New Standards for Testing and Certifying Cured-In-Place Pipe

By Chuck Hansen, BSc, MBA, Founder Electro Scan Inc., Former Chair ASTM F36.20, Former Chairman & Founder Hansen Software Inc. (1983-2007).

Introduction

It is estimated that nearly 75,000 miles of wastewater and water pipelines have been lined with Cured-In-Place Pipe (CIPP), with nearly $3 billion spent annually on the trenchless renovation method, worldwide.

Yet, little if any testing has been done once CIPP lining has been fully installed. Instead, agencies have relied on visual inspection or closed-circuit television (CCTV) cameras to approve large and small projects. In contrast, German sewer authorities, at a minimum, require CIPP lined pipes to undergo independent testing of samples taken from each liner at the manhole. In 2016, liners from 24 European contractors underwent rigorous testing by the Institute for Underground Infrastructure GmbH (IKT), publishing all results.

Recognizing the growing use of CIPP and inability of CCTV inspection to accurately or consistently certify trenchless rehabilitation as *defect-free*, this paper chronicles the emergence of new guidelines to test, certify, and accept CIPP lining projects, using *Focused Electrode Leak Location (FELL)* inspection.

Trenchless Industry Development

It all started in 1971 in London, England when Eric Wood had a leaky pipe under his garage. To eliminate the need to dig up his entire garage floor to repair the pipe, Wood invented a new renovation method: cured-in-place pipe (CIPP) lining. He initially named the process *insit u form,* derived from the Latin meaning "form in place."

In January 1975, Wood applied for a patent for cured-in-place pipe lining that was granted in February 1977. Insituform Technologies later commercialized the patent and brought the technology to the United States shortly thereafter. Since its inception, CIPP has enjoyed widespread adoption due to its ease of installation and low cost, compared to dig and replace.

CIPP can be used to rehabilitate sanitary sewers, storm drains, and pressurized water and gas pipelines. Circular pipe, from 4 inches to 60 inches and a variety of noncircular pipe such as egg shapes, ovoids, and box culverts, can be lined. Lining removes the pipe from service for the duration of the CIPP installation and reinstatement process, with bypass pumping sometimes necessary.

Prior to lining, the pipe must be cleaned by jetting to remove corrosion and debris. Protruding lateral connections must also be removed, with some repairs required where the existing pipe is substantially deformed, damaged, or collapsed. After lining, each service connection or lateral must be reinstated before the pipe can be returned to service, usually within the same day. Lined water mains must also be disinfected before returning to full service.

"After selling Hansen Software in 2007, I got a call from Ken Kerri[1] asking me to look for ways to find & measure defects in CIPP liners, missed by CCTV (Figure 1).

I had no idea how widespread the problems were with CIPP and glad my team could find a solution – now recognized as the new standard for testing, certifying, and accepting liners."

Chuck Hansen

CIPP liners of non-woven polyester felt or fiber reinforced fabric are manufactured to fit each host pipe. Liners are typically impregnated with a polymer resin, which creates a lined pipe within the host pipe when cured or cooked. Liners are designed with sufficient thickness when cured to sustain the loads imposed by external groundwater and internal service pressure, soil, and overhead traffic.

Liners are typically saturated with polyester, vinyl ester epoxy, or silicate resin using vacuum, gravity, or other applied pressure. The resin includes a chemical catalyst or other hardener to facilitate curing. The outermost layer of the liner tube is typically coated with a polymer film to protect the liner during handling and installation, with impregnated liner typically chilled for transportation to the job site to maintain stability until installed.

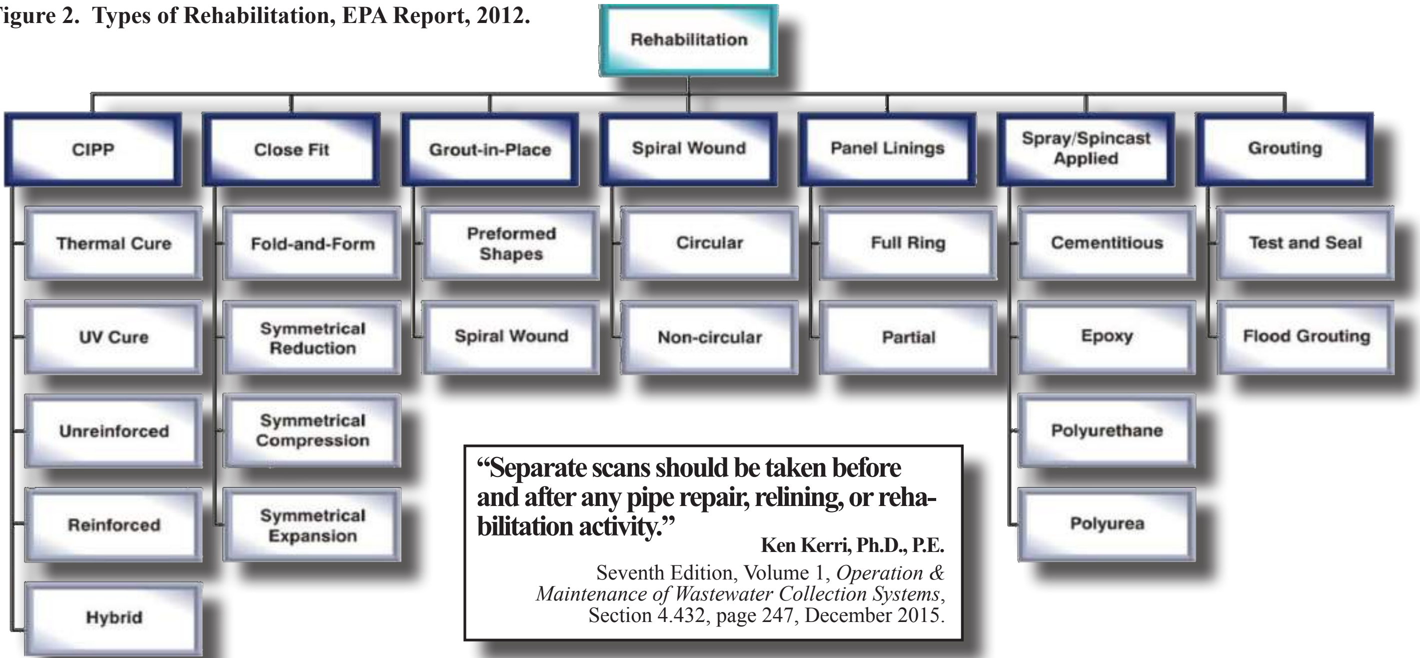
In the mid-1990s, patents for cured-in-place pipe expired, opening up competition from foreign and domestic suppliers. As the number of lining companies grew, the overall cost for CIPP declined. As municipal contracts continued to be awarded to the lowest bidder requiring only *visual inspection* to accept a contractor's work, post-CIPP inspection, prior to contractor acceptance, has never been more important.

Figure 1. Cured-In-Place Pipe lining installed in 2014 by a national lining contractor, approved by CCTV inspection in 2014, in accordance with ASTM F1216 (See Table 1). FELL inspection in 2017 located nineteen (19) measured defects and over 100 pinhole leaks and is now recommended to certify all CIPP liners as leak free, prior to acceptance.

1. Ken Kerri, Ph.D., P.E., Chief Project Consultant, Office of Water Programs, California State University, Sacramento. Ph.D., Sanitary Engineering, Oregon State University, Corvallis, 1965, MS, Sanitary Engineering, University of California, Berkeley, 1959, BS, Civil Engineering, Oregon State College, Corvallis, 1956. WEF Fellow, 2014. Water Distribution and Water Treatment O&M Committees, American Water Works Association, 1998–2014.

2. Twenty-four (24) European lining companies submitted 1,845 CIPP samples in 2016 to IKT (Gelsenkirchen, Germany), performing laboratory only testing on modulus of elasticity, flexural strength, wall thickness, and water tightness. While 61% of all samples passed all test criteria, 59% did not. Results are from the Institute for Underground Infrastructure (IKT) 13th Annual Liner Report, published February 2017.

Figure 2. Types of Rehabilitation, EPA Report, 2012.



> **"Separate scans should be taken before and after any pipe repair, relining, or rehabilitation activity."**
>
> **Ken Kerri, Ph.D., P.E.**
>
> Seventh Edition, Volume 1, *Operation & Maintenance of Wastewater Collection Systems*, Section 4.432, page 247, December 2015.

A Call For New Acceptance Standards for CIPP

In 2010, Ken Kerri, Ph.D., P.E. began reaching out to industry contacts to learn why a growing number of his former students – now managing leading sewer agencies – were finding problems in recently lined CIPP pipes, not seen by initial CCTV or visual inspection.

Having sold Hansen Information Technologies Inc. in 2007, former principals at Hansen were contacted for advice. Previously hearing of a new technology that might be capable of finding defects commonly missed by CCTV cameras, smoke testing, and dye flooding, an earlier prototype of the technology was located and modified for field testing.

At about the same time, geophysicist, Robert Harris, President, Leak Busters, Inc., had been attempting to interest local investors to fund a new company. Development efforts would focus on using low voltage conductivity to automatically find and measure defects. Initial meetings and product trials, including Dr. Kerri, provided early indications that leaks could be identified in a variety of pipe materials and diameters, including CIPP liners, without relying on visual observations or false-positive indications commonly encountered by other techniques.

Just releasing the Seventh Edition, Volume 2 of *Operation and Maintenance of Wastewater Collection Systems* manual, Dr. Kerri had shifted his focus to Volume 1. Last updated in 2003, Dr. Kerri wanted to find new ways to help sewer agencies more accurately inspect and rate the condition of sewer mains and service laterals. As a result, Dr. Kerri was seeking new standards for inspecting and testing wastewater collection systems.

Without revealing his plans, Dr. Kerri felt that new technologies could help overcome the drawbacks of CCTV inspection to better prioritize repairs and certify wastewater projects, before and after rehabilitation.

In July 2011, the EPA published *Field Demonstration of Condition Assessment Technologies for Wastewater Collection Systems* (Figure 3) where it benchmarked several new technologies, including early versions of a device referred to as FELL. Conducted in Kansas City, MO, the study verified the use and advantages of FELL technology to consistently find defects missed by CCTV inspection.

Figure 3. EPA Report. Field Demonstration of Condition Assessment Technologies for Wastewater Collection Systems, July 2011.

Founding Electro Scan Inc. in October 2011, occupying the same building where Hansen Software was founded in 1983, company management acquired the assets and intellectual property of two separate companies: Leak Busters, Inc. and PDQ Scan, Inc. Financed with private equity capital, technical staff began to design and develop a machine-intelligent device that could automatically identify and measure, i.e. locate and determine gallons per minute (gpm) or litres per second (lps) of defect flows, in sewer, water, and gas pipelines, without relying on operator judgment or third-party expertise.

EPA Releases Study on CIPP in Municipal Gravity Sewers

In January 2012, the US EPA published *A Retrospective Evaluation of Cured-in-Place Pipe (CIPP) Used in Municipal Gravity Sewers* (Figures 2, 4, and 5). As part of the study, independent testing of CIPP was conducted in both large and small diameter sewers in two cities: Denver, CO and Columbus, OH.

