Designation: F3095 − 17a (Reapproved 2022)

Standard Practice for Laser Technologies for Direct Measurement of Cross Sectional Shape of Pipeline and Conduit by Rotating Laser Diodes and CCTV Camera System[1]

This standard is issued under the fixed designation F3095; 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.

1. Scope*

1.1 This practice covers the procedure for the post installation verification and acceptance of buried pipe deformation using a visible rotating laser light diode(s), a pipeline and conduit inspection analog or digital CCTV camera system and image processing software. The combination CCTV pipe inspection system, with cable distance counter or onboard distance encoder, rotating laser light diode(s) and ovality measurement software shall be used to perform a pipe measurement and ovality confirmation survey, of new or existing pipelines and conduits as directed by the responsible contracting authority. This standard practice provides minimum requirements on means and methods for laser profiling to meet the needs of engineers, contractors, owners, regulatory agencies, and financing institutions.

1.2 This practice applies to all types of material, all types of construction, or shape.

1.3 This practice applies to gravity flow storm sewers, drains, sanitary sewers, and combined sewers with diameters from 6 in. to 72 in. (150 mm to 1800 mm).

1.4 The Laser Light Diode(s) shall be tested, labeled and certified to conform to US requirements for CDRH Class 2 or below (not considered to be hazardous) laser products or certified to conform to EU requirements for Class 2M or below laser products as per IEC 60825-1, or both.

1.5 The profiling process may require physical access to lines, entry manholes and operations along roadways that may include safety hazards.

1.6 This practice includes inspection requirements for determining pipeline and conduit ovality only and does not include all the required components of a complete inspection. The user of this practice should consider additional items outside this practice for inspection such as joint gap measurement, soil/water infiltration, crack and hole measurement, surface damage evaluation, evaluation of any pipeline repairs, and corrosion evaluation.

1.7 This standard practice does not address limitations in accuracy due to improper lighting, dust, humidity, fog, moisture on pipe walls or horizontal/vertical offsets. Care should be taken to limit environmental factors in the pipeline that affect accuracy of the inspection.

1.8 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.

1.9 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* There are no safety hazards specifically, however, associated with the use of the laser profiler specified (listed and labeled as specified in 1.3).

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F1216 Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube

[1] This practice is under the jurisdiction of ASTM Committee F36 on Technology and Underground Utilities and is the direct responsibility of Subcommittee F36.20 on Inspection and Renewal of Water and Wastewater Infrastructure.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

F2019 Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic Cured-in-Place (GRP-CIPP) Using the UV-Light Curing Method

2.2 *Other Documents:*

IEC 60825-1 Safety of Laser Products—Part 1: Equipment Classification and Requirements, Jan 2011[3]

CDRH Regulations CFR 21, Section I, Subchapter J, Parts 1002 to 1040.11[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *authority, n*—party reasonable for the generation and verification of performance to job specification(s) and contract requirements.

3.1.2 *barrel distortion, n*—distortion of an image produced by an optical system that causes straight lines at image margins to bulge outwards.

3.1.3 *CCTV, n*—a closed circuit pipeline and conduit inspection television system including a camera, camera transporter, integrated lighting, central control system, video monitor and recording device.

3.1.4 *laser, n*—a solid state device that produces a monochromatic and coherent beam of visible light in an intense, narrow beam.

3.1.5 *laser light diode, n*—a mobile, certified "eye safe" laser light source and internal optics capable of projecting a narrow beam of laser light onto an internal pipe wall in pipes from 6 to 72 in. (150 to 1800 mm) in diameter regardless of material, design, or shape.

3.1.6 *laser profile, n*—the spatial intensity profile of a laser beam at a particular plane transverse to the beam propagation path.

3.1.7 *laser profiling survey, n*—a survey composed of taking measurements of the cross sectional shape of the pipe at various stations along its alignment, processing the data using an appropriate software and producing a condition assessment report using laser profiling technology.

3.1.8 *ovality, n*—percentage of shape deflection in circular and noncircular pipes as calculated per Practice F1216 or Practice F2019 as defined in Annex A1.

3.1.9 *profiling software, n*—the software that analyzes the collected data from a laser profiling effort into deformed cross sectional profiles along the pipe of conduit alignment.

4. Significance and Use

4.1 Laser profiling assessment is a quality control tool for identifying and quantifying deformation, physical damage, and other pipe anomalies after installation, providing means and methods for determining the quality of workmanship and compliance with project specifications. Laser profiling capabilities include:

4.1.1 Measurement of the structural shape, cross sectional area and defects;

4.1.2 Collection of data needed for pipe rehabilitation or replacement design; and

4.1.3 Post rehabilitation, replacement or new construction workmanship verification.

4.2 A laser profile pre-acceptance and condition assessment survey provides significant information in a clear and concise manner, including but not limited to graphs and still frame digital images of pipe condition prior to acceptance, thereby providing objective data on the installed quality and percentage ovality, or degree of deformation, deflection or deviation, that is often not possible from an inspection by either a mandrel or only CCTV.

5. Contract Responsibilities

5.1 Apart from the provisions generally included in a testing and certification contract, the laser profiling survey contract shall define and assign responsibilities for the following items:

5.2 Access to the survey site to be provided to the extent that the contracting authority can provide such access.

5.3 The utility owner shall ensure that all lines to be profiled are free of debris, obstructions, and cleaned within 24 h prior to the profiling inspection. Standing or flowing water or debris shall not exceed 10 % of the nominal pipe diameter, or six (6) in. (150 mm) in depth, whichever is the lesser.

