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Gasket Sealing Technology:
A Solution to Sealing Deficiencies in Cured in-Place Pipe Lining

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ABSTRACT: There are many misconceptions about CIPP linings and water migration. Although the myth that CIPP linings bond to the host pipe has largely been discredited, it is still not commonly known that due to the physical properties of thermo-set resins, CIPP liners shrink during polymerization resulting in an annular space between the liner and the host pipe. This annular space allows groundwater to track behind the liner and migrate back into the collection system causing not only a significant amount of avoidable wastewater treatment, but also sanitary sewer overflows (SSOs) and potential groundwater contamination if a seal in the collection system is breached. The awareness of this issue in the CIPP rehabilitation marketplace has initiated research, leading to the development of cylindrically shaped compression gasket end seals engineered to address the annular space at manhole connections and lateral connections using seamlessly molded hydrophilic gaskets in combination with CIPP installations. A full-circle CIPP lining is a structural solution to sub-par piping infrastructure. However, CIPP lining is not a water-tight repair as explained above. As such, end users who rely on CIPP linings to attain a watertight seal, run the risk of allocating funds and resources to solve these issues without achieving their objectives.

1. INTRODUCTION

Current CIPP technologies for rehabilitating a sewer may not create a total sealed system. Resin does not bond to the host pipe due to Fats, Oils, and Grease (FOG) in the sewer line.[1] All resins shrink due to thermal expansion/ contraction after polymerization of the resin resulting in an annular space between the liner and the host pipe (Burkhardt, Hüsgen, Kalwa, Pötsch, & Schwenzer, 2011) (Rahaim, 2010). Secondly, overlapping CIPP liners "cold joints" also do not offer bonding capabilities. These cold joints also possess an annular space between liners due thermal expansion/ contraction after polymerization and therefore are not water-tight. The result of these deficiencies is water infiltration migrating into the collection system from the host pipe defects behind the liner and re-entering the collection system. As such, end users who rely on CIPP linings to attain a watertight seal, run the risk of allocating funds and resources to solve these issues without achieving their objectives.

Typically, the points in a system which leave the access to infiltration are the services, the manhole penetrations, and overlapping CIPP. These connection points are susceptible to defects and allow water to migrate back into the collection system, even once a structural repair is achieved, because a purely structural repair is not water-tight (Rahaim, 2010). Previously there were attempts to seal this annular space and cure the water migration problem using multiple methods. Each of these has been addressed by other technologies including gaskets in the

[1] (Bosseler & Kaltenhauser, 2004), Today, our industry is more knowledgeable on CIPP linings; many owners, specifying engineers and third party testing laboratories confirm that CIPP linings will restore the structural integrity of a sewer pipe yet they recognize the lining does not actually bond to the sewer pipe due to Fats, Oils, and Grease (F.O.G) that exist in sewer lines.

form of hydrophilic rope, hydrophilic grout, and lateral connection liners. However, the technology has continued to move forward to address the sealing deficiencies with these seal types and develop a functional, long lasting sealed system.

A uniform sealing process has been developed with the objective of creating a total sealed system. This total sealed system is defined as the water-tight repair of an area of infrastructure when linings incorporate the use of compression gasket seals (a widely accepted standard for joining and sealing of bell/ spigot piping). **Therefore, a total sealed system is comprised of an industry approved mainline liner, an industry approved lateral connection liner for each service, and an industry accepted manhole rehabilitation product, each with the corresponding compression gasket seal for their connections.**

2. COMPRESSION GASKET SEALING AT JUNCTIONS FOR A TOTAL SEALED SYSTEM

Junctions in the sewer system have been tagged as a major source of the I&I in the system as well as cold joints (overlapping CIPP liners). Ground water tracks behind the liner because the liner is not bonded to the pipe due to FOG in the system and liner shrinkage. When the service lateral connections are sealed the water migrates behind the mainline liner and re-enters the collection system at the manhole connection. Faulty pipe joints and fractured pipe sections within a lateral pipe also leak ground water and contribute to overtaxing a collection system. An area (such as southern California) where ground water is not the primary concern but exfiltration and root intrusion is another case where the system must be sealed. To create an effective total sealed system these problem areas must be renewed in logical order (mainlines, laterals, and manholes) and include a sealing apparatus that is comparable to gaskets which are used in new pipe as described in ASTM F477 - 10 Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe (ASTM, 2010).