The purpose of the study was to determine whether the originally expected lifespan of CIPP (typically assumed to be 50 years) was reasonable, based on the current condition of the liners. Despite the large public investment in CIPP, prior to this study there had been little quantitative analysis to confirm if structural or operating performance was as expected.

Field samples were retrieved from CIPP linings, along with specific measurements and tests taken to measure liner thickness, annular gap, ovality, density, gravity, porosity, flexural strength, flexural modulus, tensile strength, tensile modulus, surface hardness, glass transition temperature, and Raman spectroscopy.

Figure 5. EPA Report. A Retrospective Evaluation of Cured-in-Place Pipe (CIPP) Used in Municipal Gravity Sewers, January 2012.

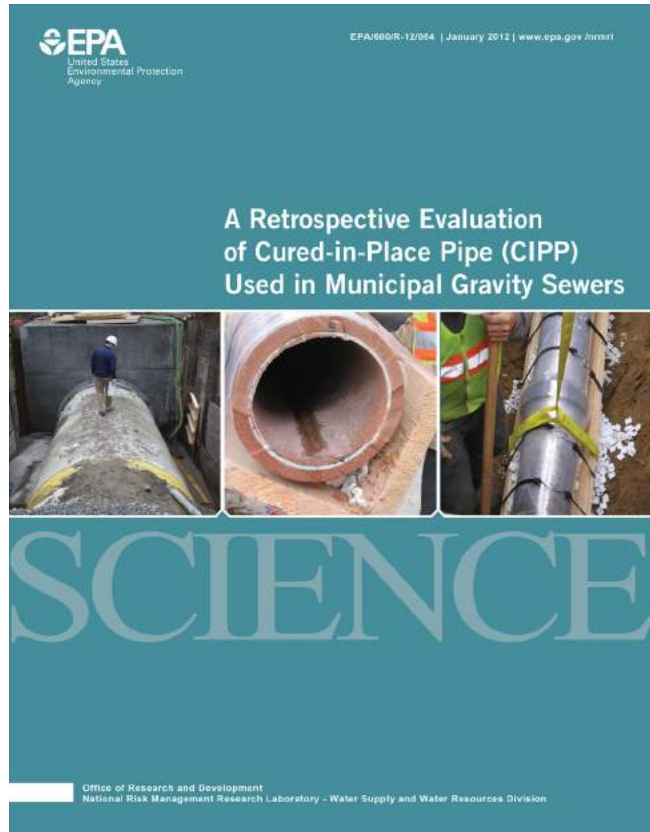
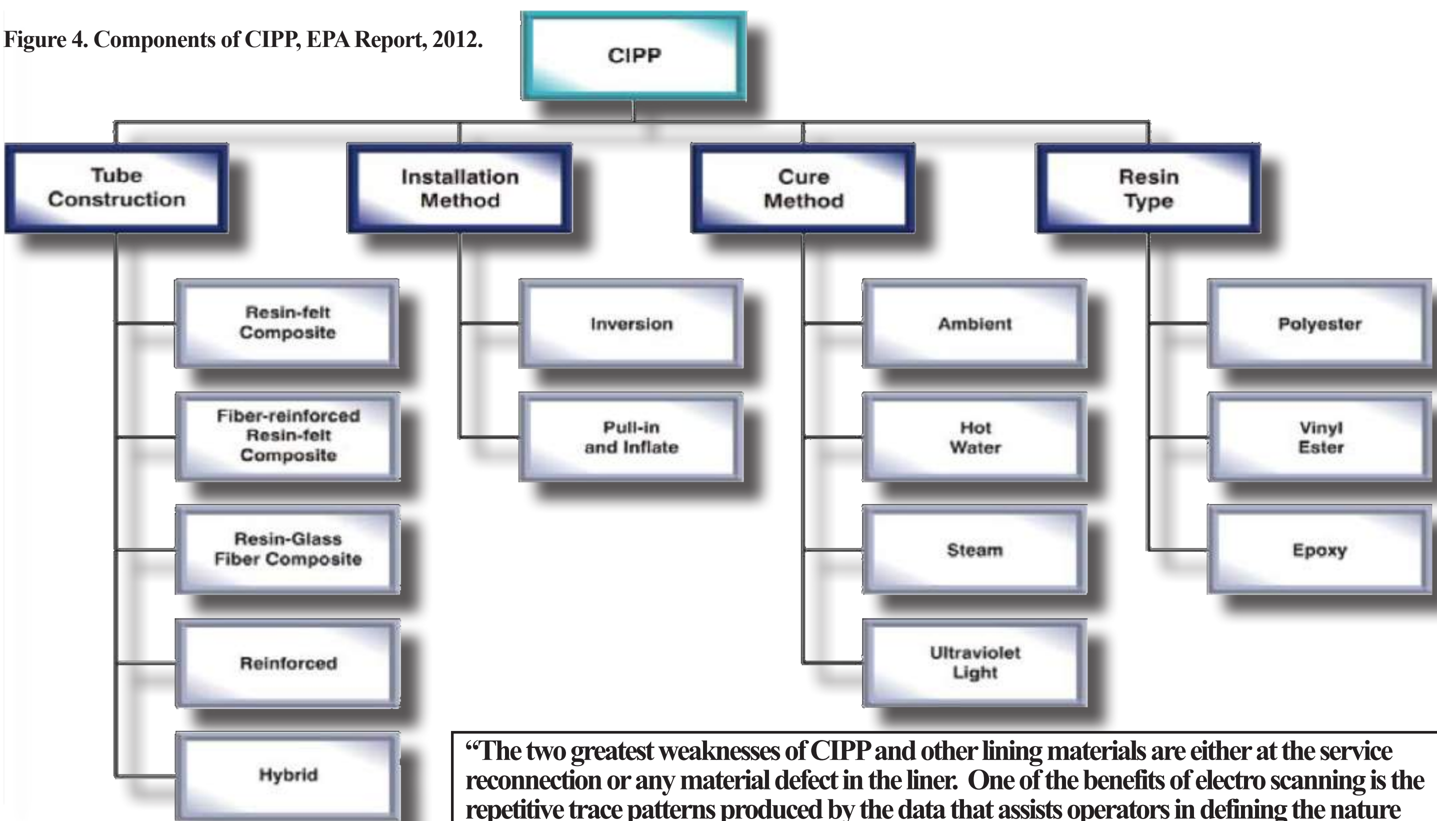


Figure 4. Components of CIPP, EPA Report, 2012.



"The two greatest weaknesses of CIPP and other lining materials are either at the service reconnection or any material defect in the liner. One of the benefits of electro scanning is the repetitive trace patterns produced by the data that assists operators in defining the nature and type of defect.

Ken Kerri, Ph.D., P.E.

Seventh Edition, Volume 1, Operation & Maintenance of Wastewater Collection Systems, Section 4.432, page 247, December 2015.

Table 1. Key ASTM Standards Covering CIPP Installations, US EPA Report, 2012

ASTM F1216	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube
ASTM F1743	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)
ASTM F2019	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled-in-Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)
ASTM F2599	Standard Practice for the Sectional Repair of Damaged Pipe by Means of an Inverted Cured-in-Place Liner
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

The report utilized a variety of approaches to evaluate the state of deterioration of previously installed CIPP liners; however, prior to this study researchers were able to only find scattered efforts that thoroughly evaluated the long-term performance of rehabilitated sewer sections.

Typically, rehabilitated sections of collection systems were evaluated using only visual inspection or CCTV inspection before and immediately following the lining of a pipe. After CIPP lining, pipes were often moved to the lowest priority level for ongoing inspection, assuming that CIPP liners were near new in quality.

In general, research staff noted several advantages and disadvantages of CCTV inspection, including:

Advantages of CCTV Inspection
- Relatively low cost.
- Familiar to agencies.
- Can uncover other operating problems such as potential blockages.
- Can provide broad coverage of relined sections within an agency leading to statistically meaningful results.

Disadvantages of CCTV Inspection
- Can only identify deterioration or defects that are easily identified visually.
- Liner distortion difficult to identify.
- Not possible to evaluate intermediate stages of deterioration.

In Denver, CO, a total of 5,797 LF (1,767m) of lined pipe was surveyed which included sixteen (16) lines installed with CIPP in 1984 (Table 2).

In the absence of more advanced assessment technologies, in 2009 each surveyed liner was limited to television inspection, finding a number of defects, including:

Table 2. Denver, CO Host Pipe Information

Category	Specific Description
City	City of Denver, CO
Address	Monroe Street and 1st Street
Host Pipe	Circular, 8 in. diameter, vitrified clay pipe (VCP)
Pipe Depth	5 ft (above crown)
Dimension	8 in. diameter; 6 mm thick
Resin	Reichhold 33-060; an isophthalic, polyester, unfilled resin
Primary Catalyst	Perkadox 16
Seconday Catalyst	Trigonox C
Felt	Unwoven fabric (similar to products used today)
Seal	Polyurethane, 0.015 in. thick (today CIPP liners use polyethylene coating)
Year Installed	1984
Liner Vendor	Insituform
Resin Supplier	Reichhold
Tube Mfg	Insituform

- Several break-in defects and lining failures at undercut connections that could be attributed to robotic cutters.
- Root intrusion via tap connections that resulted in partial blockage of the line.
- One (1) liner failure in the vicinity of a tap break-in.
- One (1) liner failure where a bulge was found at the invert of the liner that prevented advancement of CCTV.
- One (1) liner failure attributed to improper restoration of a nearby lateral connection, with a significant portion of the polyurethane coating hydrolyzed along this line.
- Similar occurrences of a liner connection cut shift.

The EPA study also tested several CIPP liners from the City of Columbus, OH. One site represented a relatively new liner – a five year old CIPP liner installed in an 8-inch clay pipe. Given the recent installation, consultants were able to compare test results from the quality assurance (QA) sample retained immediately following the installation five years earlier. Results were compared to current test results, both in accordance with ASTM D638 and ASTM D790 (Table 1).

It should be noted that many municipalities take QA samples or coupons for either laboratory testing or possible warranty claims. But no actual testing had been done on the Columbus pipes after CIPP samples had been taken five years earlier.

Significant differences were found. Testing of the QA coupon from the 8-inch Columbus CIPP liner performed immediately following the installation showed a finished thickness of 7.5 mm. In contrast, the EPA-funded study showed an average measured liner thickness of 5.72 mm and a design value of 6.0 mm.

One possible explanation for the difference between the two measurements was that the original QA coupon was taken at the upstream end of the CIPP liner, while the recently exhumed coupon came from the downstream end of the lined pipe. A relatively steep slope (i.e. approximately 8% pipe gradient) was also found, which could have resulted in stretching the liner, causing a subsequent thinning of the pipe wall.

Another potential explanation is that QA samples are typically prepared by curing an extension of the liner within the manhole. Since this practice does not have the same installation and curing conditions within the sewer line itself, the study concluded that such samples generally will have higher test results than coupons cut from within a sewer.

Needed Improvements in CIPP Liner Testing

While the EPA study on CIPP concluded that there was "no reason to anticipate that tested liner samples would not last for their intended lifetime of 50 years (and perhaps beyond)," the study did not address or attempt to quantify the severe degradation in operating performance of the post-rehabilitation pipe where break-ins, root intrusions, and other failures were found.

Also, shortfalls in CIPP liner wall thickness measured for most of the liners, coupled with the differences in results from QA coupons taken within a manhole, pointed to the need to develop better non-destructive tests for assessing the acceptability of newly installed CIPP liners, and then tracking their deterioration over time.

