Designation: F2550 – 13

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

This standard is issued under the fixed designation F2550; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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.

1. Scope

1.1 This practice covers procedures for measuring the variation of electric current flow to detect and locate potential pipe leaks in pipes fabricated from electrically nonconductive materials such as brick, clay, concrete, and plastic pipes (that is, reinforced and non-reinforced). The method uses the variation of electric current flow through the pipe wall to locate defects that are potential water leakage paths either into or out of the pipe.

1.2 This practice applies to mainline and lateral gravity flow storm sewers, sanitary sewers, and combined sewers with diameters between 3 and 60 in. (75 and 1500 mm). The pipes must be free of obstructions that prevent the probe passing through the pipe.

1.3 The scanning process requires access to sewers, filling sewers, and operations along roadways that are safety hazards. This standard does not describe the hazards likely to be encountered or the safety procedures that must be carried out when operating in these hazardous environments. (7.1.3) There are no safety hazards specifically associated with the use of an electro-scan apparatus that complies with the specifications provided in this standard. (6.7 and 6.10.)

1.4 The measurement of the variation of electric current requires the insertion of various items into a sewer. There is always a risk that due to unknown structural conditions in the sewer such items may become lodged in the pipe or may cause the state of a sewer in poor structural condition to further deteriorate. This standard does not describe methods to assess the structural risk of a sewer.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *lateral, n*—sewer pipe connecting the common sewer collection system to the user.

2.1.2 *mainline, n*—pipe that is part of the common sewer collection system.

2.1.3 *maintenance hole, n*—(MH) vertical shafts intersecting a sewer that allows entry to the sewer for cleaning, inspection and maintenance.

2.1.4 *owner, n*—entity holding legal rights to, and responsible for the operation and maintenance of the sewer pipe.

2.1.5 *probe, n*—scan electrode placed in a pipe.

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2.1.6 *sliding pipe plug, n*—device that blocks the flow through a pipe and at the same time can be pulled through the pipe.

3. Significance and Use

3.1 The testing of sewers for leaks is a regular practice necessary for the maintenance and optimal performance of sewer collection systems so remedial action can be prioritized, designed, and carried out to reduce infiltration and exfiltration.

3.2 This practice serves as a means to detect and locate all types of pipe defects that are potential sources of water leaks either into or out of electrically non-conducting pipes. Leaking joints and defective service connections are detected that often may not show as a defect when viewed from inside the pipe. The scan data may be processed and analyzed to provide some information on the size and type of pipe defect. (8.4.1)

3.3 This practice applies to mainline and lateral gravity flow storm sewers, sanitary sewers, and combined sewers fabricated from electrically non-conducting material with diameters between 3 and 60 in. (75 and 1500 mm). The pipes must be free of obstructions that prevent the probe passing through the pipe.

4. Contract Responsibilities

4.1 Apart from the provisions generally included in a testing services contract, testing contracts for measuring the variation in electric flow through a pipe wall should define or affix responsibility for or make provisions for the following items:

4.1.1 Access to the site of work is to be provided to the extent that the owner is legally able to so provide or, if not so able, a written release from responsibility for the performance of work at sites where access cannot be made available;

4.1.2 Clearances of blockages or obstructions in the sewer system;

4.1.3 Location and exposure of all maintenance holes (MH);

4.1.4 MH numbering system for all areas of the project and MH invert elevations and depths;

4.1.5 Shutdown or manual operation of certain pump stations if such becomes necessary for performance of the work;

4.1.6 Permission to use water from fire hydrants at the work site, or other suitable designated sources within a reasonable distance from the work areas, which is necessary for contracted work performance;

4.1.7 Authorization to perform work that must be performed during nighttime hours, weekends, or holidays; and

4.1.8 Traffic control by uniformed officers or contract personnel when the safety of workers or the public requires such protection.

5. Principle of Operation

5.1 Most sewer pipe materials such as clay, plastic, concrete, reinforced concrete, and brick are poor conductors of electrical current. A defect in the pipe wall that leaks water will also leak electrical current, whether or not water infiltration or exfiltration is occurring at the time of the test.