However, while CIPP linings may reduce infiltration and exfiltration, but they do not form a verifiable non-leaking new pipe. To actually seal the system and be comparable to a new piping system; compression gasket seals must be utilized during installation of these liners. Compression gasket sealing technology has been used for many years in pipe joining applications, such as bell and spigot piping. Similar gasket sealing is accomplished when rehabilitating the main and lateral pipes with CIPP by placing a seamlessly molded hydrophilic gasket at each manhole and lateral connection. For instance, when sealing a lateral connection, even if the mainline sealing member is a full circle structural liner, it is not water-tight and so it requires a seal at the junction. *Figure 1* is an illustration of a CIPP project which reduced infiltration in the system but did not eliminate it. Additionally, a full length mainline liner will still allow water to migrate behind and back into the collection system unless a flexible compression seal is placed at the termination ends of the liner to prevent water tracking (ASTM, 2010). Lastly, when overlapping CIPP liners in a system, it is good practice to install them with compression seals at the termination points to ensure a water-tight repair.

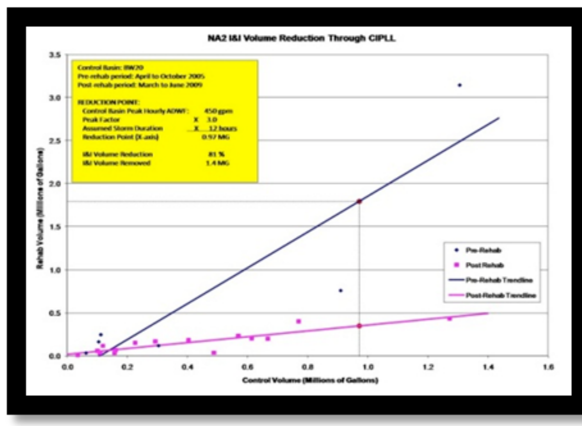

Fig 1. Flow Data from CIPP Project

The intent of sewer rehabilitation is to structurally renew the main and lateral pipes and prevent infiltration of groundwater, wastewater exfiltration, and root intrusion. A lateral pipe can be structurally renewed and sealed with the mainline liner by use of hydrophilic seals as described in ASTM F2561-11, but without the inclusion of end seals at the mainline and manhole junction water will migrate behind the mainline liner and enter the collection system at manhole connections. There have been attempts to seal the sewer system as discussed in the introduction but testing and further research has concluded these previously mentioned sealing attempts are not efficient for eliminating excess infiltration.

3. PREVIOUS MATERIALS AND METHODS FOR SEALING JUNCTIONS

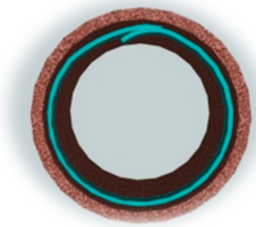

Fig 2. Overlapping Hydrophilic Rope

Previous attempts for sealing the end of pipe linings have been tried with inconsistent results. The gasket material consisted of a hydrophilic rubber in the shape of a flat rope with each end overlapping when wrapped around the interior of the pipe; this method was not self-supporting and contained a weak point[2] and therefore was not a viable option for a non-leaking compression seal (Fig. 2). Further attempts to place a compression seal between the host pipe and the liner post insertion of the liner were also deemed unsuccessful and ineffective[3]. Another concern is the thickness of the gasket and the sealing area. Typically, the flat rope measures 6mm thickness by 12mm-24mm in width which significantly reduced the liner inner cross section causing complications when inserting robotic cutting devices, lateral sealing equipment and CCTV equipment into the lined pipe.

Fig3. Failed Brim

Until recently, the engineering society assumed a lateral connection could be sealed by gluing a brim to the inside of a mainline liner (Fig. 3). Today, engineers understand that bonding a CIP-lateral liner to a CIP-main liner is unsustainable and requires end seals to prevent leakage at each end of the lateral liner. Testing confirms that long-term bonding is problematic and that brim style connection seals leak[4] (Gage, Establishing Objective Test Protocols for the Quantification of Water-Tightness of a Rehabilitated Main/Lateral Sewer Connection, 2011), (Bosseler & Kaltenhauser, 2004), and (Gage & Kiest Jr., A Comprehensive Understanding of ASTM F2561-06 "The Standard Practice for Rehabilitation of a Sewer Service Lateral and its Connection to the Main Using a One-Piece Main and Lateral Cured-in-Place Liner.", 2009) and therefore is also not an efficient option for sealing the lateral connection and do not contain a compressible material held in place by a structural element[5] for making a repair that is comparable to new piping.

