Trouble Shooting for Trenchless Liner Installation During Sewer Line Rehabilitation

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ABSTRACT

Lining is being used by the utility industry as a cost effective solution to rehabilitate utility lines. Many types of liners, such as, cured-in-place-pipe (CIPP), fold and form PVC, deformed & reformed HDPE, etc., are being used to restore structural integrity of deteriorated pipes and to reduce inflow/infiltration. Most of the lining installation is carried out without any problem, however, sometimes installation does not proceed as expected and problems occur during and after installation. Occasionally it is necessary to rectify problems such as uncured soft liner from insufficient curing, bottom lift-up, ribs, pinholes, pokeholes, delamination, wrinkles, blockages due to liner shifting over openings, severed tie-ins at manhole locations, and non-advancement during inversions. This paper highlights several lining problems encountered in the field and offers trouble-shooting guidance. Experiences described herein include problems that occurred with CIPP and deformed & reformed HDPE liner installations. The review of these problems, remedial actions taken, and discussion of the lessons learned on the projects are intended to assist the engineer, owner, and contractor in taking appropriate actions to prevent potential problems and to correct problems on future projects. Field experiences from five (5) different lining projects are the basis of this paper.

KEYWORDS

Sewer line rehabilitation, lining, cured-in-place-pipe (CIPP), deformed & reformed HDPE, point repair, trouble shooting.

INTRODUCTION:

Lining is widely used by the utility industry to rehabilitate deteriorated pipes, including sewer, water and gas lines. The lining industry provides a cost-effective solution to aging utility lines in the United States and other countries. The lining method is very effective in reducing inflow/infiltration (I/I) and restoring the structural integrity of deteriorated lines. There are a number of lining products and methods available in the market. The methods can broadly be categorized as CIPP, fold & form, deformed & reformed, and spiral-wound. Although all types of linings have been successfully installed in the field, occasionally problems occur during and after installation. This paper discusses some problems that were encountered, reasons that created the problems, and remedial actions taken on five different lining projects completed in
Northern California. To protect the name of the project and the contractor, the projects are denoted as Projects A, B, C, D, and E. Lessons learned from all five projects are also presented.

**PROJECT A**

**Construction Sequence and Problems Encountered- Project A**

Project A consisted of CIPP lining of 24-inch, 30-inch, and 84-inch storm sewer pipes. The contractor installed several segments of lining with no difficulty and then moved to the 24-inch lining. After all preparatory work was complete, the inversion of 24-inch lining started at about 12:30 p.m. on January 08, 2004. It was a wet day with low temperature (approximately 45 degrees) and rain showers. The pipe was flowing about ¼ full due to drainage from the yard of a commercial establishment. The ground was wet and moderate infiltration through cracks was noticed in CCTV inspection prior to inversion. The contractor elected not to use by-pass pumping because the flow was limited and the lining segment was only 80 feet. However, a standby pump was onsite to pump from upstream manhole as needed.

The inversion was quick and easy and 80 feet of 24-inch lining completed in 30 minutes. The inversion head was maintained at a level recommended by the felt tube manufacturer. Thermocouples set at the upstream and downstream ends measured the “cooking” temperature and determined when exotherm occured. The entire curing process lasted for 5 hours after which the liner ends were opened (at approximately 6:00 p.m.). Visual observation from the manhole showed a very soft and collapsed liner inside the host pipe. It was not possible to run the TV camera through the pipe due to the blockage from the uncured, soft liner. The infiltrating water was flowing heavily through the annular space between the liner and the host pipe and into the downstream manhole. When the uncured liner was inspected, another crew team was immediately contacted. The new crew came overnight with a higher capacity steamer and attempted to re-pressurize and re-cure the soft liner the next morning. Since both ends were open and no water inversion was possible, the ends of the liner were plugged with inflatable plugs before re-pressurizing the liner. This technique did not work well despite numerous attempts as the inflatable plugs were not able to sustain the 5 to 6 psi stream curing pressure. The new crew postponed the re-curing process on the second day at about 6:00 pm. On third day, the crew members were able to install suitable plugs on the ends of the liner and were able to “cook” the 2-day old soft liner for about 6 hours. When the cured liner was opened, visual observation showed an improved result; however, there was still liner lift-up at the invert in the middle of the pipe, as shown in Figure 1. The TV camera was able to proceed 30 feet from the manhole to the obstruction, but could not pass the obstruction. It was estimated that the lift-up, which was blocking 1/3 of the pipe opening but allowing the flow, was about 25 feet long in the 80-foot CIPP lining segment.
In addition to the bottom lift-up of the 24-inch CIPP liner, several other problems were also developed during and after construction of Project A. These problems included ribs, pinhole, wrinkles and dry spots in the 30-inch and 84-inch CIPP liner.

