Designation: F3080 − 21

Standard Practice for Laser Technologies for Measurement of Cross-Sectional Shape of Pipeline and Conduit by Non-Rotating Laser Projector, Infrared Measurement, and CCTV Camera System[1]

This standard is issued under the fixed designation F3080; 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 Laser profiling is a non-contact inspection method used to create a pipe wall profile and internal measurement using a standard CCTV pipe inspection system, 360 degree laser light projector, a measurement by means of infrared sensors and geometrical profiling software. This practice covers the procedure for the measurement to determine any deviation of the internal surface of installed pipe compared to the design. The measurements may be used to verify that the installation has met design requirements for acceptance or to collect data that will facilitate an assessment of the condition of pipe or conduit due to structural deviations or deterioration. 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 pipe material, all types of construction, and pipe shapes.

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

1.4 This standard does not include all aspects of pipe inspection, such as joint gaps, soil/water infiltration in joints, cracks, holes, surface damage, repairs, corrosion, and structural problems associated with these conditions.

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

1.7 *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 ring profiler specified (listed and labeled as specified in 1.3).

1.8 *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

2.2 *Other Standards:*

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]

[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.

Current edition approved March 1, 2021. Published March 2021. Originally approved in 2014. Last previous edition approved in 2017 as F3080-17a. DOI: 10.1520/F3080-21.

[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.

[3] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, 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.

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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

3.1.3 *barrel distortion correction confirmation target*—an X-Y axis grid patterned for the post processing verification of "fisheye distortion" lens correction within the processing software.

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

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

3.1.6 *CCTV pipeline and conduit inspection system*—CCTV inspection system is composed of CCTV camera, transporter, controller and video recording unit.

3.1.7 *deflection*—any change in the inside diameter of the pipe resulting from installation and imposed loads. Deflection may be either vertical or horizontal and is usually reported as a percentage of the base (undeflected) inside pipe diameter.

3.1.8 *laser, n*—a solid state device that produces a monochromatic and coherent beam of visible light in an intense, narrow 360 degree beam.

3.1.9 *laser profile*—the spatial intensity profile of a laser beam at a particular plane that is perpendicular to the trajectory of the laser device along the axis of the pipe.

3.1.10 *laser profiling survey*—a survey composed of taking measurements of the cross sectional shape of the pipe at a rate greater than 24 images per second along its alignment, processing the recorded data using compatible software and producing a condition assessment report, including deviation, using laser profiling or infrared technology, or both.

3.1.11 *laser projector assembly*—a 360 degree laser light projector assembly composed of two primary components: laser signal modulation unit.

3.1.12 *non-rotating laser projector, n*—a mobile, certified "eye safe" laser light source and internal optics capable of projecting a 360 degree narrow beam of laser light onto an internal pipe wall in pipes from 6 in. to 72 in. (150 mm to 1800 mm) in diameter regardless of material, design, or shape.

3.1.13 *ovality, n*—percentage of shape deflection in circular and noncircular pipes as calculated in accordance with Practice F1216 as defined in Annex A1.

3.1.14 *PAL*—Phase Alternating Line—A color encoding system for analog television not used in North America containing 25 half frames, 50 frames per second. Each frame contains 625 lines.

3.1.15 *profiling software*—the software that analyzes the collected data from a laser or infrared profiling survey into cross sectional profiles along the pipe of conduit alignment.

3.1.16 *survey calibrator*—a calibrated measurement reference placed and recorded on the same plane and distance from the CCTV camera as the projected laser light ring or infrared sensor during the profiling survey.

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 can be used for:

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, deformation, deflection or deviation, that is often not possible from an inspection by either a mandrel or CCTV only survey.

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:

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

5.1.2 The utility owner shall ensure that all lines to be profiled and free of debris, obstructions and cleaned within 24 h prior to the profiling inspection and survey. If the pipe condition is the cause for unacceptable results then the re-inspection shall be borne by the client of the inspection provider. Standing or flowing water or debris shall not exceed 10 % of the nominal pipe diameter, or 6 in. in depth, whichever is the lesser.