Since it has been established that bonding of CIPP is unpredictable, it was concluded that research and development was needed to address the concerns with cured in-place pipe in relation to its ability to seal the collection system by using compression gasket seals.

4. ENGINEERED GASKETS FOR CONNECTIONS

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[2] Since the flat rubber rope was not self-supporting, even the attempt to secure it with double sided tape was unreliable due to conditions in the pipe which prevent bonding (footnote 4).

[3] Placing the flat rope in the pipe after the liner had been inserted was also inefficient and unreliable. Technicians confirm that this is difficult due to conditions in a manhole, exposure to resin, and ensuring ends are overlapped when fitting the between the liner and host pipe.

[4] Lubricants are applied to the plastic coating on the liner to reduce friction as the liner is inverted as described in ASTM F1216. These lubricants are release agents on the inside of the new liner that actually prevent adhesion. Even with correct surface preparation specifying engineers have no means for confirming the surface of the mainline liner is suitable for long-term bonding. Currently there are no proven methods, practices, ASTM standards or studies that substantiate the success of removing lubricants from a mainline liner. The brim is only effective if it bonds and only for so long as it remains bonded. Since a brim style lateral seal cannot be designed by producing specific repeatable bond strength, then likewise a calculated service life is absent.

[5] This structural element is a hollow cylinder as described in ASTM F1216 whereby the cylinder can be designed for structural loading, specifically hydrostatic loading.

4.1 Sealing Liners at Lateral Connections

Fig 4. Main/Lateral Hydrophilic Gasket

The solution for making a long-term seal at each lateral connection is to incorporate a flexible *compression gasket*. Gasket sealing is a proven long-term pipe sealing method specified by engineers for joining bell/spigot pipe (ASTM, 2010). Gasket sealing has been used extensively for many years to join and seal bell and spigot piping and is compatible for use with all types of piping i.e. concrete, VCP, PVC, DI, CI, and etc. ASTM F2561-11 describes an engineered structural lateral connection liner that includes flexible compression gasket seals that are compatible with all full-length main lining materials (Fig. 4). The flexible gaskets create a seal which is not compromised by thermal expansion or thermal contraction, F.O.G., and incompatible materials. These hydrophilic compression gaskets were tested in a hydrostatic test tank (Fig. 5) at 30-psi (71-feet of external hydrostatic loading) confirming that a structural CIPP liner with the inclusion of compression gaskets is comparable to that of a new sewer pipe.

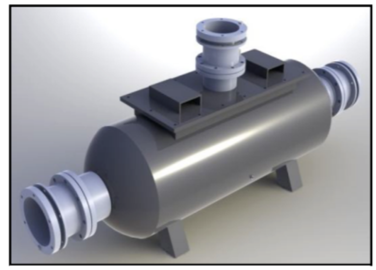

Fig 5. Hydrostatic Test Tank

4.2 Sealing Liners at Manhole Connections

The solution for making a long-term seal at each manhole connection is the incorporation of a flexible *compression gasket*. To improve upon the previous materials and methods, a tubular shaped gasket was developed to overcome the historical issues and inconsistent results. The development focused on:

- Separations in the gasket
- Reducing gasket wall thickness
- Increasing the sealing surface area
- Securing the gasket in the pipe prior to liner insertion

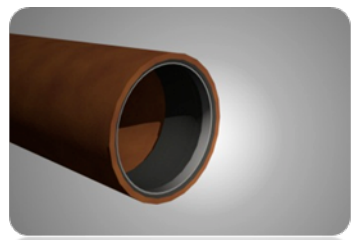

Fig 6a. End Seal 3D Rendering

To ensure no separation in the gasket, a seamless gasket was developed (Fig. 6a). The gasket thickness was a concern due to the significantly reduced pipe cross section. As a result, the seamless gasket was designed with a 2mm-3mm wall thickness. Additionally, the seamless gasket was designed to significantly increase the sealing surface by molding a tubular gasket measuring 3.5-inches in width. The final design included a retaining ring that secures the gasket in the pipe by pressing the gasket against the pipe wall ensuring the gasket does not move during liner insertion (Fig. 6b).

