect of the decision making process during the evaluation of grouting as a rehabilitation technology.

**PIPE APPROPRIATENESS**

Structural soundness of the pipe is not the only criteria. Grouting can not be accomplished if the packer cannot be seated. It takes a sound pipe wall on both sides of the joint or lateral connection to properly seat the packer. The pipe surface must be relatively smooth and should be cleaned. Some pipe materials, such as cast iron, are subject to excessive pitting that make obtaining proper seating of packer extremely difficult.
The bulk of time needed to perform grouting is tied up in the setup of the equipment. Once the equipment is properly set up, the grouting process is fairly quick. Therefore, large offset joints and transitions in pipe size (an important consideration in laterals) must also be examined carefully and disclosed (when possible) to the Contractor prior to grouting. Side by side laterals cannot be sealed if the length of sound pipe between the laterals is less than 6 inches. Protruding laterals should be cut back within 5/8” prior to sealing. Any impediments that can be highlighted to the Contractor prior to setup will ensure a smoother project for all parties.

Laterals themselves pose problems. Cleaning of the laterals and removal of roots in the absence of cleanouts can be problematic. The use of a lateral launching cleaning device is recommended.

**Figure 6 – Lateral Launching Cleaning Device**

Many studies of damaged sewer lines reveal that root intrusion is a common operation and maintenance problem. Vapor leaks at the top of an otherwise water-tight joint will encourage microscopic growth. As cells multiply, roots grow rapidly. Nourished by the sewage flowing within the line, roots will quickly grow into the sewer. Cutting out the roots alone does not solve the problem because they generally grow back thicker and stronger than before. If root growth is heavy, the joint space may be filled with root material, preventing grout from penetrating the joint. Cutting the roots may result in much of the root material being pulled out of the joint, in which case using grout with a root growth inhibitor additive can be effective. However, in order to maximize the effectiveness of grouting, chemical root treatment should be applied approximately six months prior to grouting to cause the root masses in the joints to die and slough off.

**SELECTING THE RIGHT GROUT**

There are typically three types of grout that are used in sealing sewer infrastructure with particular emphasis on pipe joints. These are:

- Acrylamides
- Acrylates
- Urethane Gels

Acrylamide, acrylate, and urethane gels used in sewer rehabilitation all have the ability to interact with water, are non-soluble, are resistant to normal sewage flows, are generally heavier than water, are non-biodegradable after “gelation”, and are flexible (not brittle) after curing. In addition, grout components should be capable of being pumped through a minimum of 500 feet of ½-inch to ¾-inch diameter hose and residual cured grout must be easily removable from the sewer line to prevent blockage of the sewage flow.

Other characteristics of the various grouts are summarized below in Table 1.

### Table 1 – Typical Grouts Used in Sewer Rehabilitation

<table>
<thead>
<tr>
<th></th>
<th>Acrylamide</th>
<th>Acrylate</th>
<th>Urethane</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Viscosity</strong></td>
<td>1.2 cps</td>
<td>2.0 cps</td>
<td>10.0 cps</td>
<td>1.0 cps</td>
</tr>
<tr>
<td><strong>Compressive Strength</strong></td>
<td>130 psi</td>
<td>130 psi</td>
<td>200 psi</td>
<td></td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>1.04 g/cm³ (Increasable using diatomaceous earth)</td>
<td>1.08 g/cm³ (Increasable (DE))</td>
<td>1.11 g/cm³</td>
<td>1.0 g/cm³</td>
</tr>
</tbody>
</table>
| **Major Benefits**   | -Low Shipping Costs  
                        -Most Contractor Familiarity  
                        -Common Delivery Systems | -Contractor Familiarity  
                        -Common Delivery Systems | -High Strength |
| **Major Drawbacks**  | -Sensitive Gel Times  
                        -Uncured Powder is a Neurotoxin | -Sensitive Gel Times  
                        -Increased Shipping | -Urethane Delivery System Required  
                        -Tackiness Increases Installation Issues  
                        -Cost |

Acrylamides have been the most traditionally used chemical grout for sealing sewer pipe joints. Due to some concerns regarding worker safety and health (uncured acrylamide powder is a neurotoxin), acrylates are becoming more common. Urethane gels have advantages due to their higher strengths, but many contractors do not have the packers for use with urethane gels. The tackiness of the urethane component also makes plugging of the delivery hoses and test medium ports more frequent than acrylamide or acrylate gels.