5.2 The test is carried out by applying an electrical potential of 9 to 11 Volts rms with a frequency of 500 Hz to 30 kHz between an electrode in the electrically nonconductive pipe and an electrode on the surface, which is usually a metal stake pushed into the ground. A simplified electrical circuit for this procedure is shown in Fig. 1. The water in the pipe is at a level that ensures that the pipe is full at the electrode location. Provided electrical current is prevented from flowing along the inside of the pipe, the electrical resistance of the current path between the electrode in the pipe and the surface electrode is very low except through the electrically nonconductive pipe wall. The high electrical resistance of the pipe wall allows only a very small electrical current to flow between the two electrodes unless there is a defect in the pipe such as a crack, defective joint, or faulty service connection. The greater the electric current flow through the pipe opening, the larger the size of the leak.

6. Apparatus

6.1 The method for measuring the variation in electric flow through a pipe wall requires a means of preventing the electric current from the electrode in the electrically nonconductive pipe from traveling along the inside of the pipe before reaching

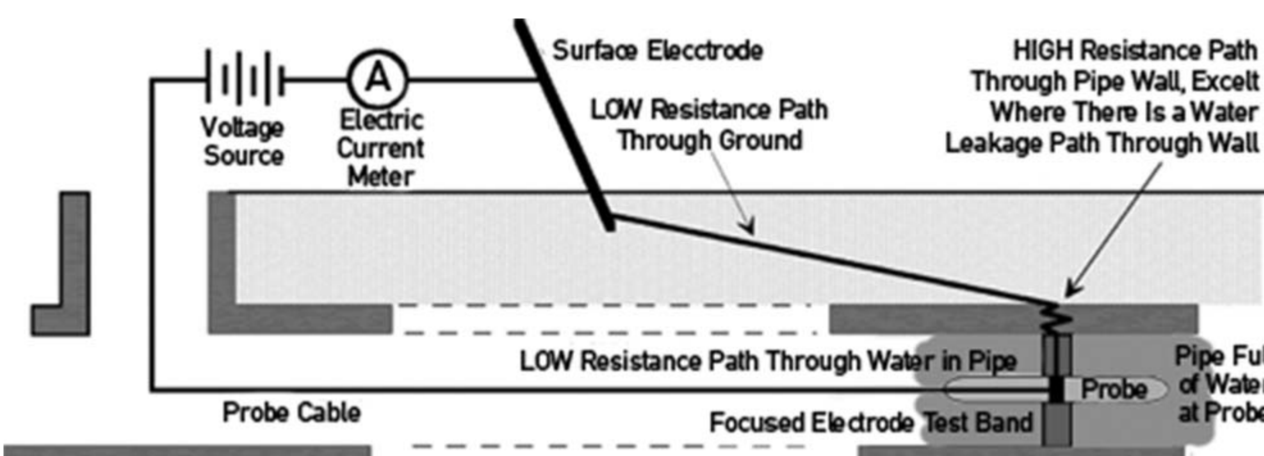

FIG. 1 Schematic of a Simplified Electrical Scanning Circuit in a Non-Conductive Pipe

the ground electrode. Such a means is a three-electrode array, known as a probe. The probe is constructed in such a way that when equal voltages are applied to all three electrodes, the electric fields of the outer electrodes prevent electrical current from the center electrode flowing along the pipe. This also causes the electric field of the center electrode to be focused into a disk about 1 in. (25 mm) wide. This electric field projects onto the pipe wall as a circumferential band with a width of about 10 % of the pipe diameter. The center of the band is located at the center of the probe. As a result, the electrical current flow through the center electrode of the probe, called the focused current, is dependant on the electrical resistivity of the pipe wall within the area of the band around the circumference of the pipe.

6.2 The essential components of the scanning apparatus are: a controlled voltage source; the probe; an insulated cable to connect the probe to the voltage source and move the probe through the pipe; a system to measure the position of the probe in the pipe; a system to measure the focused current; a system to measure the electrical current flowing through all three electrodes in the probe, called the total current; and a surface electrode. When a sliding pipe plug (7.1.6.2) is used, a system to measure the water pressure in the pipe at the location of the probe, called the water head, is required.