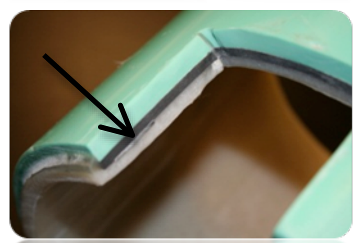

Fig 6b. Actual End Seal Cut-Out

5. DESIGN LIFE VERSUSES SERVICE LIFE

The words "service life" can be misleading. You often see owners and specifying engineers state that the lining must produce a minimum 50-year service life, yet the service life of a rehabilitation product is quite different from the design life of the materials that make the repair. The design life for cured-in-place pipe is derived by applying the formulas in ASTM F1216 for calculating strength. However, the service life is more than just the structural design; it is also the water tightness of the pipe lining. The seal design must match the structural design life, therefore the service life is the time period until the seal fails and the rehabilitated pipe requires maintenance or repair.

If the design life is stated as 50-years and the service life of a pipe renewal product is less than 50-years then the engineer should estimate the timing and cost for repairs that will be required to reach the prescribed design life. This is done to compare multiple methods of repair where each provides different service lives. For example: grouting a service connection may provide an estimated service life of 8-years meaning that repair product will require 6 renewals to achieve a 50-year design life cycle. The initial cost of this alternative is estimated at $650, while the grouting must be renewed on an 8-year cycle means the overall costs for meeting the 50-year design life (not including the time value correction) will be $4550 (or $650 + (6*650)). In another example: a brim style CIP-lateral connection liner (25'in length); while the service life of the <u>*liner tube*</u> should last 50-years per the design life, the water-tightness service performance of the <u>*brim seal*</u> will most likely be less than 5 years requiring renewal at least 6-times by grouting to achieve the desired 50-year service life. Extending the numbers out, the initial cost of this alternative is estimated to be $2800, while the brim must be renewed by grouting on a 5-year cycle means the overall costs for a 50-year design life (not including the time value correction) will be $6,700 (or $2800 + (6*650)).

The seal with the main has to be robust enough to survive over time and that requires a seal that is flexible and fully seated around the main/lateral juncture to ensure long-term performance. The service life value for various alternatives must deliver all of the potential costs. We have discussed the initial cost, and the overall costs, but in so doing we must also acknowledge the transportation and treatment costs if nothing is done for maintenance or repair on products that have a service life less than the design life. Case in point, at 1.5gpd/lateral over a 45 year span at $6.0 per gallon for its transportation and treatment, that equates to over $147,825 added to the initial cost of $2800 for the brim style CIP-lateral liner. A similar scenario would play out for the grouting alternative if renewal is not made on the 8-year cycles.

6. THE BENEFITS OF A SEALED SYSTEM

The benefits to utilizing an engineered gasket seal in conjunction with CIPP technologies, is a total sealed system with consistent results. A sealed system reduces maintenance cost, sewer overflows, and wastewater treatment cost. The city of Naperville is a fine example of a city that experienced rapid growth over the past 20-years. The increased population combined with extraneous flows during wet weather events resulted in a planned multi-million dollar treatment plant expansion. The city of Naperville is a very forward thinking municipality with resources to properly engineer and implement their collection system rehabilitation projects. Naperville has been renewing manholes, sewer mains, lateral pipes and installing cleanouts as part of their rehabilitation program.