For all grouts, drying is an issue. Long-term evaluations have indicated that soil humidity is generally sufficient to prevent significant shrinkage of the gel. Also, chemical grouts are susceptible to some acids including sulfuric acid (common in many sewer systems). The chemical resistivity of grouts should be a consideration when selecting grouting as a rehabilitation method.
Additives

A number of additives are available to enhance the properties of the grout mix. Additives can increase mix viscosity, density, strength, and appearance. A number of additives are recommended for most grouting programs and are summarized in Table 2.

Table 2 – Additives to Grout Mixtures

<table>
<thead>
<tr>
<th>Additive</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latex Additive (or equal)</td>
<td>Increase physical properties of grout and reduces potential shrinkage, adds white coloration to cured grout</td>
</tr>
<tr>
<td>2, 6, Dichlorobenxonitrile (Dichlobenil)</td>
<td>Root growth inhibitor (does not kill roots)</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>Reduce freezing temperature of grout and reduces potential dehydration of cured grout</td>
</tr>
<tr>
<td>Dye (Green for clay, red for PVC)</td>
<td>Colors normally clear acrylamide/acrylate gel</td>
</tr>
<tr>
<td>Potassium Ferricyanide (KFe)</td>
<td>Extends gel time for acrylamide/acrylate gel</td>
</tr>
</tbody>
</table>

CONTRACT DOCUMENTS

ASTM Standards have been released on packer injection grouting in the last decade. These standards help to establish sound practices and consistency for grouting. Currently there are ASTM Standard Practices for chemical grouting to seal sewer mains (ASTM F2304-03), manholes (ASTM F2414-04) and lateral connections and lines (ASTM 2454-05), covering the three main applications of chemical grouting.

However, there are a number of things that an Owner or Engineer should specify in their Contract Documents that are not clearly addressed by the ASTM standards. These include:

- Specific percentage of base material (e.g., acrylamide or acrylate) in grout mixture
- Verification that the 2 psi drop allowed by ASTM F2454 for lateral testing is acceptable
- Calculation of the volume of annular space between the packer and host pipe
- Requirements regarding strict control of gel time due to the many influences
- Pre-construction submittal requirements
- Contractual payment mechanisms to “incentivize” grouting
- Prequalification of potential contractors

Percentage of Base Material

The ASTM standards set 10% as the minimum amount of acrylamide or acrylate in the final mix. The percentage can be increased to increase strength or reduce the effects of dilution from water. The minimum percentage of base material used to be 12% (55 pound bags of acrylamide used to be common, but newer shipping rules have reduced the bag size to 50 pounds). Given the presence of groundwater with longer gel times, a higher percentage (i.e., 12%) of base material is recommended.
Determination of Gel Times

Gel time is one of the most critical components of a successful grouting project. Gel time is the time it takes for the grout to catalyze from liquid form to gelatinous form. Gel times should be set to ensure that the grout moves through the open pipe joint and into the surrounding soil before hardening, thus forming a soil-grout matrix around the pipe joint and sealing it from future groundwater infiltration. Even if the correct grout mixture is selected, if the grout gels too quickly, it cannot be forced through the pipe joint and into the surrounding soil. This can result in a layer of grout just on the surface of the joint which results in a positive air test but lacks the intended soil-gel ring surrounding the pipe. This is what engineers often refer to as “veneering” the joint.

Conversely, if the grout does not gel quickly enough, it may not form into a strong, watertight collar around the outside of the pipe joint without pumping excessive amounts of grout. From an engineering perspective, pumping too much grout is preferred over veneering the joint.

Gel time of acrylamide or acrylate gels can be controlled by changing the ratios of the catalyst to the grout mixture. If long gel times are needed (especially when working with high temperatures), additives such as Potassium Ferricyanide (KFe) can be used to extend gel time. For urethane gels, the proportion of water to urethane will modify the gel time.

For mainline sewer pipe joint sealing and sealing laterals connected to manholes by traditional low void packers, gel times should normally be set between 30 and 40 seconds. This gel time should be modified based on the volume of the void in the packer.