6.3 The geometric dimensions of the probe shall be such that the change of focused current as a result of a hole in the pipe with a diameter of 0.5 % of the pipe diameter will be detected and potential leaks separated by more than 25 % of the pipe diameter will be resolved. That is for a 10 in. (250 mm) diameter pipe a hole with a diameter of 0.05 in. (1.3 mm) will be detected and openings more than 2.5 in. (62 mm) apart will be shown as two separate leaks.

6.4 The focused current and the total current flowing between the surface electrode and the probe and the water head shall be measured and recorded at not less than 0.40 in. (10.0 mm) intervals along the pipe while the probe is pulled through a pipe at a speed of 32.8 ft/min (10.0 m/min).

6.5 The accuracy of the probe position measurement system shall be within ±0.5 % with a resolution 0.05 %. That is for a pipe test section that is 100.00 ft long the length of pipe measured by the system shall be 100.00 ± 0.5 ft and the smallest distance readout unit will be 0.05 ft or less

6.6 The resolution of the current measurements shall be equal to or less than 0.1 % of the maximum current. That is if the maximum current is 40 mA then the smallest current readout unit will be 0.04 mA

6.7 The applied voltage between the probe and the surface electrode shall have a frequency between 500 and 30 000 Hz and a voltage range of 9 to 11 volt rms. The maximum current between the probe and the surface electrode shall be 0.04 A rms. These parameters prevent the occurrence of sparks or electric shock to humans during normal operation or in the event of a short circuit.

6.8 The measurement of the probe location, total current, focused current, and water head shall be stored in real time as digital data in an electronic device.

6.9 The probe position, total current, focused electrode current, and the water head shall be displayed in real time on an electronic device on the surface when the system is activated.

6.10 The design of the electrical circuits shall prevent the occurrence of sparks or electrical shock to humans if faults or damage occur such as a severed cable.

6.11 Power cable winches shall have an automatic slip clutch to prevent overstrain of the probe cable that may occur if the probe becomes stuck in the pipe.

7. Procedure

7.1 *Sewer Preparation:*

7.1.1 The test is usually carried out by moving the probe through the sewer at approximately 30 ft/min (10 m/min). For the average MH interval of 300 ft (100 m), this takes about 10 min. The time to set up and dismantle the test equipment and fill the sewer in the region of the probe usually takes up most of the field time. Appropriate selection of the sewer section test sequence, establishment of a setup routine, and ready availability of suitable equipment can considerably reduce the test preparation time.

7.1.2 Generally, testing does not require any pipe preparation. However, the sewer must be clear of obstructions that prevent the probe passing through the pipe such as severe root intrusion or protruding service connections. Inability to pass the haul line (7.1.5) through the pipe will indicate the presence of such obstructions and should be reported (7.2.4).

7.1.3 *Person-Entry into Sewer MH's*—Field operations should not require person-entry of MH's. Person-entry is hazardous and requires additional time to carry out the safety checks and set up safety equipment. However, unforeseen situations may occur that require person-entry of a MH. Suitably trained personnel and safety equipment should be on hand just in case person entry is required. Prior to a person entering a MH the atmosphere in the MH must be evaluated for toxic or flammable gases and oxygen depletion in accordance with local, state or federal safety regulations and must be carried out in accordance with the owner's person-entry of MH procedures.

7.1.4 *Sewer Flow*—Testing can be carried out in all conditions of sewer flow, from dry to surcharged.

7.1.5 *Haul Line:*

7.1.5.1 A line is required to pull the probe between the MH's of the pipe section to be tested. The haul line is flushed between the MH's at each end of the pipe section to be scanned using either water or air.

7.1.5.2 An effective haul line is a jet cleaner hose.

7.1.6 *Filling the Sewer at the Probe Location*—Water in the pipe provides the electrical connection between the probe and the pipe wall (Fig. 1). To scan the complete circumference of a electrically nonconductive pipe, it must be full of water at the location of the probe, otherwise pipe leaks not in contact with water will not be detected, that is, the top part of the pipe. Filling the sewer at the probe location can be achieved by using a sliding pipe plug or a conventional sewer plug. Situations may arise where filling the pipe at the probe location is not feasible. In such cases scanning may be carried out as long as the depth of flow in the pipe is recorded and the data annotated that it is only applicable to that part of the pipe covered with water.