Researchers were disappointed to find that commercially available ultrasonic thickness gauges did not work adequately on field CIPP samples; even though they gave good results on laboratory prepared samples with moderate thickness. The report went on to describe issues encountered with the use of ultrasonic thickness probes used on field samples.

The inability of commercially available tools to measure the thickness of large diameter CIPP liners from the inner surface only – an important QA issue because large diameters are prone to thickness variation around the circumference – is a clear call for the need to develop new technologies to accomplish this task in a cost-effective and reliable manner.

It was also noted that significant differences existed in data reported from QA/QC testing at the time of installation compared with data from tests conducted by different laboratories. This suggested that more attention needed to be done on documenting and reducing the variability of test results derived from coupon recovery procedures and comparing test results from different laboratories.

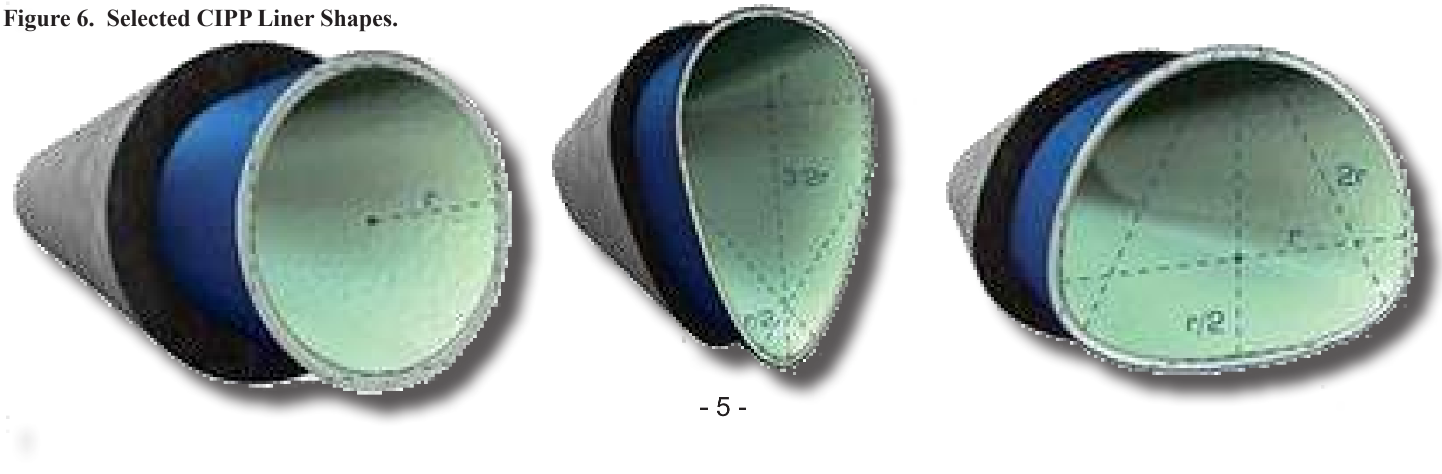
Finally, the report stated that "while liner cross-sections should continue to be laboratory-certified, long-term operating performance of CIPP may not be assured, especially if proper installation and inspection protocols are not satisfied."

The Emergence of New Non-Destructive Testing Standards

In 2012, Electro Scan Inc. began offering its FELL technology for sewer mains from 3-inches to 8-inches in diameter, and in 2013 was able to add equipment to standard CCTV trucks and vans to handle pipe diameters from 6-inches to 66-inches, allowing operators to switch from CCTV to FELL, and back, in less than 10 minutes.

Given their industry experience and pioneering computer applications, principals of the new company created a sophisticated cloud-based reporting system, allowing data to be wirelessly uploaded to servers located around the globe. With over 10,000 data points for every 300 ft (100 m) of scanned pipe, final reports are generally available within ten minutes after completing a survey. Each report identifying specific locations and severity of defect in gpm or lps for all diameters and shapes (Figure 6).

Figure 6. Selected CIPP Liner Shapes.



Establishing New Standards for Pre- and Post-Rehabilitation Condition Assessment

With results of the EPA Report on its investigation of previously installed CIPP liners already being circulated at conferences, principals of Electro Scan Inc. believed it was time to introduce new standards to certify post-rehabilitation projects to more accurately and consistently locate and measure defects capable of leaking water into or out of a pipe after repair, relining, or renewal.

The advantages of providing pre- and post-rehabilitation defect measurements in either gpm or lps, are numerous. Key benefits of a quantitative analysis of defect flows, before and after rehabilitation, include the ability to:

- Establish a baseline defect flow rating to prioritize critical sewers and water distribution pipes.
- Overcome the shortcomings of visual observations and cataloging defects using CCTV cameras.
- Quantify specific flow reductions from repairs, relining, and renewal projects, by testing lines before and after rehabilitation.
- Create minimum allowable standards for defect flows.
- Certify post-rehabilitated repairs, relining, and renewal of pipes as leak-free.

Historically, CCTV surveys had been the principal means to identify sources of water infiltration into sewer and stormwater networks; however, its low success rate for identifying defects that leak, inability to be used in partially or fully surcharged pipes, limited ability to locate or quantify defects at joints – sometimes referred to as invisible leaks – and conflicting cataloging of visual defects often made CCTV inspection an unreliable diagnostic tool, unable to consistently find sources of infiltration or certify post-rehabilitated pipes.

Unsuccessful in finding sources of infiltration in sewer mains, sewer utilities began to change their focus from sewer mains to sewer laterals – frequently going beyond the service connection and focusing on the pipe condition of laterals and illegal connections from storm drains or downspouts from residential homes and commercial businesses.

But, "what if utilities have simply been incorrectly assessing sewer mains, limited to visual inspection, therefore, under-estimating the severity of defects in their sewer mains?" This question was one of many brought forward by Dr. Kerri.

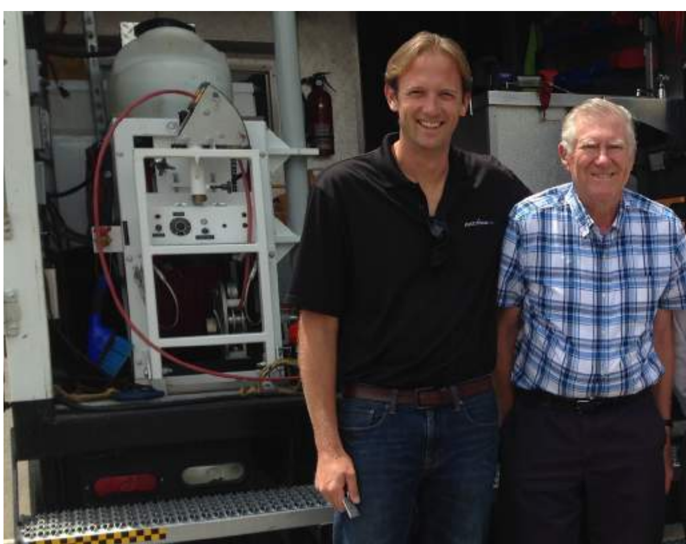
Commented Dr. Kerri, "Maybe utilities would be better served by re-investigating their sewer mains & certifying rehabilitation projects, if more accurate assessment tools were available."

In November 2013, after reviewing over 100 benchmark studies and field tests, Dr. Kerri asked permission from principals at Electro Scan Inc. to begin writing a new lesson on Electro Scanning Inspection for addition in the Seventh Edition of his *Operation and Maintenance of Wastewater Collection Systems*, Volume 1 (Figure 7).

Previously published ten years earlier, the new edition was expected to revamp the chapter on *Inspecting and Testing Collection Systems*, offering new recommended guidelines to assess pre- and post-rehabilitation.

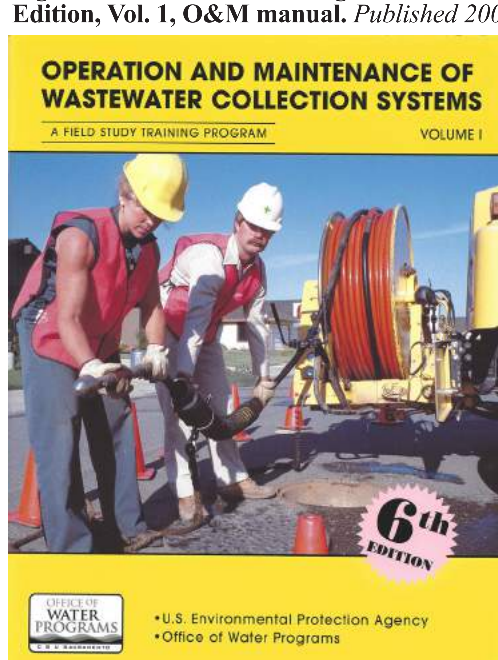
Chapters for the Seventh Edition, Volume 1, would include:

1. Introduction to Wastewater Collection
2. Wastewater Collection Systems
3. Safe Procedures
4. Inspecting and Testing Collection Systems
5. Pipeline Cleaning and Maintenance Methods
6. Underground Repair and Construction



Pictured. Mark Grabowski, Vice President and General Manager, Electro Scan Inc. and Ken Kerri, Ph.D., P.E. in testing of Electro Scan technologies.

Figure 7. Office of Water Programs, Sixth Edition, Vol. 1, O&M manual. *Published 2003.*

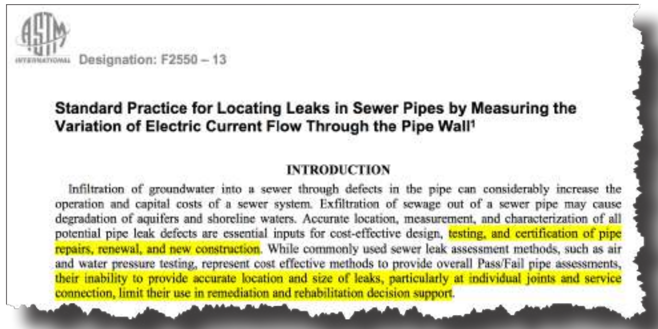


Publication of ASTM F2550-13

In November 2013, the American Society for Testing and Materials International (ASTM International) ratified and published ASTM F2550-13 *Standard Practice for Locating Leaks in Sewer Pipes By Measuring the Variation of Electric Current Flow Through the Pipe Wall* (Figures 8, 9, and 10).

Managed by ASTM Committee F36, ASTM F2550-13 had been previously issued in 2006 as ASTM F2550-06. Building on its earlier scope, terminology, significance, use, principle of operation, apparatus, field procedures, and reporting, the 2013 version was modified to state the following:

Figure 8. ASTM F2550-13, Introduction.



Designation: F2550 – 13

Standard Practice for Locating Leaks in Sewer Pipes by Measuring the Variation of Electric Current Flow Through the Pipe Wall[1]

INTRODUCTION

Infiltration of groundwater into a sewer through defects in the pipe can considerably increase the operation and capital costs of a sewer system. Exfiltration of sewage out of a sewer pipe may cause degradation of aquifers and shoreline waters. Accurate location, measurement, and characterization of all potential pipe leak defects are essential inputs for cost-effective design, testing, and certification of pipe repairs, renewal, and new construction. While commonly used sewer leak assessment methods, such as air and water pressure testing, represent cost effective methods to provide overall Pass/Fail pipe assessments, their inability to provide accurate location and size of leaks, particularly at individual joints and service connection, limit their use in remediation and rehabilitation decision support.

