



Standard Practice for Laser Technologies for Direct Measurement of Cross Sectional Shape of Pipeline and Conduit by Rotating Laser Diodes and CCTV Camera System¹

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.

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 to 72 in. (150 to 1800 mm). 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 or 6 in. (150 mm) in depth whichever is the lesser.

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 and health 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).

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

F2019 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)

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.



FIG. 1 CCTV—Rotating Laser Profile Camera in Pipe

2.2 Other Documents:

IEC 60825-1 Safety of Laser Products—Part 1: Equipment Classification and Requirements, Jan 2011³

CDRH Regulations CFR 21, Section I, Subchapter J, Parts 1002 to 1040.11⁴

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 *CCTV camera transporter*, *n*—the device that provides mobility for the CCTV camera to move up and down the pipe alignment once it enters the inside of the pipe through manholes and/or other access openings.

3.1.5 *CCTV pipeline and conduit inspection system*, *n*—CCTV inspection system is composed of CCTV camera, the transporter, controller, video recording unit, and at times its own power.

3.1.6 *computer*, *n*—an electronic machine that performs rapid, complex calculations, correlates the processed data, generates imaging and corresponding alpha numeric information.

3.1.7 *curvature*, *n*—the reciprocal of the radius of the inner surface at a location along the perimeter of the noncircular shaped pipe, culvert or conduit.

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

3.1.9 *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.

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

3.1.11 *laser profile calibration software*, *n*—software created to determine and store the calibration values collected from the laser profile calibration unit.

3.1.12 *laser profile calibration unit*, *n*—a device to create the calibration profile of a rotating laser diode camera. The camera is placed inside the calibration unit, a target is moved to pre-defined positions along the unit and the resulting series of laser measurement values and focal lengths are to be used with the profile software.

3.1.13 *laser profiling equipment*, *n*—equipment used in performing a laser profiling observation.

3.1.14 *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.

3.1.15 *MTBF*, *n*—mean time between failures.

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

3.1.17 *processing or measurement software*, *n*—a software program for processing the CCTV images of a laser light on the internal surfaces of a pipe while moving through a pipeline or conduit. The speed of travel shall not exceed a maximum established rate jointly determined by the user and the contractor, considering the objectives and the size of the pipe or the conduit or stationary and generating specified reports.

3.1.18 *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 Operational experience and independent testing have fully documented that the usable life, maintenance and failure and mean time between failures (MTBF) in buried storm and wastewater lines can be directly affected by the defects during manufacturing, incorrect pipe storage, and improper installation, including improper compaction often resulting in the deformation and physical damage in newly installed, repaired and replaced pipelines. Laser profiling assessment is an effective quality control tool for identifying and quantifying deformation, physical damage, and other pipe anomalies after installation, providing valuable means and methods for determining the quality of workmanship and compliance with project specifications. Laser profiling capabilities include:

³ Available from International Electrotechnical Commission (IEC), 3, rue de Varembe, 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>.

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

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

4.1.3 Post rehabilitation, replacement or new construction workmanship verification.

4.2 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.

4.3 A laser profile pre-acceptance and condition assessment survey shall provide 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.

4.4 This practice applies to gravity flow lines—storm sewers, sanitary sewers, combined sewers, siphons, edge drains, highway drains, and culverts, and to all other pipelines, ducts and conduits that are made accessible and meet the requirements of 1.3, regardless of shape, design configuration or material. The line shall be free of excess debris and obstructions with a maximum flow level or stagnant water, during laser profiling, not to exceed 10 % of nominal pipe diameter or 6 in. (150 mm) in depth, whichever is the lesser.

5. Accuracy and Precision

5.1 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. 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.

5.2 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 2σ (94.7 %) for precision (repeatability) or better.

5.3 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.

6. Contract Responsibilities

6.1 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:

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

6.3 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.