7.1.6.1 *Sliding Pipe Plug:*

(*1*) A sliding pipe plug can be used to plug mainline sewers immediately downstream of the probe and can slide along the pipe with the probe while continuing to plug the pipe (Fig. 2). It can be used in pipes with diameters between 6 and 12 in. (150 and 300 mm). Using a sliding pipe plug enables testing to be carried out without completely filling the pipe over the length of the MH-to-MH section, and it reduces the amount of water and time required to prepare the pipe for testing. It also reduces the water head required to between 2 and 12 in. (50 and 300 mm). This considerably reduces the risk of backing up and flooding connected services.

(*2*) The sliding pipe plug, together with the probe, is placed in the pipe at the upstream end of the pipe section. Then the sewer is filled until the water is between 2 and 12 in. (50 and 300 mm) above the pipe crown. This initial water head is selected according to the flow volume and pipe gradient. The sliding pipe plug and probe are then pulled down the pipe. However, the sliding pipe plug does not form a perfect seal at all times. For instance water will bypass the sliding pipe plug for a few seconds when it passes service connections and MH's or encounters obstructions in the pipe such as roots, offset joints, or longitudinal cracks. It is likely that during a test sufficient water will bypass the sliding pipe plug so that the section of pipe in the immediate vicinity of the probe will no longer be completely full of water.

(*3*) When scanning with a sliding pipe plug, the probe must contain a pressure gauge that continuously measures the water pressure that is displayed by an electronic device in real time during the test. The water pressure should be displayed as a distance versus depth of water head plot and numerical value. From this information, the water head at the probe can be monitored during the test. If the water head becomes less than a predetermined level, the test should be interrupted and the pipe filled to the required water head and the test continued. Similarly, action should be taken to prevent the water head exceeding a level that may present a risk of flooding connected services.

(*4*) The sliding pipe plug must be fitted with a device that can be activated if required, to collapse the sliding pipe plug and enable water to flow past the plug while it is in the pipe and also enable it to be pulled upstream if an obstruction prevents it and/or the probe from being pulled downstream.

(*5*) *Integration with Regular Sewer Pipe Jet Cleaning Operation* (7.8.3)—The low volume of water required to fill the pipe in the region of the probe using the sliding pipe plug makes it feasible to use a sewer jet cleaning truck as a source of water to partially fill the pipe. The jet hose is also used as the haul line.

7.1.6.2 *Conventional Sewer Plug:*

(*1*) The alternative to the sliding pipe plug is to surcharge the entire length of the MH-to-MH mainline sewer length by plugging the pipe at the downstream end of the pipe test section. The sewer is full when the water level is just above the crown of the sewer at the upstream MH. Situations may occur