6. Equipment

6.1 The laser profiling or infrared sensor equipment, including laser projector, infrared sensors, and CCTV inspection system (Fig. 1), shall be configured in accordance with the manufacturer's technical specifications and the specifications of the equipment "Certificate of Accuracy," as required under Section 9.

6.2 Only calibration and lens distortion barrel correction software algorithms, as specified by the software manufacturer, shall be used in accordance with the specifications of the equipment "Certificate of Accuracy."

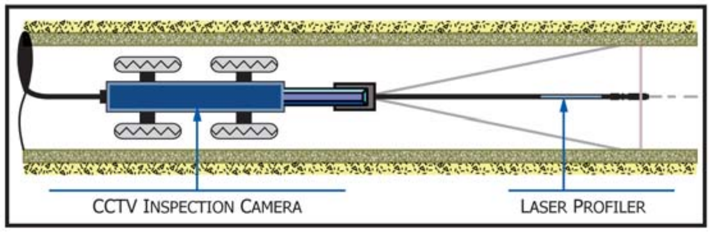

FIG. 1 CCTV—Laser Profiler Assembly

6.3 The inspection and survey CCTV camera system "Image Barrel Distortion" shall be corrected by the software and recorded within the processing software for post inspection verification, and in accordance with the specifications of the equipment "Certificate of Accuracy."

6.4 The survey software used shall be the currently supported version as provided by the software manufacturer.

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

7. Software

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

7.2 The applicable camera "barrel distortion" correction shall be selected and verified based on the actual CCTV camera and lens as used in recording the laser or infrared imaging data.

7.3 Horizontal and vertical calibration shall be performed as stipulated by the manufacturer of the software.

7.4 The profile software shall have the capability to analyze the laser image or infrared sensor measurement of each recorded video frame. The image center shall be calculated by the processing software for each recorded video frame. A minimum of 1080 radius data points shall be interrogated per video frame. The distance from each usable data point shall be automatically calculated and stored. Using the stored measurement data, the pipeline and conduit median diameter shall be calculated and established as the diameter for calculating percentage deviation from line ovality (deformation). Data points affected or impaired by water, debris, fog, etc., shall be discarded and not used in the calculation of line ovality and deformation.

7.5 The ovality shall be calculated in accordance with Practice F1216 as given in Annex A1 for all pipe shapes. 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 masked, changes in curvature shall be considered as a better measure of the degree of pipe deformation. For CIPP installation, the ovality shall be calculated in accordance with Practice F1216 as given in Annex A1 for all pipe shapes. If the shape of the original pipe deviates significantly (more than 10 % from the normal diameter) from that of an equivalent circle when the flow area is masked, changes in curvature shall be considered as a better measure of the degree of pipe deformation.

7.6 For non circular designed pipes, the deviation of the observed inspection from the original pipe design shall be calculated in accordance with the software manufacturer's shape algorithm.

7.7 The accuracy of the system must be maintained to meet the requirements of 9.1 if sensors are removed or water impedes the measurement of a sensor(s) and be so tested pursuant to 9.1 that accuracy is maintained with each number of sensors removed.

8. Procedure

8.1 The pipe shall be precleaned and free of debris that would prevent the CCTV camera and laser projector 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. 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 map 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. A TV only line inspection shall be recorded on a digital storage as agreed between the contractor and the client. The contractor shall consult the manufacturer for prior conversion approval if the standard format other than that required.

8.3 The transporter with camera and infrared sensor or laser line shall be advanced at a speed commensurate with the software's capacity to accurately measure and digitally record 30 individual light ring images per second in a high resolution image format. The transporter with camera and infrared sensor or laser line illuminated is retracted to the pipe entry at a speed not to exceed 30 ft/min (9.1 m/min). As a minimum, five full laser ring images or infrared sensor measurement rings shall be taken every inch or two full laser ring images or infrared measurement rings 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 shall be shown when it exceeds allowable deflection limits.