The 30-inch CIPP liner did not show any significant problems during installation, however, post-CCTV revealed a “rib” approximately 24 feet in length in the middle of a 90-foot liner as shown in Figure 2. This “rib” was about 2 to 3 inches high and 3 inches wide, but the rib was not blocking the flow and the TV camera could pass over the rib.
Post CCTV also revealed a pinhole on one side of the 30-inch CIPP liner as shown in Figure 3. Active infiltration through the pinhole was observed during post-CCTV inspection. Other minor problems of fins and wrinkles were also observed in the 84-inch CIPP liner as shown in Figure 4, however, these problems were found to be structurally insignificant and did not require the liner to be removed or repaired.

**Figure 3: Pinhole w/Active Infiltration**

![Image of a pinhole with active infiltration in a CIPP liner]

**Figure 4: Fins and Wrinkles in Liner**

![Image showing fins and wrinkles in a CIPP liner]
Possible Reasons of Problems Encountered- Project A

A. **Bottom Lift-Up:** Factors which might have contributed to bottom lift-up of 24-inch CIPP liner in Project A were as follows:

1. The boiler unit which was used for cooking the CIPP liner on the first day of installation did not have enough capacity to provide necessary thermal units for curing the 24-inch liner. As the water infiltration was significant and the weather was cold and rainy, the water infiltration through the broken pipe joints could have acted as a heat sink and reduced the heat available for cooking the resin.

2. The active infiltration through cracks may have diluted and washed away the resin, making the cooking process ineffective. Depleted resin in the felt layers could cause the liner to be soft upon curing and the groundwater pressure could cause the liner bottom to lift-up.

3. While monitoring the cooking and exotherm temperatures, the temperature reading indicated an error. It is possible that the thermocouples at downstream end malfunctioned during the cooking/curing process and the correct temperature could not be measured. This may have resulted in immature termination of the cooking and curing process.

4. The re-circulation and heating of water inside the liner may not have functioned properly since the temperature at the steam/boiler inlet was errant.

5. The installation head used for liner inversion into the host pipe may not have been sufficient to counter balance the active groundwater infiltration through broken joints. The ideal inversion head, as recommended by the felt tube manufacturer, was 14 feet. This head was to be maintained during the initial inversion. A higher inversion head, such as maximum hot head may have been more appropriate, for the field conditions encountered, to keep the liner pressed against the wall and to prevent water from intruding between the advancing liner and pipe wall. The maximum head of 19 feet (calculated as maximum hot head for the felt tube used) was used for inversion during final installation, three months after the failed installation, and the head was seen to be more effective in preventing water entrapment.

B. **Rib:** A possible reason for the development of the rib in the 30-inch CIPP liner was the significant groundwater infiltration during installation, which might have acted as heat sink and prevented the liner from gaining full strength during curing. The cooking of 30-inch CIPP liner was done by the same boiler unit that cooked the failed 24-inch CIPP liner at the initial attempt mentioned above. As such, the rib might also have been developed due to insufficient re-circulation and curing of the liner. For this 30-inch liner, the entire curing process lasted for four hours before the crew rushed to the next lining segment on the same day.

C. **Pinhole:** The pinhole in the 30-inch liner might have developed from a pre-existing hole in the felt tube which was not covered by resin during curing. The hole may also have been developed during storage and handling of felt tube and/or resin impregnation.
D. **Fins and Wrinkles:** Minor problems of fins in the 84-inch CIPP liner might have resulted from shape mismatch of the host pipe and the liner tube. The host pipe for the 84-inch CIPP liner was an 84-inch corrugated metal pipe that was irregular shaped throughout the length. Wrinkles that developed in the 84-inch CIPP liner were minor and might have resulted from shape irregularity and less than perfect curing. Wrinkles at both ends of the 24-inch liner were under the inflated packers, which were used to seal open ends before steam curing the previously uncured 24-inch CIPP liner.

E. **Dry Spots:** A few dry spots and tiny soft spots were observed in the upper layer of the 84-inch liner, which might have developed from non-uniform spreading of resin into the felt tubes during resin impregnation.