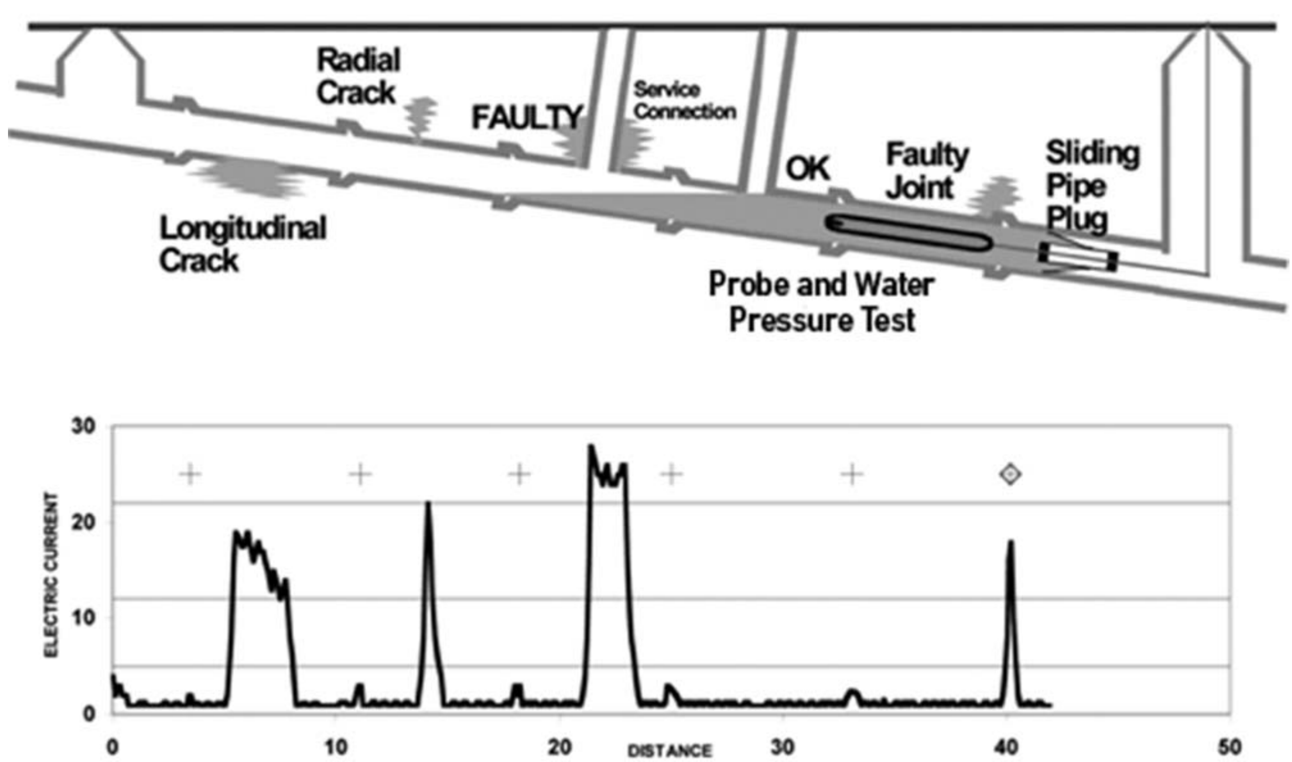

FIG. 2 Electric Current Variation Testing and Plot of Variation of Focused Current by Distance

in which completely filling the sewer pipe section may cause the downstream MH to overflow or houses to flood. Obviously, this must be avoided. In such circumstances and if the pipe diameter is 12 in. (300 mm) or less, the sliding pipe plug should be used.

(*2*) The flow in 6- to 10-in. (150- to 250-mm) main sewers is often too low for flushing the haul line or filling the sewer in a reasonable length of time (less than 15 min) and another source of water is required. The most effective source of water is either a fire hydrant or tanker truck. The use of a jet cleaning truck as a source of additional water when using a conventional plug is not recommended, as the water volume output is usually too low.

(*3*) Blocking the flow of sewers with diameter greater than 12 in. (300mm) to surcharge a MH-to-MH section is a particularly hazardous operation. It requires personnel experienced with this operation and the provision of appropriate plugs and ancillary equipment. Particular attention should be paid to the ability of the plugging system to be quickly and safely extracted under all possible sewer flow or surcharge conditions.

7.2 *Test Information:*

7.2.1 *Distance Measurement Units*—It is recommended that distances be measured and recorded to the nearest 0.1 ft (0.01m) using an engineering tape or measuring wheel marked in 0.1 ft (0.01m).

7.2.2 *Test Distance Offsets*—The middle of the probe detects the pipe leakage. At the start of the test, the probe is placed in the pipe and the middle of the probe is usually offset from the center of the MH. This distance is the "start offset" and must be measured and recorded so the leaks found are located correctly on the test record. Similarly, there is an "end offset." This should also be measured and recorded so a comparison check can be made between the sewer length recorded by the test and the measured sewer length.