Calculation of Annular Space Between Packer and Host Pipe

In order to calculate gel times, it is important to understand the correlation between gel time, pumping rate, and amount of grout needed to seal the joints or lateral connections. Most contractors when working in smaller diameter pipes (e.g., 24” or less) use low void mainline packers with void spaces as small as ¼ gallon. With typical pumping rates of 3 to 4 gallons per minute (gpm), the ¼ gallon void space will not make much of a difference. However, if the void is large, if the pumping rate is impeded, or if the gel time is relatively fast, this may impact getting adequate amounts of grout through the joints into the surrounding soil and resulting in a veneered joint.

Packer equipment manufacturers will know the approximate void space in the main line packer. For lateral packers, either from the sewer main or push packers from manholes, the void will vary based on the length of the lateral being grouted. The effective volume of grout used for rehabilitation is the total volume pumped less the void volume of the packer chamber.

Prior to grouting, the Contractor should submit calculations of the expected annular space between the packer and the lateral pipe for approval. This will aid the Engineer in setting the appropriate gel time. For example, for lateral tap connection sealing for laterals directly connected to the mainline sewer and for lateral pipe joints sealing for laterals directly connected to manholes, one way to calculate gel times is the following:
Another way to determine the volume of annular space is by using an above-ground setup. The volume of the packer chamber is measured in the above ground lateral and pipe connection set up by simulating the actual sealing, using water only, and measuring the quantity of water necessary to fill up the void area.

Influences on Gel Time

The gel time of grouts can also be significantly influenced by the grout temperature, the pH of the grout solution, the amount of oxygen dissolved in the grout solution. In addition, gel time can be influenced by contact with certain metals, by exposure to ultraviolet rays from sunlight, or by the presence of certain mineral salts in the water used to make the grout solution.

The gel time obtained from a given mix should be verified and modified accordingly in the field. Tests of gel time under ambient conditions using the actual water which will be mixed with the grout are recommended.

One of the greatest and most difficult to manage influences on gel time is changes in temperature. For typical grout used in sewer joint sealing, manufacturers state that gel times can be doubled (or halved) for every 10°F change in temperature. The gel times decrease with an increase in temperature and vice versa.

Figure 7 – Gel Time Changes With Temperature

This is especially problematic in summer months. For example, if the grout components are mixed at 7:00 a.m. when the ambient temperature is 60°F and the water pulled from a nearby hydrant is 50°F, the temperature of the grout components may be 55°F when the above ground gel test is performed. By the late afternoon when the ambient temperature is 95°F, if the grout
tanks are not temperature controlled (most grout trucks do not have temperature-controlled tanks or even temperature monitors), the temperature of grout components may have increased by almost 40°F to 95°F. This can lead to dramatic gel time decreases.

Since the packer and some of the hoses are in a sewer environment that is often much cooler (normally 50-60°F) and not subject to dramatic temperature swings, one can argue that the temperature of the grout components at the packer may be cooled by down by the time it is injected. However, from Table 3, even if the grout components have cooled to only 75°F, the gel time still is not even close to the intended 40 seconds.

**Table 3 – Gel Time Decreases with Increasing Temperature**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Gel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°F</td>
<td>40 seconds</td>
</tr>
<tr>
<td>65°F</td>
<td>20 seconds</td>
</tr>
<tr>
<td>75°F</td>
<td>10 seconds</td>
</tr>
<tr>
<td>85°F</td>
<td>5 seconds</td>
</tr>
</tbody>
</table>

Many contractors are not aware of the sensitivity of gel time to temperature. In many instances, contractors will just dilute the mixture with water to extend gel time. However, this results in an even lower percentage of base material with weaker physical properties. Even using an additive such as KFe that lengthens gel time does not reduce the affects of temperature on gel time. Strict monitoring of temperatures and, if possible, temperature control of the grout tanks should be specified and enforced on all grouting projects.