ASTM F2550-13, Section 8.5.1

"It is recommended that separate scanning tests be taken before and after any pipe repair, relining, or renewal activity to compare electrode current values, and for closed-circuit television (CCTV) video to re-examine pipes to determine if any visual defects were missed or not recorded during initial examination."

Figure 9. Schematic of a Simplified Electrical Circuit in a Non-Conductive Pipe.

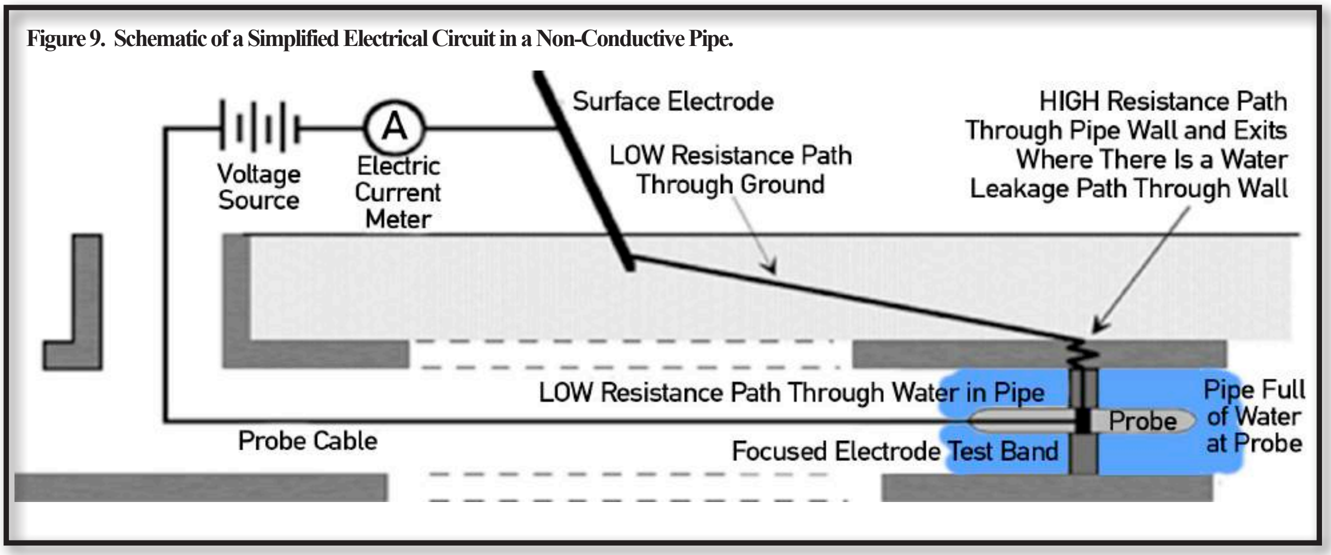


Figure 10. Actual Field Set-Up for Assessing Pre- and Post-Rehabilitated Sewer Mains.

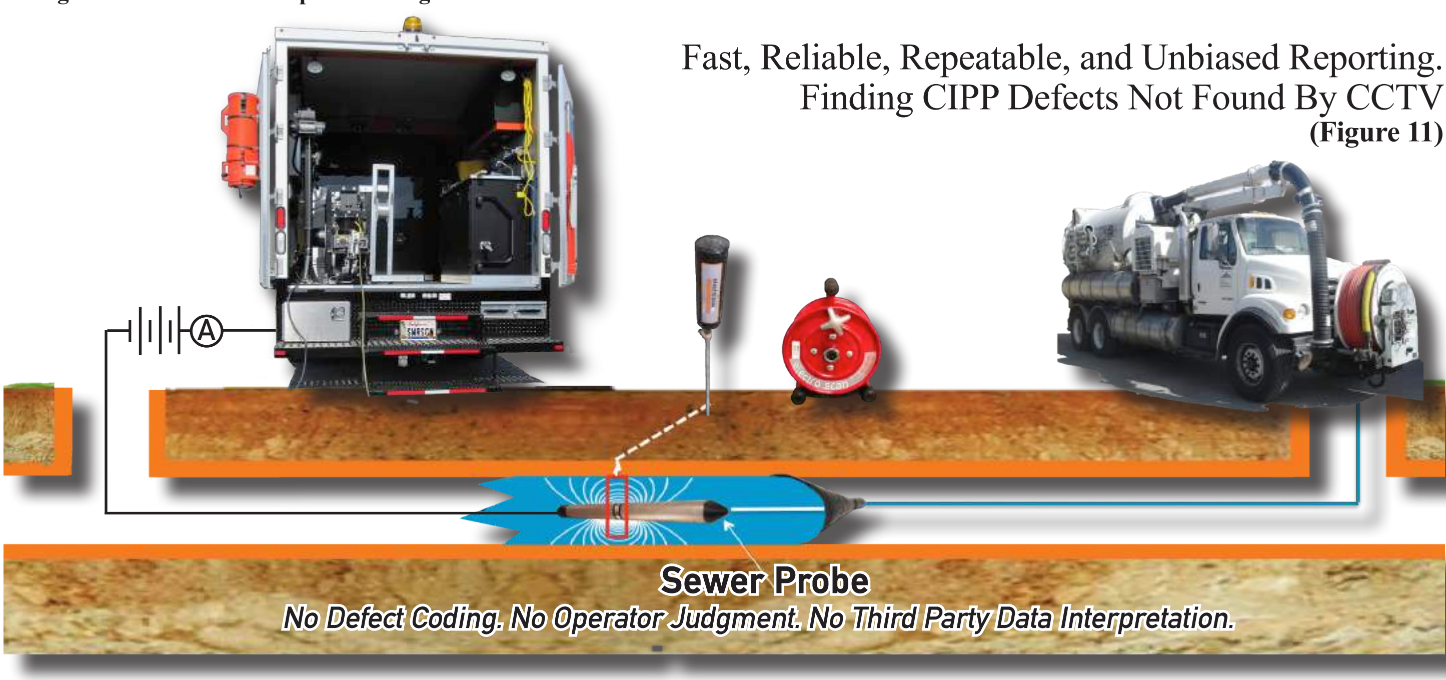
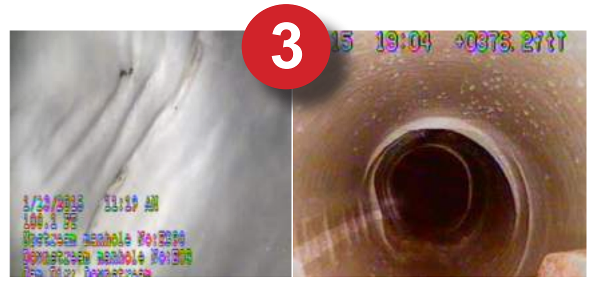


Figure 11

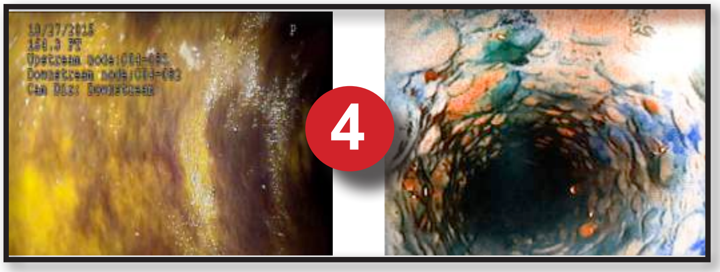
CIPP Defects Not Found, Recorded, or Measured By CCTV