7.2.3 *Test Description*—To be recorded for each test and attached to the digital record of the test (6.8):

7.2.3.1 Test date/time;

7.2.3.2 The MH name/number at the start and the end of the test and any intermediate MH;

7.2.3.3 The street address of the upstream MH, if applicable;

7.2.3.4 The distance between the center of the start and end MH's and any intermediate MH's. This distance should be measured in the field at the time of the test;

7.2.3.5 Start offset: the distance between the center of the start MH and the center of the probe at the start of the test;

7.2.3.6 End offset, the distance between the center of the end MH and the center of the probe at the end of the test;

7.2.3.7 The direction that the probe was pulled through the pipe during the test relative to sewer flow;

7.2.3.8 Method used to plug the pipe;

7.2.3.9 The percentage of flow in the pipe before the pipe is plugged;

7.2.3.10 Pipe material and diameter;

7.2.3.11 The probe size and cradle size; and

7.2.3.12 The name of the entity and the operator carrying out the test and a project/job identifier.

7.2.4 *Obstructed Pipe Sections*—Pipe sections that cannot be tested because of obstructions in the pipe should be noted and included in the test report.

7.3 *Probe Size Selection*—The size of probe used to carry out a test is selected according to the diameter of the pipe as per the recommendation of the apparatus manufacturer.

7.4 *Surface Electrode:*

7.4.1 The electrical current flows from the probe in the sewer through the water in the pipe, the pipe wall, and the ground to the surface electrode. The surface electrode is connected to the electrical earth of the electro-scan system via an earth cable. (Fig. 1).

7.4.2 The surface electrode is usually a metal stake pushed into the ground to a depth of about 6 in. (150 mm). To avoid damage to underground infrastructure the stake should only be pushed into the ground using manual force and not driven using a hammer or similar. The stake can be located at a distance of a few feet to 100 feet from the probe cable winch. There is no need to change the position of the surface electrode during the test of a MH-to-MH pipe section. If there is no open earth in the vicinity, a ground connection can also be obtained by connecting the earth cable to a metal fence, water pipe, parking sign, or similar.

7.4.3 In dry or sandy earth or both, the earth connection may have a high resistance and limit the current flow. This can be improved by pouring about 0.5 pint (250 ml) of water around the metal stake. The ground connection can be further improved by mixing a small quantity of salt and detergent in the water.

7.4.3.1 *Ground Conditions*—The nature of the material surrounding the pipe or the material on the surface above the pipe does not have any affect on the data with respect to detecting pipe leaks. The volume of material available for the electrical current to return from outside the pipe to the ground stake is effectively infinite. Provided the ground stake has a good electrical connection to the ground, variations in the electrical conductivity of the material in the vicinity of the pipe has no significant effect on the flow of electrical current through the ground.

7.5 *Field Operator Training and Experience:*

7.5.1 It is recommended that the data collection field crew consist of at least two personnel that have training and experience suitable for general operations and maintenance of sewer collection systems of the size of pipe being scanned.

7.5.2 The scanning field apparatus operator will require novice computer skills.

7.5.3 The field test apparatus operator does not require experience in interpreting or analyzing electro-scan data. Other than ensuring that the system is operating correctly (7.6), scanning a pipe does not require any judgments to be made on the part of the operator.

7.6 *Confirmation of Proper Apparatus Operation:*

7.6.1 On completion of setting up the system for collecting data, including setting the surface electrode and placing the probe in the pipe, the total current must show a value that is greater than the value specified by the apparatus manufacturer for the pipe size and pipe material type being tested.

7.6.2 The operator shall continuously observe the total current value and the real-time distance versus current plot displayed on the surface electronic device (6.9) as the probe is pulled through the pipe to ensure that the total current remains above the specified minimum level, the system records data over the entire length of the test section, and that the pipe is full of water at the probe location.

7.7 *Data Storage*—The test information (7.2.3) and distance versus current data shall be stored on an electronic device at the time of the test. The data shall be backed up daily either by storage on an independent electronic digital medium such as floppy disks, CD-ROM, or electronically transmitted to another computer.