In addition, there are a number of other influences on gel time. These influences should be carefully considered for each specific project area when determining the gel time.
Table 4 – Other Influences on Gel Time

<table>
<thead>
<tr>
<th>Influences</th>
<th>Affect</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>In general, as the pH of the grout solution drops, gel time will increase. The use of highly alkaline or acidic water will significantly influence the gel time.</td>
<td>Use water with known and controlled pH.</td>
</tr>
<tr>
<td>Presence of Entrained Oxygen in the Solution</td>
<td>Oxygen entrained and dissolved during vigorous mixing of the solutions will increase gel time</td>
<td>Allow mixture to settle before testing gel time</td>
</tr>
<tr>
<td>Contact with Certain Metals</td>
<td>Metals such as iron and copper have an unpredictable effect on the gel time</td>
<td>Utilize plastic or stainless steel tanks</td>
</tr>
<tr>
<td>Ultraviolet Rays</td>
<td>Ultraviolet rays also initiate gelation</td>
<td>Keep all components out of direct sunlight. Utilize equipment that protects against ultraviolet light</td>
</tr>
<tr>
<td>Presence of Groundwater in Grouting Zone</td>
<td>The set time will be 2 to 4 times longer if the grout is diluted in the grout zone with an equal volume (100% dilution) of water</td>
<td>Adjust specified gel times to account for expected amount of groundwater (e.g., seasonal influences, wet-weather events)</td>
</tr>
</tbody>
</table>

Specifying Price of Grout

One key component of a successful grouting program is to ensure that the joints that fail the testing or come close to failing the testing be grouted with as much grout as possible. The cost of the grout is not so important in the overall sealing cost and shall not be a limiting factor. The cost of grout itself is a relatively small percentage of the total project cost. The only possible measurement of a satisfactory seal is the pumping to an agreed upon refusal pressure.

One way to ensure that the contractor grouts is to fix the price of grout in the bidding documents. The price should be set slightly higher than the actual cost of the grout, plus shipping and a typical overhead and profit markup. By fixing the price of grout (rather than letting bidders potentially low-ball the price of grout), this adds incentive for the contractor to inject as much grout as possible. Payment by the gallon of effective grout shall be an incentive to pump enough grout.

Another additional conservative method of incentivizing grouting is to also fix the price of grouting a joint, if grouting is a separate pay item from testing. Again, this levels the playing field among the various bidders and, if the price is fixed such that the contractor makes a profit, eliminates the temptation for a contractor to not grout a joint in favor of productivity.
Submittal Requirements

The Contract Documents should specify a number of submittal requirements so that the Utility Owner, Engineer, and Resident Project Representative are fully aware of the Contractor’s planned activities prior to actual construction.

If a utility decides to give potential contractors a choice in type of grout (e.g., acrylamide versus acrylate), it is important that the type of grout be submitted along with the delivery equipment planned for injection of the grout. All parties will be properly informed of the proper grout mixture ratios, additives being used, MSDS sheets to ensure worker safety, and equipment operating procedures. Also, if the price of grout has been fixed to incentivize grouting, only low void packers with minimal annular space should be used. If lateral grouting is being specified, the Contractor should submit the volume annular space between the lateral tap connection packer and host pipe in order to properly set the gel time for lateral grouting, as described above.

Upon completion of grouting each reach, the Contractor should submit to ENGINEER a report showing the following data for each joint tested and/or grouted or attempted to be grouted.

1. Location of the pipeline segment.
2. Time and date.
3. Ambient Outside Temperature.
4. Location of each joint tested (i.e., Stationing).
5. Location of any joints not tested and the reason for not testing.
6. Grout mixture formation, including additives and catalyst mixture formulation and proportion of each. Include procedure for adjusting grout mixture for variations in ambient temperatures and changes of temperature of grout through hoses exposed to the atmosphere.
7. Pumping pressure and duration of test.
8. Test pressure achieved and the duration of test maintained for each joint passing the air test.
9. Grout tank temperatures.
10. Gel time and time last verified.
11. Quantity of grout (if applicable) used to seal the joint.
12. Post-grout pressure test results.
13. Regrouting and retesting giving above data as required.

Selecting the Right Contractor

Prequalifying the potential bidders, especially before undertaking a large grouting project or program, is a very important step. All contractors should be required to establish their qualifications to install chemical grout before being allowed to submit a bid. Each contractor should submit information which details the company’s experience, equipment, and references. In addition, the prequalification requirements should indicate who the day-to-day foreman will be with associated experience and references. The Engineer should do due diligence and verify...
both the overall contractor’s references as well as the foreman’s references. This process will help eliminate inexperienced potential bidders and those who have produced poor quality work in the past.

The Bidding Documents should include statements such as, “CONTRACTOR shall have a history of at least five years of pressure testing and grouting sewers,” and, “All Work shall be supervised by a foreman having previously performed pressure testing and chemical grout sealing of a minimum of 3,000 sewer pipeline joints and 250 lateral tap connections.”