8.4 At the completion of the processing, the operator will select and hard copy color print a number of optional reports including a line graph of pipelines ovality and a reference to calibration. This reference to calibration image will be generated from two independent data sources. Image one source will be generated solely from the alphanumeric entry of the shape (circle, oval, arch, etc.) and the alphanumeric pipe diameter (6 in. or 150 mm) by the processing operator. The second image is generated solely by the software from the processed laser or infrared sensor image. The images must overlay each other to confirm calibration. Addition still frame images (digital or video) of each image that exceeds the acceptance parameters or are of significant engineering value can also be provided.

8.5 The contractor shall calibrate equipment to the manufacturer's requirements at the end of each CCTV survey. Calibrations shall include all that were performed to calibrate the equipment prior and immediately following the testing by the independent certifying agency.

8.5.1 The operator performs an image calibration from the recorded image of the manufacturer's supplied calibration jig. The operator then sets the profiling start and stop points within the recorded profile data stream.

8.5.2 At the completion of the processing, the operator will select and hard copy color print a number of optional reports including a line graph of pipelines ovality and a reference to calibration. This reference to calibration image will be generated from two independent data sources. Image one source will be generated solely from the alphanumeric entry of the shape (circle, oval, arch, etc.) and the alphanumeric pipe diameter (6 in. or 150 mm) by the processing operator. The second image is generated solely by the software from the processed laser image.

8.5.3 The images must overlay each other to confirm calibration. Additional still frame images (digital or video) of each image that exceeds the acceptance parameters or are of significant engineering value can also be provided.

8.6 The laser light projector or infrared sensor shall be tested, labeled, and certified to conform to U.S. 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 in accordance with IEC 60825-1, or both.

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 projector system, or infrared sensor measurement 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. The independent testing agency shall have met a minimum level of proficiency in testing and professional standards for a laboratory to certify the accuracy of the equipment.

9.3 The longitudinal position of the pipe 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 %; in addition, a tolerance of 2 ft (0.6 m) for the insertion and exit distance between the CCTV, the infrared sensor, or the laser projection unit, or combinations thereof, shall be allowed in the data and the reports.

9.3.1 Accuracy is independent of pipe size provided the following conditions are met:

9.3.1.1 The CCTV camera is looking directly down the pipe (home position) for both profile inspection, and again during calibration.

9.3.1.2 The laser ring or infrared sensor measurement can be seen by the camera clearly through 360 degrees. The laser line or sensor measurement is crisp and clear, not fat and fuzzy—the laser heads are tailored to suit the camera and pipe size/material.

9.3.1.3 The laser or infrared measurement is projected perpendicular to the pipe wall so that the profile is an accurate representation of the pipe shape.

9.3.1.4 The snapon and skid systems are all designed to provide a perfect pipe profile, regardless of pipe size.

9.3.1.5 The camera, sensor, and laser are optimal in the center; nevertheless, when the above are followed, satisfactory profiling is achievable.

9.3.1.6 If the camera cannot be centered, the infrared sensor/laser system is adjusted farther away from the camera.

9.3.1.7 The central position of laser or infrared sensor system is not of significance; the strength and the orientation of the light on the pipe wall, however, are more significant.

10. Reports

10.1 At the completion of the software processing the following report(s) 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. The non-structural mask when present shall be displayed in the required "match to reference" image.

10.2 *Observation Report:*

10.2.1 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 deformation as specified by the contracting authority. Still frame video or digital images, for each profile that exceeds the specified maximum deformation, shall be included. The calculated median diameter shall be included in the report in addition to image data and allowable percentage deformation. Any masking, software corrections, data manipulation, or smoothing shall also be clearly noted.