1. Post-CIPP, Bad Invert Connection

2. Post-CIPP, Bad Service Reconnection

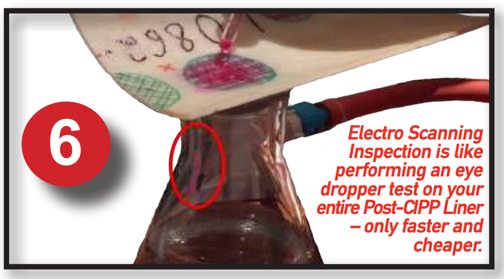


3. Wrinkles.

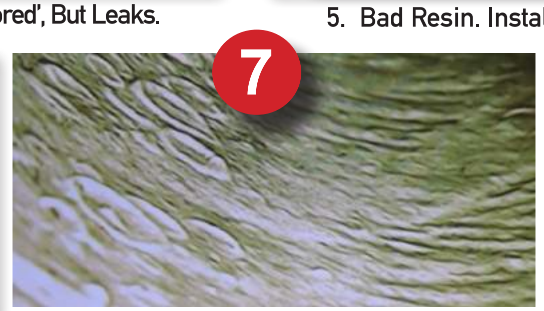


4. Accelerant Burns, Called Out As 'Discolored', But Leaks.

5. Bad Resin. Installed less than 16 months prior.

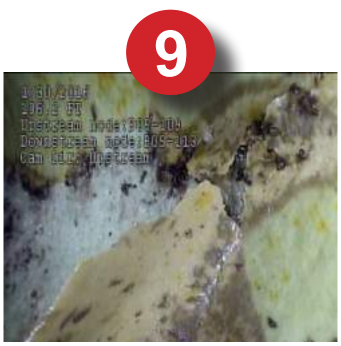


6. Defective/Weak Liner



7. Overcooked Liner

8. Unreported Contractor Damage



9. Defective Epoxy

10. Misreported Bad Reconnection. Same Leak Running 4 Years.

11. Annular Space

12. Bad Sectional Spot Repair

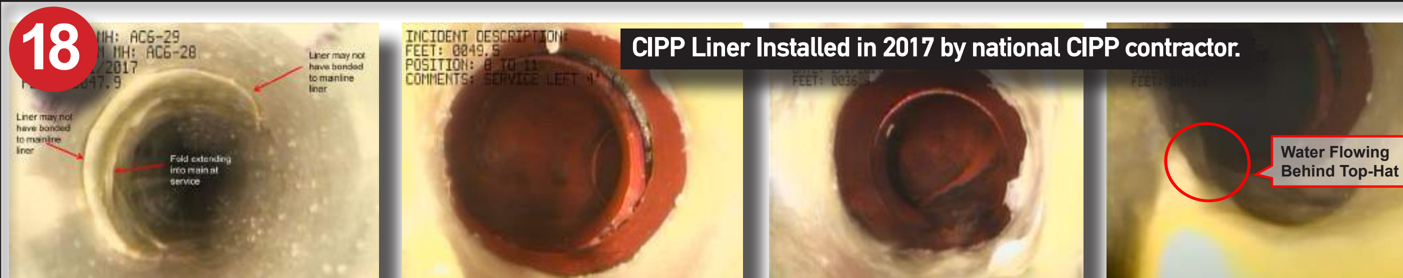
13. Infiltration Spotting

14. Bulges

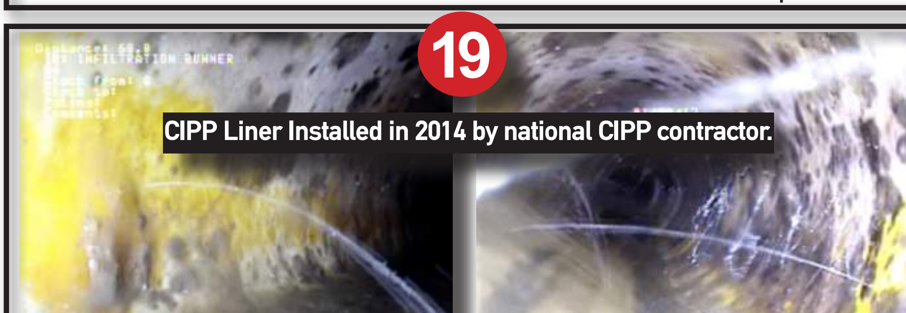
15. Missed Lateral Reinstatement

16. Bad Epoxy Lining

17. Sag In Liner

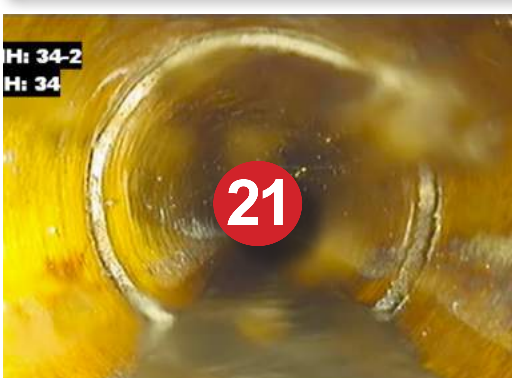


18. Defective Top-Hats



19. Pinhole Leaks

20. Infestation



21. Post-CIPP Misaligned / Open Joint

22. Blistering

CASE STUDY: Large Metropolitan Sewer Agency's Post-CIPP Assessment Project

In April 2014, a large metropolitan sewer agency surveyed 8,718.6 LF (2,657m) of CIPP lined pipe. representing forty-nine (49) sewer main pipe segments all lined in the year 2000. High rates of flow prompted the agency to undertake a comprehensive Smoke Testing & CCTV survey. With only a limited number of defects found by Smoke Testing or CCTV inspection, Electro Scan was recommended for follow-up assessment using Focused Electrode Leak Location (FELL).

Representing the first large-scale use of Electro Scan technology to assess post-CIPP liners, all forty-nine (49) lined pipes were found to have defect flows: 46 lined pipes (94%) registered greater than 1,000 gallons per day (0.043 LPS) of defect flow and 20 lined pipes (41%) registered greater than 10,000 gallons per day (0.438 LPS) of estimated defect flow (Table 3).

Given such a significant percentage of lined pipes (at less than half their useful life) showing moderate to severe defect flows, sewer utilities with current or near-term CIPP projects should now consider altering acceptance criteria for post-rehabilitated sewer mains.

Table 3. Post-CIPP Assessment Project Using Focused Electrode Leak Location (FELL) Inspection

		Distance				Number of Defects				Defect Flow (GPM)					
	Electro Scan ID	mm	ft	Raw Data Points	Filtered Data Points	Small	Med	Large	TOTAL	Small	Mod	Severe	Total	Estimated Defect Flow (Gallons Per Day)	Estimated Defect Flow (Litres Per Second)
		2,657,420	8,719	196,187	121,527	156	36	24	216	57	76	200	333	479,822	21.0
1	00000179_apr012014_144919PM	73,685	241.7	5648	4158	25	1	3	29	8.59	3.84	30.00	42.43	61,099	2.7
2	00000175_apr012014_111742AM	91,435	300.0	4701	3725	1	0	2	3	0.85	-	19.74	20.59	29,650	1.3
3	00000186_apr022014_092453AM	22,244	73.0	1573	763	2	0	2	4	0.34	-	17.62	17.96	25,862	1.1
4	00000178_apr012014_140110PM	96,692	317.2	4988	4211	1	5	0	6	0.76	14.99	-	15.75	22,680	1.0
5	00000102_mar262014_154308PM	75,310	247.1	4704	2724	1	2	1	4	0.19	4.98	10.00	15.17	21,845	1.0
6	00000180_apr012014_145714PM	82,865	271.9	4451	3576	4	2	1	7	2.61	3.97	6.66	13.24	19,066	0.8
7	00000191_apr022014_113856AM	94,769	310.9	4696	3619	0	1	1	2	-	2.48	10.00	12.48	17,971	0.8
8	00000176_apr012014_120759PM	92,114	302.2	5410	4454	1	1	1	3	0.99	1.22	10.00	12.21	17,582	0.8
9	00000344_apr222014_111205AM	38,109	125.0	3890	2168	4	0	1	5	1.35	-	10.00	11.35	16,344	0.7
10	00000171_apr012014_084724AM	68,832	225.8	5116	3767	3	0	1	4	1.38	-	9.50	10.88	15,667	0.7
11	00000237_apr112014_090747AM	62,299	204.4	5051	2803	1	0	1	2	0.67	-	10.00	10.67	15,365	0.7
12	00000347_apr222014_132003PM	14,011	46.0	3877	888	3	2	1	6	1.12	3.20	6.27	10.59	15,250	0.7
13	00000169_mar312014_162416PM	57,561	188.8	3079	2078	1	0	1	2	0.16	-	10.00	10.16	14,630	0.6
14	00000168_mar312014_161732PM	32,279	105.9	1759	1242	0	0	1	1	-	-	10.00	10.00	14,400	0.6
15	00000353_apr222014_152723PM	49,228	161.5	4859	2309	1	0	1	2	0.85	-	8.52	9.37	13,493	0.6
16	00000181_apr012014_152848PM	86,032	282.3	4722	3808	1	1	1	3	0.42	3.26	5.57	9.25	13,320	0.6
17	00000221_apr082014_161927PM	54,501	178.8	3748	2558	4	1	1	6	1.28	1.41	6.28	8.97	12,917	0.6
18	00000378_apr242014_153826PM	54,592	179.1	3673	1963	5	1	1	7	1.91	2.67	4.10	8.68	12,499	0.5
19	00000348_apr222014_133601PM	27,494	90.2	1975	1466	2	1	1	4	0.55	1.23	5.37	7.15	10,296	0.5
20	00000385_apr252014_095246AM	36,018	118.2	5388	1884	13	2	0	15	4.22	2.78	-	7.00	10,080	0.4
21	00000190_apr022014_113039AM	67,015	219.9	3963	2829	3	0	1	4	2.21	-	4.15	6.36	9,158	0.4
22	00000183_apr012014_165922PM	44,817	147.0	2412	1856	0	0	1	1	-	-	6.10	6.10	8,784	0.4
23	00000374_apr242014_122905PM	48,327	158.6	3347	2650	2	2	0	4	0.46	5.40	-	5.86	8,438	0.4
24	00000177_apr012014_135222PM	22,649	74.3	2888	1203	1	1	0	2	0.46	3.98	-	4.44	6,394	0.3
25	00000358_apr232014_095823AM	50,197	164.7	3482	2251	12	0	0	12	4.14	-	-	4.14	5,962	0.3
26	00000332_apr172014_140957PM	60,254	197.7	3546	2625	5	1	0	6	1.49	2.62	-	4.11	5,918	0.3
27	00000172_apr012014_092348AM	30,097	98.7	3172	1300	6	1	0	7	2.78	1.04	-	3.82	5,501	0.2
28	00000245_apr112014_144404PM	73,151	240.0	4118	3754	0	1	0	1	-	2.91	-	2.91	4,190	0.2
29	00000330_apr172014_113224AM	30,913	101.4	3023	1479	4	1	0	5	1.68	1.18	-	2.86	4,118	0.2
30	00000352_apr222014_151801PM	49,594	162.7	5153	3053	1	1	0	2	0.37	2.37	-	2.74	3,946	0.2
31	00000174_apr012014_110812AM	39,033	128.1	2568	1801	1	2	0	3	0.19	2.41	-	2.60	3,744	0.2
32	00000182_apr012014_165448PM	20,352	66.8	4805	936	5	1	0	6	1.33	1.24	-	2.57	3,701	0.2
33	00000197_apr022014_153244PM	79,477	260.8	4365	3464	1	1	0	2	0.10	2.10	-	2.20	3,168	0.1
34	00000193_apr022014_133540PM	70,465	231.2	4026	2633	5	1	0	6	0.99	1.13	-	2.12	3,053	0.1
35	00000345_apr222014_113115AM	20,260	66.5	3551	1122	1	1	0	2	0.45	1.35	-	1.80	2,592	0.1
36	00000244_apr112014_143559PM	40,704	133.5	1852	1509	10	0	0	10	1.75	-	-	1.75	2,520	0.1
37	00000220_apr082014_151116PM	64,574	211.9	9922	3494	1	1	0	2	0.34	1.19	-	1.53	2,203	0.1
38	00000173_apr012014_100117AM	115,343	378.4	6482	4531	2	0	0	2	1.36	-	-	1.36	1,958	0.1
39	00000326_apr172014_091952AM	57,103	187.3	4196	2728	1	1	0	2	0.30	1.03	-	1.33	1,915	0.1
40	00000192_apr022014_132822PM	63,978	209.9	3648	2845	2	0	0	2	1.20	-	-	1.20	1,728	0.1
41	00000196_apr022014_152354PM	81,842	268.5	5030	4021	4	0	0	4	1.19	-	-	1.19	1,714	0.1
42	00000184_apr022014_083802AM	14,911	48.9	2510	921	3	0	0	3	1.13	-	-	1.13	1,627	0.1
43	00000185_apr022014_092136AM	70,228	230.4	3519	2510	2	0	0	2	0.92	-	-	0.92	1,325	0.1
44	00000222_apr082014_165915PM	27,281	89.5	2991	1429	2	0	0	2	0.90	-	-	0.90	1,296	0.1
45	00000236_apr112014_085748AM	51,013	167.4	3920	2561	2	0	0	2	0.86	-	-	0.86	1,238	0.1
46	00000246_apr112014_144719PM	8,035	26.4	1175	374	2	0	0	2	0.78	-	-	0.78	1,123	0.0
47	00000363_apr232014_141617PM	47,740	156.6	4175	2717	2	0	0	2	0.67	-	-	0.67	965	0.0
48	00000167_mar312014_161327PM	62,002	203.4	3792	2760	2	0	0	2	0.54	-	-	0.54	778	0.0
49	00000325_apr172014_085541AM	35,995	118.1	5248	2007	1	0	0	1	0.52	-	-	0.52	749	0.0
		2,657,420	8,718.6	196,187	121,527	156	36	24	216	57.35	75.98	199.88	333.21	479,822	21.0

***Operation and Maintenance of Wastewater Collection Systems*, Seventh Edition, Volume 1**

2014 was a significant year for Focused Electrode Leak Location (FELL) and Low Voltage Conductivity (LVC), and now referred to as Electro Scanning Inspection in Chapter 4, Inspecting and Testing Collection Systems, Seventh Edition, Volume 1, of the O&M manual (Figure 12). A brief comparison of the 7th and 6th Edition is provided in Table 4.

Written by Ken Kerri, Ph.D., P.E., prior to his passing in December 2014, a 27-page section on Electro Scanning Inspection was included in the new 7th Edition publication, revamping the recommended approach that collection systems should be inspected, tested, and certified, before and after rehabilitation.

Table 4. Chapter 4. Inspecting and Testing Collection Systems. Comparison from 7th Edition to 6th Edition, Volume 1.