7.8 *Field Operation*—The recommended sequence is as follows:

7.8.1 *Using the Sliding Pipe Plug:*

7.8.1.1 Open MH at each end of the pipe section to be tested;

7.8.1.2 Thread a line, called the haul line, between the two MH;

7.8.1.3 Set the surface electrode;

7.8.1.4 Attach the sliding pipe plug and probe to the upstream end of the haul line;

7.8.1.5 Fill the pipe in the region of the probe with water;

7.8.1.6 Activate the probe and recording device;

7.8.1.7 Pull the probe from the upstream MH to the downstream MH;

7.8.1.8 Remove the sliding pipe plug from the sewer through the downstream MH;

7.8.1.9 Remove the probe and cable through the upstream MH; and

7.8.1.10 Retrieve surface electrode, close MH.

7.8.2 *Using a Conventional Sewer Plug:*

7.8.2.1 Open MH at each end of the pipe section to be tested;

7.8.2.2 Thread a line, called the haul line, between the two MH;

7.8.2.3 Set the surface electrode;

7.8.2.4 Attach the probe to the haul line and pull the probe to downstream MH;

7.8.2.5 Plug the pipe and fill so that the water level is just above the crown of the upstream MH;

7.8.2.6 Activate the probe and recording device;

7.8.2.7 Pull the probe from the downstream MH to the upstream MH;

7.8.2.8 Remove the probe and haul line from the sewer;

7.8.2.9 Remove the sewer plug; and

7.8.2.10 Retrieve surface electrode, close MH.

7.8.3 *Integrated with Regular Sewer Pipe Jet Cleaning Operations:*

7.8.3.1 Clean pipe from downstream MH;

7.8.3.2 Pull hose out of upstream MH and remove jet;

7.8.3.3 Attach sliding pipe plug and probe to jet hose and place in sewer;

7.8.3.4 Fill pipe in region of probe with water through jet hose;

7.8.3.5 Record scan data while using jet hose to pull sliding pipe plug and probe to downstream MH;

7.8.3.6 Disconnect hose and sliding pipe plug from the jet hose; and

7.8.3.7 While the jet cleaner moves off the MH, refills with water, and cleans the next pipe section, the probe and cable is retrieved from the tested section, moved to the next MH, and is prepared for attachment to the jet hose.

8. Report

8.1 *General*—A report shall be provided to the owner by the operator as described in 8.2 – 8.5. The objective of the report is to provide sufficient information for the owner to analyze and assess the distribution and severity of the pipe leakage shown by the test.

8.2 *Summary of Pipe Sections Tested*—A table of pipe sections tested shall be provided that shows the name/number of the upstream and downstream MH, the distance between MH, the pipe diameter, and pipe material. The table shall show any discrepancies between these parameters observed at the time of the test and the information provided by the owner before the test. The table shall show any pipe sections that were not scanned because of obstructions in the pipe.

8.3 *Summary of Pipe Sections Showing Exceptional Anomalies*—A table should be provided that lists and describes pipe sections tested that show exceptionally large current values or other variations that are different from the general pattern of electrical current values that are shown by the test.

8.4 *Field Recorded Scan Data:*

8.4.1 All the information recorded in 7.2.3 shall be provided for each test section.

8.4.2 For each test section, a graphical representation shall be provided of the data as recorded in the field in the form of a distance plot of the focused current. A distance plot of the water head shall also be included when a sliding plug is used.

8.5 *Data Processing:*

8.5.1 The focused electrode current data may be processed to grade the variations of the focused electrode current values into those that represent small, medium, and large pipe leaks according to the maximum amplitude of focused electrode current. The apparatus manufacturer should be consulted regarding the relationship between focused electrode current and pipe leak size and classification. Detected leaks may be classified into those that are likely to be due to pipe joints or other types of pipe leaks resulting from faulty service connections or pipe cracks by associating focused electrode current maxima that occur at regular location intervals with pipe joints. 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.

8.5.2 The processed focused electrode current data may be presented as a distance versus current plot showing the location, grading, and classification of the focused electrode current variations. In some instances, it may be worthwhile to include television inspection logs or air pressure testing data or both on the plot.