**Remedial Actions- Project A**

1. Problems of bottom lift-up, ribs, and pinholes in the 24-inch and 30-inch CIPP liners eventually caused the liners to be completely removed from the host pipe and re-installed with new CIPP liners. The contractor first proposed to use a thin-walled liner over the entire length of the 24-inch CIPP liner and then apply high pressure to smooth out the bottom lift-up that developed during initial installation. However, since there was significant groundwater entrapped between the liner and host pipe, it was determined that this repair method would not work well to push the entrapped water back through cracks or to downstream manhole along the annular space. Moreover, since the liner lift-up was in the middle of the pipe, approximately 25 feet from upstream and downstream manholes, and the liner beyond the lift-up adhered to pipe wall, the only exit for the entrapped water was through the pipe cracks as no annular space path existed to the manholes.

2. The contractor also proposed to manually remove only the lift-up or rib portion of the liners and then insert thin-walled liner for the entire segment. Since this repair method would have made the final liner wall very thin over the removed section and would be structurally deficient, this repair method was also rejected.

3. Grouting and structural epoxy coating was proposed to repair the pinholes in the 30-inch lining.

4. The contactor finally removed the entire liner manually and re-installed new CIPP liner in both the 24-inch and 30-inch pipes. Both the 24-inch and 30-inch CIPP liners were re-installed in April, 2004, three months after the initial installation.

5. Fins that developed in the 84-inch CIPP liner were cut/grinded and removed, and coated with epoxy. However, after cutting the fins, no gap or hole was observed behind the fins, which ensured that the liner had full thickness where the fins had developed.

6. Wrinkles developed in 84-inch and 24-inch liners were small and did not cause any structural deficiency. In addition, they did not reduce the flow area. All minor wrinkles that developed in the 84-inch CIPP liner were accepted.

7. Dry spots and tiny soft spots that developed in the 2-inch thick 84-inch CIPP liner were not causing any concerns related to structural integrity or strength and were accepted.
PROJECT B

Construction Sequence and Problems Encountered- Project B

Project B consisted of 6-inch, 8-inch, 10-inch, and 12-inch CIPP liners and several 6-inch CIPP point repairs. The contractor installed all the liners without any difficulty except one 6-inch lining segment and one 6-inch CIPP point repair. The 6-inch CIPP lining which encountered problems during installation was in a section specified for night-work only. After moving in to the site at 9:00 pm, the contractor finished all preparatory work by 12:00 a.m. and then started the inversion at 12:15 a.m. The segment was about 400-feet of 6-inch sanitary sewer line at a depth of 18 feet. The first problem with the inversion was the rate of advancement of liner. An advancement rate of 2 to 4 feet per minute was estimated, however, to advance the tail end from the insertion platform to the pipe inlet in the manhole took approximately 2 hours. The insertion proved to be difficult from the beginning as the advancement required lots of kicking and hitting of the liner. Also, a pump was used to raise the inversion pressure head beyond the recommended limit to force the liner to advance. After installing about 120 feet liner into the pipe, the inversion completely stopped and the process was abandoned at about 3:30 a.m. The crew had restriction on working hours and had to be out of the busy roadway by 6:00 a.m. Since the resin soaked felt liner was still soft, the crew cut a slit in the liner, drained the water, and started to pull back the liner. The abandonment of the 6-inch CIPP liner is shown in Figure 5 and 6. Complete removal of the uncured liner was not possible by 6:00 a.m., so the crew cleaned as much as possible to make sure that the sewer flow was not blocked and the roadway was open to the public. On the next night, the crew came back and removed the remaining liner and then re-installed new liner without incident.

Figure 5: Abandoning Partially Inverted CIPP Liner
A second crew installed 6-inch CIPP point repair on another segment of the sanitary sewer. The point repair involved covering a 4-foot crack with a 6-foot CIPP point repair section. After positioning the liner section over the crack, it was inflated and cured with steam. However, post-CCTV showed that approximately 1 foot of the crack was not covered by the first point repair section, as shown in Figure 7, due to misplacement of liner over the crack. The 6-inch host pipe proved to be very difficult for CIPP internal point repair due to restrictions on maneuvering the equipment inside the pipe.

Figure 7: Crack not Covered by the Initial Section of CIPP Point Repair
As the first section of CIPP point repair could not cover the 4-foot crack in one pass, another section of CIPP point repair was required to cover the remaining crack with a minimum of 1 foot overlapping. The second lining section was installed at 3:30 a.m. with approximately 3 feet of overlap. After curing the liner with stream, post-CCTV inspection revealed that the 1-foot crack was covered, however ribs had developed over the overlapping sections, as shown in Figure 8. Since the crew did not have any small cutter/grinder tools to cut and remove the ribs, the ribs in the liner were left in the pipeline. After almost one month, the crew came back with a special smaller grinder and removed the ribs. Epoxy was applied over the grind surface to make a smooth and structurally sound CIPP point repair lining section.