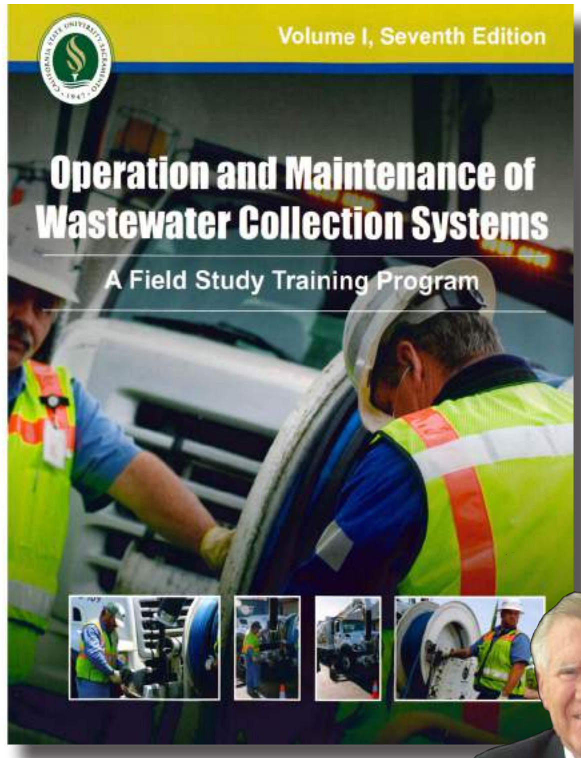
Lesson	Description	Page Count	
		7th Ed	6th Ed
1	Reasons for Inspecting and Testing	4	4
2	Manhole Inspections	5	2
3	Closed-Circuit Television (CCTV) Inspections	35	42
4	Electro Scanning Inspection	27	
5	Smoke Testing & Dye Testing	11	7
6	Pipeline Lamping	DELETED	1
7	Air and Water Testing	DELETED	1
Appendix	CCTV Inspection	DELETED	20
TOTAL PAGES BY O&M EDITION		**82**	**77**

After two years of research, including comparisons with earlier development prototypes, competitive benchmarks with CCTV and other inspection standards, and client discussions, Dr. Kerri finalized *Lesson 4, Electro Scanning Inspection*, to be added in his new edition of the O&M manual, specifically recommending the new technology to assess wastewater assets.

Other key statements by Dr. Kerri, included:

- Electro scanning accurately locates and measures specific defects resulting from defective joints and other subtle defects not easily identified by CCTV inspection - and which often cause infiltration and exfiltration.
- Electro scanning's ability to help system operators accurately prioritize sewer main repairs represents an advancement in the way that sewers can be assessed.
- Using electro scanning can also help system operators significantly change their acceptance criteria for rehabilitated pipes
- Because electro scanning is designed to automatically find defects that may not be identified when using other inspection methods, some utilities may wish to review past television inspection videos to assist operators in better identifying and cataloging defects.

Figure 12. Seventh Edition, Volume 1, *Operation and Maintenance of Wastewater Colleciton Systems* manual ISBN 978-1-59371-066-8. *Released Dec. 2015.*



Ken Kerri, Ph.D., P.E.
Author, Electro Scanning Inspection,
Chapter 4, Inspection and Testing Collection Systems
7th Edition, Volume 1, O&M manual.

- Due to its speed, accuracy, and compatibility with CCTV equipment, utilities may opt to use electro scanning in their sewers first, and then conduct CCTV inspections of locations identified by electro scanning for side-by-side comparison and assessment.
- Using both electro scanning and CCTV inspections methods allows systems to conduct wet and dry weather pipe inspection and assessment - a combination that provides important information about the system in all its operating conditions.

Unlike CCTV inspection, smoke testing, dye flood testing, ground-penetrating radar, hydrostatic pressure testing, and laser profiling technologies, no third-party data interpretation is required of Electro Scanning Inspection.

In addition, no visual observations or manual coding is required by an operator and each defect found is given an estimated defect flow (in gpm or lps) representing the potential amount of water that may flow through a known defect.

By providing an objective numeric value for each defect, Dr. Kerri concluded that electro scanning took the guesswork out of quantifying pipe defects. Also, its ability to be added directly to a standard CCTV truck or van, using the same footage encoder, allowed pinpoint accuracy of all defects.

WRc & Electro Scan Sign UK Alliance Agreement

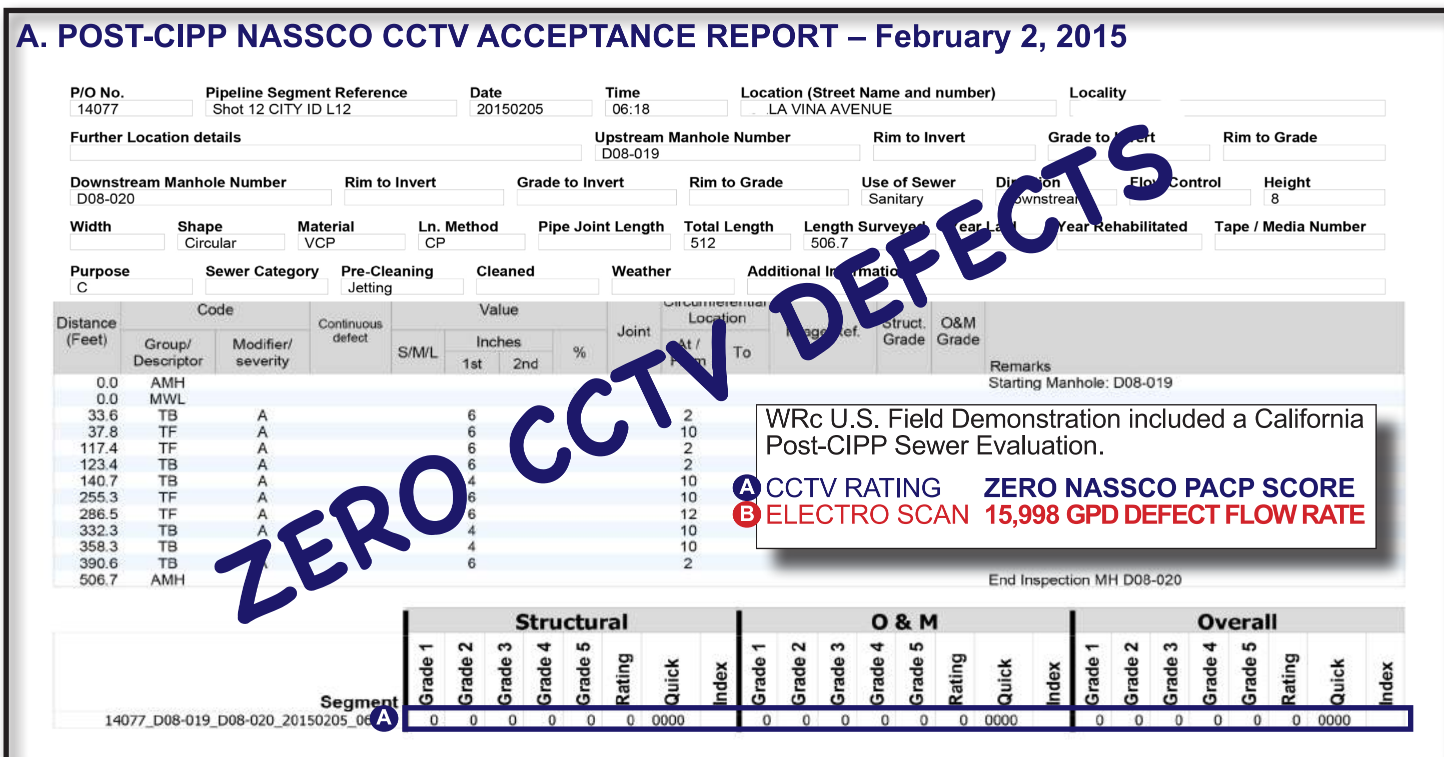
After several years operating as an independent company in the United Kingdom (UK), Electro Scan Inc. and Electro Scan (UK) Limited signed a Strategic Alliance Agreement with British-based WRc plc (Swindon, England).

Developers of the UK's Manual of Sewer Condition Classifications (Figure 13), first published in 1980 and used by US-based NASSCO for PACP CCTV training and certification, WRc now offers Electro Scanning Inspection Services, in accordance with ASTM F2550, on an exclusive basis, for pre- and post-rehabilitation assessment projects throughout the UK.

Prior to executing its Agreement in September 2015, WRc and Electro Scan completed a number of benchmark projects in the United States and England, including several demonstration projects in California. One project, shown in Figure 14, assessed several post-CIPP lined sewer mains at a California coastal city. By September 2016, WRc was conducting an Electro Scan Masterclass scheduled for delivery at each water company.

Figure 13. WRc's Manual of Sewer Condition Classifications used as the base for NASSCO's PACP CCTV manual.

Figure 14. CCTV v. ELECTRO SCAN WRc Benchmark held at a California Sewer Agency. ***"Are All CIPP Projects In The U.S. This Bad?"*** WRc



P/O No.: 14077 | Pipeline Segment Reference: Shot 12 CITY ID L12 | Date: 20150205 | Time: 06:18 | Location (Street Name and number): LA VINA AVENUE | Locality:

Further Location details: | Upstream Manhole Number: D08-019 | Rim to Invert: | Grade to Invert: | Rim to Grade:

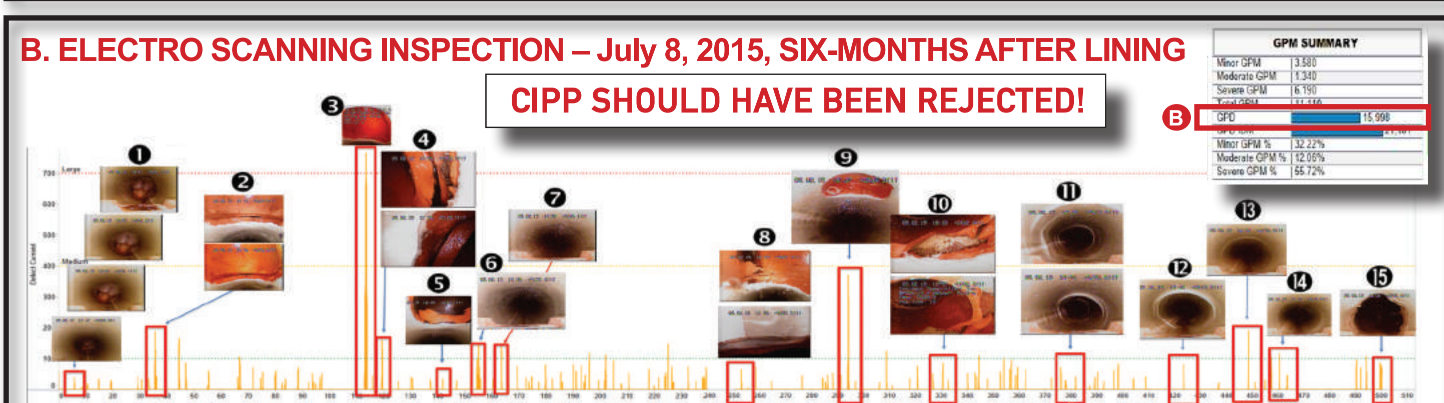
Downstream Manhole Number: D08-020 | Rim to Invert: | Grade to Invert: | Rim to Grade: | Use of Sewer: Sanitary | Direction: Downstream | Flow Control: | Height: 8

Width: | Shape: Circular | Material: VCP | Ln. Method: CP | Pipe Joint Length: | Total Length: 512 | Length Surveyed: 506.7 | Year Laid: | Year Rehabilitated: | Tape / Media Number:

Purpose: C | Sewer Category: | Pre-Cleaning: Jetting | Cleaned: | Weather: | Additional Information:

Distance (Feet)	Code: Group/ Descriptor	Code: Modifier/ severity	Continuous defect	Value: S/M/L	Value: Inches 1st	Value: Inches 2nd	Value: %	Joint	Circumferential Location: At / From	Circumferential Location: To	Image Ref.	Struct. Grade	O&M Grade	Remarks
0.0	AMH													Starting Manhole: D08-019
0.0	MWL													
33.6	TB	A			6				2					
37.8	TF	A			6				10					
117.4	TF	A			6				2					
123.4	TB	A			6				2					
140.7	TB	A			4				10					
255.3	TF	A			6				10					
286.5	TF	A			6				12					
332.3	TB	A			4				10					
358.3	TB				4				10					
390.6	TB				6				2					
506.7	AMH													End Inspection MH D08-020

Segment	Structural Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Rating	Quick	Index	O & M Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Rating	Quick	Index	Overall Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Rating	Quick	Index
14077_D08-019_D08-020_20150205_06	0	0	0	0	0	0	0000		0	0	0	0	0	0	0000		0	0	0	0	0	0	0000	



Risk of Leakage in Today's CIPP Projects

Assessment of CIPP lined pipe, completed between January 1 and December 31, 2016 showed that 69% of Cured-In-Place Pipe lining had defects (Table 5).