FIELD CONTROLS

A key component of a successful grouting project is having a resident project representative (RPR) that is qualified to observe grouting activities. The RPR must be aware of what is required to install grout properly, and how he or she might be misled during the installation process. For example, if a packer pressure gauge is not calibrated correctly, the RPR cannot know the true condition of a joint. Therefore, the Contract Documents should specify an above-ground pressure test of each packer at the beginning of each work shift and at other random times, in accordance with the ASTM Standards. The RPR should be familiar with these tests and should watch the test gauge each time the packer is deflated to make sure the gauge returns to zero. If it doesn’t, the operation must be stopped until the gauge is properly calibrated.

Another example would be verifying the amount of grout pumped. Many contractors do not have a true flow meter on their equipment, so often times the number of pump displacement strokes can be counted to determine the amount of grout pumped. Traditional acrylamide and acrylate grout components are normally set at a 1:1 ratio, so the RPR should verify that the levels in the tanks match at all times. If unequal levels are noted in the tanks, the packer should be pulled from the sewer and a pump test should be performed.

Root Inhibitor Additive

Dichlobenil becomes a suspended solid when mixed in a grout solution. To avoid settlement, continuous mixing is recommended. However, excessive oxygen entrainment in the grout tanks will influence gel times. A trained RPR will be able to balance these requirements and be able to hold the contractor to the specifications accordingly.

Testing Gel Times

The RPR should also verify the gel time of the grout. After the temperature of the grout tanks are recorded, and the grout mixture is allowed to settle, grout should be injected into a small container directly from the packer above ground. The traditional cup test at the tanks is a good indicator of gel times, but measuring the gel time at the packer ensures that the grout has passed through the hundreds of feet of hoses as it would in the actual sewer itself.

At the beginning of each day, when new batches of grout are mixed, when grout additives are modified to change gel times, at the beginning of any new pipe segment or manhole, and
whenever the temperature in the tanks and hoses have changed by more than 10°F from the previous gel test, the specifications and the RPR should require a grout gel test to determine the grout mixture gel time.

**Defining “Refusal”**

An RPR should be familiar with the term “refusal”. As the mixed chemical grout has flowed throughout the void space in the packer and through any joint failure into the surrounding soil, the grout has gelled and formed a cohesive seal stopping further grout flow. Therefore, 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 (the gel set time will usually be extended as a result of groundwater dilution), 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 s. This is considered the “point of refusal,” and grout pumps are stopped and the grout should be allowed gel the additional gel time before deflating the packer. Some blowby (grout squeezing past the packer ends, as most packers ends are generally rated at 10 psi) may occur and is allowable past the packer end seals at this “point of refusal.”

After the packer ends are deflated, the RPR should verify that the void pressure meter should zero psi. If it does not read zero psi, grout may be on the pressure port and the equipment must be cleaned of residual grout or other equipment repairs/adjustments may be needed to produce accurate void pressure readings. A quick burst of air is often effective clean the pressure port on the packer.

The RPR should also verify that upon completion of the injection, the packer deflated and moved at least one packer length in either direction to break away the ring of gel formed by the packer void. If the ring of gel does not break away, this ring must be broken away by other means (e.g., by jetting the sewer) before the verification that the grouting was successful.

**Figure 8 – Gel Ring After Packer Deflation**

Once the gel ring is broken away, the packer should then be repositioned over the joint, the packer ends inflated, and the joint retested at a pressure equal to the initial test pressure. If the
joint or lateral tap fails this air test, the grouting procedure must be repeated. The test after sealing will be full-proof only if the inside grout plugging the crevice is removed. This is especially problematic with lateral grouting, as the inner surface of the lateral is often completely covered with grout.

Figure 9 – Photo of Inside of Lateral Immediately After Grouting

Stage Grouting

If the grout is pumped into the void and surrounding soil and a void pressure point of refusal is not reached when pumping typical grout quantities (i.e., ¼ to ½ gallon per inch-diameter of pipe,) or when the grout flows outside the pipe from one crevice to another before gelling, then this condition usually indicates an excessively porous soil, washed out soil pockets or voids outside the pipe, extreme dilution and washing away of the grout in the soil as a result of extreme groundwater flow rates outside the pipe, or extremely influenced gel times. These conditions may be overcome by staging the grout and building a soil sealed grout wall outside the sewer line. Staging are repetitive cycles of pumping and curing carried out until refusal conditions can be reached. When using stage grouting, the applicator must avoid sealing the inner surface of the pipe from the inside (i.e., veneering) before building up a durable impermeable wall or ring outside the pipe. The intervals between the pump strokes must be shorter than the gel time. Before staging is attempted, the RPR should be notified and approval obtained due to the potentially large volumes of grout utilized in this technique. The RPR should be familiar with stage grouting in order to make the determination that the grout consumption is too high and stop subsequent attempts to seal the joint(s).