Figure 8: Ribs Developed at Overlapped Two CIPP Point Repair Sections

Remedial Actions- Project B

1. To facilitate advancement of liner during inversion, specially for smaller diameter pipes, carefully plan the field work and keep every back-up available. It may be prudent to specify high strength liner for smaller pipe diameters so that the thickness can be reduced allowing the material to be more pliable for inversion through the smaller pipe. Another option to facilitate advancement of the liner during inversion is to add a supplemental tie rope/string at the invert end, as shown in Figure 9. The pull rope allows the liner to be pulled from the other manhole in addition to the pressure inversion. This pull force may facilitate the inversion process and reduce the risk of seam failure from higher head being applied to advance the liner from the insertion manhole. The tie rope/string could save a project when the inversion does not proceed due to non-advancement of the tail end.
2. Another option to avoid potential non-advancement of the liner is to specify CIPP Pull-In-Place Insertion Method (ASTM F1743) in addition to the most commonly used CIPP Inversion and Curing Method (ASTM F1216). The contractor can then choose the most suitable method based on specific site conditions and pipe size.

3. The ribs developed in the overlapping CIPP point repair liner section were ground by a special grinder and coated with epoxy. CIPP point repair liner overlapping and other related problems can be avoided by making sure that the repair bladder is long enough to cover the entire damaged section of pipe plus a minimum of 1 foot on each end of repair section. Development of ribs in this case could have been avoided if the crack was covered by one CIPP point repair section.

PROJECT C

Problems Encountered- Project C

Project C used HDPE deformed & reformed liner for 6-inch to 15-inch sanitary sewer lines. The problems encountered with this liner included movement of service opening and subsequent blockage of service, severed HDPE tie-ins at manhole, increased annular space between the liner and host pipe, and open cut removal of a few substandard HDPE linings. Figure 10 shows severed HDPE tie-ins at a manhole. The liner was pulled inside due to shrinkage and creep and caused the tie-in failure. Although the tie-in was in place to prevent movement of liner due to shrinkage, it moved about 4 to 5 inches from the manhole. The liner movement, after installation and lateral reinstatement, also caused blockage of the lateral opening as shown in Figure 11. This figure shows the excavated and removed section of the host pipe and liner, along with the PVC lateral. Since most of the residential sewer laterals are 4 to 6 inches, movement of 4 to 5 inches blocked the lateral completely as evident from this picture. Also evident in Figure 11 is the excessive annular space that was created due to radial shrinkage of the HDPE liner.
Possible Reasons and Remedial Actions- Project C

The problems above may have resulted from the following factors:

1. After installing the deformed & reformed HDPE liners inside the host pipe, adequate relaxation time may not have been allowed. The tie-in at the manhole and openings of the laterals were completed before immediate shrinkage or relaxation of the liner took place. The tie-in was inadequate to account for the shrinkage of the liner.
2. The HDPE liner material may have been defective and may not have met the specific requirements for the project.

3. When HDPE liner shifts and blocks a lateral, the lateral connection can be re-opened using a remote lateral opener. Also the section of HDPE lining blocking the opening may be removed, the section lined with a CIPP point repair section, and then the service connection re-opened in the CIPP section. The sectional CIPP point repair can also be used at the manhole location when the installed HDPE liner is severed at the manhole connection.

PROJECT D

Problems Encountered- Project D

Problems encountered in Project D include misidentification of service openings, pokeholes and difficulties reinstating laterals. On this project, the 6-inch to 12-inch CIPP liners were installed in sanitary sewer lines. Positive identification of service connections created a problem in one segment. A lateral was located near a severely broken section of 8-inch clay pipe. The broken pieces of pipe were washed away and the soil behind the pipe was exposed, creating a hole in the pipe wall. During pre-CCTV inspection, the hole was noted along with identification of the nearby lateral. However, after CIPP liner installation, CCTV inspection identified the broken pipe hole as the lateral opening and it was opened using the remote lateral opener. Discovering the error, known as a pokehole, the adjacent lateral was opened and the damaged liner at the pokehole was repaired with a CIPP point repair section.

Lateral openings also experienced problems where the mainline and lateral joints had concrete covers. In some cases, the concrete was seen to be partially blocking the lateral opening. It is likely that those joints between the mainline and lateral had gaps during initial construction or during subsequent repair and concrete was placed to seal the gaps. However, the gaps also allowed the concrete to move inside the joint and partially block the opening. This type of blockage had hindered accurate lateral reinstatement from inside.