6. Equipment

6.1 The laser profiling equipment, including laser diode(s) and CCTV inspection system (Fig. 1) shall be configured and calibrated by the laser profiling equipment manufacturer, as per the same specifications of the equipment "Certificate of Accuracy" in accordance with Section 9.

6.2 Only calibration and laser distance software algorithms, as specified by the software manufacturer, shall be used as per the same specifications of the equipment "Certificate of Accuracy."

FIG. 1 CCTV—Rotating Laser Profile Camera in Pipe

[3] Available from International Electrotechnical Commission (IEC), 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, http://www.iec.ch.

[4] Available from Center for Devices and Radiological Health (CDRH), Food and Drug Administration, 10903 New Hampshire Avenue, WO66-4621, Silver Spring, MD 20993, http://www.fda.gov.

6.3 The profiling survey software shall be a version that meets or exceeds the contents of this practice.

6.4 The processing computer shall be equal to or exceed those specified by the software manufacturer.

7. Software

7.1 The recorded pipeline and conduit survey video shall be loaded into a computer with CCTV pipeline and conduit inspection and profiling processing software, meeting the technical requirements as stated herein installed.

7.2 The profile software shall analyze the laser image of each recorded video frame. By using a combination of camera head position, laser position, and known calibration values the software will calculate the measurement data.

7.3 The ovality shall be calculated per Practice F1216 as given in Annex A1. If the shape of the original pipe deviates significantly (more than 10 % from the nominal diameter) from that of an equivalent circle when the flow area is matched, changes in curvature shall be considered as a better measure of the degree of pipe deformation.

8. Procedure

8.1 The pipe shall be pre-cleaned and free of debris that would prevent the CCTV camera and laser diode assembly, shown in Fig. 1, from moving through the pipe, or adversely affect the accuracy of the survey. Flow or debris, within the line, shall be less than 10 % of the nominal pipe diameter of 6 in. (150 mm) in depth whichever is the lesser.

8.2 A CCTV pipeline and conduit inspection system shall be placed into the pipeline and conduit to be surveyed. A recorded inspection header shall contain complete pipe data including location, pipe type, pipe size, and date of inspection. The CCTV distance counter shall be set to zero and displayed in the video without overlapping or distorting the video image. The TV only line inspection shall be recorded on a digital storage device in a digital video format as agreed among the contractor and the client.

8.3 The laser profile consists of two types of scans: point and line measurement.

8.4 The point measurement is taken while the camera is stationary at single point. The camera will rotate 360 degrees to capture measurement data.

8.5 A line measurement is captured by rotating the camera head 360 degrees continuously while the system traverses the length of a pipe.

8.6 A profiler shall project visible laser (light) while rotating around the internal pipe surface. A pipeline and conduit inspection CCTV analog or digital video camera system shall continuously capture the laser image as the laser profile system is moved through the line at a longitudinal travel speed of 30 ft/min (9.1 m/min). For pipelines with an interior corrugated pipe wall, the pitch needed to capture a 360 degree view shall not exceed the pipe wall pitch (crest to crest of the corrugated pipe wall). The header of the printed and stored reports shall include the distance traveled to capture a 360 degree view of the pipeline. As a minimum, five full laser ring (complete rotations) images shall be taken every inch or two full laser ring (complete rotations) images per centimeter along the longitudinal distance of the pipeline. Any filtering or averaging of readings and data points shall be reported and approved by the engineer. In areas where the pipe exceeds performance limits, a full ring (stationary scan) shall be shown when it exceeds allowable deflection limits.

8.7 All CCTV video shall be recorded in a digital format and resolution, assuring acceptable image resolution.

8.8 By comparing the known calibrated measurements of the laser diodes, the profiling software shall be able to determine the distance from the camera to the pipe wall.

8.9 Upon completion of the point or line scan the processing software will calculate the pipe size at each measured position.

9. Accuracy and Precision

9.1 The accuracy of a measurement system is the degree of closeness of measurements of a quantity to that quantity's actual (true) value. The laser light diode system, with the profiling software, shall be tested and approved, by an independent testing agency, and shall include a "Certificate of Accuracy" equal to or better than 0.5 % of the lower nominal cross sectional dimension.

NOTE 1—The precision of a measurement system, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results. A measurement system can be accurate but not precise, precise but not accurate, neither, or both. For example, if the data collection method is affected by a systematic error, increasing the number of times the instrument is run through the pipe increases precision but does not improve accuracy. The result would be consistent yet inaccurate results from the flawed method. Eliminating the systematic error improves accuracy but does not change precision.

9.2 The testing of the independent testing agency shall be to a traceable standard of the National Institute of Standards and Technology (NIST), or equivalent. A minimum of five measurements shall be taken and shall result in a standard deviation of 2 σ (94.7 %) for precision (repeatability) or better.

9.3 The longitudinal position of the equipment is measured by a device in contact with the connection cable, positioning cable, or rope. The longitudinal location shall be measured to within an accuracy of 2 % of length between two consecutive joints; in addition, a tolerance of 2 ft (0.6 m) for the insertion and exit distance between the CCTV and the laser projection unit shall be allowed in the data and the reports.

10. Reports

10.1 At the completion of the software processing the following report shall be available in both digital and hard copy format. Where water or debris exists the software may use a non-structural mask prior to calculating the deviation.

10.2 *Observation Report*—An "Observation Report" shall include line graphs and still frame digital images, for the clarification and confirmation of the survey data. A typical image is shown in Fig. 2. A deformation line graph shall be included as generated solely from the image data, as recorded and software processed. A second "deformation limit line"