More importantly, data showed that 21% of liners showed defect flow rates of 20 gpm or more. In fact, a number of studies in 2016 showed CIPP liners with greater defect flow measurements *after* rehabilitation, compared to measurements taken *before* rehabilitation.

Table 5. CIPP Defect Test Summary

Focused Electrode Leak Location Testing Summary	Twelve Months 2016	Life to Date 2011 -2016
CIPP Liners with Defect Flows	**69%**	**76%**
CIPP Liners with ZERO Defect Flow Leak-Free Certification	31%	24%
Defect Flow By Severity		
More than 1 GPM	57%	62%
More than 2 GPM	46%	51%
More than 3 GPM	43%	46%
More than 4 GPM	40%	43%
More than 5 GPM	39%	39%
More than 10 GPM More Leakage Than Pre-CIPP	**32%**	**31%**
More than 20 GPM More Leakage Than Pre-CIPP	**21%**	**19%**

Source: Electro Scan Inc., CriticalSewers® Cloud Application, December 31, 2016.

Sewer agencies are encourgaged to work with CIPP liners or suppliers that have had their linings pre-qualified by FELL in accordance with F2550-13; however, each project would still require separate testing, certification, and acceptance.

Unlike other inspection tools, FELL devices are not susceptible to false-positive readings or readings for defects that do not actually exist. Given the requirement for positive pipe wall openings at a defect to generate a corresponding jump, pop, or spike in defect current, CIPP lining projects can be correctly certified.

RECOMMENDED BID STANDARD FOR REHABILITATION ACCEPTANCE

Agencies are recommended to require contractors to deliver a Maximum Leakage Acceptance Rate not to exceed 100 Gallons Per Day Per Inch Diameter Mile (GPD/IDM).

Assuming an 8-inch Cured-In-Place Pipe (CIPP), the Allowable Leakage Rate for a 100 ft, 8-inch Diameter Pipe Divided by 5,280ft, representing 0.151515 gallons per foot.

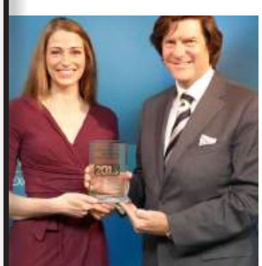
Computation,
= 0.151515
Divided By 1440 minutes per day
= 0.00010522 gallons/foot/minute

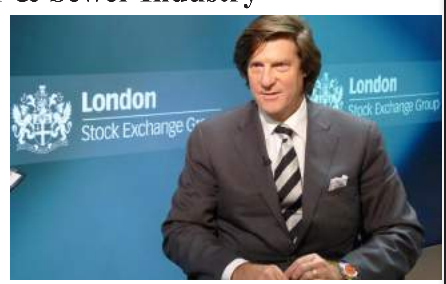
= 0.00010522 or G/F/M x 300ft Sewer Main
= 0.03156 Gallons Per Minute
= 45.5 Gallons Per Day

2015
UK Society of Trenchless Technology
Best Project Award

2013
Water Environment Federation
Best Innovative Technology Award

2013
Best Clean Tech Company Award
Water & Sewer Industry





2013
North American Trenchless Technology
Innovative Product Award


INNOVATIVE PRODUCT AWARDS

NASTT annually recognizes one company with state-of-the-art products in either new installation or rehabilitation for their achievements in advancing the trenchless industry — called the Joseph L. Abbott Jr. Innovative Product Awards. This year, Electro Scan Inc. won.

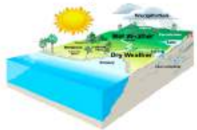
The award is given in memory of the late Joseph L. Abbott Jr., who was an active member of the society since its inception in 1990.

2013

Why is CCTV No Longer Recommended to Certify Rehabilitation or Cured-In-Place Pipe (CIPP)?

Reliance on Dry Weather Pipes

A key reason for curtailing CCTV inspection is that it is primarily used during dry weather conditions – when pipes are less likely to leak.



Pipe Half Full or Half Empty?

TV cameras are not effective in full or half-full pipes, missing any defects below the waterline.

Fats, Oil, and Grease

While grease is a frequent call out for certified TV operators, it often disguises structural problems that may only be assessed if the pipe is thoroughly cleaned.

Roots

Representing a clear pathway between the inside of a pipe and surrounding ground, roots are an obvious potential source of infiltration, yet national coding standards recommend that operators rate the level of roots, and not identify or measure the potential defect flow resulting from roots.

Encrustations

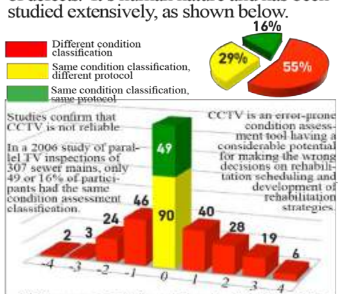
Often referred to as self-healing defects – *at last check encrustations are still not an approved rehab method* – encrustations can harden and cover-up cracks and fissures to the point of passing some pressure tests; but its non-conductive feature still can be positively passed through to determine the location and size of a potential defect flow.

Same Code, Different Defects

A corollary for using different codes indicating the same defect, is finding that TV operators frequently use the *same codes* to describe *different defects*. As confirmed in the EPA/WERF sponsored study in Milwaukee, Wisconsin, it was found that certified TV operators frequently used the same code for widely different defects, creating highly questionable Overall Pipe Rating Index (OPRI) metrics frequently used to determine rehabilitation priorities.

Different Codes, Same Defect

It is unfortunate, but true: train and certify two TV operators on the *same* day, using the *same* course instructor, utilizing the *same* materials (i.e. videos, photographs, etc.), test both using the *same* video, and you may get completely different interpretations of defects, not to mention a different number of defects. It's human nature and has been studied extensively, as shown below.



Differences in CCTV condition classification of 307 sewer reaches after parallel inspections (Müller, 2006).

The introduction of Electro Scan has not only shed light on defects not found by television inspection, but also highlights why CCTV inspection is not recommended to certify post-CIPP rehabilitation.

Can't Record What You Don't See

CCTV is not good at assessing the condition of pipe joints, primarily due to the basic design of joints. No matter how close an operator zooms into the surface of a joint, there is no possible way to assess the integrity or remaining useful life of the mortar. That is, unless pressure testing the joint or using Electro Scan.

Silt

Silt is a dangerous thing to find in a sewer as it oftentimes represents the liquefaction of bedding surrounding a pipe that may indicate the early start of a void -- a warning to all sewer utilities that have an over-reliance on vac trucks to routinely remove silt. But while TV cameras cannot see through silt on the bottom of a pipe, Electro Scan can. When wet, silt is a conductive material, allowing Electro Scan's low voltage current to go right through silt to find defects where leaks can occur.

CAUTION: Finding Excessive Levels of Silt, Combined With Large Electro Scan Leak Locations, Indicate Location of Possible Voids.

Clean v. Dirty Pipe Assessments

In 2010, the EPA arranged a benchmark in Kansas City, MO to compare Electro Scan and CCTV. While Electro Scan found 40% more defects and selected critical pipes that were rated in *good condition* by a nationally certified CCTV operator, comparisons were also evaluated on whether the pipe had been cleaned or not, prior to evaluation. While cleaning may eliminate fats, oils, and grease, roots, debris, and silt, it also eliminates key evidence of water leaks. As a result, TV inspections in the study did find fewer defects after cleaning, as clues to locating leaks were removed, and therefore more difficult to see with a camera.

Cracks

Unfortunately, CCTV cameras are not able to tell the difference between a superficial surface crack and a crack that goes completely through the pipe wall. Too often, cracks are blamed for the infiltration, when in reality, the unsealed joint, a few inches away has a larger leak potential.

Favorite Code, Different Defects

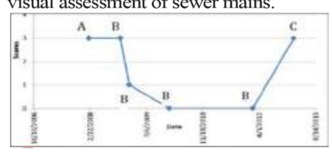
Some operators often use 'favorite' codes that may or may not relate to the *same* or *different* defects.

Different Codes, Same Operator

Not including data entry, CCTV operators may enter different observations on the same sewer main.

Repeatability

Recent studies suggest that certified TV operators are often unable to repeat the same CCTV observations, when evaluating the same pipe at different times – undermining development of an accurate visual assessment of sewer mains.



Fittings & Ferncos

CCTV cameras do not have the ability to test or validate the water tightness of fittings or Ferncos often used in VCP pipes, and located outside the pipe. The subject of an open trench smoke testing benchmark, Electro Scan accurately found defective ferncos (shown below), missed after repeated CCTV inspections.

Dark-Colored Pipe

Darkened pipe walls not only mask visual signs of defects, but dark colors typically absorb a camera's lighting, further reducing the chance of a proper inspection. Ductile iron pipe, polyethylene, and high density polyethylene pipes are just some of the materials that may have darkened surfaces that are difficult to observe and assess.

Point Repairs

CCTV is not a reliable tool to certify point or spot repairs. Whether completed with a trenchless or open-cut method, CCTV is not able to see if newly-created seams are watertight.

Pre-Rehabilitation Selection

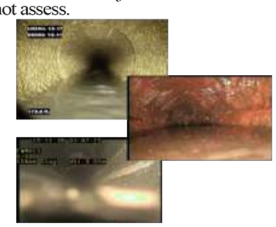
Too often, a rehabilitation program is deemed "unsuccessful" when flows are not reduced. Unfortunately, since CCTV cameras cannot properly assess pipes for leakage potential, TV programs should not be used to rank or prioritize needed repairs, rehabilitation, or renewals.