Possible Reasons and Remedial Actions- Project D

The dimple, similar to one shown in Figure 12, was not correctly identified during the pre-CCTV and post-CCTV inspection. Although this kind of error is not common, it does occur if careful inspection is not conducted. Determining if a lateral opening is partially blocked by concrete fill, careful CCTV inspection at each lateral should be conducted. If the existing lateral joints show severe concrete blockage, the joint may require open-cut replacement before lining the mainline.

Figure 12: Typical Dimple at Lateral
For sanitary sewers, most laterals are 3- to 6-inch in diameter, and dimples may be easily identified. However, for pressure pipe lining, such as water lines, most of the service taps are approximately ¼- to 2-inches in diameter and dimples may be hard to identify. Greater precision is required for identifying and opening taps for pressure pipe lining. Structural integrity and full leak-proof are other important factors for pressure pipe liner opening and sealing.

PROJECT E

Problems Encountered- Project E

The problems encountered in Project E include bottom lift-up and humps developed in 30-inch CIPP lining. The total inverted lining segment was 1038 feet long, passing through several intermediate manholes. The post-CCTV revealed substantial lift developed in the liner as shown in Figure 13, approximately 105 feet long and 6-inches high, located in the middle of lining segment.

Figure 13: Lift-Up CIPP Liner

Possible Reasons and Remedial Actions- Project E

Two possible causes for the liner lift-up were identified: under capacity of the boiler unit and inadequate re-circulation of water inside the liner during the cooking and curing process. No groundwater infiltration was observed at the location of the liner lift-up. The total volume of the curing exceeded the capacity of the boiler unit. The length also made it difficult to properly re-circulate water inside the liner during cooking and curing.

The repair method of lift-up soft liner is shown in Figure 14. A new liner was inverted from a nearby manhole with 105 feet of the liner saturated with resin to cover the gap in the lining, created by removal of lift-up section. The remaining liner from the insertion end was only a felt tube with no resin. The tail end stopped after passing over the gap. After curing, the resin saturated felt section formed the liner of the same thickness and strength as the initial liner. The remaining unsaturated felt tube was cut and removed and the transition was treated with epoxy.
LESSONS LEARNED

Based on trouble shooting experiences from projects investigated and reviewed, the following key lessons learned could be of value for lining contractors as well as engineers and owners of utilities:

1. Calculate the capacity of the boiler unit based on the volume of water to be heated inside the inverted liner. The boiler or steamer unit should have sufficient BTUs for the required water to be heated. One should not discount the effects from the water that is infiltrating into the pipeline during the inversion process and how that might impact the overall temperature. Always keep a standby boiler or steamer unit onsite.

2. If infiltration is observed through pipe joints, consider cooking for longer time to compensate the heat being lost due to presence of cold water coming into contact with the liner.

3. Water infiltration can also wash away or dilute the resin in the felt tube when it comes in contact with flowing water. Using pre-liner can help retain the resins (soaked in felt layers), and make the liner wall strong upon curing. The weak liner wall may cause lift-up or ribs in the liner when groundwater pressure is higher.
4. Inversion of CIPP liner can be accomplished in long lengths, passing through several intermediate manholes, however, inversion length should be limited to reduce difficulty in water re-circulation during curing. It may be better to install liners in shorter passes to reduce circulation and eventual curing problems than in longer lengths. The length of the inversion is also depended on the diameter of the pipe being lined and the volume of water used.

5. Use of higher inversion head in pipelines below the water table may help the liner to tightly fit against the wall and push the groundwater out with the advancing tail end.

6. Tie-in and lateral opening for HDPE liners should be carried out after relaxation period of HDPE liner to avoid manhole tie-in severance and shifting and blockage of lateral opening due to shrinkage of the liner. In some cases, laterals may have to be connected by open cut due to movement of liner.

7. Careful identification of laterals is essential to avoid opening the lateral in a wrong location.

8. CIPP point repair should be done in one pass, if possible, to cover the entire crack. The inflatable bladder used for sectional repair should be long enough to cover the repair length.

9. It is advisable to add a section in the specifications requiring a certain time period within which the contractor should correct any lining problem encountered. Without this provision, a contractor may wait till the end of construction to correct the problem which was seen in two of lining projects described earlier.

CONCLUSION

Lining is the most viable method of rehabilitating utility lines. Most of the problems occur because of poor workmanship and/or adverse field conditions. When problems occur, the engineer, owner and the contractor should make a decision to correct the problem within a shortest possible timeframe to avoid disturbance to services. The engineer should inform the owner about all of the available options for correcting the problem and should recommend the most feasible repair method. The contractor should make all diligent efforts to avoid problems, however, if they occur during or after installation, the contractor should be willing to work with the owner/engineer to implement the most feasible solution.

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