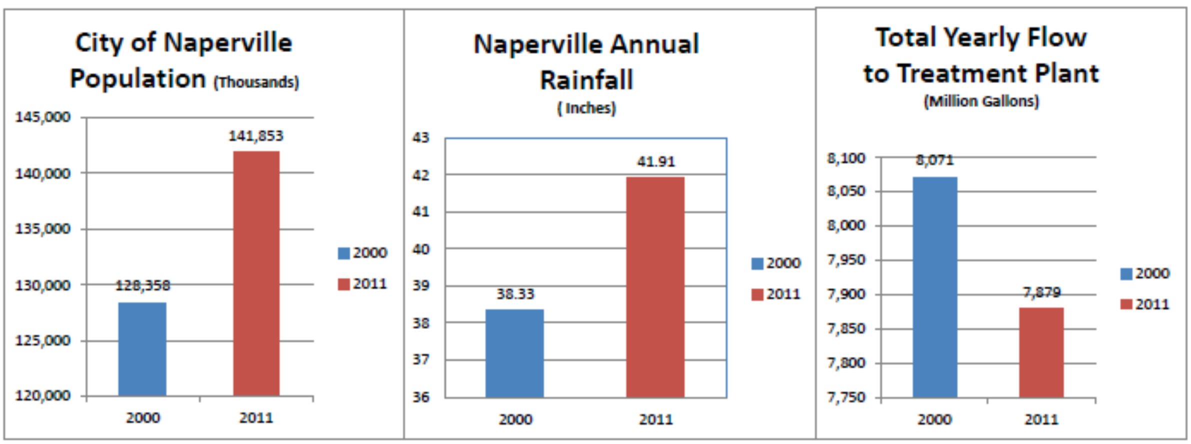

Fig 7. Naperville 2011 Flow Data

The lateral lining materials and installation practice has been in compliance with ASTM F2561 which requires a full-circle structural lateral connection that incorporates compression gaskets. The Naperville Department of public utilities primarily utilizes trenchless technologies. The Department of public utility employees self-install cleanouts by means of a trenchless vacuum installation. The city crews also work in coordination with rehabilitation contractors, which saves money and produces better results than compared to outsourcing the entire scope of work.

The Naperville department of public utilities has lined more than 65-miles of sanitary sewer mains since 1992, and more than 3,000 sewer service laterals since 2003. Sanitary sewer rehabilitation is already paying off. The ongoing elimination of groundwater infiltration has resulted in a measurable decrease in incoming flow at the Springbrook Water Reclamation Center. These rehabilitation methods in turn saved treatment cost such as power, chemicals, labor and other related expenditures tied to daily wastewater treatment. Even as the population rose from 128,000 to 142,000 from 2000-2011 (Fig. 7) the wastewater treated on a daily basis actually went down significantly from 8,071x10^6 in 2000 to 7,879x10^6 in 2011(Fig. 7).

The planned multi-million dollar plant expansion has been deferred as a result of creating more system capacity by sealing the sanitary sewer system. Likewise, Naperville is also benefitting from the greatly reduced maintenance costs associated with renewing and sealing their sewer collection system. Areas that were root sawed yearly no longer need such and renewed mainlines also require far less cleaning. The basins that have been lined and sealed require cleaning every four years instead of yearly.

These savings are significant and should not be overlooked. One benefit not often discussed is the increased capacity the sewer main will have once the system is sealed. Recovered capacity in many cases will allow for more service connections which represent a revenue enhancement that does not involve an increase in fees and or taxes. The city of Naperville spends about 2.8 million dollars per year on sealing the sanitary sewer system. This money is spent on the lining of mains and laterals and on the sealing of manholes. Concentrating system sealing in troubled basins has provided the most effective method of reducing I&I. By doing so, all of the benefits above have been achieved.

7. REFERENCES

ASTM. (2010). Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe. In S. F17.20, *ASTM Standards International* (Vol. 8.04, pp. F477-10). Atlantic City, New Jersey : ASTM International . Retrieved from http://www.astm.org/Standards/F477.htm

Bosseler, D. B., & Kaltenhauser, G. (2004). *Testing Top Hat Liners and Robotic Systems for Repair of Lateral Liners.* IKT. Exterbruch, Gelsenkirchen Germany: IKT- Institute for Underground Infrastructure. Retrieved January 25, 2012, from http://www.ikt.de/down/english/Testing_Liners_2005.pdf

Burkhardt, G., Hüsgen, ,. U., Kalwa, M., Pötsch, G., & Schwenzer, C. (2011). *Ullmann's Encyclopedia of Industrial Chemistry.* Verlag GmbH & Co. KGaA: Wiley-VCH. Retrieved January 30, 2012, from http://onlinelibrary.wiley.com/doi/10.1002/14356007.o20_o01/full

Gage, R. (2011). Establishing Objective Test Protocols for the Quantification of Water-Tightness of a Rehabilitated Main/Lateral Sewer Connection. *No Dig Show* (pp. 1-5). Washington D.C.: Benjamin Media.

Gage, R., & Kiest Jr., L. (2009). A Comprehensive Understanding of ASTM F2561-06 “The Standard Practice for Rehabilitation of a Sewer Service Lateral and its Connection to the Main Using a One-Piece Main and Lateral Cured-in-Place Liner.". *International No-Dig Show* (pp. 2-7). Ontario, CA: Benjamin Media.

Rahaim, K. (2010, January 25). Adhesion of Cured in-Place Pipe Resins. St. Paul: Interplastic Coporation.