Pull Back Testing

As stated earlier, a large percentage of the contractor’s cost in grouting is in the time to setup up grouting operations at a particular sewer line segment. Therefore, additional testing after completion of grouting and before a breakdown of the equipment is a relatively inexpensive requirement. At the completion of the sewer line segment (i.e., manhole to manhole), the contractor should conduct joint grouting verification testing of grouted joints and laterals for quality control purposes on 5% of the grouted main line joints (minimum of two repaired joints)
or 25% of the grouted lateral taps (minimum of one lateral tap). This can be referred to as pull-back testing, since the equipment has to be pulled back to the initial setup manhole anyway. Within a sewer line segment, if any joints, lateral taps fail the retest after sealing, all joints and laterals should be retested, as applicable, in the sewer line segment.

Warranty Testing

Conducting warranty testing prior to termination of the Contract can be a low-cost method to verify the grouting was performed correctly and to ensure peace of mind. If the contractual mechanisms and contracting community can manage longer-duration contracts and maintain performance bonds, warranty testing 1.5 to 2 years after completion of grouting is recommended, normally during seasonally high groundwater conditions. This provides verification that the grouted joints continue to be watertight, that root growth inhibitors continue to be effective, and that joints that previously passed testing did not falsely pass the tests during the initial work. Warranty testing can also reveal if joints that were not grouted may now be failing due to increased hydrostatic pressure.

Since reinspecting and retesting all the work is cost-prohibitive, warranty testing should be performed on all of the joints in 15% of the pipe segments and laterals rehabilitated. If more than 10% of the warranty tested joints fail, test an additional 15% of the pipe segments. If more than 10% of the second group of warranty tested joints fail, test 100% of the joints in the remaining untested pipe segments at no additional compensation.

NEW TECHNOLOGIES

There are constantly developing technologies that build on the same principles as packer injection grouting. Flood grouting techniques are being developed to systemically grout an entire manhole-to-manhole segment, including laterals, at once. Flood grouting, if successfully, may add the benefit of being able to grout some structural defects as well.

New mixtures that are substituted for traditional gels, such as epoxy resins, are being introduced to add even greater structural benefits to the surround soil. These, along with other developing and new technologies, hold a lot of promise for the sewer rehabilitation industry. But like any of the trenchless technologies where the “manufacturing” process takes place in the field under a variety of conditions, they must be specified, observed, and performed by experienced and well-trained people.

CONCLUSIONS

The nation’s sewer pipelines have now become an urgent national concern. Restoring or replacing this aging buried infrastructure will represent by far the largest capital investment for most municipal utilities in the coming decades. Years of under funding have forced utility owners into a reactive management style, with most operational resources allocated to
emergency response and repair. Meanwhile, sewers that have not exhibited problems continue to age and, if left unchanged, will become the operational and structural problems of the future.

Given this state, it is becoming increasingly critical that monies for rehabilitation efforts are used judiciously. Many utility owners have poor past experiences and justified reasons for discounting the effectiveness of grouting. But grouting of structurally sound pipes and manholes is one of the most cost effective means of reducing infiltration and inflow, if it is done correctly. Selection of the appropriate pipes and manholes, developing contract documents that add incentive for the contractor (e.g., fixing the price of grout) and provide the checks (e.g., warranty inspections) to make him grout conservatively, and having a resident project representative that understands the technology (e.g., gel times and their many influences) and what to watch for are all key components to a grouting project. Just as critical are the long-term life-cycle approach to rehabilitation and the understanding that grouting programs are needed prior to making decisions on grouting. From an engineering perspective, if specified conservatively, performed by an incentivized contractor, and observed by a qualified and trained RPR, there is no reason why grouting cannot be one of the most efficient and cost-effective methods in any I/I program.

REFERENCES