OPRI Grading		Structural Performance Grade (SPG)	Pipe Failure
5	Immediate Attention	Collapse or collapse imminent	Pipe has failed or will likely fail within the next 5 years
4	Poor	Collapse likely in foreseeable future	Pipe will probably fail in 5 to 10 years
3	Fair	Collapse unlikely in near future	Pipe may fail in 10 to 20 years
2	Good	Minimal collapse risk	Pipe unlikely to fail for at least 20 years
1	Excellent	Acceptable structural condition	Failure unlikely in the foreseeable future

CCTV 1-5 RATING SYSTEM NOT RECOMMENDED FOR REHABILITATION SELECTION

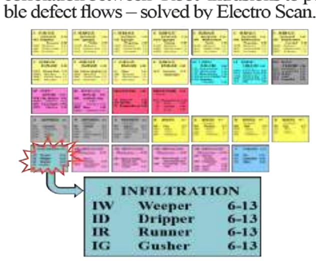
Missed Defects

Relying on a visual technology results in missed defects more often than not. Smudges on the lens, build up of debris and effluent on pipe walls, high flows, and operator inattentiveness, all contribute to missed defects. Not to mention the most common missed source for leaks – unsealed joints – which cameras cannot assess.



Infiltration

The requirement to have an empty pipe during CCTV inspection and inability to readily quantify openings in a pipe make identification of "infiltration" difficult, if not impossible. Further complicating the accurate identification of infiltration, is the lack of any correlation between 'Root' intrusions to possible defect flows – solved by Electro Scan.



Camera Breakdown

A multitude of moving parts coupled with considerable heat build up while inside a pipe, results in a treacherous environment for cameras and their crawlers. As a result, breakdowns may occur for a variety of reasons including entanglements from roots & debris, getting stuck in thick silt, or caught in a broken joint, all contributing to compromised video quality or an abandoned survey.

How Can a CIPP Project Deliver A Successful Reduction in Flow and 'Leak Free' Certification?

In the past, managers, consulting engineers, and contractors were limited to visual inspection to certify rehabilitation effectiveness. Unable to consistently or accurately find defects in CIPP lining using existing CCTV, Electro Scan now offers independent, unbiased, and unambiguous assessments of a contractor's CIPP lining project.

Given the cost per foot of trenchless rehabilitation and competitive offers from CIPP contractors, the additional cost of Electro Scanning Inspection can most often be easily accommodated in existing Engineer Estimates, allowing utilities to require both pre- and post-rehabilitation assessment evaluations, therefore providing a Baseline Defect Flow Rating, for each pipe, expressed in gpm or lps.

At a cost from $5 to $10 per foot, depending on pipe diameter, access, traffic control, and mobilization requirements, sewer agencies and their consulting engineers can use Electro Scanning Inspection to determine a quantified reduction in flow prior to Acceptance.

As shown in a recent 5,600 LF project, Electro Scan's FELL inspection allows a pipe-by-pipe assessment, matching defects before and after CIPP lining (Figure 15).

While the overall project achieved a 75% reduction in defect flow, an individual line-by-line assessment of the twenty-eight (28) sewer mains showed that four (4) segments, totaling 1,067 LF or 19% of the 5,563 LF, had defect flows greater <u>**AFTER CIPP**</u>, than <u>**BEFORE CIPP**</u>.

How is it possible for CIPP liners to have higher defect flows after rehabilitation compared to before rehabilitation? Simple. Mechanical cleaning of pipes prior to lining may cause damage not present before lining. Root cutting and removal may exacerbate this. Also, remote tap cutting of service laterals that under-shoot or over-shoot the lateral, may cause large defects.

The Goal: Manage Rehabilitation to ZERO GPM (Figure 16).

Figure 16. Three-Steps To Achieve ZERO DEFECT FLOW.

Three scans may be necessary to ensure that required defect flow reductions are accomplished. As shown in the example, below.

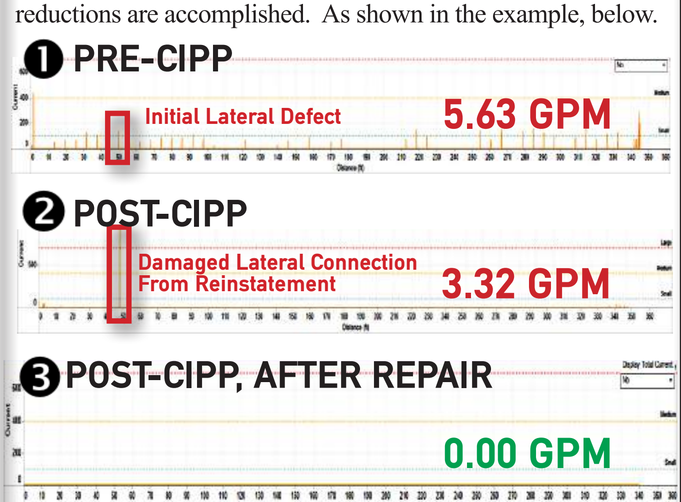
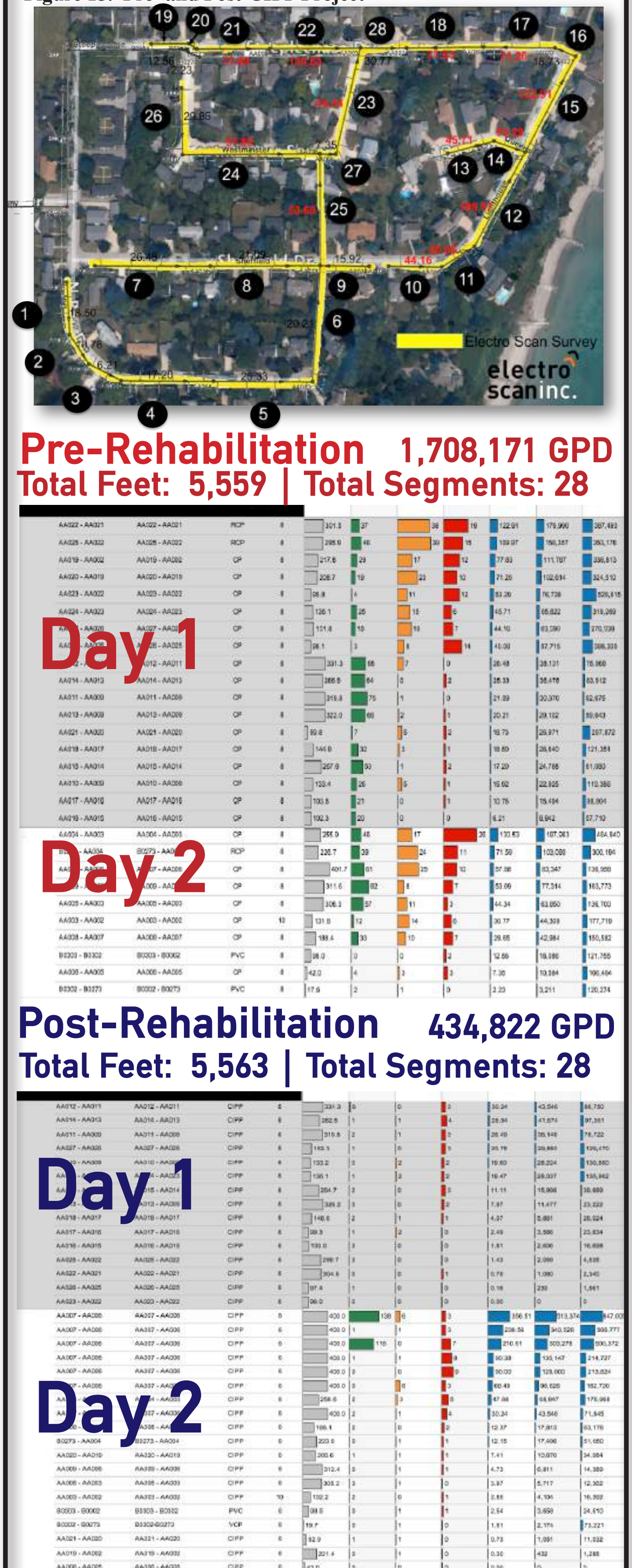


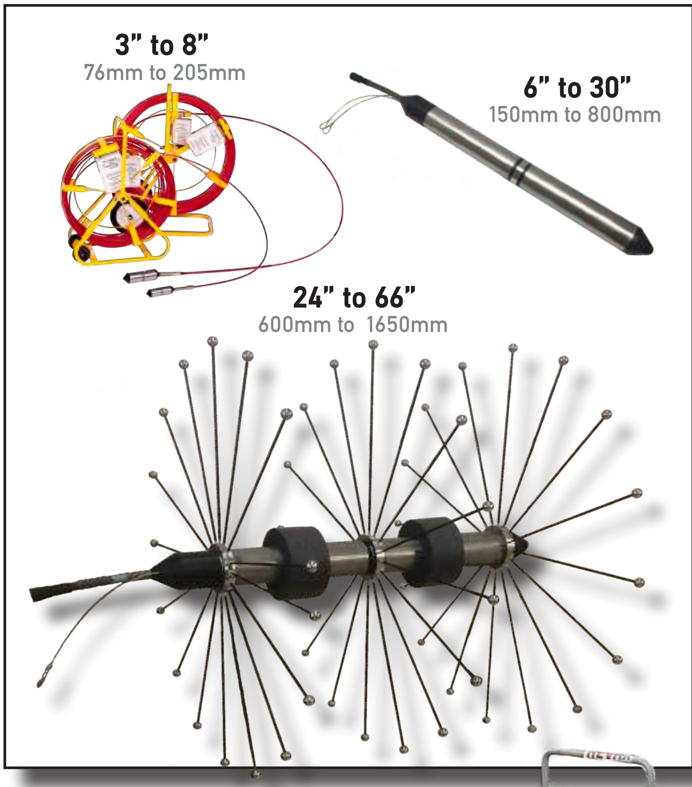
Figure 15. Pre- and Post-CIPP Project



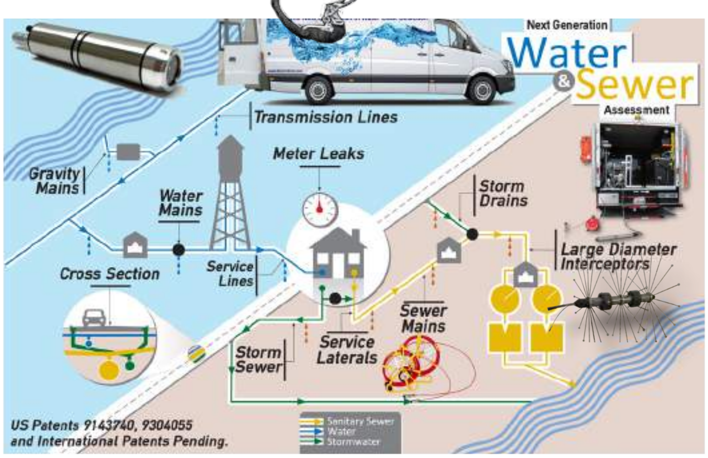
What Products & Services Are Offered to Certify CIPP Projects?

Available for purchase by municipal sewer agencies and utilities and available through authorized business partners, Electro Scan offers a wide range of devices matched to specific pipe diameters and rugged terrain, if required.

Figure 17. Electro Scan Probes By Pipe Diameter



Portable equipment may be provided for projects and for sale, with reporting of results no different than other Electro Scan products and services.



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Other U.S. and International patents pending.

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