7. Pipeline and Conduit Laser Profiling-Principle of Operation

7.1 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. The distance to capture a full rotation shall be established jointly by the user and the contractor, by both parties considering the objectives and the size of the pipe or conduit, neither to exceed a longitudinal travel speed of 30 ft/min nor exceed the pitch of 4 in. for pipe materials other than those with a corrugated pipe wall. For the pipelines with a 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) or 4 in. whichever is smaller. The header of the printed and stored reports shall include the distance traveled to capture a 360 degree view of the pipeline.

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

7.3 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. Equipment

8.1 The laser profiling equipment, including laser diode(s) and CCTV inspection system, shall be configured and calibrated by the laser profiling equipment manufacturer, as per the same specifications of the equipment Certificate of Accuracy.

8.2 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.

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

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

9. Software

9.1 The recorded pipeline and conduit survey video shall be loaded into a Windows⁵ or another operating system based computer with CCTV pipeline and conduit inspection and profiling processing software, meeting the technical requirements as stated herein installed.

9.2 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.

9.3 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.

10. Procedure

10.1 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.

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

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

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

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

11. Reports

11.1 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.

11.2 *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” shall display the maximum allowable percentage of deforma-

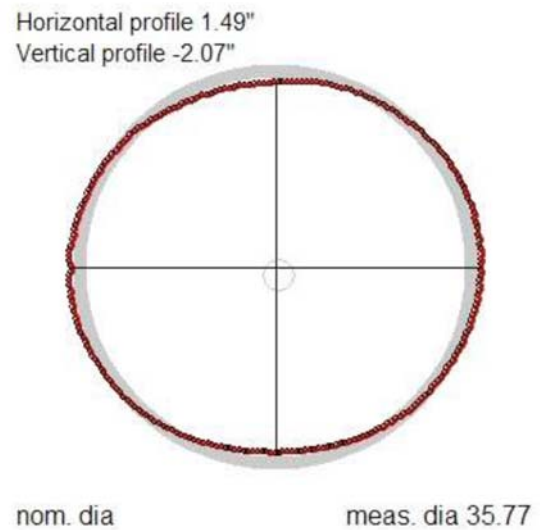


FIG. 2 Single Point Image of Uneven Deformation of Pipe

tion as specified by the contracting authority. Still frame video or digital images, for each profile that exceeds the specified maximum deformation, shall be included. A “Match to Reference Shape and Size” digital image observation shall also be included where the line size and shape matches the median calculated diameter for confirmation of calibration. The report to also include the operator, technician that performed the data analysis, list of equipment used and serial numbers, profile system travel speed through the line, direction of travel and the software version used.

11.3 Any software corrections or changes such as non-structural mask, image barrel distortion correction, raw data changes, and software smoothing shall be listed in the final report and original data archived. The original unaltered data shall be provided at the owner’s request.

12. Quality Control

12.1 Quality control measures shall include the following: a) the contracting authority, client or owner shall physically check and verify equipment calibration/accuracy certificates prior to deployment; b) operational characteristics such as speed of longitudinal travel shall be checked; and c) a final inspection shall be for the protection of the acquired data. The operators of the equipment shall undergo training recommended by the manufacturer and be certified in accordance with the requirements set from time to time by the manufacturer or the purchasing agency, or both. References for the equipment calibration are Practices E691 and E177.

13. Keywords

13.1 buried; CCTV; combined sewer; condition assessment; conduit; culvert; curvature; deflection; deformation; deviation; direct measurement; installation; laser diode; ovality; pipe; pipeline; rotating laser; sanitary sewer; shape; size; software; storm sewer; windows

⁵ Windows is a registered trademark of Microsoft Corporation.

ANNEX**(Mandatory Information)****A1. OVALITY EQUATION**

$$\begin{aligned} &\% \text{ ovality of original pipe} = \\ &\frac{(\text{Mean Inside Diameter} - \text{Minimum Inside Diameter}) \times 100\%}{\text{Mean Inside Diameter}} \end{aligned}$$

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