TABLE 1 Summary of Focused Current Data

Sewer Section	MH Dist.	Pipe Diam.	Pipe Material	Joint Interval	Faulty Service Connection	% Anomaly Length of Pipe Length Tested					
						Large	Medium	Small	Joint	Other	Total
R_09_02 Cheryl Dr	328	6	VCP	4	6	0.3 %	1.1 %	0.4 %	0.3 %	1.4 %	1.8 %
R_09_03 Cheryl Dr	351	6	VCP	4	6	0.0 %	0.2 %	0.7 %	0.2 %	0.7 %	0.8 %
R_09_05 Cheryl Dr	351	6	VCP	4	0	0.1 %	0.0 %	0.2 %	0.2 %	0.2 %	0.3 %
R_09_06 Cheryl Dr	337	6	VCP	4	2	0.1 %	0.2 %	0.3 %	0.4 %	0.2 %	0.6 %
R_09_08 Cheryl Dr	226	6	VCP	4	0	1.8 %	0.2 %	1.4 %	1.6 %	0.4 %	3.4 %
R_09_16 Loma Vista Dr	348	6	VCP	4	4	0.5 %	0.3 %	0.9 %	0.4 %	0.6 %	1.7 %
R_09_23 Gary Ct	345	6	VCP	4	5	6.0 %	2.6 %	1.2 %	8.9 %	0.9 %	9.8 %
R_09_34 Traverse St	312	6	VCP	4	3	1.0 %	3.0 %	3.1 %	6.5 %	0.6 %	7.1 %
R_09_35 Traverse St	308	6	VCP	4	2	0.0 %	1.6 %	2.9 %	4.3 %	0.2 %	4.5 %
R_09_44 Gary Ct	300	6	VCP	4	3	0.1 %	1.2 %	1.0 %	2.0 %	0.3 %	2.3 %
S_09_01 Cheryl Dr.PR2	311	6	VCP	4	3	0.0 %	0.0 %	1.8 %	0.1 %	0.7 %	0.8 %
S_09_02 Cheryl Dr.PR2	400	6	VCP	4	5	0.4 %	0.2 %	1.6 %	0.1 %	0.8 %	1.2 %
S_09_03 Cheryl Dr.PR2	285	6	VCP	4	5	0.7 %	0.0 %	0.3 %	0.1 %	0.9 %	1.0 %

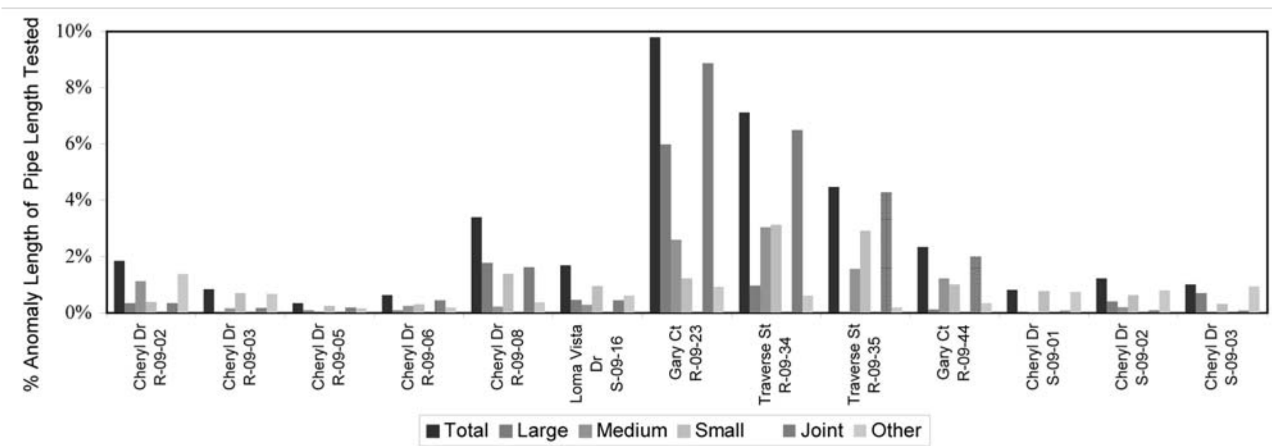

FIG. 3 Summary of Focused Current Data—Graphical Representation

8.5.3 The processed current data may be presented in summary form as a table (Table 1) or graphically (Fig. 3).

9. Keywords

9.1 electric current flow; infiltration; leaks; sewer pipes